IBIS The International Journal of Avian Science
BOU
Ibis (2010), **152**, 299–309

The use of infrared-triggered cameras for surveying phasianids in Sichuan Province, China

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We report on the use of infrared-triggered cameras as an effective tool to survey phasianid populations in Wanglang and Wolong Nature Reserves, China. Surveys at 183 camera-trapping sites recorded 30 bird species, including nine phasianids (one grouse and eight pheasant species). Blood Pheasant *Ithaginis cruentus* and Temminck's Tragopan *Tragopan temminckii* were the phasianids most often detected at both reserves and were found within the mid-elevation range (2400–3600 m asl). The occupancy rate and detection probability of both species were examined using an occupancy model relative to eight sampling covariates and three detection covariates. The model estimates of occupancy for Blood Pheasant (0.30) and Temminck's Tragopan (0.14) are close to the naïve estimates based on camera detections (0.27 and 0.13, respectively). The estimated detection probability during a 5-day period was 0.36 for Blood Pheasant and 0.30 for Temminck's Tragopan. The daily activity patterns for these two species were assessed from the time/date stamps on the photographs and sex ratios calculated for Blood Pheasant (152M : 72F) and Temminck's Tragopan (48M : 21F). Infrared cameras are valuable for surveying these reclusive species and our protocol is applicable to research or monitoring of phasianids.

Keywords: adult sex ratio, daily activity pattern, detection probability, occupancy model, temperate forest.

Of the 179 species of phasianid (Gill & Wright 2006), 63 occur in China (Zheng 2000, Zheng 2005). Although these large and mainly terrestrial birds have been closely associated with humans for centuries in China, they are currently suffering increasing threats from habitat loss, hunting, human disturbance and hybridization with released stock. Therefore, research, monitoring and conservation of phasianids in China is becoming increasingly important to the global conservation efforts focused on this group (Fuller & Garson 2000, Zhang *et al.* 2003).

Information on the basic ecology and distribution of most phasianids in China is poor (Fuller & Garson 2000). Most species in southwestern China are located within heavily forested habitats (Li 1996, Zhang 1999, Zheng 2005) or open habitats at higher elevations, such as sub-alpine rhododendron scrub, alpine meadow and grassland (Long *et al.* 1998, BirdLife International 2001). Complex terrain, steep topography and dense vegetation impede field research and monitoring activities. Traditional field survey methods based on direct observation, such as transect counts and behavioural observations, are difficult to undertake due to the inaccessibility of remote areas, lack of visibility in dense vegetation and the birds' extreme sensitivity to human disturbance (Lu *et al.* 2003). Other methods based on physical capture, such as radiotelemetry and mark–recapture, can provide robust data for the study of habitat selection, home-range and population parameters of phasianids (Sun *et al.* 2003,

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Jia *et al.* 2004, Ji *et al.* 2005) but are relatively time consuming, costly and potentially harmful to the individuals (Long *et al.* 1998, Cutler & Swann 1999). The most common indirect survey methods for phasianids in China include calling counts and counts of moulted feathers (Lu & Zheng 2001, Lu *et al.* 2007), but these are usually season-dependent (Conroy & Carroll 2000, Lu & Zheng 2001, Lu *et al.* 2003). For example, as with many avian species, the White Eared Pheasant *Crossoptilon crossoptilon* only undergoes a complete moult after breeding, in this case between late July and early September (Lu & Zheng 2001, Lu *et al.* 2003). Phasianids can be potential indicators of habitat quality and human pressure on the environment (Fuller & Garson 2000), and there is clearly a need for a methodology that can effectively detect these reclusive birds with little disturbance and monitor the trends in population dynamics (Conroy & Carroll 2000).

