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Note

Seasonal Variation and Sexual Difference of Home Ranges by Takins

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ABSTRACT The takin (*Budorcas taxicolor*) inhabits mountainous forests and exhibits seasonal migration along an altitudinal gradient. Its home range is largely unknown, yet this information is important to help guide the conservation of this threatened species. We conducted a global positioning system (GPS) radio-tracking study to determine the home ranges of 10 takins in the middle range of the Qinling Mountains, China, from August 2013 to August 2015. Their annual home ranges averaged 69.7 km^2 (range = 21.3–188.5 km^2) using the 100% minimum convex polygon (MCP), and 25.3 km^2 (range = 10.4–44.8 km^2) using a 95% kernel density estimate (KDE) revealing variation among individuals. Because takins are sexually dimorphic, we predicted that males would have larger home ranges than females. However, annual and seasonal home ranges of females were as large as, or larger than, those of males. These results are attributed to body size, sex, reproduction, and grouping behavior. Home range sizes of takins varied seasonally with the smallest range in winter (MCP = $F_{3,44} = 4.40$, $P = 0.009$; KDE = $F_{3,44} = 6.28$, $P = 0.001$); this variation was caused by their migratory behavior and the seasonal environment. For effective conservation of takins, managers of the Nature Reserves should unify management and conserve habitats used at all elevations. © 2017 The Wildlife Society

KEY WORDS *Budorcas taxicolor*, conservation, home range, seasonality, sexual dimorphism.

The takin (*Budorcas taxicolor*) is a forest-dwelling ungulate mainly distributed in remote mountainous areas of China (Wu et al. 1990, Zeng et al. 2002). It occurs in a range of habitats, including deciduous broadleaf forests, mixed conifer-broadleaf forests, conifer forests, and alpine meadow up to elevations of 4,000 m (Song et al. 2008). The International Union for Conservation of Nature (IUCN) has classified the takin as threatened and vulnerable because of population declines and habitat loss (Song et al. 2008). Additionally, it is a category I species in the National Protected Animal List in China (Zeng et al. 2002).

Only 2 studies on the home range of takin have been conducted. Song et al. (2000) described home ranges of 4 radio-collared golden takin (*B. t. bedfordi*) in the Qinling Mountains, China, and Guan et al. (2015) reported on 5 individuals of Sichuan takin (*B. t. tibetana*) in the Minshan Mountains, China. Sichuan takins have smaller annual home ranges (range = 4–32 km^2) than golden takins (range = 35–98 km^2). This difference indicates that we need more data on home range size of the species to understand its spatial behavior. For ungulates, home range size can fluctuate depending on available resources, so it can indicate abundant resources when their ranges are contracted (Morellet et al. 2013). However, when resources are scarce, their home ranges can be extensive (Richard et al. 2014). In large herbivores, selection for locations with high forage abundance enhances individual fitness (Moen et al. 1997). Consequently, for a vulnerable takin species, understanding its space use in mountain forest ecosystems is crucial for the future design of effective conservation strategies.

The takin is a large ungulate (200–350 kg) with dimorphic body size; generally, adult males are about 40% heavier than are adult females (Zeng et al. 2002). They live mostly in herds with >10 individuals (Zeng et al. 2002). Seasonal changes in weather and available food resources can influence seasonal movements of takins along an altitudinal gradient

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(Zeng et al. 2008, 2010). As a browser species, takin forage on various species of plants, including mosses, ferns, herbs, shrubs, and trees (Zeng et al. 2001).

Our objectives were to determine home range size of takins in the middle range of the Qinling Mountains, China, and identify any differences in home range size between sexes or seasons. Takins are sexually dimorphic; therefore, we predicted that males would have larger home ranges than females because of their difference in absolute energy requirements. There are many factors affecting a takin's decision to settle in an area, but one of the most important is the availability of forage. The availability of resources is lower in winter than in summer (Zeng et al. 2010). Large takins need to range more widely to obtain more food for their energetic needs in the winter because of the decrease in resource availability. Resource-poor environments increase the size of ungulate home ranges (Teitelbaum et al. 2015). Therefore, we also predicted that home ranges of takins would be larger in winter than summer. Detailed knowledge of the home range is important to make effective conservation-management decisions for this species.

