Spatial and temporal activity patterns of Golden takin (*Budorcas taxicolor bedfordi*) recorded by camera trapping

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Understanding of an animal's migration, distribution and activity pattern is vital for the development of effective conservation action plans; however, such data for many species are lacking. In this study, we used camera trapping to document the spatial and temporal activity patterns of golden takins (*Budorcas taxicolor bedfordi*) in Changqing National Nature Reserve in the Qinling mountains, China, from April 2014 to October 2017. Our study obtained 3,323 independent detections (from a total of 12,351 detections) during a total camera trapping effort of 93,606 effective camera trap days at 620 sites. Results showed that: (1) the golden takin's utilization distribution showed seaonal variation, with greater utilization distribution during spring and autumn compared to summer and winter; (2) the species was recorded at the highest elevations in July, and lowest elevations in December, with the species moving to higher-elevations in summer, lower-elevations in spring and autumn, and mid-elevations in winter; (3) during all four seasons, golden takins showed bimodal activity peaks at dawn and dusk, with activity intensity higher in the second peak than the first, and overall low levels of activity recorded from 20:00-06:00; and (4) there were two annual activity peaks, the first being in April and the second in November, with camera capture rate during these two months higher than in other months, and activity levels in spring and autumn higher than in summer and winter. This study is the first application of camera traps in determining the spatial and temporal activity patterns of golden takins from a population level, and provides a broad overview of factors that can influence conservation decisions for the species.

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Abstract:

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Keywords: Bovidae; Wildlife behavior; Seasonal migration; Utilization distribution; Capture rate; National Park.

Introduction

Animal behavior as a discipline seeks to understand how animals perceive their external environment and their relationships with surrounding habitat characteristics (Alcock, 2001). The adjustment of behavior is the most direct manifestation animal response to environmental stimuli, forming a certain regularity of expected behavioral patterns (Marco and Marco, 2003). However, quantifying the behavior of wild animals is challenging (Rowcliffe et al., 2014). For example, behavioral metrics and data may be lacking due to the distribution of animals in remote mountains that are difficult for humans to access. In addition, the animals of interest may occur at low densities, actively avoid humans, or are nocturnal or crepuscular (O'Connell, Nichols & Karanth, 2010).

Traditional methods for surveying animal behavior depend on direct observation, and tagging (e.g. radio tracking via the attachment of telemetry devices to animals) (Nathan et al., 2012). However, these methods have limitations that impede the understanding of behavioral ecology. Direct observations can be extremely labour intensive and weakened by the influence of human presence on focal animals. Further, only a limited number of species are amenable to direct, field-based observation (Bridges & Noss, 2011; Nowak et al., 2014). Tag-based approaches are invasive and can be applied to only a small sample size, which may not be representive of the population at large (Guan et al., 2013; Rowcliffe et al., 2014). An alternative method is the placement of infrared sensors within the animal's environment, rather than on the animal itself, as is done with camera trapping. Camera trapping automatically records images of wildlife using motion sensor detection. This removes the need for an observer *in situ* and does not disturb the species being studied (Forrester et al., 2016).

Camera trapping is a non-invasive method, can be unattended in the field for several months, and is well suited for studying nocturnal/crepuscular and rare/elusive species (Bowler et al., 2016; Agha et al., 2018). Furthermore, animal behavior recorded by camera traps is typically a cumulative composition of many individual animals, allowing for population level measures. The use of technology in nature studies confers a number of important benefits (Hamel et al., 2012), and has become an increasingly popular tool for examining animal behavior as it provides opportunities to undertake extensive and detailed sampling of a species' behavioral repertoire (Burton et al., 2015; Caravaggi et al., 2017). Many categories of animal behaviour have been previously studied with camera traps, including reproduction (Crawford et al., 2019), dispersal or seasonal migration (Srivastave & Kumar, 2018), foraging (Mengüllüoğlu et al., 2018), and predation (Caravaggi et al., 2018; Akcali et al., 2019). Activity patterns are a subset of animal behavior. Animals must divide their time between various behaviors. Thus, the proportion of time spent active is a key metric for understanding fundamental behavioral trade-offs, and is the focus of several strands of behavioral and ecological science (Halle and Stenseth, 2000; Rowcliffe et al., 2014). Camera trapping provides an effective way for researchers to examine activity patterns by extracting behavioral information form camera data (image/video/date/time/temperature/location) (Bridges and Noss, 2011). A number of recent studies have demonstrated the utility of this technique to quantify the activity patterns of target species (Gerber, Karpanty & Randrianantenaina, 2012; Ikeda et al., 2015; Xue et al., 2015; Bu et al., 2016; Frey et al., 2017; Blake and Loiselle, 2018; Bohm and Hofer, 2018). Resulting data stemming from this method can provide detailed biological information on seasonal activity patterns throughout the year under natural conditions.

Takins (*Budorcas taxicolor*) are gregarious bovid herbivores comprised of four subspecies that reside in steep and dense montane regions of central and southeastern China, with two of the four subspecies extending into Bhutan, northeast India and northern Myanmar (Wu, 1986; Sangay, Rajaratnam & Vernes, 2016). All four subspecies are listed as Vulnerable by the IUCN red list due to their limited geographic range, over-hunting, deforestation, and habitat loss (Song, Smith & MacKinnon, 2008). Over the past few decades, the Chinese government has implemented numerous conservation programs, including the Grain-to-Green program and the Natural Forest Conservation Program (Li et al., 2013; Zhang et al., 2007), to protect and improve habitats for native wildlife. At present, most of the known pre-existing key threats for the species have been mitigated, and populations are beginning to increase (Yuan & Sun, 2007). To date, previous behavioral studies of the species have included home range size (25-98 km^2; Guan et al., 2015), feeding type (grazing on non-woody grasses, forbs and bamboo leaves; Schaller et al., 1986; Zeng et al., 2001a, 2001b), the time of licking salt (usually occurs at 06:30-08:00 and 19:00-20:00; Ge and Hu, 1988), determination of rutting season (occurs in summer and calves are born in winter; Wang et al., 2006), diurnal activity rhythms and time budgets (Zeng et al., 2001; Chen et al., 2007; Powell et al., 2013), and seasonal migrations (found to be along altitudinal gradients; Ge et al., 2011; Guan et al., 2013). However, the majority of past takin behavioral studies have monitored over only relatively short time periods (e.g. a single season), and data on seasonal and diel activity patterns are still lacking. Broadly, little remains known about temporal and spatial activity patterns of takins and current literature is sparse despite is necessity in effective species conservation.

