Relative Abundance of Mammals and Estimation of Minimum Trapping Effort Using Camera Traps in Jangsudae, Seoraksan National Park

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Original paper

Relative abundance of mammals and estimation of minimum trapping effort using camera traps in Jangsudae, Seoraksan National Park

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Abstract. In Jangsudae of Seoraksan National Park, South Korea, 14 mammal species have been listed, including ten medium- and large-sized species; additionally, this region is an important habitat for the endangered long-tailed goral (*Naemorhedus caudatus*). In this study, a camera trap survey was conducted over 103 monitoring days at 18 sites in Jangsudae to evaluate the minimum trapping effort (MTE) needed to detect the ten listed mammal species. The most photographed species were the long-tailed goral, wild boar (*Sus scrofa*), and Asian badger (*Meles leucurus*), accounting for 77.1% ($n = 366$) of the total independent photographs. Long-tailed goral, the most frequently captured mammal species (44.8%), was captured at 17 camera sites (relative abundance index = 206.8). According to the rarefaction analysis, 1840 camera days (102.2 monitoring days at 18 camera sites) were required to photograph all ten resident species. Moreover, at least 1010 and 664 camera days were required to detect 95% and 90% of the ten residential species, respectively. MTE was evaluated in summer when wild species were highly detectable owing to their high activity. Future studies should evaluate MTE through one-year long-term monitoring that includes all four seasons, and compare the results with those of this study.

Key words: camera trapping, large terrestrial mammals, long-tailed goral, rarefaction analysis, species richness.

Camera trapping is an essential tool to directly observe wild animals in their various habitats (Cutler and Swann 1999; Silveira et al. 2003; O’Connell et al. 2011) and it is presently a commonly used method in mammalian studies (Rovero and Marshall 2009). Cameras traps can assist in estimating the population size of animals having specific spot patterns or other morphological features (Kelly 2001; Karanth et al. 2006; Kittle and Fernando 2017), and in acquiring the activity patterns (Giman et al. 2007; Kim 2018; Lee et al. 2019; Ríos-Solís et al. 2021) and habitat preferences of wildlife (Lee and Song 2008; Wang and Macdonald 2009; Cho et al. 2015). Additionally, camera traps have been used to identify the age of the endangered long-tailed gorals (*Naemorhedus caudatus*), based on the horn shape and horn ring patterns (Kim et al. 2020).

Among the analytical methods used for assessing camera-trap data, relative abundance index (RAI) measures the relative abundance per 100 days of camera capture for each species (O’Brien et al. 2003; Henschel et al. 2011; Palmer et al. 2018). Analytical methods for quantifying relative abundance differences based on RAI are relatively economical and simple, and can estimate the abundance of species that lack specific morphological characteristics (O’Brien et al. 2003; Jenks et al. 2011; O’Brien 2011; Ancrenaz et al. 2012). Further, RAI can be used to conserve and manage wildlife at the regional level, as it tends to be linearly correlated with the overall abundance (Caughley 1977; Jennelle et al. 2002; O’Brien et al. 2003; Sollmann et al. 2013; Srbek-Araujo and Chiarello 2013; Palmer et al. 2018).

In Korea, camera traps have been widely used for wildlife surveys and monitoring in national parks (Chung et al. 2014; Shin et al. 2016; Choi et al. 2020). In Jirisan National Park, the appearance frequency of 17 wild animal species (12 birds and five mammals) was calculated using RAI (Woo et al. 2013). Moreover, in Bukhansan

