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Original Article

Home Range Characteristics and Habitat Selection by Daurian Hedgehogs (*Mesechinus dauuricus*) in Ikh Nart Nature Reserve, Mongolia

Mirka Zapletal[1], Batdorj Sodnompil[2], Jon Atwood[3], James D. Murdoch[4] and Richard P. Reading[5]

[1]Antioch University New England, P.O. Box 205, Lincoln, NH 03251, Fax: +1-603-745-2250, Tel.: +1-603-715-4688, e-mail: mirkazapletal@yahoo.com
[2]Mongolian Academy of Sciences, Institute of Biology, Ulaanbaatar 210351, Mongolia, e-mail: Batdorj100@gmail.com
[3]Biodiversity Research Institute, 652 Main Street, Gorham, Maine 04038 USA, e-mail: jon.atwood@briloon.org
[4]University of Vermont, Wildlife and Fisheries Biology Program, Rubenstein School of Environment and Natural Resources, George Aiken Center, Burlington, Vermont 05405 USA, e-mail: jmurdoch@uvm.edu
[5]Denver Zoological Foundation, Conservation Biology Department, 2300 Steele Street, Denver, Colorado 80205 USA, e-mail: rreading@denverzoo.org

Abstract

Key words: compositional analysis, Daurian hedgehog, habitat selection, home range, *Mesechinus*, Mongolia, steppe

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Correspondence:
mirkazapletal@yahoo.com

We examined home range characteristics and habitat selection of Daurian hedgehogs in Ikh Nart Nature Reserve, Mongolia. Home ranges of hedgehogs varied from 113.15 ha to 2,171.97 ha, and were larger in early summer than late summer. Hedgehogs showed relative preference for rocky outcrops and low-density shrub habitats, and relative avoidance of high-density shrub areas. Habitat selection also changed between early and late summer, shifting to greater use of low-density shrub areas and decreased use of forb-dominated short grass. Our baseline data on home ranges and habitat selection expand understanding of hedgehog ecology and provide guidance for future management decisions in Ikh Nart Nature Reserve and elsewhere in Mongolia.

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Introduction

Daurian hedgehogs (*Mesechinus dauuricus*) are insectivores found in eastern Mongolia and adjacent areas of Siberia and China (Stubbe *et al.*, 2008). Researchers have studied several aspects of European hedgehog (*Erinaceus europaeus*) ecology (Reeve, 1982; Boitani & Reggiani, 1984; Micol *et al.*, 1994; Doncaster *et al.*, 2001; Riber, 2006), but less ecological research has focused on Daurian hedgehogs. All hedgehogs share a number of anatomical features, such as spines, the orbicularis muscle, and a body-plan described as 'basic' (Reeve, 1994), but behaviors and ecological requirements of populations vary among species and environmental conditions (e.g. food availability, predator density, human impact on the landscape, and other factors [Doncaster, 1992; Cassini & Krebs, 1994; Micol *et al.*, 1994; Hubert *et al.*, 2011]).

Understanding a species' ecology begins with basic research examining patterns of resource use. Home range analysis, assessing the area used by an individual during its normal activities, provides a measure of the spatial requirements for a species (Millspaugh & Marzluff, 2001), and analysis of location data provides insight into patterns of habitat selection (Johnson, 1980; Horne & Garton, 2006). We studied home range characteristics and habitat use by Daurian hedgehogs in a semi-arid environment to gain baseline information on the species' ecology. The objectives of our study were to 1) quantify the home range characteristics, including size and shape of Daurian hedgehogs, and 2) assess patterns of habitat selection at multiple spatial scales.