The activity pattern of golden takins (*B. t. bedfordi*) is a fundamental behavior that has received relatively little attention *in situ* due to the inherent difficulty in accessing location and terrain. In this study, we conducted an intensive long-term camera trapping effort in Changqing National Nature Reserve to survey the activity patterns of golden takins with the following objectives: (1) elucidate seasonal spatial distribution; (2) determine seasonal migration patterns; and (3) examine daily, seasonal, and annual activity patterns. Our results allow for an accurate description of the spatial-temporal activity patterns of the species, which can be used to guide species management.

Materials & Methods

Study sites

The study area is in the Changqing National Nature Reserve (107°25′to 107°45′ E, 33°26′to 33°43′ N). Changqing Reserve was established in 1994, selected as the first checklist of the IUCN green list of protected areas in 2014 (https://www.iucn.org/theme/protected-areas), and further upgraded to a National Park in 2017. The reserve is located on the southern slopes of the Qingling mountains in southwest China, and serves to provide protection for the giant panda (*Ailuropoda melanoleuca*), golden monkey (*Rhinopithecus roxellarae*), and other sympatric species in addition to the golden takin. The diverse habitats present support a large number of wildlife. Among species present, 10 are listed as Class I state key protected wild animals in China and 52 as class II. An isolated subspecies of takins, golden takins reside the Qinling mountains (Appendix I). The area serves as the northern most range of the species, with approximately 5, 000 individuals present in total (Forestry Bureau of Shaanxi Province, 2001). Approximately 400 individuals inhabit Changqing National Nature Reserve (Yuan & Sun, 2007). The reserve covers an area of approximately 299.06 km^2, with elevations ranging from 800 to 3,000 m. The average annual temperature is 7.26 °C and the average annual rainfall is 813.9 mm. According to local weather data, June through August is the warmest and wettest period, which we termed summer, and December through February is the driest and coldest period, here termed winter, with March through May and September through November forming the seasons of spring and autumn, respectively (Ren, Yang & Wang, 2012). Vegetation in the study area varies with elevation (Figure 1). Deciduous broadleaf forest are mainly found at lower elevation, and the overstory is dominated by oak (*Quercus spp.*), poplar (*Populus spp.*), birch (*Betula spp.*), Bashania bamboo (*Bashania fargesii*). Shrubs form the understory. Mixed broadleaf-conifer forest are found at mid-elevation, and is dominated by Farges fir (*Abies fargesii*) and

Chinese larch (*Larix chinensis*), while Bashania bamboo with birch are intermixed. Coniferous forest interspersed with some subalpine shrubs and meadows are found at high elevation. Farges fir, arrow bamboo (*Fargesia spathacea*) and herbaceous plants are common in these zones.

Data collection

We used 100 infrared cameras (Ltl-6210; Shenzhen Ltl Acorn Electronics Co. Ltd) to survey golden takins in Changqing National Nature Reserve from April 2014 to October 2017. A simple random design (see Wearn and Glover-Kapfer, 2017) was used to survey the species. The reserve was divided into 4 km^2 blocks using ArcGIS 10.1 (ESRI Inc., Redlands, CA) (total of 118 blocks; cell size 2 km×2 km, Figure 1). Each block was then divided into four smaller cells (cell size 1km×1km). One infrared camera was placed in each cell for 4 to 6 months, then moved to an adjacent cell within the same block with >300 m spacing maintained between cameras. Due to harsh terrain leading to difficult navigation in the field, two or more cameras were occasionally placed in one cell. A total 620 sites were surveyed, representing 90 blocks total (approximately 76% of all blocks). Of these 620 sites, 47 failed due to camera damage, malfunction, and loss, resulting in 573 sites for data analysis.

Infrared cameras were attached to trees at an average height of 50 cm above the ground in areas likely to be used by animals (e.g., water holes, trails) and where signs were present (e.g., faeces) at a distance of 3-8 m away to maximize detection probability and with the aim of obtaining fully body images. Infrared cameras were programmed as follows: mode was set to "Image + Video", the passive infrared sensor was set to moderate, time was set to 24 hours a day with a 2-min delay between photographs. Each trigger resulted in 2 photos and a 15 s video, and each photograph was taken with high-quality full colour resolution of 12 Mpx and video at 1080p resolution. All other default settings were used. Each trigger event automatically collected information on date, time, GPS location and ambient temperature. SD cards and batteries were replaced upon movement of cameras between cells every 4 to 6 months.

Data analysis

We summarized photographs and videos by location, hour, and date at each camera placement site. We considered only independent detections to determine activity patterns. Detections of golden takins were considered independent detections if taken at intervals of >30-min apart (Blake et al., 2011; Li et al., 2010).

The number of effective camera trap days were calculated from the time the camera was placed in operation to the time the last photograph or video was taken if a malfunction occurred (based on date and time stamp).

Spatial analysis- Kernel home range (KHR) estimates using animal locations are the most commonly used approach to quantify an animals' spatial utilization distribution. We used the Animal Movement Analysis Extension (Version 2.0) in Arc View 3.3 (http://www.absc.usgs.gov/glba/gistools/) to determine 50% and 70% (fixed kernel home range method) of camera trapping detected sites to delineate seasonal utilization distribution of all golden takins in Changqing National Nature Reserve. Additionally, we calculated the mean monthly elevation of takins using the number of monthly sites to describe the spatial distribution of the species over time. We interpreted a seasonal change in the spatial distribution of golden takins as evidence of migratory behavior.

We used the percentage of independent detections in each vegetation type, deciduous broadleaved forest, mixed broadleaf-conifer forest and coniferous forest, to compare golden takin vegetation use over seasons (Figure 1).

Temporal analysis- We used Capture Rate (*CR*) to estimate the annual activity pattern of golden takins (Li et al., 2010; Blake et al., 2014). Each camera's independent detections were summed for each month, multiplied by 100, and divided by the number of effective camera trap days for each month, *CR*= No. of independent detections *100 / No. of effective camera trap days. We then calculated *CR* for each camera and each month, and averaged them to estimate a value indicative of annual activity pattern.

All photos recorded date and time. We counted the number of independent detections during each two hour period as an indicator of activity level. We defined two hour time periods based on seasonal changes in sunrise and sunset: e.g. dawn (06:00-08:00 in spring and autumn, 05:30-07:30 in summer, and 07:30-09:30 in winter), and dusk (16:00-18:00 in spring and autumn, 17:30-19:30 in summer, and 15:30-17:30 in winter), and so on. We used a Daily Activity Index (DAI%) of 2-h durations to examine the daily activity patterns: DAI % = No. of independent detections within each 2h period / Total no. independent detections (Li et al., 2010).