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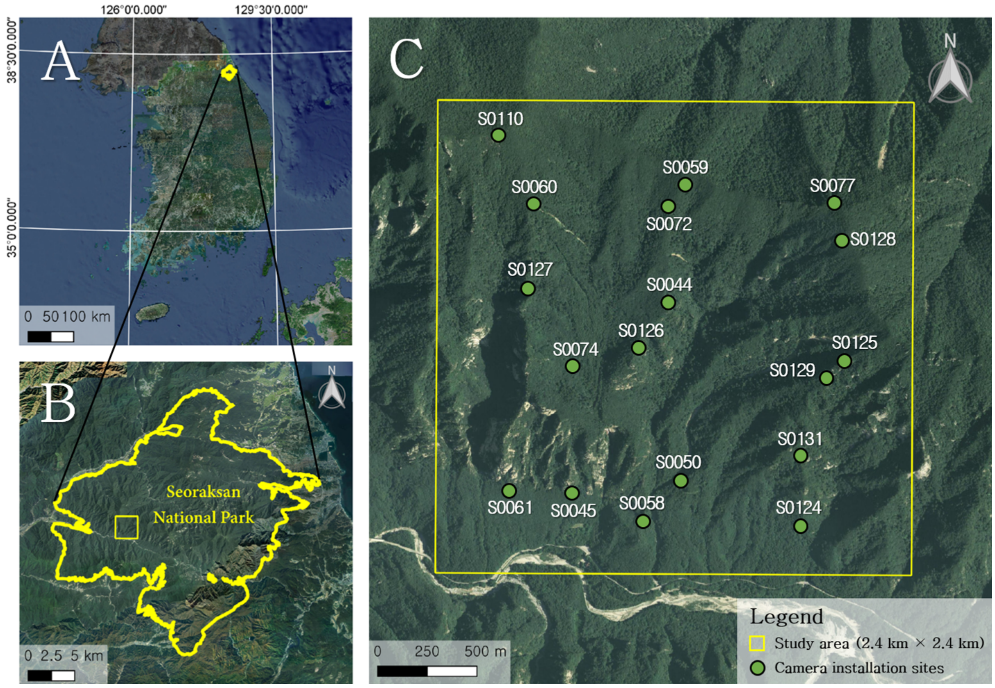

Fig. 1. Survey area and camera installation sites. (A) Seoraksan National Park in South Korea, (B) Jangsudae (square box) on the western side of Seoraksan National Park, and (C) locations of 18 camera sites in Jangsudae. This figure was created using QGIS.

National Park, the appearance frequency of nine mammal species was compared using RAI between 22 forests and two forest wetlands (Kim et al. 2021).

With their increasing use, the efficiency of camera traps, such as the number of cameras and the length of camera operation, has received increasing attention (Si et al. 2014; Xu et al. 2014; Huarcaya et al. 2019). The application of an efficient camera trap can be estimated using the minimum trapping effort (MTE) method, which calculates the optimal number of cameras and operation periods based on their relationship with each other (Si et al. 2014; Xu et al. 2014). Thus, the MTE method can be used to design an efficient operation plan for a camera trap survey. Additionally, the efficiency of camera trapping can be estimated if all species in the survey area are listed.

In South Korea, 22 national parks exist including 19 terrestrial national parks and three marine national parks (Kang and Jeong 2016), and wild species are surveyed in each of these national parks every five years (Shin et al. 2016). Recently, camera traps have been used for wildlife surveys in parks (Chung et al. 2014). Despite their popularity, efforts to offer guidelines for an efficient study design for camera trapping are scarce. Understanding the efficiency of camera operation during wildlife surveys in national parks is thus necessary. Accordingly, this study aimed to determine the relative abundance of medium to large terrestrial mammals in the Jangsudae area of Seoraksan National Park and estimate the optimal operating period and number of camera sites required to identify the mammalian diversity.

Materials and methods

Study site and mammal diversity

The survey area, Jangsudae, is located on the western side of the Seoraksan National Park. In total, 18 cameras were installed at random intervals of 300–500 m within the survey area of 5.76 km^2 (2.4 × 2.4 km). Camera installation sites were selected in areas where traces of wild animals were frequently observed (Fig. 1).

The terrain of Jangsudae has an average slope, altitude, and aspect of 25.3°, 883.6 m, and 194.4°, respectively (Shin et al. 2016). The average age of the forest is 3.2 age class, and the forest type consists of 18% coniferous forest, 58% hardwood forest, and 24% mixed forest (Shin et al. 2016). Owing to the high habitat density of the endangered long-tailed gorals in Jangsudae, this area needs to be protected and efficiently managed.

Of the 125 species of mammals inhabiting the Korean Peninsula, ten medium- and large-sized mammalian species have been listed in Jangsudae, namely, the raccoon dog (*Nyctereutes procyonoides*), Asian badger (*Meles leucurus*), Siberian weasel (*Mustela sibirica*), wild boar (*Sus scrofa*), water deer (*Hydropotes inermis*), Siberian roe deer (*Capreolus pygargus*), Korean hare (*Lepus coreanus*), and three endangered species, leopard cat (*Prionailurus bengalensis*), yellow-throated marten (*Martes flavigula*), and long-tailed goral (Choi et al. 2020).