Materials and Methods

Study area. We conducted the study in Ikh Nart Nature Reserve (45.723° N, 108.645° E). Ikh Nart was established in 1996 in Dornogobi Aimag, which lies at the northeast edge of the Gobi Desert and consists mainly of semi-arid steppe habitats, including rocky outcrops, shrublands, grasslands, and forb-dominated areas (Jackson *et al.*, 2006; Murdoch *et al.*, 2010; Reading *et al.*, 2011). The area features a dry continental climate, and receives <200 mm of precipitation annually (Reading *et al.*, 2011). Temperature is highly variable and ranges from -40°C in winter (December to March) to +45°C in summer (June to August). Several freshwater springs provide a majority of the available water, although these springs are rare throughout the reserve. Plant communities feature semi-desert steppe varieties, including grasses with some forbs in flatter sections, and primarily shrubs in rockier terrain (Reading *et al.*, 2011). Two species of hedgehogs occur in this reserve including Daurian hedgehog and long-eared hedgehog (*Hemiechinus auritus*) (Murdoch *et al.*, 2006).

Capture and tracking. We quantified home range characteristics and habitat selection by capturing, marking, and tracking the movements of individual hedgehogs. We captured hedgehogs in May and June 2011. We captured 1 male opportunistically while checking under rock ledges. We captured a second male (originally captured in 2010) after it emerged from hibernation, and located 2 females using a spotlight at night. We attached a 7g Very High Frequency (VHF) radio transmitter (Advanced Telemetry Systems, Isanti, Minnesota, USA) to an area of clipped quills on the back of each captured animal using dental composite (Protemp 4 Garant, 3M ESPE Dental Products, St. Paul, Minnesota, USA) (Murdoch *et al.*, 2006). As part of a parallel morphologic study, we weighed, sexed, and measured each hedgehog for total length, girth at the chest, inner ear length, outer ear length, foreleg, hind leg, hind foot, and tail. We also attached a numbered ear tag (model 1005-1, National Band and Tag, Newport, Kentucky, USA) to each hedgehog. We chemically restrained each hedgehog using ketamine anesthesia (up to 80 mg/kg body weight) following a Denver Zoological Foundation protocol. We held captured hedgehogs for up to 24 hours and provided them with insects, meat, and water *ad libitum*, before releasing them back at their capture sites.

We tracked hedgehogs using hand-held antennas and radio receivers (model R-1000, Communications Specialists, Orange, California, USA). To investigate if the temporal changes in European hedgehog space-use seen by Boitani & Reggiani (1984) extended to Daurian hedgehogs, we divided the summer into 2 periods: June 11- July 17 (Early Summer) and July 21- August 31 (Late Summer) and continuously tracked each animal 5 times per period (0-2 times per week) using focal-animal sampling (Altmann, 1974). Following Riber (2006), our tracking methodology usually involved finding the daytime resting location (day-nest) of a hedgehog approximately 1-hour before sunset, and then following that individual from a distance of 10-40 m once it emerged and became active (typical follow distance = 20-30 m, within the range used by Boitani & Reggiani [1984], Riber [2006], and Dowding *et al.* [2010]). At times we located the focal animal after emergence, we recorded its location every 10 minutes using a handheld Global Positioning System (GPS), and logged the complete track of the followed hedgehog. Tracking sessions lasted 4-9 hours until the focal animal entered a day-nest (typically at daybreak).

Home ranges and habitat selection. We analyzed location data using Geographic Information Systems software (ArcGIS10, ESRI, Redlands, California, USA) with a Geospatial Modelling Environment (GME) extension (Spatial Ecology, Toronto, Canada). We estimated home ranges as 100% Minimum Convex Polygons (MCP- Minimum Convex Hull in ArcMap10) and kernel densities (in GME) for Early Summer and Late Summer. We created MCPs by connecting all available data for an individual within each time period to provide a simple home range 'snapshot' (Mohr, 1947). MCPs provide a standard home range estimate that is easily comparable to estimates from elsewhere (Harris *et al.*, 1990). Kernel densities provide probability estimates for an animal's use of each 'kernel' based upon data (Worton, 1989); the resulting estimates provide more-nuanced analyses of home range data based not only on an animal's locations, but also the frequency of locations within an area. We visually separated kernel density values into 7 classes using natural breaks. We combined the area within the top 2 classes (44.50% of Early Summer kernel values and 41.86% of Late Summer kernel values) by study animal, clipped any overlapping sections between Early Summer and Late Summer, and considered the resulting polygons repeated-use zones (we omitted 1 female from this analysis because she showed no overlap). We report all mean estimates with ± 1 S.D.