Finally, we used a One-Way ANOVA to compare elevational change among months and seasons, and capture rate change among months and seasons. This was followed by a Post Hoc Test (Duncan's Multiple Range Comparison Test) to determine significant differences in elevation between pairs of months or seasons.

Seasonal migration and activity patterns lend themselves particularly well to graphical representation, and thus the interpretation of these data were also drawn on visual inference from boxplots and relative proportions (O'Connell et al., 2011). Data were expressed as Mean ± Standard Error (Mean±SE). Statistical significance was considered at $P < 0.05$. Statistical analyses were performed in SPSS 19.0 (IBM Inc., New York, NY).

Results

1. General summary

Takins were recorded at 382 of the 573 camera trap sites. We obtained 3,323 independent detections (from 12,351 total detections) during a total camera trapping effort of 93,606 effective camera trap days across 573 sites (Table 1 and Figure 1). Golden takins were detected at 234 sites (72 blocks) in spring, 115 sites (53 blocks) in summer, 244 sites (69 blocks) in autumn, and 102 sites (48 blocks) in winter. The number of independent golden takin detections fluctuated, with 1088 independent detections in spring and 1169 in autumn, and a marked reduction in independent detections over summer (686 independent detections) and winter (380 independent detections).

2. Seasonal utilization distribution analysis

The golden takin's utilization distribution size varied widely among seasons (Table 2 and Figure 2). In the spring, the 50 % KHR and 75% KHR utilisation distribution was calculated as 46 km^2 and 113 km^2, respectively. In autumn, the 50 % KHR and 75% KHR was 43 km^2 and 104 km^2, respectively. Golden takin were mainly distributed in mixed broadlef-conifer forest (percentage of independent detections, 40.26% and 40.72%, respectively; Table 3 and Figure 3) and deciduous broadleaf forest (48.35% and 42.00%; Table 3 and Figure 3) in both spring and autumn. The winter 50 % KHR and 75% KHR utilisation distribution declined to 15 km^2 and 67 km^2, with distribution of the species occuring mainly in mixed broadleaf-conifer forest (39.47%), deciduous broadleaf forest (30.79%) and coniferous forest (24.47%). The 50 % KHR and 75% KHR in summer was only12 km^2 and 29 km^2, respectively, and was mainly distributed in coniferous forest (42.57%), mixed broadleaf-conifer forest (34.40%), and deciduous broadleaf forest (19.10%).

3. Seasonal migration

Golden takins were detected at elevations ranging from 985 m to 2,958 m, and exhibited distinct elevational change across months (F=7.31, df=11, P<0.001) and seasons (F=6.23, df=3, P<0.001). Duncan's multiple range test between any two given months and seasons are shown in Table 4. The species was recorded at the highest elevations in July (2079±51 m; Table 4 and Figure 4) and lowest elevations in December (1731±56 m). Seasonal migration patterns were as follows: the first migration occurred from May (1893±32 m) to November (1766±33 m), as takin steadily ascended in elevation until reaching their highest point in July. The second migration occurred from December to February (1771±56 m), with takin moving up from lower elevations from December to mid-elevation where they remained for the month of January (1836±63 m). From February to April, golden takins gradually returned to lower elevation valleys.

4. Daily activity patterns and seasonal differences

Golden takins showed bimodal activity peaks around at dawn and dusk for all four seasons (Table 5 and Figure 5), with activity intensity greater during the second peak (dusk) compared to the first peak (dawn). Lower levels of activity were recorded at night (around 20:00-06:00) relative to daytime. Interestingly, a small number of takins were still locomoting, or engaging in other activities (foraging or mating) at later night time hours (around 23:30-02:00). In spring and autumn, according to the number of independent detections per two hours, golden takins showed bimodal activity peaks around 06:00-08:00 (DAI=10.48% in spring and 12.75% in autumn), with the second peak in spring around 18:00-20:00 (DAI=17.19%) and 2-h earlier (16:00-18:00, DAI=16.85%) in autumn. In summer and winter, golden takins also showed bimodal daily activity patterns with the first peak at 07:30-09:30 (DAI=12.39% in summer and 11.05% in winter) during both seasons, but and the second peak in winter around 15:30-17:30 (DAI=11.05%) and 2-h later (17:30-19:30, DAI=15.45%) in summer.

5. Annual activity pattern

Capture rates differed across months (F=8.46, df=11, P<0.001) and seasons (F=20.73, df=3, P<0.001). Duncan's multiple range test results between any two given months and seasons are showed in Table 1. There were two annual activity peaks of golden takins (Figure 6). The first being in April (CR=6.88±0.91) and the second in November (CR=6.47±1.18). Capture rates from these two months were higher than in other months and exhibited distinct elevational change with other months (Duncan's multiple range test results see Table 1); and activity levels in spring (CR=5.13±0.47) and autumn (CR=5.04±0.43) were higher than in summer (CR=2.23±0.24) and winter (CR=1.79±0.18) (Table 1 and Figure 6). The annual activity pattern was as follows: low levels of activity from January to February with a gradual increase in March followed by a peak in April and gradual decline until low levels were reached again in July. Activity then began to increase and reach another peak in November followed again by a gradual decline.

Discussion

The majority of previous takin activity studies have focused on a single individual's seasonal migration (Ge et al., 2011; Guan et al., 2013). Information on golden takin daily acitivty patterns were limited to direct observation (Zeng et al., 2001a) or ex situ populations (Chen et al., 2007). Our study surveyed golden takins using non-invasive camera trapping continuously from April 2014 to October 2017, covering all four seasons. Our results are the first application of camera traps to elucidate seasonal spatial utilization distribution and vertical migration, and the daily, seasonal and annual activity patterns of golden takins at a population level.