Camera trapping

The participants installed 18 cameras for three days from July 7 to 9, 2016, and the corresponding camera data were recovered on October 18, 2016. Each camera was operated for 103 days and the cameras (Moultrie's M-990i and SPYPOINT Force-12 models) featured a motion sensor (passive infrared; PIR) that automatically captured wild animals when they passed in front of the camera. PIR sensors detect the difference between the ambient background temperature and the rapid change in heat caused by an animal's presence. To photograph medium- and large-sized mammals, cameras were installed on trees at heights of 0.7–1.2 m above the ground and the direction of the camera lens was adjusted to observe the front of the ground. To maximize the chances of capturing animals on cameras, the cameras were installed on animal trails or places where excrement had been found. The interval for capturing photographs was three consecutive photographs with a time delay of 1 min. Some species can be caught by a camera multiple times as they move slowly at a camera site, resulting in dozens of photographs of the same individual (Kauffman et al. 2007). To exclude the effect on RAI values in which one object is captured repeatedly (Otis et al. 1978; O'Brien et al. 2003; Li et al. 2010), independent photographs were created through deduplication. The proportion of independent photographs refers to the percentage of photos that were deduplicated out of the total number of shots (see Table 1; PI). According to Si et al. (2014), a common resident species is defined as a proportion of independent photographs greater than 1% (column PI in Table 1). By classifying common resident species, species that frequently appeared in cameras installed in the survey area could be identified. The proportion of common resident species refers to the ratio of the number of common species / total number of species. In this study, the proportion of common resident species was 0.7, as seven out of the total ten medium- and large-sized mammal species had a proportion of independent photographs exceeding 1%.

Table 1. List of mammals in the Jangsudae of Seoraksan National Park

Order/Family	Common name	Scientific name	RP	IP	PI	S0110	S0060	S0127	S0074	S0061	S0045	S0058	S0050	S0126	S0044	S0072	S0059	S0124	S0131	S0129	S0125	S0128	S0077	Total (%)
Artiodactyla																								
Suidae	Wild boar	*Sus scrofa*	279	96	20.21	0.0	6.3	0.0	4.2	12.5	20.8	7.3	6.3	1.0	0.0	0.0	7.3	4.2	1.0	3.1	5.2	13.5	7.3	100
Cervidae	Water deer	*Hydropotes inermis*	96	39	8.21	0.0	2.6	0.0	2.6	0.0	2.6	23.1	12.8	5.1	0.0	0.0	23.1	0.0	0.0	0.0	2.6	23.1	2.6	100
	Siberian roe deer	*Capreolus pygargus*	81	42	8.84	0.0	2.4	0.0	0.0	14.3	16.7	9.5	21.4	0.0	0.0	0.0	2.4	0.0	0.0	0.0	2.4	19.0	11.9	100
Bovidae	Long-tailed goral	*Naemorhedus caudatus*	881	213	44.84	1.9	4.2	9.9	4.2	6.1	10.3	1.9	6.1	5.6	3.8	7.0	1.4	4.2	3.3	14.1	10.8	5.2	0.0	100
Carnivora																								
Canidae	Raccoon dog	*Nyctereutes procyonoides*	3	2	0.42	0.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	0.0	100
Mustelidae	Asian badger	*Meles leucurus*	107	57	12.00	0.0	3.5	0.0	17.5	14.0	29.8	12.3	0.0	0.0	0.0	1.8	8.8	0.0	0.0	1.8	8.8	1.8	0.0	100
	Siberian weasel	*Mustela sibirica*	7	6	1.26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	16.7	0.0	66.7	0.0	0.0	100
	Yellow-throated marten	*Martes flavigula*	5	3	0.63	0.0	0.0	0.0	0.0	0.0	0.0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
Feildae	Leopard cat	*Prionailurus bengalensis*	21	16	3.37	0.0	0.0	0.0	0.0	6.3	43.8	12.5	0.0	0.0	0.0	6.3	0.0	0.0	0.0	0.0	6.3	25.0	0.0	100
Lagomorpha																								
Leporidae	Korean hare	*Lepus coreanus*	1	1	0.21	0.0	0.0	0.0	0.0	0.0	0.0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
Total			1481	475	100																			

RP, recoded photographs (n = 1481); IP, independent photographs (n = 475); PI, proportion of independent photographs (%).
Value in the columns for each camera trap indicates the proportion of the animals taken in each camera trap.
The total number of RP in the table is 1481 medium- and large-sized mammalian photos of 1916 photos, including small mammals.