We generated 8 random MCP home ranges in GME for comparison with the 8 actual MCP home ranges generated over the summer to investigate non-random habitat use in home range placement. We classified the 4 largest random home ranges (mean area = 1,007.05 ± 169.57 ha) as Early Summer and 4 smallest (mean area = 286.02 ± 163.82 ha) as Late Summer (Fig. 1). We generated alternate hedgehog trails in GME to investigate habitat selection during nightly foraging and used correlated random walks (CRW), following Maude (2010). Each CRW contained 36 segments (Early Summer mean = 142.22 ± 117.87 m; Late Summer mean = 56.42 ± 48.09 m) to simulate 6 hours of tracking with GPS points collected every 10 minutes. We used a normal turn-angle distribution (mean = 5 ± randomly set 1-3°).

Using vegetation maps created by Jackson *et al.* (2006), we calculated the proportion of each habitat type (e.g. rocky outcrop, high-density shrub, low-density shrub, forb-dominated short grass, semi-shrub, tall vegetation, and water) within the study area, real and random home ranges, and repeated-use zones. We created a

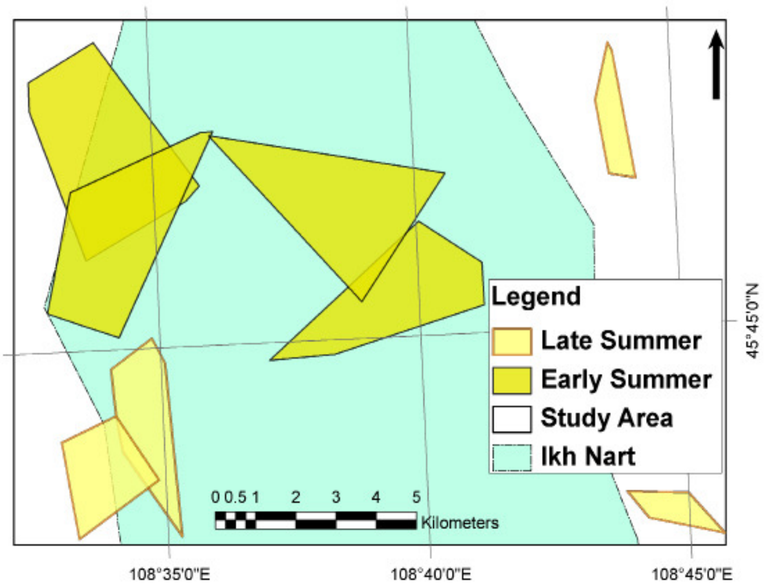

Figure 1. Randomly-generated home ranges for Daurian hedgehogs in Ikh Nart Nature Reserve, Mongolia during the summer of 2011. We designated the four largest home ranges (mean area = 1,007.05 ± 169.57 SD ha) as Early Summer (June 11- July 17) and the four smallest (mean area = 286.02 ± 163.82 SD ha) as Late Summer (July 21- August 31) to correspond to the larger Early Summer (mean area = 1,015.16 ± 841.28 SD ha) and smaller Late Summer (300.06 ± 206.88 SD ha) actual home range estimates from tracking data.

1.5 m-radius buffer around all GPS locations, including points from CRWs, and overlaid this buffer on the vegetation maps to determine habitat selection within home ranges. We extracted vegetation values at all GPS locations collected during tracking and used likelihood ratios to investigate changes in vegetation use between Early and Late Summer.

We developed a hierarchy for vegetation types following Johnson's (1980) relative ranking. We created compositional analysis matrices following Aebischer *et al.* (1993) to determine non-random habitat selection based on the proportion of use relative to the proportion of availability for different vegetation types, both between the study area and home ranges, and between actual home ranges and locations taken from tracking. When evaluating habitat selection by hedgehogs within the study area in compositional analysis, we followed the recommendation of Aebischer *et al.* (1993) and substituted 0.000001 (0.0001%) for 0 values in real home ranges and 0.00001 (0.001%) in random home ranges. Because areas classified as water in the vegetation maps did not appear in any hedgehog's home range, we excluded this category from both relative ranking and compositional analysis of tracked locations. At the tracking level, we substituted 0.00001 (0.001%) for 0 values. We used nonparametric multivariate analysis of variance (MANOVA, Kruskall-Wallis) tests to investigate the difference in habitat rankings between real and randomly-generated home ranges (Aebischer *et al.*, 1993; Beasley *et al.*, 2007; Dowding *et al.*, 2010).