STUDY AREA

We conducted fieldwork in and around the Foping National Nature Reserve (33°30′ – 33°50′ N, 107°39′ – 107°58′ E), which was located on the middle range of the Qinling Mountains, Shaanxi Province, China (Fig. 1). Laoxiancheng, Zhouzhi, and Guanyinshan were 3 National Nature Reserves adjacent to the Foping. The study area covered about 827 km^2 and encompassed rugged mountains with an altitudinal range of 810–2,904 m. This region was located in a warm temperate zone but shows various temperate zones along an altitudinal gradient, including warm temperate zone (810–1,200 m), mid temperate zone (1,201–2,400 m), and cold temperate zone (2,401–2,904 m; Chen 1992). Temperature varied from −10°C to 37°C at the altitude of 827.2 m, with annual mean temperature of 11.5°C and monthly mean temperatures of −3°C in January and 28°C in July (Zeng et al. 2002, 2008). In the mountains the first snowfall usually occurred in November and at altitudes <1,500 m approximately a month later. Snow melt started in early March to late March, depending on elevation. Annual rainfall was about 920 mm, with most rain occurring from July to September. We defined June–August as summer season, December–March as winter, with April–May and September–November as spring and autumn, respectively (Zeng et al. 2010).

The study area was primarily forest vegetation comprised of mainly deciduous broadleaf forests, mixed conifer-broadleaf forests, conifer forests, shrub, and subalpine meadow (Ren et al. 1998). Mammals within the study area were mainly golden takin, giant panda (*Ailuropoda melanoleuca*), golden snub-nosed monkey (*Rhinopithecus roxellana*), Asiatic black bear (*Ursus thibetanus*), Chinese goral (*Naemorhedus goral*), serow (*Capricornis sumatraensis*), forest musk deer (*Moschus berezovskii*), and golden cat (*Profelis temmincki*).

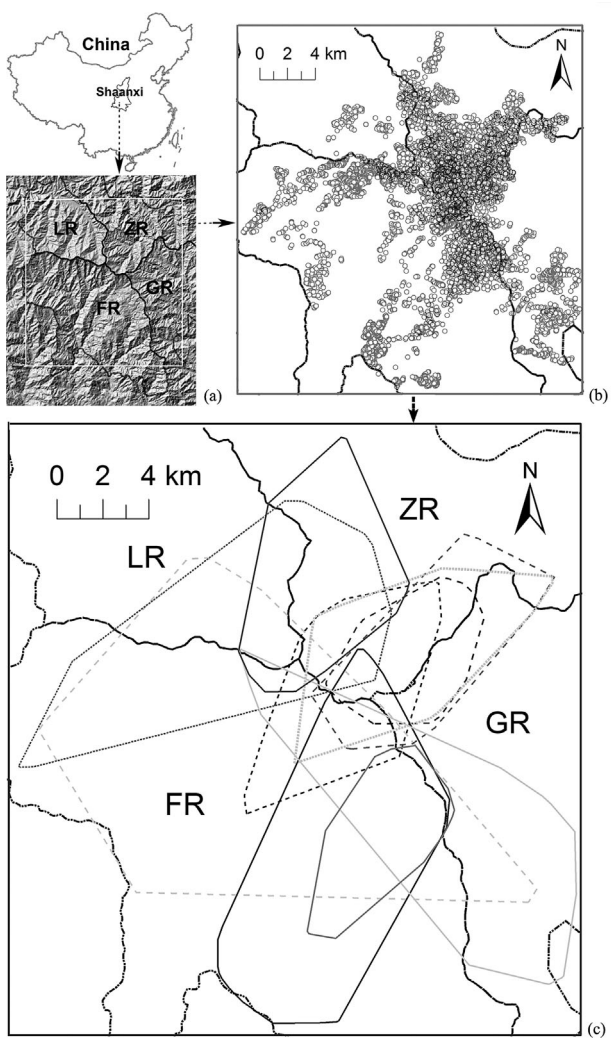

Figure 1. Study area and home ranges of collared takins in Shaanxi Province, China. We show Foping National Nature Reserve (FR) and adjacent Reserves (a), the locations from 10 takins between 2013–2015 (b), and home ranges made by the minimum convex polygon for each individual (c). LR = Laoxiancheng National Nature Reserve; ZR = Zhouzhi National Nature Reserve; GR = Guanyinshan National Nature Reserve.

METHODS

Takin Data

We conducted this study from August 2013 to August 2015. In 2013 and 2014 (Table 1), we captured and collared golden takin using a dart rifle with an immobilizing anesthetic. We used a solution of xylazine hydrochloride (100 mg/ml; Jilin Huamu Animal Health Product, Changchun, China) delivered intramuscularly at a dose of 1.3–1.5 ml/100 kg followed by a reversal of a solution of tolazoline (400 mg/ml; Jilin Huamu Animal Health Product) injected intramuscularly at an equal dose of the anesthetic. We followed an animal capture protocol approved by the Animal Ethics Committee of the Institute of Zoology, Chinese Academy of Sciences, and the National Forestry Agency of China (Linhuxuzhun#[2012]1630).