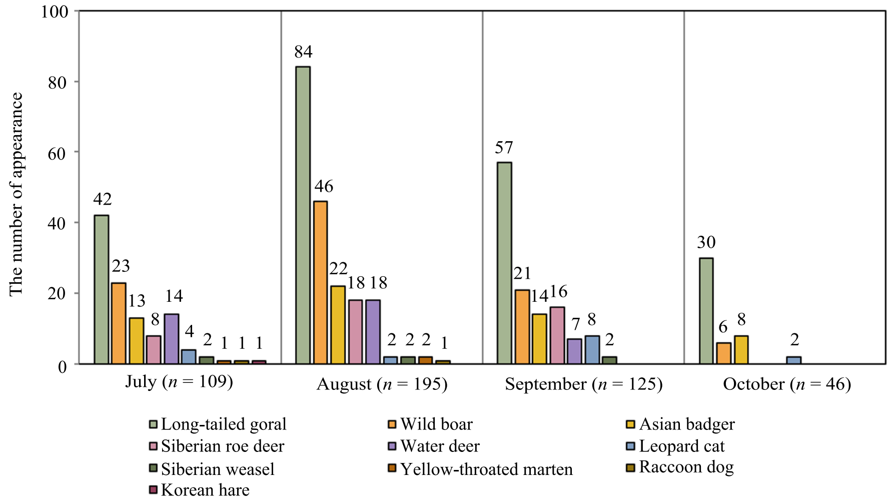

Fig. 2. Monthly appearance frequencies of wild animals in Jangsudae, Seoraksan National Park. The numbers above the bars indicate the number of photographs per species captured by cameras, and the numbers in parentheses indicate the total number of monthly photographs.

Statistical analysis

The RAI was calculated as (number of independent pictures / total monitoring days) × 100 (Henschel et al. 2011; Palmer et al. 2018). All analyses of the relationship between trapping effort and species richness were performed using R 3.5.3 (R Core Team 2019) and RStudio 1.4.1103 (RStudio Team 2021). To estimate the relationship between trapping effort and the species number, a regression distribution curve was produced using the R function "specaccum" as part of the vegan library (Oksanen et al. 2013). Using the regression distribution curve, we evaluated the relationship between camera days (number of cameras × operational days per camera) and the number of species. Further, a contour map was generated using the rarefaction analysis results of the relationship between species and trapping effort (Simberloff 1978; James and Rathbun 1981; Si et al. 2014). The contour map was used to evaluate the relative value of adding more camera sites or monitoring days in a survey of species diversity (Si et al. 2014). A map of the survey area was constructed using QGIS 3.10.13 (QGIS Development Team 2009).

Results

Species richness and distribution

In total, 1916 wildlife photographs were taken as a result of monitoring 18 camera sites over 103 days (1854 camera days), including all 14 mammal species registered in Jangsudae. Of these, 739 photos were created through deduplication for the 14 mammal species. The Siberian flying squirrel, an endangered arboreal mammal, was photographed on the 43rd monitoring day at S0050 (Fig. 1). As this study targeted medium- to large-sized terrestrial animals, photos of the following small mammals (264 photos) were excluded: Siberian chipmunk (101 photos), red squirrel (156 photos), Amur hedgehog (two photos), and Siberian flying squirrel (five photos). Finally, 475 photographs of ten medium- and large-sized mammals were used for further analysis.

Among the ten medium- and large-sized species, seven were common resident species with a proportion of independent photographs being > 1% (column PI in Table 1). Long-tailed goral, wild boar, and Asian badger, which accounted for 77.1% of the total mammal photos, were the most frequently photographed species (Table 1).

Except for the leopard cat, which appeared most frequently in September, other mammals were observed most frequently in August (Fig. 2). The number of appearances of long-tailed goral, wild boar, and Asian badger was much higher than that of other mammals from July to October. Except for the four aforementioned species, no wild animals were recorded at the camera sites in October.