Daily activity patterns are often driven by circadian rhythms and periodic changes in environmental stimuli (Aschoff, 1966). Animals may optimize time for different activities, and distribute those activities during a 24-h cycle (Fernandez-Duque, 2003). Golden takins exhibited bimodal activity peaks at dawn and dusk, similar to previous findings from radio-collared takins (Zeng & Song, 2001). Peak activity occurred at dawn and dusk when temperatures were relatively cool with low humidity, and these periods were spent foraging and moving slowly (Zeng and Song, 2001; Chen et al., 2007). Peaks in rumination behavior often occurred adjacent to peaks in foraging behavior from 10:00 to 16:00 and rumination was often accompanied with resting. Golden takins may lay under tall trees or stone cliffs, overall reducing their movement and energy expenditure during these periods (Zeng & Song, 2001; Chen et al., 2007). However, some lower levels of activity may still be present. For example, we found that most golden takins rested between 00:00 to 02:00 at night, but lower degree active behaviors were still observed. Previous studies have indicated that there may be a sentry system that exists in some populations during these periods (Wu, Han & Qu, 1990).

According to our analysis, the annual activity patterns of golden takins are consistent with seasonal vertical migration and reproductive periods. Golden takins were recorded at a lower frequency during calf-rearing months (February to March). During this time, females spend time with their young, and males stay nearby to assist (Wang et al., 2005, 2006). From June to August, when golden takins were observed in larger groups at higher altitudes and engaging in rutting behavior, the utilisation distribution of activities was lower (Guan et al., 2012). During migration months (from mid-April to early June), the activities of golden takins were quite evenly distributed and capture rates increased again in October to November, which could be related to a greater effort needed to forage (Zeng et al., 2010). Seasonal utilisation distribution of golden takins are also consistent with seasonal migration, as spring and autumn showed larger kernal home ranges than summer and winter.

Seasonal migration is a common survival strategy that allows grazing ungulates to optimize living conditions throughout the year (Gwynne and Bell, 1968; Pettorelli et al., 2007). We found that seasonal migration patterns of golden takins were relatively complicated, with movement from high-elevation meadows in summer to mid-elevation fir forest and bamboo in winter, and low-elevation valleys in spring and autumn. This migration pattern was similar to a previously completed study (Zeng et al., 2008). Seasonal temperature shifts and changes in plant phenology and its influence on food resources are the likely key forces driving golden takin migration (Zeng et al., 2001b). Golden takins gradually descended to lower-elevation presumbly in response to the first greening of vegetation within the valley to replenish energy after the cold winter. The species next ascended to higher-elevations in summer as more nutritious foraging became available. In addition, the cooler environment afforded at high-elevations brings about fewer biting insects and safer mating places (Wu, Han & Qu, 1990; Zeng et al., 2010). Colder weather, and the senescence of vegetation in high-elevation areas would then force the species to return to lower-elevation ranges in autumn in search of unwithered forage to accumulate energy for the coming winter. However, the golden takin's seasonal migration from autumn to winter was not consistent with observed temperature changes. This could be due to the availability of bamboo and fir forest to use the bamboo at mid-elevations, and the forest acting as a thermal shelter from heavy snow and cold wind. In addition, selection for mid-elevation areas with high solar radiation could be a strategy of thermal adaptation during winter (Zeng et al., 2008; Zeng et al., 2010; Guan et al., 2012). The underlying mechanisms and signals that initiate seasonal migrations are not yet fully understood and require further study.

As a flagship species in China, golden takins are a heavy focus of conservation efforts. The government of China has listed golden takins in the key program of biodiversity conservation (Minstry of Environment Protection, 2011), and will establish a national park intended to protect the species in the Qinling mountain range (State Forestry and Grassland Administration, 2019). Previous studies have documented that golden takins only reside at elevations higher than 1,360 m in Qinling mountain (Wu, Han & Qu, 1990; Zeng et al., 2008). However, our camera traps detected a lower elevation for golden takin's distribution (985 m vs. 1360 m). This change may be due to the implementation of conservation programs that have returned low-elevation farmland to forests. Consequently, we propose to further investigate the golden takins' migration routes in low-elevation areas and call for the inclusion of these elevational ranges in the proposed national park plans.

Human presence and lower quality habitat will most likely create conservation challenges for golden takins (Zeng et al., 2008). While it is unclear if human activities affect the species' seasonal migration, the daily life of local villagers is closely linked to reserve resources (e.g. collecting bamboo, and harvesting mushrooms and herbs). Golden takins may also forage and damage local agricultural crops (e.g., wheat, lettuce) in low-elevation areas, where local villagers keep domestic dogs (*Canis lupus familiaris*), creating many potential sources of conflicts between humand and takins. Our camera traps detected domestic dogs frequently in the forest, indicating that predation pressure on golden takin calves could be present. Consequently, we recommended that management programs focus on regulating human behavior to avoid conflicts (e.g., tying domestic dogs, changing crop types). In addition, diseases such as conjunctivitus (pinkeye) and tumour growth were first seen on a video of golden takins capture in this study (Appendix I), showcasing the need for epidemeological studies to be carried out with the species. These many knowledge gaps and potential risks to species preservation warrant the establisment of long-term monitoring programs that regularly assess the advancement of ongoing threats to the species.

We contend that our study had some limitations. First, gaps in camera placement were present due to the difficultly in navigating remote areas of the study site. This may result in detection error, whereby golden takin may have been present at these sites regardless of our ability to survey them. However, our field survey still covered 76% of the study area, a sizable portion of the intended land mass, and our activity pattern results were consistent with past tagging methods (Zeng & Song, 2001; Zeng et al., 2008) not subject to detection error. On the opposing side, detection probability aggregated across an array of cameras may increase the rate of double detection, leading to inaccurate conclusions surrounding population abundance, behavior (e.g. habitat selection, migration routes, home range, and inter-specific interactions) and distances between camera sightings (Ikeda et al., 2016). Double counting, if it occurred, would not be of concern in this study as we focused on questions surrounding activity as opposed to abundance. Accounting for imperfect detection in camera traps surveys of unmarked species is difficult, and identifying individuals, sex and age classes from camera trap images can be challenging. We submit that a combination of techniques such as telemetry and direct observations will be required to supplement studies susceptible to detection error.

Conclusions

Our study systematically surveyed golden takin activity across all seasons using infrared camera trapping. Results herein represent the first application of camera traps to elucidate seasonal spatial utilization distribution and vertical migration, as well as the daily, seasonal and annual activity patterns of golden takins at a population level. Our findings suggest that the proposed national park should be designed to include golden takin habitat extending to elevations as low as 985 m and that ongoing consistent monitoring efforts will be crucial to mitigating novel and ongoing threats to the species.

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Table 1 (on next page)

A summary of the no. of effective camera days, no. of independent detections, mean monthly capture rate and mean quarterly capture rate.

Data are expressed as Mean ± Standard Error (Mean±SE), superscript letters represent significant ($P<0.05$) differences between groups. We defined seasons as spring (March-May), summer (June-August), autumn (September-November), and winter (December-February).

