Camera-trapping Survey of Birds and Mammals in Xinjiang Tianshan Tianchi Bogda Peak Nature Reserve (Postprint)

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Abstract

Infrared camera technology has currently become a commonly used technical method for monitoring terrestrial mammals and ground-dwelling birds. To monitor bird and mammal resources within the Xinjiang Tianchi Bogda Peak Nature Reserve, from July 2019 to September 2020, 30 infrared camera sites were selected within the reserve and a total of 58 infrared cameras were deployed, accumulating 29,730 working days, obtaining 99,850 image and video data files, and collecting 5,744 independent effective photographs; a total of 29 species of wild terrestrial vertebrates from 9 orders and 19 families were observed, including 15 mammal species from 5 orders and 10 families, and 14 bird species from 4 orders and 9 families. Among the observed animals were the snow leopard (Panthera uncia), a nationally designated Class I key protected wild animal, and six species of nationally designated Class II key protected wild animals, namely the Siberian ibex (Capra sibirica), elk (Cervus canadensis), Eurasian lynx (Lynx lynx), red fox (Vulpes vulpes), black kite (Milvus migrans), and Himalayan snowcock (Tetraogallus himalayensis). In forest habitats, the mammal with the highest relative abundance index (RAI) was the elk (RAI=60.569), while the bird with the highest RAI was the oriental turtle dove (Streptopelia orientalis, RAI=0.854); in alpine meadow and bare rock habitats, the mammal with the highest RAI was the elk (RAI=18.693), and the birds with the highest RAIs were the Himalayan snowcock (RAI=0.316) and the yellow-billed chough (Pyrrhocorax graculus, RAI=0.854). Species accumulation curve results showed: the number of mammal species almost ceased to increase after 200 d, whereas the number of bird species, after slowing down after 100 d, continued to increase steadily, indicating that the 450 d infrared camera monitoring effort was relatively sufficient for mammals in the reserve but insufficient for birds. The research results can provide data references for monitoring and assessing wild terrestrial vertebrate diversity in the Xinjiang Tianchi Bogda Peak Nature

Reserve and offer a scientific basis for conservation and management efforts in this reserve.

Full Text

Camera Trapping Survey of Birds and Mammals in the Tianchi Bogda Peak Nature Reserve of Xinjiang, China

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Abstract

Infrared camera technology has become a commonly used method for monitoring terrestrial mammals and ground-dwelling birds. To monitor bird and mammal resources in the Tianchi Bogda Peak Nature Reserve of Xinjiang, 58 infrared cameras were deployed at 30 sites from July 2019 to September 2020, accumulating 29,730 camera days. A total of 99,850 images and videos were obtained, from which 5,744 independent valid photos were collected. We observed 29 wild terrestrial vertebrate species, including 15 mammal species and 14 bird species. Among the observed animals, there was one Class I National Key Protected Wildlife species, the snow leopard (Panthera uncia), and six Class II National Key Protected Wildlife species: Siberian ibex (Capra sibirica), red deer (Cervus canadensis), Eurasian lynx (Lynx lynx), red fox (Vulpes vulpes), black kite (Milvus migrans), and Himalayan snowcock (Tetraogallus himalayensis). In forest habitat, the mammal with the highest relative abundance index (RAI) was red deer (RAI=60.596), and the bird with the highest RAI was Oriental turtle dove (Streptopelia orientalis, RAI=0.854). In alpine meadow and bare rock habitat, the mammal with the highest RAI was red deer (RAI=18.693), and the birds with the highest RAIs were Himalayan snowcock (Tetraogallus himalayensis, RAI=0.316) and yellow-billed chough (Pyrrhocorax graculus, RAI=0.854). Species accumulation curve results showed that the growth rate of mammal species slowed after 200 days but continued to increase, while bird species growth

slowed after 100 days but continued to increase until the end of the study, indicating that the 450-day infrared camera monitoring duration was relatively sufficient for mammals in the reserve but insufficient for birds. The research results can provide data reference for monitoring and assessing wild terrestrial vertebrate diversity in the Tianchi Bogda Peak Nature Reserve of Xinjiang, and provide scientific basis for the conservation and management of the reserve.