After camera installation, long-tailed gorals and Asian badgers were the first species photographed, which were detected on Day 1, whereas yellow-throated martens were detected on Day 15 (Fig. 3A). In the camera sites with the detected animal species, the average number of camera days required for the first photograph was the shortest for the Korean hare (five days; $n = 1$ camera site), followed by the long-tailed goral (average ± standard deviation: 10

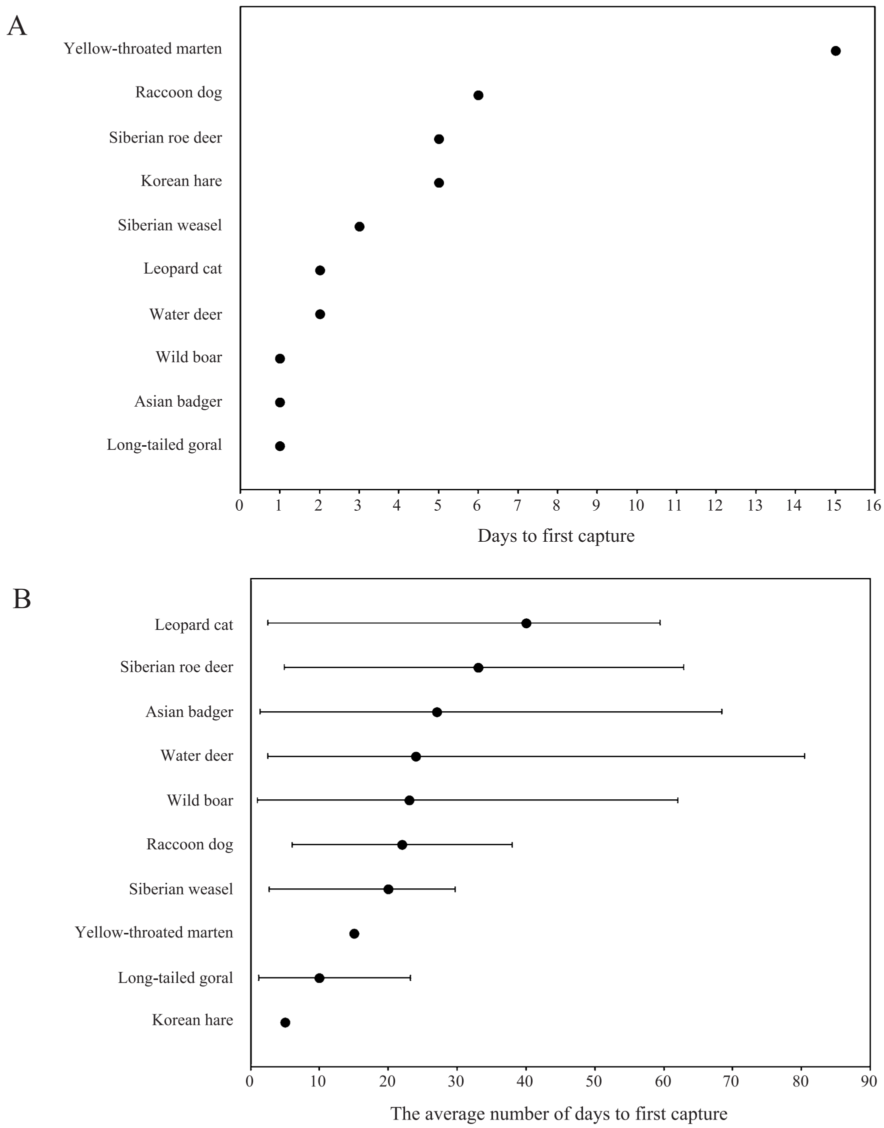

Fig. 3. (A) Days required to capture the first photograph for species in the Jangsudae of Seoraksan National Park and (B) average number (closed circle) and range (bar) of days required to capture the first photograph of the wild animals at the camera sites.

± 8.3 d; *n* = 17 sites; range = 1–23 d) and yellow-throated marten (15 d; *n* = 1 site), whereas it was the longest for the leopard cat (40 ± 27.6 d; *n* = 6 sites; range = 2–59 d) (Fig. 3B).

Of the 18 camera sites, more than six species appeared on the slopes of hardwood and mixed forests near the base of the rock wall (S0045 and S0061), in coniferous forests on the lower Bojoam Ridge (S0058), and in mixed and hardwood forests on the mid to upper Seonbawi Ridge (S0125 and S0128) (Fig. 4, Supplementary Table S1). At S0058, 80% of the ten targeted species, including the three endangered species, were photographed, whereas only one long-tailed goral appeared at S0044, S0110, and S0127 (Fig. 4, Supplementary Table S1).

The long-tailed gorals were photographed at 17 camera sites, except for S0077, which accounted for 44.8% of the total mammal photos. Wild boars were photographed at 14 camera sites, and Asian badgers were photographed at ten camera sites. The RAI was the highest for the long-tailed goral, followed by the wild boar, whereas it was the lowest for the Korean hare and raccoon dog (Fig. 5).