Table 1

Month	No. of independent detections	No. of Effective camera days	Mean monthly capture rates (Mean±SE)	Mean quarterly capture rates (Mean±SE)
Mar	193	6642	(2.77±0.39)[abc]	
Apr	505	7169	(6.88±0.91)[e]	(5.13±0.47)[a]
May	390	9412	(4.32±0.62)[bc]	
Jun	261	9111	(2.51±0.53)[ab]	
Jul	168	9203	(1.74±0.33)[a]	(2.23±0.24)[b]
Aug	257	8959	(2.41±0.38)[ab]	
Sep	387	8435	(4.66±0.59)[cd]	
Oct	400	8541	(4.33±0.44)[bc]	(5.04±0.43)[a]
Nov	382	6844	(6.47±1.18)[de]	
Dec	170	6831	(2.33±0.39)[ab]	
Jan	96	6740	(1.36±0.24)[a]	(1.79±0.18)[b]
Feb	114	6099	(1.69±0.29)[a]	
□	3323	93606	F=8.46, df=11, P=0.000	F=20.73, df=3, P=0.000

Note: Mean separation within columns by Duncan's multiple range test at $P<0.05$.

Table 2(on next page)

Seasonal utilization distribution using Kernal home range estimates (KHR) of golden takins in Changqing National Nature Reserve.

Table 2

	50% Utilization distribution (km^2)	75% Utilization distribution (km^2)
Spring	46	112
Summer	12	29
Autumn	43	104
Winter	15	67

Table 3(on next page)

Percentage of independent detections of golden takins in different vegetation types across four seasons in Changqing National Nature Reserve.

1 **Table 3**

Vegetation types	No. of independent detections (%)			
	spring	summer	autumn	winter
Meadow	2(0.18%)	22(3.21%)	3(0.26%)	0(0%)
Shrub forest	3(0.28%)	1(0.15%)	6(0.51%)	1(0.26%)
Arrow bamboo	6(0.55%)	4(0.58%)	17(1.45%)	19(5.00%)
Deciduous broadleaf forest	438(40.26%)	131(19.10%)	476(40.72%)	117(30.79%)
Coniferous forest	113(10.39%)	292(42.57%)	176(15.06%)	93(24.47%)
Mixed broadleaf-conifer forest	526(48.35%)	236(34.40%)	491(42.00%)	148(39.47%)
Total	1088	686	1169	380

2

Table 4(on next page)

A summary of no. of monthly and quarterly sites, mean monthly elevation and quarterly elevation.

Data are expressed as Mean ± Standard Error (Mean±SE). The different superscript letters represent the significant ($P<0.05$) differences found between groups.

Table 4

Season	Month	No. of monthly sites	Mean monthly elevation (Mean±SE) (m)	No. of quarterly sites	Mean quarterly elevation (Mean±SE) (m)
	Mar	74	(1742±44)[a]		
Spring	Apr	146	(1753±24)[a]	234	(1789±22)[a]
	May	97	(1893±32)[bc]		
	Jun	59	(2036±50)[de]		
Summer	Jul	50	(2079±51)[e]	115	(1945±34)[b]
	Aug	72	(1944±38)[cd]		
	Sep	115	(1887±30)[bc]		
Autumn	Oct	143	(1872±27)[abc]	244	(1806±22)[a]
	Nov	118	(1766±33)[ab]		
	Dec	49	(1731±56)[a]		
Winter	Jan	52	(1836±63)[abc]	102	(1755±41)[a]
	Feb	60	(1771±56)[ab]		
Total		1035	F=7.31, df=11, P=0.000	695	F=6.23, df=3, P=0.000

Note: Mean separtion within columns by Duncan's multiple range test at P<0.05

Table 5(on next page)

Seasonal patterns of the daily activity of golden takins.

Table 5

Hour of day	Spring	Autumn	Hour of day	Summer	Winter
00:00-02:00	6.25%	5.39%	23:30-01:30	3.35%	6.05%
02:00-04:00	5.79%	3.51%	01:30-03:30	2.62%	3.95%
04:00-06:00	4.50%	2.57%	03:30-05:30	3.35%	1.58%
06:00-08:00	10.48%	12.75%	05:30-07:30	11.66%	2.89%
08:00-10:00	8.55%	12.15%	07:30-09:30	12.39%	11.05%
10:00-12:00	7.63%	9.15%	09:30-11:30	7.00%	9.21%
12:00-14:00	7.26%	9.24%	11:30-13:30	11.37%	10.79%
14:00-16:00	10.94%	13.86%	13:30-15:30	9.48%	15.26%
16:00-18:00	14.06%	16.85%	15:30-17:30	14.29%	20.53%
18:00-20:00	17.19%	8.64%	17:30-19:30	15.45%	14.21%
20:00-22:00	2.76%	1.71%	19:30-21:30	6.41%	1.32%
22:00-24:00	4.60%	4.19%	21:30-23:30	2.62%	3.16%

Figure 1

The Changqing National Nature Reserve is located in central China (A) and primarily consists of deciduous broadleaf forest, conifer forest, and mixed forest (B).

Forest types are driven by elevation, which ranges from 800 to 3,000m. Camera traps were deployed within a series of 2 kmx2 km blocks.