We fitted all animals with global positioning system (GPS) collars (7000M; Lotek Wireless, Ontario, Canada) after we aged them by tooth eruption and estimated a mass (kg) from

Table 1. Takins monitored in the Qinling Mountains, China, 2013–2015.

Individual identification	Estimated age	Sex	Estimated mass (kg)	Group size[a]	Monitoring period (days)	Bihourly locations
M1	12	M	250	5	730	8,315
M2	10	M	250	27	725	7,118
M3	13	M	300	20–25	373	3,075
M4	12	M	280	7–10	369	3,345
F1	8	F	210	20–30	377	3,640
F2	10	F	230	50–65	427	4,252
F3	8	F	200	20–25	427	3,764
F4	7	F	210	10–20	368	3,306
F5	7	F	200	20–30	378	3,704
F6	6	F	190	30–35	427	4,896

[a] We counted the group size by observing visible individuals and by estimating other individuals from spoor counts and sounds in the forest.

body size. The GPS collar was programmed to record a location and ambient temperature every 2 hours for up to 3 years. We used only 3-dimensional locations with a dilution of precision <10 to remove the less accurate locations (Adrados et al. 2002). We evaluated positional error of validated GPS locations in the study area from 1–10 June 2014. The positional error of validated locations was 10.73 ± 0.24 (SE) m ($n = 550$). In the field, before the time of capture, we calculated the group size each collared takin occurred in by counting visible individuals and by estimating other individuals from spoor and sounds in the forest.

Home Range

We used Geospatial Modeling Environment (GME version 0.7.2.1; Beyer 2012) to create home ranges of collared takins for each period using a 100% minimum convex polygon (MCP; Jennrich and Turner 1969) and a 95% kernel density estimate (95% KDE; Beyer 2012). We used 100% MCP home ranges for comparisons with previous studies. We calculated home range size and mean daily movement distances (km) of takins in ArcGIS 10.1 (Environmental System Research Institute, Redlands, CA, USA). We calculated home range overlaps between different individuals using the formula in Millspaugh et al. (2004): overlap $= \frac{A_{1,2}}{(A_1+A_2)-A_{1,2}} \times 100\%$, where A_1 and A_2 are the areas of home ranges of individuals 1 and 2, respectively, and $A_{1,2}$ is the overlapping area between home ranges of individuals 1 and 2. We performed all statistical analyses in SPSS 20.0 (SPSS, Chicago, IL, USA). We compared annual and seasonal home ranges between sexes using the 2-way Welch's t-test, which we used to account for small sample size and heterogeneous variances (Chynoweth et al. 2015). We used analysis of variance (ANOVA) to compare seasonal and monthly differences in home range sizes and test for differences in the mean daily movement distances between seasons. We used Tukey's test in the ANOVA to carry out all pairwise comparisons for monthly home range sizes.

RESULTS

In August and September 2013, we captured 2 male takins (M1 and M2) and in June 2014 we captured 2 males (M3 and M4) and 6 females (F1–F6); they lived in 10 distinct herds (Table 1). From September 2013 to August 2015, we obtained 3,075–8,315 GPS locations for each animal (Table 1; Fig. 1). We did not document collared animals moving together. The range of each collared takin represented the home range of its herd. Mean home range size of all collared takins was $73.5 \pm 15.0\ km^2$ (range = 29.5–188.5 km^2) using 100% MCP and $26.0 \pm 3.1\ km^2$ (range = 10.9–44.8 km^2) using 95% KDE during the whole tracking period. Their home ranges overlapped (Fig. 1), with $6.5 \pm 2.9\%$ (range = 0–16.8% by the KDE; $n = 6$) overlap between male ranges and $15.1 \pm 4.0\%$ (range = 0–48.4% by the KDE; $n = 15$) overlap between female ranges. The MCP ranges of 3 individuals (F2, F3, and M3) included 4 Reserves (Foping, Guanyinshan, Laoxiancheng, Zhouzhi). The MCP ranges of other 7 takins included 2 or 3 Reserves (Fig. 1).