Minimum trapping effort

The number of species differed between the camera sites (Fig. 6A). At S0044, S0110, and S0127, only one species was observed on Days 39, 48, and 95, respectively. At S0050, after four species were observed on Day 68, no other species were observed, which is similar to

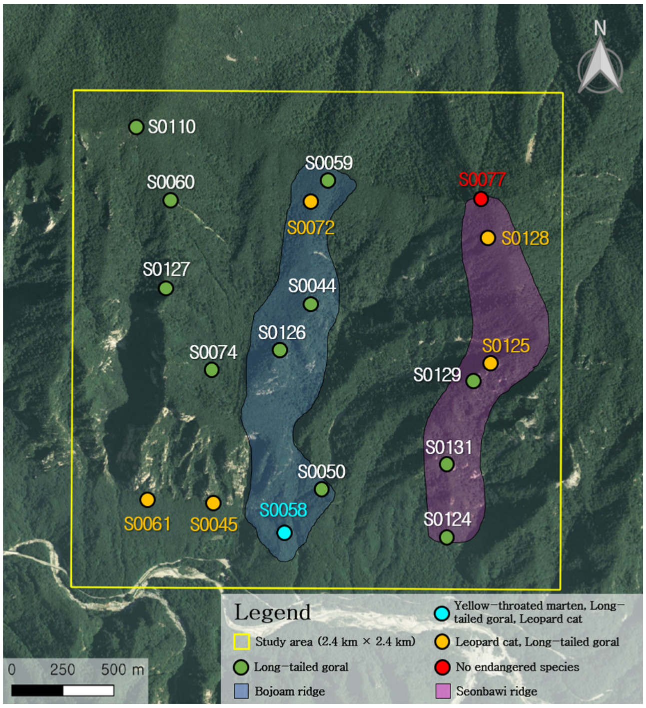

Fig. 4. Distribution of the endangered species in the survey area. The circles represent the camera sites. The open (green in the color version of this figure) circles represent the sites where only long-tailed gorals are photographed. The light gray (light blue) circle represents the site where the three endangered species, namely, yellow-throated marten, long-tailed goral, and leopard cat, were photographed. The dark gray (orange) circles are the sites where the two endangered species leopard cat and long-tailed goral were photographed. Long-tailed goral appeared at 17 sites, except for S0077. The closed (red) circle (S0077) is the site where endangered species were not observed. This figure was created using QGIS.

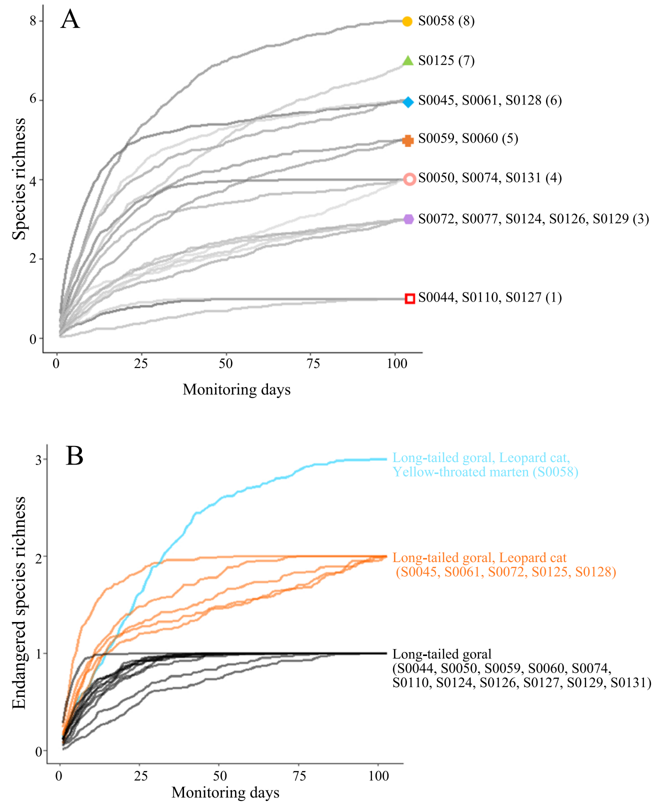

Fig. 6. Species rarefaction curves for 18 camera sites monitored over 103 days. Each curve represents the cumulative number of total species (A) and endangered species only (B) for each camera site against the increasing number of monitoring days.