Results

We recorded a total of 1,532 GPS locations during tracking (726 in Early Summer and 806 in Late Summer). We collected 354-420 locations for each hedgehog. Mean MCP home range size was larger in Early Summer (1,015.16 ± 841.28 ha) than in Late Summer (300.06 ± 206.88 ha) (Fig. 2). Mean MCP home range size across both periods was 1,154.85 ± 791.86 ha. Due to small sample size, we did not examine differences in home range size between sexes. However, mean size of male home ranges was 1,723.26 ± 765.02 ha, and of female home ranges was 586.44 ± 59.56 ha. Mean size of repeated-use area was 25.75 ± 1.47 ha, and no hedgehog core ranges overlapped.

When we compared study area, randomly-generated home range, actual home range, and repeated-use zone composition, rocky outcrop and low-density shrub areas had greater mean percent values in actual home ranges and repeated-use zones than in the study area or randomly-generated home ranges (Fig. 3). Low-density shrub and tall vegetation areas had

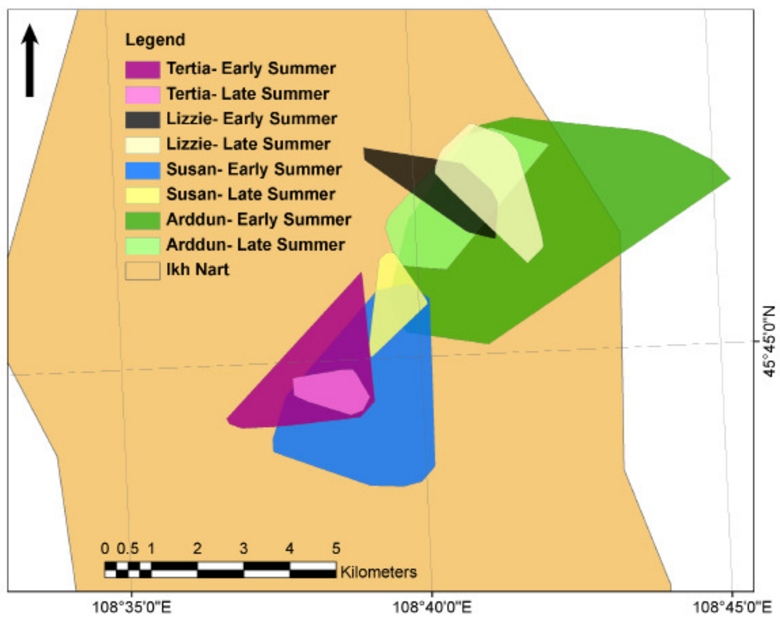

Figure 2. Minimum convex polygon home range estimates using all locations for Daurian hedgehogs collected during Early Summer (June 11- July 17) and Late Summer (July 21- August 31) in Ikh Nart Nature Reserve, Mongolia.

greater mean percent values in locations from tracking than from CRWs, while forb-dominated short grass mean percent was lower in tracked locations (Fig. 4). During Late Summer low-density shrub comprised 62.7% of locations. In contrast, forb-dominated short grass areas, while comprising roughly the same percentage of the study area (26.4%), home ranges (27.8%), and overall night-tracking locations (26.4%), decreased in use during Late Summer (16.4% of locations).