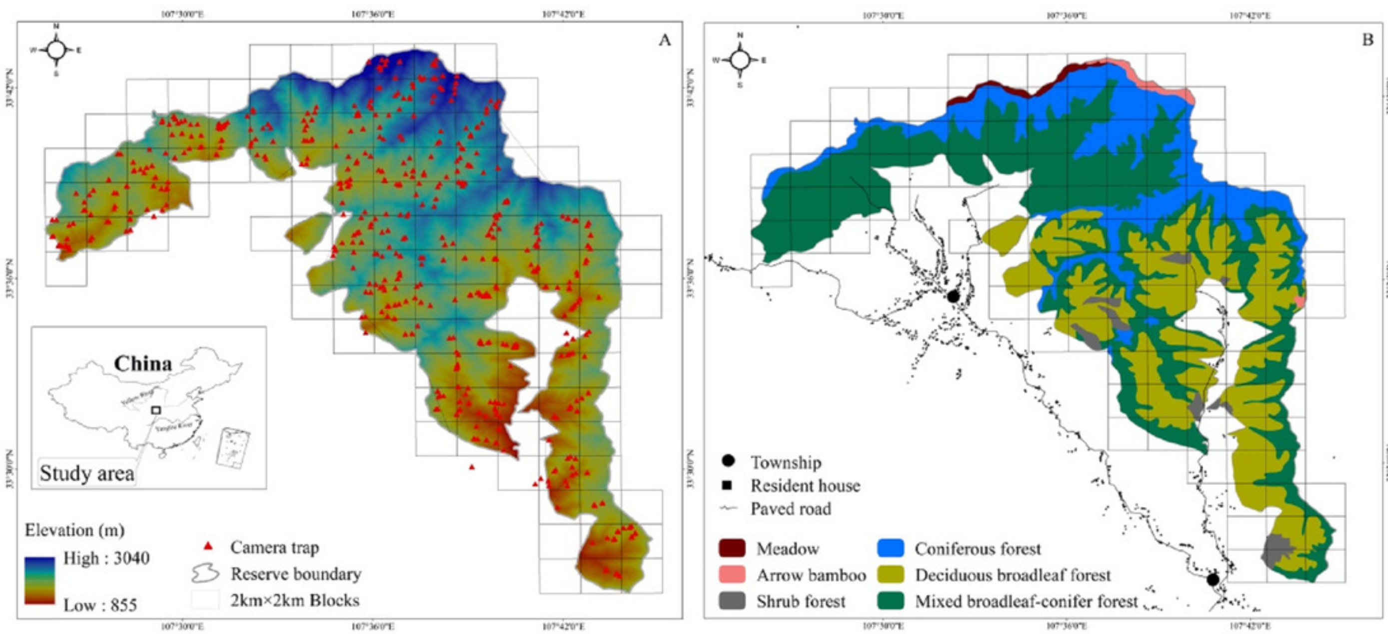

Figure 2

Seasonal differences in the number of independent detections of golden takins in the study area.

The black point represents the centre of the block, and shows its respective total number of detections. Utilization distribution of golden takins at 75% and 50% Kernal home range estimates from camera trapping during spring (A) autumn (B) summer (C) and winter (D).

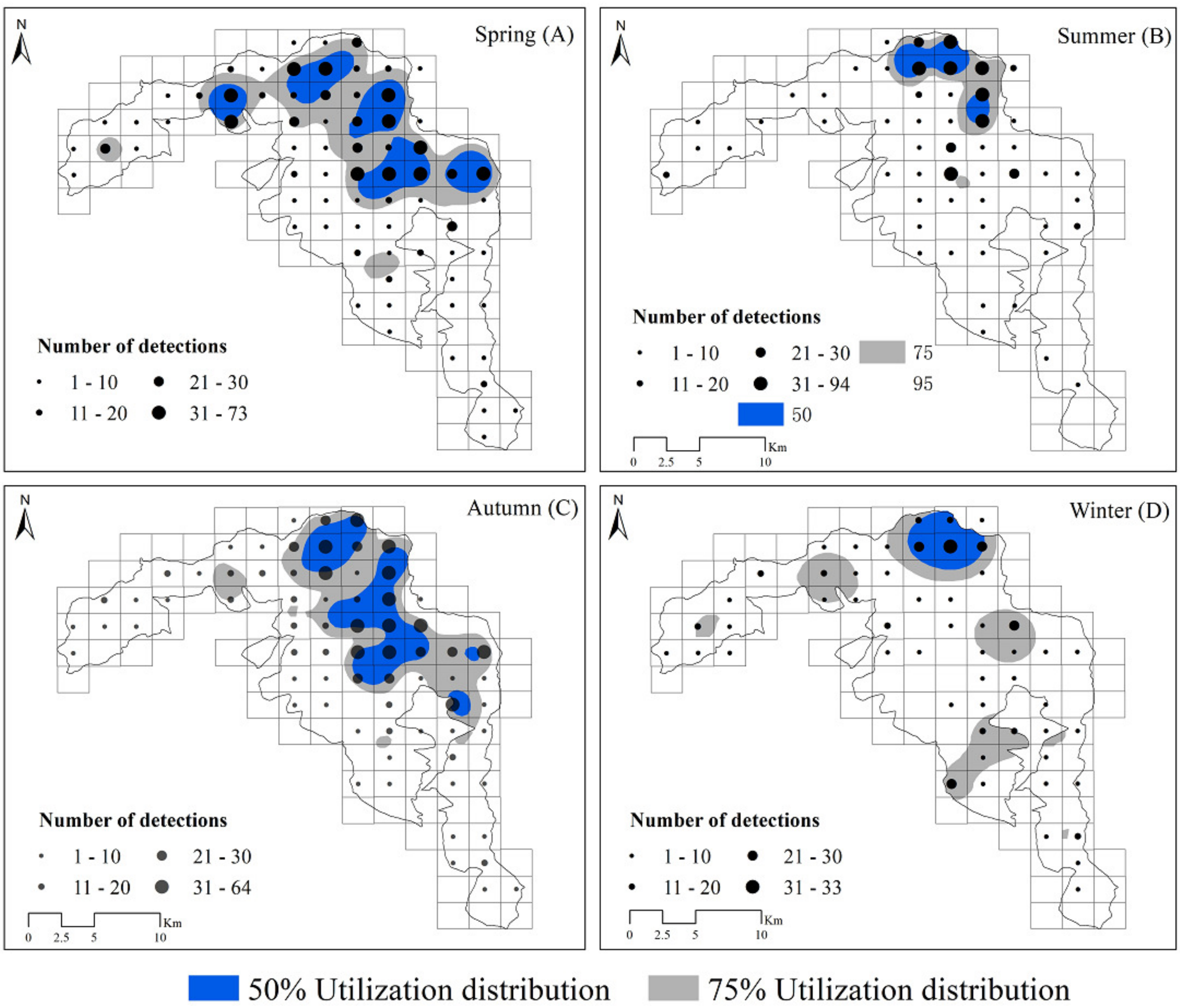

Figure 3

The percentage of independent detections of golden takins in different vegetation types across seasons.

Vegetation types in the study area included deciduous broadleaved forest, mixed broadleaf-conifer forest and coniferous forest, shrub forest, meadow, and arrow bamboo.