Infrared-triggered cameras, in which a passive infrared sensor is triggered by an abrupt change in temperature across a fan-shaped area in front of the unit, activating an autofocus camera (Swann *et al.* 2004), have proved to be an effective tool for wildlife research and have been applied successfully to studies of numerous terrestrial mammals (Karanth & Nichols 1998, Cutler & Swann 1999, Moruzzi *et al.* 2002, Numata *et al.* 2005, Wang *et al.* 2006). Infrared cameras have been used as nest monitors to study the breeding behaviour and nest predation of numerous birds (Cutler & Swann 1999) and to estimate the population demographics, habitat selection, occupied habitat proportion and activity pattern of a number of terrestrial species (Pei 1998, Jeganathan *et al.* 2002, Dinata *et al.* 2008, Winarni *et al.* 2009). Infrared-triggered cameras can fail to detect animals due to faulty settings, low battery power, electrical malfunction or short detection ranges (Swann *et al.* 2004), but these problems are not influenced by habitat if the unit is properly deployed. Camera units work 24 h/day with little if any disturbance to wildlife, making the technique suitable to record and monitor cryptic and reclusive terrestrial animals (Carbone *et al.* 2001, Silveira *et al.* 2003, Karanth *et al.* 2004). Standard methodologies for studying phasianids (Bibby *et al.* 1992, Conroy & Carroll 2000) do not include infrared-triggered cameras, although phasianids have been detected during mammal surveys in which these cameras have been used (Pei 1998, Chan *et al.* 2005, Lu *et al.* 2005).

We analysed photographs of phasianids obtained during two large mammal surveys within nature reserves in Sichuan Province, southwestern China, with the intent of determining the suitability of this tool for the detection of large, terrestrial bird species, and to highlight ecological and behavioural information that can be obtained using infrared-triggered cameras.

METHODS

Study area

The work was undertaken in two national reserves (Wanglang Nature Reserve and Wolong Nature Reserve) in Sichuan Province, southwestern China (Fig. 1), from September 2004 to June 2007. Wanglang National Nature Reserve (104°3′E, 32°56′N) is a 320-km^2 protected area established in 1965 in the Min Mountains, 380 km northwest of Chengdu, the capital of Sichuan Province. Wolong National Nature Reserve (103°8′E, 31°6′N) is a 2000-km^2 protected area established in 1963 in the Qionglai Mountains, 160 km west of Chengdu. Both reserves were created to conserve Giant Panda *Ailuropoda melanoleuca*, Takin *Budorcas taxicolor* and Golden Monkey *Rhinopithecus roxellarae*. The elevational range of Wanglang Nature Reserve is 2400–4980 m and major vegetation types are deciduous forest, conifer–deciduous mixed forest, conifer forest, sub-alpine scrub and alpine meadow. Wolong Nature Reserve has a greater elevational range (1200–6250 m) and comprises evergreen forest, evergreen–deciduous mixed forest, deciduous forest, conifer–deciduous mixed forest, conifer forest, sub-alpine scrub and alpine meadow (Wolong National Nature Reserve 1987).

BirdLife International has identified both reserves as Important Bird Areas (IBA Code: CN194 for Wolong, CN188 for Wanglang), and they fall within an Endemic Bird Area (EBA138) because they host globally threatened and range-restricted avian species including Chinese Monal *Lophophorus lhuysii* (BirdLife International 2004).

Survey design

Trained staff in each reserve used two models of infrared-triggered camera units: DeerCam™ (Non