Johnson's (1980) protocol for relative ranking of vegetation types suggested relative preference for low-density shrub and tall vegetation relative to availability within home ranges (ranking values = 0.62 and 1.12, respectively) and the 1.5 m buffers around tracked locations (ranking values = 0.12 and 0.19, respectively), and relative avoidance of high-density shrub (home range = -1.50, tracked locations = -0.50) and forb-dominated short grass (home range = -0.88, tracked locations = -0.12) (Table 1). Hedgehogs showed relative preference for rocky outcrops in home ranges (2.25) and neither preferred nor avoided it in tracked locations (0.00). Hedgehogs showed relative avoidance of semi-shrub in

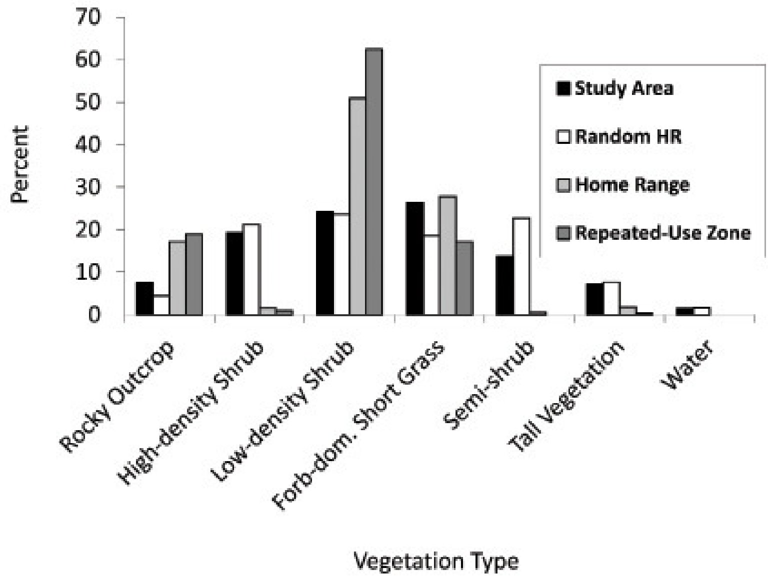

Figure 3. Percent of vegetation types within the study area, randomly-generated home ranges, actual home ranges, and repeated-use zones of Daurian hedgehogs in Ikh Nart Nature Reserve, Mongolia.

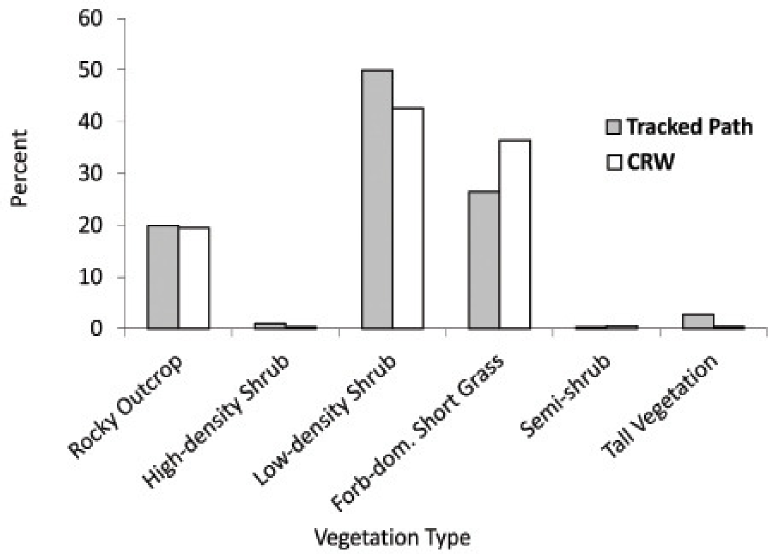

Figure 4. Percent of vegetation types of locations from tracked paths and correlated random walks (CRW) of Daurian hedgehogs in Ikh Nart Nature Reserve, Mongolia.

home ranges (-1.69), and preference in tracked locations (0.31). Hedgehogs showed relative preference for water in home ranges (0.06). Relative preference and avoidance values were greater for selection in home ranges than in tracked locations.