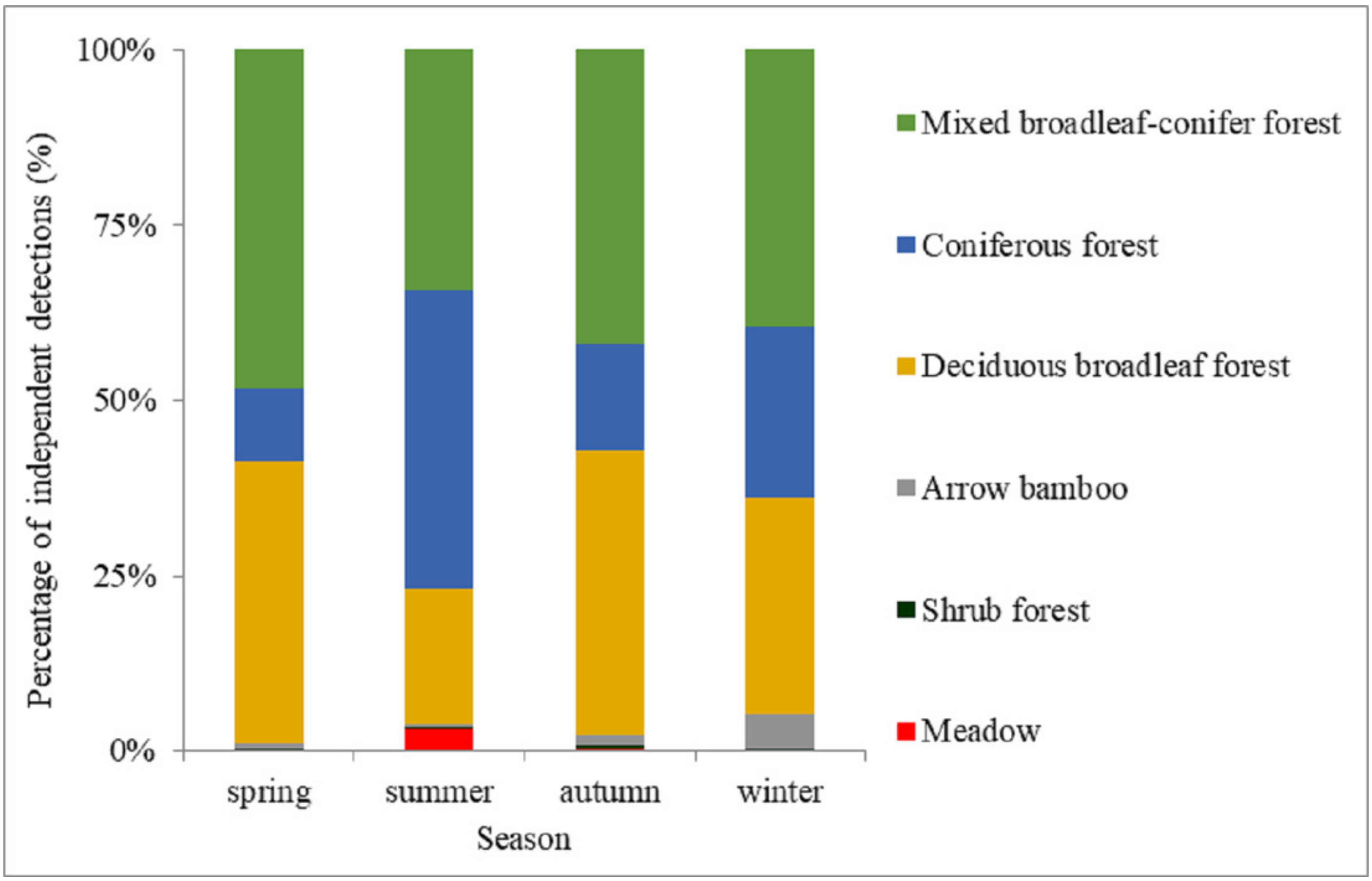

Figure 4

The seasonal elevation distribution of golden takins.

Bars represent medians, boxes represent interquartile ranges, and whiskers are ranges.