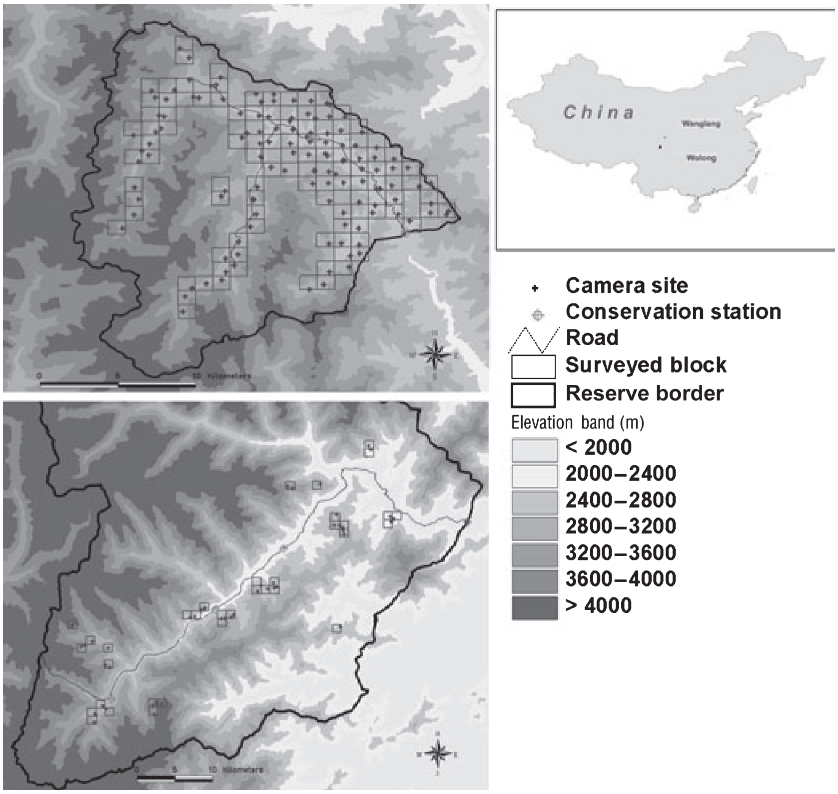

Figure 1. Location of sample sites within Wanglang National Nature Reserve (upper left) and Wolong National Nature Reserve (lower left), China.

Typical, Inc., Park Falls, WI, USA) and cameras manufactured by project staff to similar specifications; both models had similar performance in tests of sensor sensitivity and detection range. Ten DeerCam™ and 20 self-manufactured camera units were deployed in Wanglang and 20 self-manufactured camera units were deployed in Wolong. Camera units were positioned to minimize detection distances, with none exceeding 5 m. The detection range of the sensors varies with the body size of animals (Swann *et al.* 2004); for large animals, such as Takin and Giant Panda, the sensor can be triggered at distances over 20 m, while for small animals, such as Blood Pheasant and Snow Partridge *Lerwa lerwa*, the maximum trigger distance is approximately 6 m. The reaction time for both camera units (i.e. time taken between the trigger of heat sensor and activation of the camera) was 0.5–1 s. All the camera units were loaded with 400 ISO film and were set with a 2–3-min delay between photographs, and set for 24-h monitoring.

Camera units were attached to trees 30–50 cm above the ground and 3–5 m from a trail or point where animal movement might be expected. A time/date stamp accompanied each photograph and at each sample site we recorded GPS location, elevation, slope, aspect and habitat, including forest type, canopy and shrub cover and average diameter at breast height (DBH) of trees. Field staff classified the habitat of the sample point into one of six forest types based on tree species composition. At the end of each monitoring session, the units were tested to confirm that they were still operational and had unexposed frames; if not, the date on the last photograph was taken as the last operational date.

The reserves were divided into 1-km^2 blocks within a Geographic Information System (GIS) (Arc View 3.2 and Arc GIS 9.0). One camera unit was placed in each block for 1 month, and was then moved to an adjacent block. Due to difficult navigation in the field, two camera units were occasionally placed in one block (14 blocks in Wanglang and 16 blocks in Wolong). Within each survey block, cameras were placed in likely animal-use areas, as determined by field staff, and > 400 m from other cameras. We concentrated our survey effort in Wanglang (132 sites) within the elevational range containing all forested habitat (2400–3600 m). At Wolong, the 51 surveyed sites were along 11 monitoring routes within an elevation range of 2000–4200 m. Field surveys were conducted in Wanglang from September 2004 to January 2005 and from March to October 2005; in Wolong, we conducted surveys from April to December 2006 and March to June 2007. Identification of avian species was based on MacKinnon *et al.* (2000), Zheng (2000, 2002), while names and taxonomy follow Gill and Wright (2006). We differentiated chicks, but not subadults, from adult birds. For the majority of phasianid species, the sex of adults could be distinguished by body size, feather colour and pattern, or wattles on the face or neck (MacKinnon *et al.* 2000, Zheng 2002). We were able to differentiate the sex of adult individuals for five phasianid species: Severtzov's Grouse *Tetrastes sewerzowi*, Blood Pheasant, Temminck's Tragopan, Koklass Pheasant *Pucrasia macrolopha* and Chinese Monal.

Photographic encounter rates were calculated for each phasianid species for each 400-m elevational band. We defined detection at a sample point as one individual photograph of one species during a 30-min period. If more than one individual of the same species was identified on a single photograph, we considered this one detection. All detections for each species were summed for each camera site, multiplied by 100, and divided by the total sampling effort for that sample point (number of camera-days):

$$\text{Photographic Rate} = \text{No. of detections} * 100/\text{Camera-days}$$

We used this photographic rate to compare detection in different reserves and elevational bands.