Compositional analysis matrices for home ranges and tracked-location buffers (Tables 2 and 3, respectively) indicated low rankings for high-density shrub (home ranges = 2, tracked locations = 1) and semi-shrub (home ranges = 1, tracked locations = 0), and high rankings for rocky outcrops (home ranges and tracked locations = 5) and low-density shrub (home ranges = 6, tracked locations = 4). Randomly-generated home ranges (Table 2) differed from actual hedgehog space-use with high values for tall vegetation (6) and high-density shrub (5) (Table 4). We found a significant relationship between vegetation rankings within actual home ranges (K-W = 48.25, P = < 0.001), but not between vegetation rankings within random home ranges (K-W = 5.16, P = 0.52).

Habitat use patterns appeared to change over the summer. Vegetation type of tracked locations differed significantly by summer period (likelihood ratio, = 110.24, P = < 0.001). Low-density shrub, which appeared more times in Late Summer (485) than expected (392.48), contributed the largest value. With low-density shrub records excluded, vegetation type of tracked locations differed significantly by summer period (likelihood ratio, = 19.58, P < 0.01).

Discussion

We found larger Early Summer and smaller Late Summer MCP home ranges than those previously reported for the species over longer periods of time in Ikh Nart (Murdoch *et al.*, 2006). For example, Murdoch *et al.* (2006) reported home ranges of 76.24 to 921.73 ha between June and September. Our 5- and 6-week sample periods do not fully compare to the 4-month collection period of 2006; however, hedgehog tracking in 2006 started in June, and tracking of some animals possibly began at the end of what we termed "Early Summer", concealing the full extent of hedgehog space-use in June. During the 2011 field season, we followed all animals twice by June 25.

The decrease in home range area over the summer may reflect changes in food availability or in foraging strategy as the season progressed. Between 2009 and 2010 insect density varied with year and habitat (Reading, 2010), and regular rain events in July 2011 may have led

Table 1. Relative ranking of vegetation types within home ranges and among tracked locations of Daurian hedgehogs in Ikh Nart Nature Reserve, Mongolia. RO = rocky outcrop, HDS = high-density shrub, LDS = low-density shrub, SGF = forb-dominated short grass, SS = semi-shrub, TV = tall vegetation, W = water. Rankings based on Johnson (1980); relative preference for a vegetation type decreases left to right.

Data Set	*Ranked Habitat Sequence*						
Home ranges	RO >	TV >	LDS >	W >	SGF >	HDS >	SS
Tracked locations	SS >	TV >	LDS >	RO >	SGF >	HDS	

Table 2. Mean (± SE) values for pairwise differences in log-ratios of vegetation types of random home ranges (below the diagonal) and used home ranges (above the diagonal) to available (study area) vegetation types for Daurian hedgehogs in Ikh Nart Nature Reserve, Mongolia. Positive values indicate the vegetation leading the row is used more than expected compared to the vegetation heading the column (see Table 1 for abbreviations).

	RO	*HDS*	*LDS*	*SGF*	*SS*	*TV*	*W*
RO		4.305 ±0.341	-0.013 ±0.392	0.559 ±0.298	5.436 ±1.070	3.501 ±0.686	10.193 ±0.291
HDS	2.317 ±1.477		-4.431 ±0.373	-3.746 ±0.318	1.130 ±0.929	-0.804 ±0.615	5.888 ±0.298
LDS	1.336 ±0.713	-0.981 ±1.330		0.684 ±0.186	5.561 ±1.199	3.627 ±0.906	10.319 ±0.116
SGF	0.515 ±0.520	-1.802 ±1.545	-0.821 ±0.607		4.877 ±1.140	2.942 ±0.777	9.634 ±0.102
SS	1.724 ±2.194	-0.593 ±0.990	0.388 ±1.799	1.209 ±2.199		-1.935 ±0.616	4.758 ±1.132
TV	2.539 ±1.360	0.222 ±0.290	1.203 ±1.156	2.024 ±1.354	0.815 ±1.094		6.692 ±0.805
W	-0.273 ±2.067	-2.590 ±0.840	-1.609 ±1.949	-0.788 ±2.201	-1.997 ±1.021	-2.812 ±1.097	

Table 3. Mean (± SE) values for pairwise differences in log-ratios of used (tracked paths) to available (home range) vegetation types for Daurian hedgehogs in Ikh Nart Nature Reserve, Mongolia (see Table 1 for abbreviations and Table 2 for interpretation).