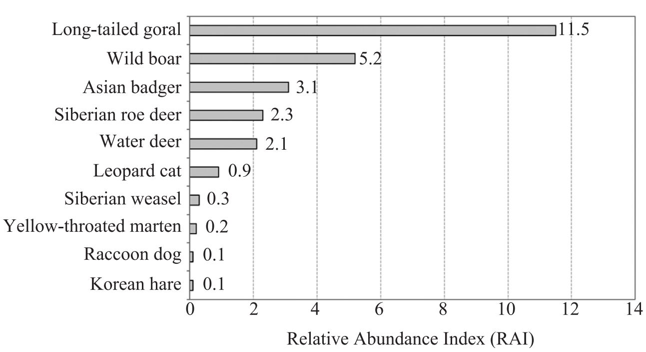

Fig. 5. Relative abundance index for medium- and large-sized terrestrial mammals in Jangsudae, Seoraksan National Park.

the S0058 after eight species were observed on Day 101. For the other camera sites, the rarefaction curve increased gradually, even towards the end of the monitoring period. All three endangered species in Jangsudae were detected on Day 98 only at S0058 (Fig. 6B).

According to the rarefaction analysis (Fig. 7), at least 1840 camera days (102.23 monitoring days) were required to photograph all ten species listed in Jangsudae. At least 1010 and 664 camera days were required to detect 95% and 90% of the ten species in Jangsudae, respectively. Further, 177 camera days (9.83 monitoring days at 18 camera sites) were required to trap all common resident species. The proportion of the detected species increased rapidly when the trapping effort was < 200 camera days, while it increased gradually when the trapping effort was > 600 camera days (Fig. 8, Supplementary Table S2). During the survey period (103 d), at least seven sites with camera trapping for at least 95 days were required to detect over 90% of the species. To detect the common resident species, monitoring two or more camera-trapping sites for at least 89 days was necessary (Fig. 8, Supplementary Table S2).

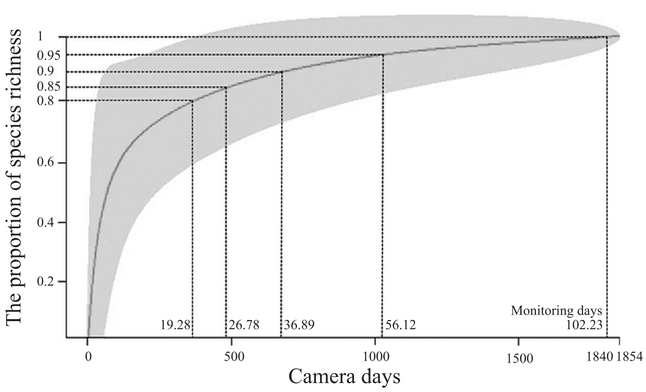

Fig. 7. Relationship between species richness and trapping effort for medium- and large-sized terrestrial mammals in Jangsudae. Rarefaction analysis was used to investigate the relationship between species richness and the number of camera days across 18 camera sites. All ten resident species listed in Jangsudae were detected during 1854 camera days (see Supplementary Table S2). Because 18 cameras were operating simultaneously in the field, each monitoring day represents 18 camera days. Gray ranges indicate 95% confidence intervals.

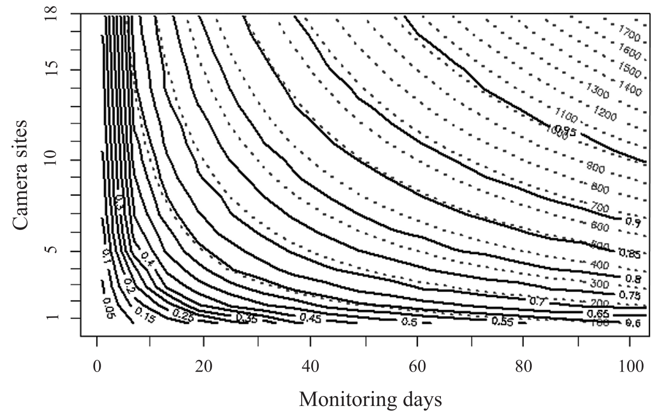

Fig. 8. Contour map of camera trapping effort across camera sites and monitoring days. This map evaluated the relative value of adding more camera sites or more monitoring days in a survey of species diversity. The black bold lines are the proportion of the total species pool (n = 10) detected. The dashed lines show the contour lines of the trapping effort (camera days). The proportion of species detected is the mean value resampled 1000 times from a dataset of 18 camera sites running for 103 days.