For the phasianid species that had sufficient detections (i.e. Blood Pheasant and Temminck's Tragopan), the sampling record at each site was divided into consecutive 5-day segments based on the date stamp on the photographs. A detection matrix of each species was established following the approach proposed by MacKenzie *et al.* (2002). We excluded sites where the sampling was less than one 5-day segment. An occupancy model (program PRESENCE, v. 2.2; MacKenzie *et al.* 2006, Hines 2006) was used to estimate the site-occupancy rate (ψ) and detection probability relative to eight sampling variables and three detection variables (Table 1). Akaike Information Criterion (AIC; Akaike 1973) values were used to rank the occupancy models and all the models whose $\Delta AIC \leq 2$ were considered as equivalent models. The summed model weight of each covariate in these models was used to determine the most influential variables for each species. The sign of logistic coefficient of each variable (positive or negative) was used to determine the direction of influence of the variable.

Table 1. Variables used to estimate the site occupancy rates and detection probabilities of Blood Pheasant and Temminck's Tragopan in the occupancy model.

Abbreviation	Name	Description
Sampling variables		
NR	Nature reserve	Categorical (Wanglang, Wolong)
FOT	Forest type	Categorical (Broadleaved, Broadleaved–conifer mixed, Coniferous)
DBH	Tree size (measured by DBH[a])	Categorical (< 30 cm, 30–50 cm, > 50 cm)
SCO	Percentage shrub cover	Categorical (< 25%, 25–50%, 50–75%, > 75%)
ELE	Elevation	Numeric (Range 1680–4220 m)
DTR	Distance to nearest river	Numeric (Range 3–1821 m)
DTT	Distance to nearest road	Numeric (Range 1–5100 m)
ASP	Aspect	Categorical (Warm – NE, E, SE, S; Cold – N, NW, W, SW)
Detection variables		
CAM	Camera model	Commercially purchased or self-manufactured
SEA	Season	Breeding (March–July) or non-breeding (August–February)[b]
LUR	Scent lure durability	Numeric (Days since application)

[a]DBH, diameter at breast height.
[b]Li (1996), Jia *et al.* (1999, 2003).

The time and date printed on the photographs has been used to determine the temporal patterns of use for highway underpasses by different species (Foster & Humphrey 1995) and the daily activity pattern of individual species (Pei 1998). We used a Daily Activity Index (DAI) of 2-h durations to examine the daily activity level:

$$\text{DAI} = \text{No. of photographs within a duration} * 100/\text{Total no. photographs}$$

A Chi-squared test using SPSS 13.0 (SPSS Inc., Chicago, IL, USA) was applied to determine the significance of differences in the daily activity patterns between species.

RESULTS

A sampling effort of 4908 camera-days across 183 sample sites (Fig. 1) was achieved in the two reserves (3793 camera-days in Wanglang, 1115 camera-days in Wolong), resulting in 2750 photographs, 427 of which contained birds. During the 2-year survey, 30 bird species were recorded, nine of which were phasianids ($n = 308$ photographs) (Table 2, Appendix I). Within each reserve, six species of phasianids were recorded.

Blood Pheasant and Temminck's Tragopan were the most frequently detected species for both reserves within the mid-elevational range (2400–3600 m). Snow Partridge, Tibetan Snowcock *Tetraogallus tibetanus*, and Chinese Monal only occurred over 3600 m in sub-alpine shrub habitats. Three species were detected in both reserves: Blood Pheasant, Temminck's Tragopan and Koklass Pheasant. Of these, Blood Pheasant was detected over the broadest elevational range (2400 and 3800 m), with the highest photographic rates (4.74 at Wanglang and 3.46 at Wolong) between 2800 and 3200 m in both reserves. Temminck's Tragopan was detected over the elevational range 2200–3200 m, and had the highest photographic rates (0.64 at Wanglang and 7.94 at Wolong) at 2400–2800 m elevation in both reserves. Koklass Pheasant was only detected at 2400–2800 m elevation in both reserves.

Blood Pheasant and Temminck's Tragopan were detected at least once at 49 sites and 23 sites, respectively. The estimates of site occupancy rate of both species were slightly higher than the naive estimates (i.e. the proportion of sites where the species was detected at least once, 0.27 for Blood Pheasant and 0.13 for Temminck's Tragopan), although the estimated detection probabilities of both species were smaller than 0.40 (Table 3), suggesting that our sampling duration (30 days, maximum 45 days) was long enough to detect the species at each site when they were present. The estimation of occupancy rate of Blood Pheasant (0.30) was higher than that of Temminck's Tragopan (0.14), indicating that Blood Pheasant was more widely distributed. Denser shrub cover, lower elevation and warmer aspect were determined as the best predictors for the occupancy of both species. Blood Pheasant occurred more commonly at Wanglang and Temminck's Tragopan at Wolong (Table 4).