Keywords: relative abundance index; grid occupancy; species accumulation curve; species diversity

Introduction

Mammals are important components of ecosystems, and studying mammal diversity is crucial for understanding ecosystem structure and function and for developing monitoring and conservation plans. Birds, as important taxonomic groups in communities, can equally reflect biodiversity. In recent years, most nature reserves in China have deployed infrared cameras to survey and assess wildlife diversity. Compared with traditional methods such as point counts and line transects, infrared cameras offer significant advantages: they can operate continuously with minimal habitat disturbance and low impact on wildlife, making them suitable for obtaining information on cryptic species active in complex habitats. Infrared cameras have been widely applied in wildlife behavior studies, baseline resource surveys, and biodiversity monitoring.

Previous studies have demonstrated the effectiveness of this method. Li et al. used infrared cameras to monitor takin (Budorcas taxicolor) in Tangjiahe Nature Reserve, Sichuan, and documented their daily activity patterns in winter and spring. Song et al. conducted long-term monitoring of North Chinese leopards (Panthera pardus japonensis) and their main prey in Qingcheng Forest Farm, Shanxi, accurately assessing the leopard population status. Liu et al. deployed infrared cameras in Daxiangling Nature Reserve, Sichuan, providing preliminary understanding of mammal and bird diversity and reference for wildlife research and conservation management. Camera trapping has captured 27.78%-72.97% of known wildlife species in certain areas, greatly aiding scholars in understanding regional faunal diversity.

The Tianchi Bogda Peak Nature Reserve (hereinafter referred to as Bogda Reserve) is located in the arid and semi-arid region of northwestern China, with rich biodiversity and many rare and endangered species. However, due to limitations in survey methods and equipment, early studies used point and line transect methods to investigate wild vertebrate diversity without examining species distribution, relative abundance, or obtaining photographic documentation. Furthermore, nature reserves at all levels are important areas for biodiversity conservation in China, and long-term wildlife monitoring is essential for biodiversity protection. To compensate for the shortcomings of conventional methods (short duration, limited scope) and to fully understand bird and mammal diversity in Bogda Reserve while accumulating relevant image data, we con-

ducted continuous monitoring of faunal diversity using infrared cameras from July 2019 to September 2020. This work aims to establish a foundation for long-term observation and analysis of species diversity, distribution, and relative abundance, and to provide scientific guidance for reserve conservation and management.

1 Study Area Overview

The Bogda Reserve is located at 43°45' ~43°59' N, 88°00' ~88°20' E, covering an area of 38,069 hm^2 with an elevation range of 1,300-5,445 m. Situated in the Tianshan Mountains, the reserve experiences a continental arid temperate climate with a mean annual temperature of 2.55°C and annual precipitation of 443.9 mm. Through long-term natural ecological processes, the reserve exhibits distinct vertical zonation, with vegetation types from top to bottom including alpine cushion vegetation, alpine meadow, subalpine meadow, montane evergreen coniferous forest, montane grassland, and valley deciduous broadleaf forest. Within a short vertical distance, dramatic elevation changes concentrate diverse natural landscapes including snow-capped mountains, glaciers, lakes, rivers, forests, and meadows. The reserve hosts numerous wild terrestrial vertebrates, including many national key protected wildlife species.

2.1 Camera Deployment

Based on the reserve' s environmental characteristics and preliminary animal distribution surveys, we selected two habitat types for camera placement: (1) forest habitat at 1,500-2,600 m elevation, where bird and mammal diversity is high and representative of Tianshan forest ecosystems; and (2) alpine meadow and bare rock habitat above the timberline at 2,600-3,800 m, with minimal human disturbance and serving as habitat for alpine rare and endangered species such as snow leopard (Panthera uncia) and Siberian ibex (Capra sibirica).

We established 30 camera-trapping sites with 58 infrared cameras [Figure 1: see original paper]. In forest habitat, we selected 22 sites; in alpine meadow and bare rock habitat, we selected 8 sites considering deployment difficulty and species distribution. To maximize capture rates, we selected specific camera locations based on: (1) animal activity signs (such as game trails, feces, feeding marks); (2) terrain (flatness, open view); (3) sun angle (avoiding direct sunlight); and (4) surrounding vegetation (providing adequate cover). At least two of these conditions had to be met for camera placement, with sites spaced at least 300 m apart and no bait placed near any site.

In forest areas with relatively flat terrain, we reached sites on foot. In areas above the timberline with rugged, steep terrain, we used horses. We set up tents at flat locations overnight until all cameras were deployed. Cameras were fixed to tree trunks in forest areas and placed on rocks or rock piles in other habitats, generally 50-80 cm above ground with the lens parallel to the ground or at an angle less than 30°. The monitoring period lasted 450 days, with

maintenance conducted every 3 months, including memory card replacement, data retrieval, battery checks, and status verification.