	HDS	*LDS*	*SGF*	*SS*	*TV*
RO	2.188 ±1.240	0.100 ±0.308	0.142 ±0.212	2.853 ±0.815	1.683 ±0.988
HDS		-2.087 ±1.044	-2.046 ±1.083	0.665 ±1.605	-0.505 ±1.061
LDS			0.042 ±0.158	2.752 ±0.878	1.582 ±1.049
SGF				2.710 ±0.850	1.540 ±0.941
SS					-1.170 ±1.396

Table 4. Compositional analysis ranking of vegetation types in actual home ranges, tracked paths, and randomly-generated home ranges of Daurian hedgehogs in Ikh Nart Nature Reserve, Mongolia (see Table 1 for abbreviations). Rankings based on Aebischer *et al.* (1993); relative preference for a vegetation type decreases left to right.

Data Set	*Ranked Habitat Sequence*
Home Range	LDS > RO > SGF > TV > HDS > SS > W
Tracked Path	RO > LDS > SGF > TV > HDS > SS
Random HR	TV > HDS > SS > LDS > SGF > RO > W

to increased insect abundance and allowed hedgehogs to find adequate food within a smaller area . Boitani & Reggiani (1984) linked European hedgehog space-use and movement in Italy to food availability, and found that home ranges contracted during the period before hibernation, shifting to greater use of refuse sites. Animals may also travel less to conserve energy once the reproductive period ends. Other researchers hypothesize that males may expand their ranges and move further in their search for mates during the mating season (Boitani & Reggiani, 1984; Riber, 2006); Morris (1988) also concluded that wide-ranging movements of one male hedgehog on the Isle of Wight, when compared with the movements of other subjects, revealed some other factor than the search for food. Zingg (1994) found male European hedgehogs had larger home ranges during the mating season than outside of it. Home ranges of the 2 focal males from our study overlapped with those of the 2 focal females, and we located other females not included in this study in those areas as well, suggesting that Daurian hedgehog males might also move more during the reproductive season to find mates.

When compared with home range estimates for other hedgehog species outside of Mongolia, both sets of Ikh Nart data suggest that Daurian hedgehogs use considerably larger home ranges than those reported elsewhere (Table 5). Following the Resource Dispersion Hypothesis, hedgehogs within the dry Eastern Gobi Steppe environment may have to travel further and utilize larger home ranges to locate adequate food and find reproductive partners (Johnson *et al.*, 2002).

Researchers conducted previous compositional analyses of habitat selection by other hedgehog species in areas with dense human populations (Doncaster *et al.*, 2001; Dowding *et al.*, 2010), unlike Ikh Nart. A large proportion of hedgehog research to-date occurred in urban and suburban study sites in Britain (Reeve, 1982; Doncaster, 1992; Cassini & Krebs, 1994; Micol *et al.*, 1994; Doncaster *et al.*, 2001; Young *et al.*, 2006; Dowding *et al.*, 2010; Hof & Bright, 2010). Dowding *et al.* (2010) found that hedgehogs preferred gardens of semi-detached, terraced, and detached homes. Doncaster *et al.* (2001) analyzed the movements of control and translocated hedgehogs, and found a greater use of urban, woodland, and pasture areas than of arable land. The semi-arid landscape of Ikh Nart is not comparable to study areas in Europe; however, Doncaster's (1992) finding that European hedgehogs quickly dispersed from areas with high badger (*Meles meles*) densities may echo habitat selection strategies of Daurian hedgehogs.

Relative ranking and compositional analysis generated alternate rankings for Ikh Nart habitat types within home ranges and tracked locations, but ranking placement typically differed by no more than three spots. Semi-shrub selection in tracked locations was an exception to this; relative ranking gave it greatest preference while compositional analysis gave it least preference. Our small sample size for this habitat type may have caused this discrepancy. Semi-shrub did not constitute more than 2% of any animal's home range and was rarely selected for tracked locations, leading to no indications of avoidance in tracked locations.