Annual home ranges averaged $69.7 \pm 15.2\ km^2$ (range = 21.3–188.5 km^2) using the MCP and $25.3 \pm 3.0\ km^2$ (range = 10.4–44.8 km^2) using the KDE for all collared animals ($n = 10$; Table 2), showing inter-individual variation (CV = 69.9% by the MCP, and 41.0% by the KDE; Fig. 2). Sexual difference in seasonal home ranges occurred only in spring ($t_{7.5} = 2.39$, $P = 0.046$), and spring home ranges estimated by the KDE were larger for females (22.0 ± 4.0, $n = 6$) than males (11.0 ± 2.3, $n = 4$). However, we did not detect a difference between mean size of annual home ranges for males and females (Table 2). Home range sizes of takins showed seasonal change, regardless of which estimator was compared (MCP = $F_{3,44} = 4.40$, $P = 0.009$; KDE = $F_{3,44} = 6.28$, $P = 0.001$). Takin's home range was the smallest in winter compared with other seasons (Table 2). Accordingly, mean daily movement distance of 10 collared takins was the shortest in winter (0.54 ± 0.05 km) compared with other seasons (1.16 ± 0.05 km in spring, 1.16 ± 0.11 km in summer, 0.94 ± 0.09 km in autumn; $F_{3,36} = 13.547$, $P < 0.001$).

Home range sizes estimated by the KDE showed significant monthly difference ($F_{11,138} = 7.43$, $P < 0.001$). Takins had largest monthly home ranges during the migratory season from April to June, and smallest monthly home ranges during winter from December to March (Fig. 3).

DISCUSSION

We determined home ranges of takins in the Qinling Mountains, and found that their range sizes had inter-individual variation (Fig. 2). Among takins the inter-individual difference in home range sizes could be attributed to the interactive influence of different factors including body size, sex, reproduction, and grouping behavior. Our results supported

Table 2. Annual and seasonal home ranges (km^2) estimated by the 100% minimum convex polygon (MCP) and the 95% kernel density estimate (KDE) for 10 takins in the Qinling Mountains, China, 2013–2015. We used 2-year mean annual and seasonal home ranges for males M1 and M2 and 1-year data for other individuals. Data are expressed as means (±1 SE).

						Sex differences	
Season	**No. locations**	**Method**	**M ($n = 4$)**	**F ($n = 6$)**	**Total**	***t***	***P***
Spring (Apr–May)	7,036	MCP	22.1 ± 3.5	31.3 ± 6.4	27.6 ± 4.2	1.26	0.245
	F: 3,535	KDE	11.0 ± 2.3	22.0 ± 4.0	17.6 ± 3.0	2.39	0.046*
	M: 3,501						
Summer (Jun–Aug)	7,603	MCP	25.1 ± 8.4	37.2 ± 8.9	32.4 ± 6.3	0.99	0.354
	F: 4,596	KDE	11.7 ± 2.9	15.0 ± 0.9	13.7 ± 1.3	1.10	0.341
	M: 3,007						
Autumn (Sep–Nov)	10,302	MCP	18.3 ± 7.0	23.2 ± 10.8	21.2 ± 6.8	0.38	0.717
	F: 5,051	KDE	8.9 ± 1.4	13.0 ± 4.8	11.3 ± 2.9	0.81	0.451
	M: 5,251						
Winter (Dec–Mar)	15,108	MCP	12.4 ± 4.5	6.5 ± 1.8	8.8 ± 2.2	−1.21	0.292
	F: 7,497	KDE	6.2 ± 2.4	3.6 ± 1.0	4.6 ± 1.1	−1.01	0.370
	M: 7,611						
Annual	40,049	MCP	58.4 ± 14.9	77.3 ± 24.1	69.7 ± 15.2	0.67	0.523
	F: 20,679	KDE	24.8 ± 7.2	25.6 ± 2.6	25.3 ± 3.0	0.11	0.917
	M: 19,370						

*α is significant at <0.05.

evidence of intraspecific variation in home range between golden takin and Sichuan takin. Early estimates of home range size (range = 35–98 km^2 by the MCP; Song et al. 2000) for golden takins are within the range of our estimates (range = 29.5–188.5 km^2 by the MCP). These estimates are about 6 times larger than the range of estimates for Sichuan takins (range = 4–32 km^2 by the MCP; Guan et al. 2015). This intraspecific variation is likely related to their differences in body size, because golden takins have larger body size than Sichuan takins (Wu et al. 1990). Body size plays a strong role in influencing home range size in ungulates (Harestad and Bunnell 1979, Richard et al. 2014). Because larger species have greater energetic requirements, home range size of a species generally increases with increasing body size (McNab 1963, Harestad and Bunnell 1979).