The DAI for Blood Pheasant and Temminck's Tragopan (160 and 46 photographs, respectively) confirmed that both species are diurnal (Fig. 2).

Table 2. Phasianid species recorded with camera units in Wanglang National Nature Reserve and Wolong National Nature Reserve (2005–2007).

			Wanglang		Wolong	
Scientific name	Common name	IUCN threat status[a]	Photos	Sites	Photos	Sites
Tetrastes sewerzowi	Severtzov's Grouse	NT	1	1	–	–
Lerwa lerwa	Snow Partridge	LC	–	–	13	2
Tetraophasis obscurus	Verreaux's Monal-Partridge	LC	4	4	–	–
Tetraogallus tibetanus	Tibetan Snowcock	LC	–	–	4	1
Ithaginis cruentus	Blood Pheasant	LC	150	43	33	6
Tragopan temminckii	Temminck's Tragopan	LC	25	8	43	15
Lophophorus lhuysii	Chinese Monal	VU	–	–	8	3
Pucrasia macrolopha	Koklass Pheasant	LC	5	2	10	3
Crossoptilon auritum	Blue Eared Pheasant	LC	12	9	–	–

Name and taxonomy based on Gill and Wright (2006), *Birds of the World.*
[a]LC, Least Concern; NT, Near Threatened; VU, Vulnerable.

Table 3. The top models for predicting site occupancy of Blood Pheasant and Temminck's Tragopan in Wanglang and Wolong National Nature Reserves.

Models	ΔAIC	AIC weight	No. par.	(−2LL)	est. ψ (± 1 se)	est. *P*
Blood Pheasant						
ψ (NR, SCO, ELE, DTR, ASP) *P*(.)	0.00	0.1311	6	533.0311	0.3016 (± 0.0111)	0.3623
ψ (NR, SCO, ELE, DTR) *P*(.)	0.75	0.0901	5	535.7777	0.3007 (± 0.0100)	0.3625
ψ (NR, ELE, DTR, ASP) *P*(.)	0.99	0.0799	5	536.0153	0.2994 (± 0.0099)	0.3629
ψ (NR, DBH, SCO, ELE, DTR, ASP) *P*(.)	1.43	0.0641	7	532.4641	0.3021 (± 0.0113)	0.3626
ψ (NR, FOT, SCO, ELE, DTR, ASP) *P*(.)	1.92	0.0502	7	532.9525	0.3018 (± 0.0111)	0.3621
ψ (NR, DBH, SCO, ELE, DTR) *P*(.)	2.00	0.0482	6	535.0332	0.3013 (± 0.0103)	0.3629
Temminck's Tragopan						
ψ (NR, SCO, ELE) *P*(.)	0.00	0.1358	4	238.5937	0.1427 (± 0.0122)	0.2983
ψ (NR, SCO, ELE, ASP) *P*(.)	0.40	0.1112	5	236.9865	0.1451 (± 0.0129)	0.2950
ψ (NR, ELE, ASP) *P*(.)	0.63	0.0991	4	239.2188	0.1434 (± 0.0120)	0.2943
ψ (NR, ELE) *P*(.)	1.18	0.0753	3	241.7730	0.1403 (± 0.0109)	0.2980
ψ (NR, DBH, SCO, ELE, ASP) *P*(.)	1.21	0.0741	6	235.7987	0.1421 (± 0.0125)	0.2981
ψ (NR, SCO, ELE, DTR) *P*(.)	1.85	0.0538	5	238.4408	0.1426 (± 0.0123)	0.2984
ψ (NR, SCO, ELE, DTR, ASP) *P*(.)	1.93	0.0517	6	236.5236	0.1454 (± 0.0131)	0.2947

We list all models whose ΔAIC ≤ 2 and present AIC weight, number of parameters (No. par.), twice the negative log likelihood (−2LL), estimated occupancy rate (est. ψ) and estimated detection probability (est. *P*) for each model. The key for the covariate codes used is given in Table 1. None of the final models contained covariates used to measure detection variability (i.e. camera model, season, or lure type) and *P*(.) was used to indicate this fact.

Table 4. Summed model weight of each sampling variable in the equivalent models listed in Table 3.