Ikh Nart's hedgehogs selected rocky outcrops and low-density shrub areas with sparse vegetation. Plant communities in these areas may support particular insect assemblages preferred as food resources, but the rocky terrain may also offer other advantages, such as ephemeral pools of water after rain events or more shelter and refuge options. Plant species characteristic of rocky outcrops and low-density shrub areas, such as *Spiraea aquilegifolia* and *Amygdalus pedunculata*, respectively (Jackson *et al.*, 2006), may maintain reliable insect populations that hedgehogs can depend upon for food throughout the summer. Daurian hedgehogs often used rock crevices and overhangs as day-nests, and rocky outcrops may provide better shelter and refuge options than other vegetation types. Relative predator density in these areas is unknown, but landscapes with sparser vegetation may give hedgehogs an advantage in detecting and/or evading predators. Summer precipitation and vegetation growth may have caused changes in usage of low-density shrub and forb-dominated short grass. Perhaps insect communities within the former expanded or those in forb-dominated short grass contracted over the summer. Finally, travel through forb-dominated short grass may have become difficult as vegetation became taller and/or denser.

Other factors may also influence Daurian hedgehog space-use in Ikh Nart. Hubert *et al.* (2011) determined that food resources and predator presence did not fully explain differences between urban and rural European hedgehog populations in France; availability of winter nest sites, urban microclimates, and traffic mortality may also have been important. Perhaps Ikh Nart's rocky areas provided different types of microclimates or reduced human-induced effects. Inter-specific competition with long-eared hedgehogs for resources in Ikh Nart may influence Daurian hedgehog space-use, although more research is needed on habitat requirements of the long-eared hedgehog (Reading *et al.*, 2010).

The small number of focal animals and GPS tracks reduced the power of our analyses and thus limits our conclusions about Daurian hedgehog ecology in Ikh Nart. For example, we estimated home ranges using GPS locations from only 5 nights of tracking for each individual.

Table 5. Mean (± SD) minimum convex polygon estimates (ha) for hedgehog home ranges in Europe, New Zealand, and Asia (ES = early summer, LS = late summer, WS = entire summer).

Location	*Species*	*Reference*	*Home range*
Italy	*Erinaceus europaeus*	Boitani & Reggiani (1984)	5.5-102.5
United Kingdom	*Erinaceus europaeus*	Morris (1988)	10-40
Denmark	*Erinaceus europaeus*	Riber (2006)	♂ = 96 ± 24 ♀ = 26 ± 15
United Kingdom	*Erinaceus europaeus*	Dowding *et al.* (2010)	♂ = 2.87 ± 1.74 ♀ = 0.77 ± 0.40
New Zealand	*Erinaceus europaeus*	Parkes (1975)	2.9
Israel	*E. europaeus concolor*	Schoenfeld & Yom-Tov (1985)	1.6
Israel	*Hemiechinus auritus*	Schoenfeld & Yom-Tov (1985)	♂ = 4.9 ♀ = 2.8
Ikh Nart, Mongolia	*Mesechinus dauuricus*	Murdoch *et al.* (2006)	422.72
Ikh Nart, Mongolia	*Mesechinus dauuricus*	Present study	ES = 1,015 ± 841 LS = 300 ± 207 WS = 1,155 ± 792

While Smith *et al.* (1981) concluded that 5 half-nights could adequately describe a wide-ranging animal's space-use and the hedgehogs in this study regularly covered large distances during nightly foraging, additional tracking would add detail and, possibly, area to each individual's home range. Expansion of data collection across seasons and with more subjects would refine our results and provide greater insight into hedgehog movement through the landscape. However, our results do provide a baseline measure of home range characteristics and patterns of habitat selection for Daurian hedgehogs, which have not been adequately quantified by other studies and may have value for developing management actions for the species.

The Mongolian Red List of Mammals (Clark *et al.*, 2006) lists Daurian hedgehog as a species of Least Concern. However, this assessment was based largely on expert opinion and sparse data as little information on Daurian hedgehog populations exists. Greater insight into Daurian hedgehog population characteristics will improve our understanding of the species' conservation status, especially in the desert-steppe environment. Our results provide quantified estimates of home range and habitat selection that provide a foundation for developing population studies.

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