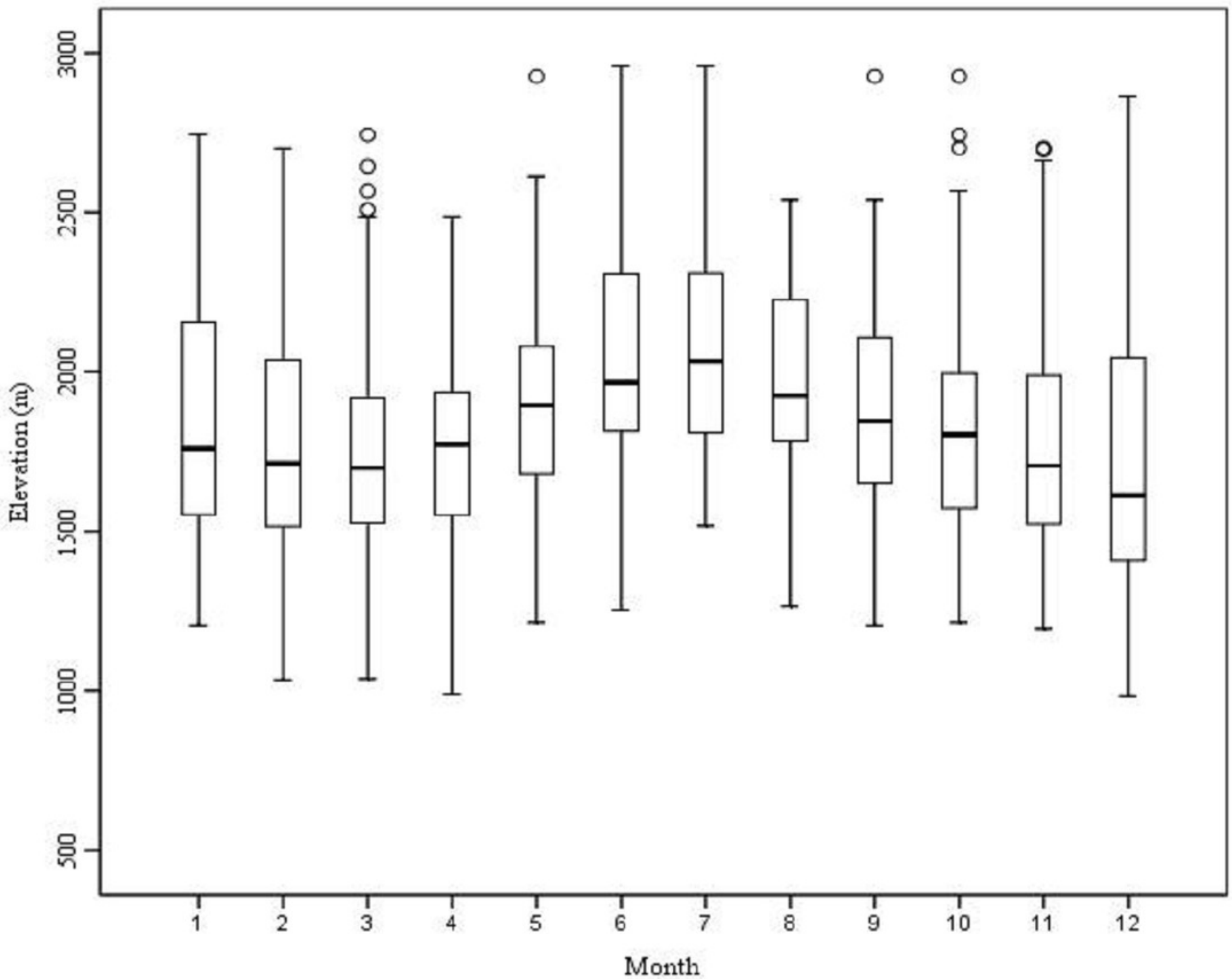

Figure 5

Seasonal patterns of the daily activity of golden takins.

Golden takins showed bimodal activity peaks at dawn and dusk for all four seasons, and activity intensity of the second peak was higher compared to the first peak. The grey shaded areas indicate night-time hours. DAI (daily activity index) %= No. of independent detections within each 2h period / Total no. independent detections.

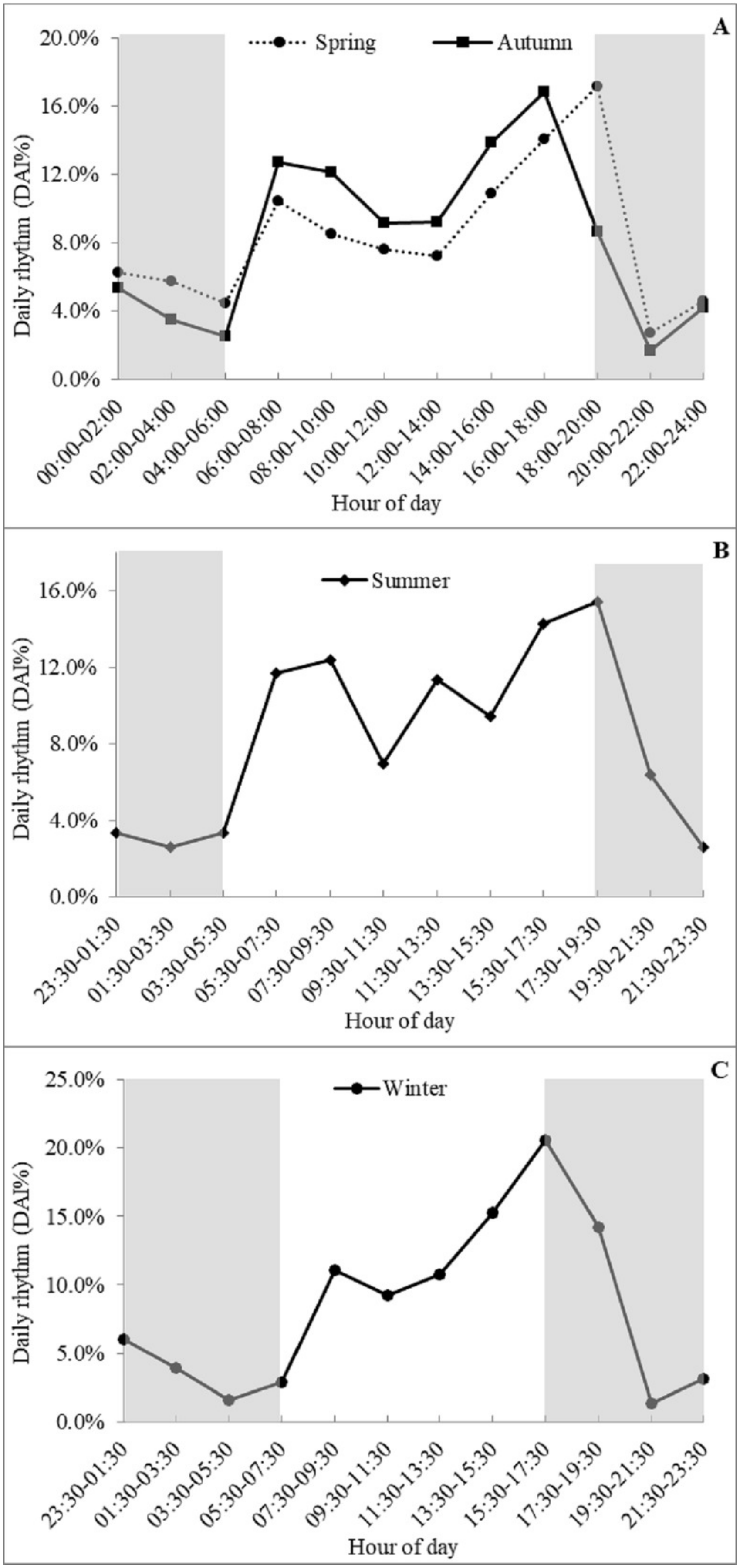
A
Spring
Autumn
20.0%
16.0%
12.0%
8.0%
4.0%
0.0%
Daily rhythm (DAI%)
00:00-02:00
02:00-04:00
04:00-06:00
06:00-08:00
08:00-10:00
10:00-12:00
12:00-14:00
14:00-16:00
16:00-18:00
18:00-20:00
20:00-22:00
22:00-24:00
Hour of day
B
Summer
16.0%
12.0%
8.0%
4.0%
0.0%
Daily rhythm (DAI%)
23:30-01:30
01:30-03:30
03:30-05:30
05:30-07:30
07:30-09:30
09:30-11:30
11:30-13:30
13:30-15:30
15:30-17:30
17:30-19:30
19:30-21:30
21:30-23:30
Hour of day
C
Winter
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
Daily rhythm (DAI%)
23:30-01:30
01:30-03:30
03:30-05:30
05:30-07:30
07:30-09:30
09:30-11:30
11:30-13:30
13:30-15:30
15:30-17:30
17:30-19:30
19:30-21:30
21:30-23:30
Hour of day

Figure 6

The annual activity patterns of golden takins in the study area over a period of 12 months.

There were two annual active peaks. The first in April (*CR*=6.88±0.91) and the second in November (*CR*=6.47±1.18). *CR*= No. of independent detections * 100 / No. of effective camera days.