	Model variables							
Species	Nature reserve (NR)	Forest type (FOT)	Tree size (DBH)	Percentage shrub cover (SCO)	Elevation (ELE)	Distance to nearest river (DTR)	Distance to nearest road (DTT)	Aspect (ASP)
Blood Pheasant	0.4636	0.0502	0.1123	0.3837	0.4636	0.4636	0	0.3253
Temminck's Tragopan	0.6010	0	0.0741	0.6010	0.4300	0.1055	0	0.3361

Blood Pheasant showed a late morning activity peak at 10:00–12:00 h, while there was no obvious activity peak for Temminck's Tragopan, but this difference was not significant ($\chi^2 = 8.06$, df = 6, $P > 0.1$).

With regard to sex, 224 adult Blood Pheasants were photographed including 152 males and 72 females (M : F = 2.11 : 1.00) (Table 5). Groups with multiple adults (i.e. female–female pairs, female–male pairs and male–male pairs) were recorded. Aggregating behaviour was recorded in eight photographs that contained more than two adult individuals, with one photograph containing a flock of eight adults. For Temminck's Tragopan, 69 adult individuals were photographed including 48 males and 21 females (M : F = 2.29 : 1.00). Only two photographs of Temminck's Tragopan contained more than one individual.

Camera unit reliability

We used data from 183 sites for our analysis, but cameras placed at additional sites did not yield useful information. Of 153 sites sampled in Wanglang, 21 camera units were not working at the 1-month check and the sites were not considered in the analysis. At Wolong, 22 of 73 camera units were not operating after 1 month. Electrical malfunction due to moisture was the reason for failure of six camera units at Wanglang and nine units at Wolong. Low-quality batteries purchased in rural areas and incorrect recharging of lithium batteries caused camera unit failure at 10 sites in Wanglang and nine sites in Wolong. Two camera units, one in each reserve, were attacked and damaged by Giant Pandas, based on bite marks left on the camera

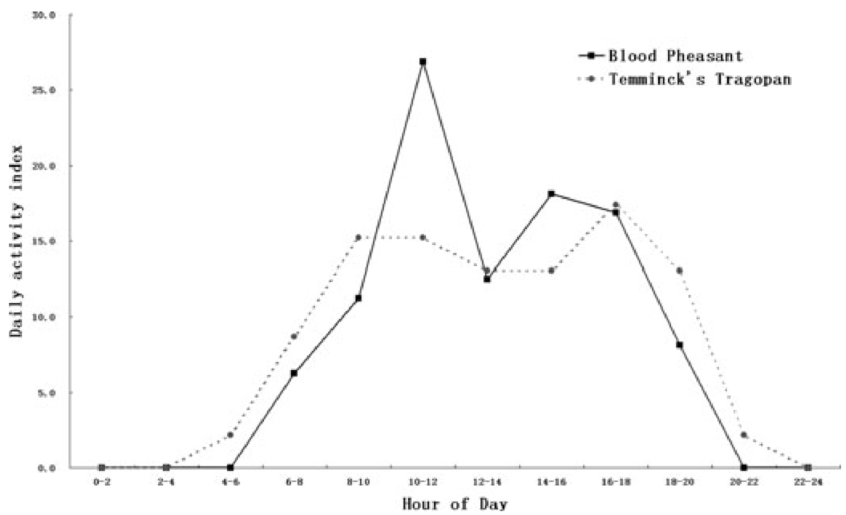

Figure 2. Daily activity pattern of Blood Pheasant (n = 160 photographs) and Temminck's Tragopan (n = 46 photographs), from combined data of Wanglang National Nature Reserve and Wolong National Nature Reserve, September 2005–August 2007.

Table 5. Occurrence by sex of Blood Pheasant and Temminck's Tragopan photographed in Wanglang National Nature Reserve and Wolong National Nature Reserve, September 2005–August 2007.

	Blood Pheasant	Temminck's Tragopan
Sex(es) in photograph	No. of photographs (proportion) n = 174	No. of photographs (proportion) n = 68
Single ♂	91 (0.52)	47 (0.69)
Single ♀	43 (0.25)	19 (0.28)
♂–♂ Pair	14 (0.08)	–
♂–♀ Pair	11 (0.06)	1 (0.01)
♀–♀ Pair	3 (0.02)	–
♀–C[a]	2[b] (0.01)	1[c] (0.01)
C	2 (0.01)	–
Multi-adults (> 2)	8[d] (0.05)	–
No. of adult individuals	152 ♂ : 72 ♀	48 ♂ : 21 ♀

[a]C, chick.
[b]Two photographs each showed 1♀–1C.
[c]One photograph showed 1♀–3C.
[d]One photograph each showed 6♂–2♀, 3♂–2♀, 3♂–1♀, 2♂–1♀, 2♂–1♀–1C, and 4♀. Two photographs showed 3♂.

unit casing and the last photographs. Seven units (four at Wanglang and three at Wolong) were stolen or damaged. In total, 19% of the sites (Number of sites failed/Total number of sites surveyed) resulted in no viable data due to camera failure or loss.