Differences between male and female home ranges are common in many sexually dimorphic ungulate species, and female home ranges are usually smaller than those of males (Fennessy 2009, Reinecke et al. 2014). Male takins are larger than females (Zeng et al. 2002), and are a polygynous species so some male takins roam between different herds to mate with estrous females (Wang et al. 2006), resulting in an increase of their home range size. However, our results did not support the prediction that male takins have larger home ranges than females. Even in the summer mating season, home ranges between males and females did not differ significantly (Table 2). In takin, this inconsistent pattern may be attributable to social behavior related to grouping (Larter and Gates 1990). Takins live mostly in large herds with stable female members, whereas males are usually not associated with a herd (Zeng et al. 2002). Collared females were associated with larger herds than collared males (Table 1). This is a reason why annual and seasonal home ranges of females were as large as, or larger than, those of males (Table 2). Female ungulates associated with larger herds require larger grazing areas as a group than do males (Larter and Gates 1990).

Some researchers also reported that the presence of a calf has an important influence on its mother's home range during certain times of the year (Rettie and Messier 2001, van Beest et al. 2011). For example, females accompanied by calves have smaller seasonal home ranges than females

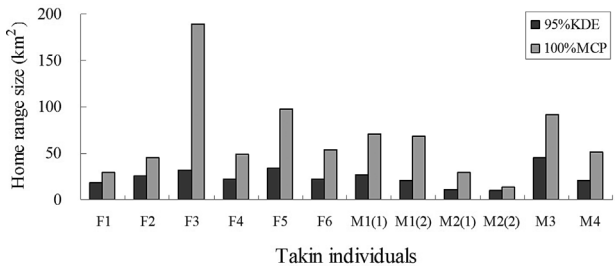

Figure 2. Annual home ranges (km^2) estimated by the 100% minimum convex polygon (MCP) and the 95% kernel density estimate (KDE) for 4 male (M1–M4) and 6 female (F1–F6) takins in the Qinling Mountains, China, 2013–2015. For M1 and M2, we present annual home ranges for each year.

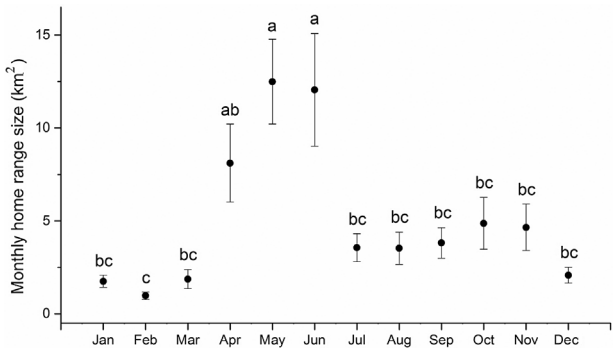

Figure 3. Monthly home range sizes estimated by the 95% kernel density estimate for takins in the Qinling Mountians, China, 2013–2015. We present means (±1 SE). Means with different letters above the error bars are statistically different (Tukey's test).

without calves for both the moose (*Alces alces*) in Norway (van Beest et al. 2011) and woodland caribous (*Rangifer tarandus*) in Saskatchewan (Rettie and Messier 2001). In this study, the female with the smallest annual home range (F1) had a calf. Also, 2 other mothers (F4 and F6) had small annual home ranges as estimated by 95% KDE (Fig. 2).

Takin's home ranges varied seasonally (Table 2), which is attributable to changes in environmental conditions (Zeng et al. 2010). Takins ranged more widely from April to June (Fig. 3). This is the elevational migration period when takins are moving down in spring and up in early summer following the phenological process along an altitudinal gradient (Zeng et al. 2008, 2010). In winter, as a response to scarce resources, large herbivores in temperate areas usually increase their home range size (Rettie and Messier 2001, Hellickson et al. 2008). However, contrary to our prediction, takin home ranges in winter were much smaller than other seasonal home ranges (Table 2; Fig. 3). Takins inhabit subalpine mountainous environments with snow and low temperatures in winter, which affects their movements (Zeng et al. 2008, 2010). As an ungulate in mountainous environments, it is very important to conserve energy by restricting movement during nutritional scarcity and to compensate winter food intake loss (Luccarini et al. 2006). Takins restrict their movements in winter resulting in smaller home ranges.

MANAGEMENT IMPLICATIONS

Takin need an average of 25.3 km^2 kernel home range for survival and reproduction. The MCP home ranges of most collared individuals in this study covered several Nature Reserves (Fig. 1). This indicates that the unified management by these related Nature Reserves is important for effectively conserving this threatened species. In addition, takin home ranges varied with season. Therefore, the Nature Reserves for takin conservation should pertinently reinforce management of their seasonal habitats at different altitudes.

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