Discussion

Species distribution and abundance

In this study, we investigated the local distribution and abundance of medium- and large-sized terrestrial mammals in Jangsudae, and among the 18 camera trap sites, we found sites exhibiting both high species diversity (S0045, S0058, S0061, S0125, and S0128) and low species diversity (S0044, S0110, and S0127). Further studies should be conducted on the biotic and abiotic environmental factors that affect the appearance of wild mammals at these sites.

This study revealed that most areas of Jangsudae served as important habitats for the long-tailed goral, which was widely distributed such that they were photographed at all camera sites, except for S0077. In Korea, the population of long-tailed gorals has been restored since 2007, and their current population across the Korean Peninsula is estimated to be approximately 1582 individuals (Ministry of Environment 2020). Seoraksan National Park is one of the three major habitats harboring over 100 gorals, along with the DMZ (Korean Demilitarized Zone) and its surrounding areas (Yanggu, Inje, and Hwacheon), and Uljin-Samcheok (Ministry of Environment 2020). Jangsudae along with Jeohanglyeong, Heukseondong, Sangpangol, Gimbujateogol, Baekundong, Osaek, and Gwidaegicheong are the eight representative habitats of long-tailed goral in Seoraksan National Park (National Park Report 2011, 2012). This study also showed that most areas within Jangsudae were important habitats for long-tailed gorals. Similar investigations of the seven long-tailed goral habitats in Seoraksan National Park in the future would assist in comparing the habitat value and relative abundance of the long-tailed gorals between these areas.

Minimum trapping effort

MTE provides information for designing an efficient camera-trapping survey, considering the number of camera locations and monitoring duration required to detect target species. In wildlife monitoring using camera traps, MTE may vary depending on habitat status, territorial size, density, species richness, and seasonal environments. In non-protected secondary forests in the Jerangau Forest Reserve in Malaysia, an MTE of 11 520 camera days was required to detect 25 species of wild mammals (Azlan 2006). For a relatively well-protected small area in the Gutianshan National Nature Reserve in China, an MTE of 8700 camera days was required to detect ten resident species (0.13 independent visits/camera day; Si et al. 2014). In this study, all mammal species (ten species) in Jangsudae were detected with lower MTEs (1840 camera days) than those observed in previous studies (Azlan 2006; Si et al. 2014). In Jangsudae, a relatively high-shooting frequency (0.26/camera day) and low MTE might be due to the well-preserved habitat and the survey time of the year (summer) when wildlife activity is relatively higher than that in other seasons.

We evaluated the relative value of adding new camera sites or running cameras for long periods at one site. According to Si et al. (2014), given the same detection proportion of species richness, using numerous camera sites during short monitoring days reduces the number of camera days than using a small number of camera sites during long monitoring days. However, in this study, the use of several cameras in a short period did not reduce the number of camera days compared to the use of few cameras over a long period. This difference in the results might be due to the shorter monitoring period (103 monitoring days) of our study compared to that of the previous study (two-years; Si et al. 2014). Thus, in this study, proving the relative values of the MTE methods was difficult because of the short monitoring period.

According to Lim et al. (2020), ten species of medium- and large-sized wild animals (excluding domestic cat, *Felis catus*) were detected during 4282 camera days (average monitoring day: 109.8 ± 44.7 d; n = 39 sites, range = 3–176 d, April–October in 2020), conducted at 39 camera sites in Seoraksan National Park (398.2 km^2). In the case of Jangsudae, nine species except for the Korean hare were detected during 675 camera days (average monitoring day: 112.5 ± 28.6 d, n = 6 sites, range = 65–144 d, May 28–October 16, 2020) in a survey with six camera sites (Lim et al. 2020). Their results were consistent with our MTE estimation of at least 664 camera days required to detect 90% of the total richness (Fig. 7).

In this study, MTE was evaluated in summer when the detection frequency of wild animals is high owing to their high activity. In the future, MTE should be evaluated through one-year long-term monitoring, including four seasons, and its efficiency should be compared with the results of this study. In addition, future studies are needed on the microhabitat environment in Jangsudae that can affect detection efficiency.

Supplementary data

Supplementary data are available at *Mammal Study* online.
Supplementary Table S1. Topographical features and forest type at 18 camera sites.
Supplementary Table S2. (A) Wildlife richness and (B) camera days between the 18 camera sites and 103 monitoring days.

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