Camera models included Ltl6210 and H881W, widely used in Chinese wildlife research. All cameras had IP66 protection rating, captured 1920$×$1080 pixel images and 1080p videos, with nighttime detection range exceeding 15 m. Based on our survey results, these camera brands showed no significant differences in performance. All cameras were uniformly configured with date, time, photo+video mode, photo resolution (12MP), burst shooting (3 photos), video (1080p), and medium sensitivity. We recorded camera ID, elevation, coordinates, and habitat information for each site.

2.2 Data Processing

We first removed photos without animals or with unclear identification, then identified and classified species in the remaining images and videos. We established Excel sheets for each camera, recording site ID, temperature, species name, number of individuals, and capture time. Mammal classification followed "Mammal Diversity of China" and bird classification followed "A Checklist on the Classification and Distribution of the Birds of China." Species identification referenced "A Guide to the Mammals of China" and "A Field Guide to the Birds of China." Endangered status was determined using the China Red List of Vertebrates and IUCN Red List. National protection status followed the National Key Protected Wildlife List.

We defined independent valid photos as images or videos of the same species captured at the same camera site within a 30-minute interval. We used Excel to summarize valid photo numbers and camera days. Relative abundance index (RAI) and grid occupancy (GO) were calculated as follows:

Relative Abundance Index:

$$RAI_i = \frac{A_i}{N} \times 100$$

where RAI_i is the relative abundance index for species i, A_i is the number of independent valid photos of species i at all camera sites in a habitat type, and N is the total number of camera days in that habitat type.

Grid Occupancy:

$$GO_i = \frac{n_i}{T} \times 100\%$$

where GO_i is the grid occupancy for species i, n_i is the number of camera sites where species i was recorded, and T is the total number of camera sites in that habitat type.

To assess survey adequacy, we established species accumulation curves with camera days as the independent variable and cumulative species number as the dependent variable. We counted cumulative species number at 50-day intervals and performed exponential fitting in Origin 2017 [Figure 61: see original paper].

3 Results and Analysis

We deployed 58 infrared cameras at 30 sites, accumulating 29,730 camera days. We obtained 99,850 photos and videos, including 5,744 independent valid photos (94.6% of total). Among 58 cameras, 2 were lost; the remainder functioned normally. [Figure 2: see original paper] shows close-up photos of cameras working in different habitats.

We recorded 29 bird and mammal species belonging to 9 orders and 19 families, including 15 mammal species (5 orders, 10 families) and 14 bird species (4 orders, 9 families). Forest habitat yielded 21 species, while alpine meadow and bare rock habitat yielded 20 species, with 12 species occurring in both habitats: wild boar (Sus scrofa), red deer (Cervus elaphus), red fox (Vulpes vulpes), red-rumped swallow (Phoenicurus erythrogastrus), horse (Equus caballus), and cattle (Bos taurus).

We recorded one Class I National Key Protected Species (snow leopard) and six Class II species: Siberian ibex, red deer, Eurasian lynx (Lynx lynx), red fox, black kite (Milvus migrans), and Himalayan snowcock (Tetraogallus himalayensis). According to the IUCN Red List, Siberian ibex and Asian badger (Meles leucurus) are Near Threatened; red deer, stoat (Mustela erminea), Eurasian lynx, and snow leopard are Vulnerable; and roe deer (Capreolus pygargus), Siberian ibex, Asian badger, red fox, squirrel (Sciurus vulgaris), and Himalayan snowcock are Near Threatened according to the China Red List . [Figure 3: see original paper] shows some animal photos captured by cameras.

In forest habitat, red deer had the highest mammal RAI (60.596), followed by roe deer (18.693). The bird with highest RAI was Oriental turtle dove (Streptopelia orientalis, 0.854), followed by spotted nutcracker (Nucifraga caryocatactes, 0.316). Red-rumped swallow was recorded by only one camera site with one independent valid photo. Grid occupancy analysis showed red deer had the highest mammal GO (82.353%), followed by wild boar (17.647%); Oriental turtle dove had the highest bird GO (11.765%).

In alpine meadow and bare rock habitat, red deer had the highest mammal RAI (18.693), with stoat recorded at only one site (RAI=1.686). Himalayan snowcock had the highest bird RAI (0.316), followed by yellow-billed chough (Pyrrhocorax graculus, 0.316). Birds recorded by only one camera site included white-winged grosbeak (Mycerobas carnipes), Himalayan accentor (Prunella himalayana), white-winged snowfinch (Montifringillla nivalis), and Eurasian thrush. Grid occupancy analysis showed Siberian ibex had the highest mammal GO (61.538%), while Himalayan snowcock had the highest bird GO (30.769%).

Species accumulation curves [Figure 4: see original paper] showed mammal species increased rapidly during 0-50 days (growth rate 66.7%), slowed during 50-200 days (26.7%), and approached an asymptote after 200 days. Bird species increased rapidly during 0-100 days (57.1%), slowed during 100-300 days (28.6%), and continued increasing slowly during 300-450 days (14.3%). The

overall species accumulation curve was similar to the mammal curve.

4 Discussion

This survey represents the first infrared camera-based investigation of faunal diversity since the reserve' s establishment. Previous surveys relied on traditional methods like point counts and line transects, which have limitations for recording low-density, nocturnal, and cryptic species. Infrared cameras solve these problems but also have limitations, such as low resolution and sensitivity for fast-moving or small-bodied birds and rodents. Cameras can only monitor ground-dwelling birds, making detection of arboreal and aquatic species 偶然 and incomplete.

In this study, birds showed significantly lower RAI, GO, and independent valid photo numbers than mammals, similar to findings in other Chinese reserves, confirming camera trapping limitations. However, cameras effectively monitor medium-to-large terrestrial birds. For example, the nationally protected Himalayan snowcock, despite its narrow distribution and low density, was frequently captured, demonstrating camera effectiveness for this species.

In forest habitat, red deer had the highest RAI and GO, indicating large population size and wide distribution. Although red deer contributed many photos, independent valid photos were far fewer, likely due to their gregarious nature and concentrated activity periods. In alpine meadow and bare rock habitat, Himalayan snowcock had the highest bird RAI and GO, indicating high density and wide distribution in this habitat. As typical alpine birds with large body size and gregarious behavior, snowcocks were frequently captured.

Carnivores play crucial roles in ecosystems, occupying top trophic levels and controlling herbivore populations, thereby influencing vegetation structure indirectly. Their presence indicates ecosystem health. This survey documented three carnivores: snow leopard, Eurasian lynx, and red fox, confirming the Bogda Reserve' s healthy ecosystem.

Snow leopard, a Class I protected species and flagship species of alpine ecosystems, had not been recorded in the reserve for nearly 20 years. This survey provides the first photographic evidence, significant for conservation and management. The wolf (Canis lupus), a widely distributed large carnivore, was notably absent. Possible reasons include: (1) strict grazing prohibition since the reserve' s World Heritage designation in 2013, reducing livestock as a food source; and (2) wolves prefer flat terrain and grasslands, while Bogda Reserve consists mainly of steep forest and alpine habitats.

The species accumulation curves indicate that 450 days of monitoring was sufficient for mammals but insufficient for ground-dwelling birds. Bird species richness likely exceeds our documented richness, similar to other reserve monitoring results.

We recorded distinct species assemblages between habitats: forest habitats dominated by red deer, wild boar, and roe deer; alpine habitats dominated by snow leopard, Siberian ibex, and snowcock. This reflects different habitat requirements and necessitates targeted management strategies.

Human disturbance poses major threats to wildlife, with grazing being the primary factor in reserves. Although no human activity was photographed, cameras at the reserve edge captured livestock images, indicating ongoing disturbance requiring management attention.

5 Conclusion

This study conducted the first continuous 15-month camera trapping survey of bird and mammal diversity in Bogda Reserve, demonstrating the method' s suitability. We obtained first photographic evidence of snow leopard presence and extensive data on nationally protected species including Eurasian lynx, Siberian ibex, and red deer.

As a provincial nature reserve, World Natural Heritage site, and UNESCO Biosphere Reserve with rich landscapes and high faunal diversity, Bogda Reserve hosts distinct assemblages: forest habitats with red deer and Oriental turtle dove; alpine habitats with red deer, Himalayan snowcock, and yellow-billed chough. The presence of three carnivores confirms ecosystem health.

These results provide reliable data reference for understanding bird and mammal diversity and scientific basis for conservation management. Future monitoring will increase camera numbers and sites, expand coverage, extend duration, and establish long-term monitoring mechanisms, potentially combining with traditional methods for more comprehensive assessment.

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Note: Figure translations are in progress. See original paper for figures.