DISCUSSION

Of the nine phasianids detected in this study, only one species (Chinese Monal) is considered globally endangered or threatened (Table 2). However, three species (Severtzov's Grouse, Verreaux's Monal-Partridge and Chinese Monal) are listed in Category I of China Nationally Protected Animals, and the other six species are listed in Category II (Zheng & Wang 1998, MacKinnon *et al.* 2000). In addition, four species (i.e. Severtzov's Grouse, Verreaux's Monal-Partridge, Chinese Monal and Blue Eared Pheasant) are endemic to central and south-western China (Lei *et al.* 2002, 2003, Zhang *et al.* 2003). For Wanglang, our photographs are the first documentation that Verreaux's Monal-Partridge occurs within this reserve despite 6 years of prior monitoring activity. For Wolong, our work provided the first photographic evidence for Snow Partridge and Tibetan Snowcock, both of which were heard during 3 years of monitoring, but never observed or photographed.

We recorded an additional 21 avian species during the camera-trapping efforts, including some as small as the Green-backed Tit *Parus monticolus* (body length = 13 cm) and Golden Bush Robin *Tarsiger chrysaeus* (body length = 14 cm). Although we photographed multiple bird species, there are problems inherent to infrared-triggered cameras when comparing species of markedly different body size and foraging strata (Hernandez *et al.* 1997, York *et al.* 2001, Moruzzi *et al.* 2002).

These issues are not as problematic for the nine species of phasianids photographed, whose body sizes (range 33–95 cm) are large enough to be detected by the camera sensor at < 5 m and who all forage primarily on the forest floor (Zheng *et al.* 1978, MacKinnon *et al.* 2000).

Our photographic survey did not detect several phasianids that are on the species list maintained by each reserve, for example Snow Partridge, Chinese Monal and Common Pheasant *Phasianus colchicus* at Wanglang (Liu *et al.* 2001), and Severtzov's Grouse, Verreaux's Monal-Partridge, Golden Pheasant *Chrysolophus pictus* and White Eared Pheasant at Wolong (Yu & Deng 1993). It is possible the missing species occur in habitats beyond our survey area or elevational range. For example, the Chinese Monal is reported to inhabit sub-alpine rhododendron shrub, sub-alpine and alpine meadows, and exposed cliffs above the treeline (Long *et al.* 1998, BirdLife International 2001), an area beyond our surveyed elevation at Wanglang. Likewise, there are approximately 800 records in the last 3 years for Severtzov's Grouse in sub-alpine shrub habitat above 3600 m in Wolong (X.G. Shi, Wolong Nature Reserve unpubl. data), but our cameras failed to detect them, probably due to our relatively small sampling effort at this elevation (three sample points, 115 camera-days). However, for species such as Verreaux's Monal-Partridge, where the preferred elevation is well within the range of our sampling, it is probable that these species are either rare or extirpated from Wolong. There have been no sightings of Verreaux's Monal-Partridge during the reserve monitoring activities in the last 3 years (X.G. Shi, Wolong Nature Reserve unpubl. data), indicating the density of this species is currently low within the reserve.

Of the three phasianids recorded in both reserves, the Blood Pheasant and Temminck's Tragopan showed a broad distribution across the mid-elevational range (2400–3600 m). Other studies on the ecology and distribution of these two species (Shi *et al.* 1996, Li *et al.* 1998, Yu *et al.* 2000) indicated that Temminck's Tragopan occupies a broad range of habitats (i.e. evergreen forest, deciduous forest, deciduous and conifer mixed forest, and conifer forest) and elevations (i.e. 650–3500 m). This is in contrast to the Blood Pheasant, which occupies deciduous/conifer mixed forest, conifer forest and sub-alpine shrub at elevations ranging from 2300 to 4500 m (Li 1996, MacKinnon *et al.* 2000, Yu *et al.* 2000). In our survey, the Blood Pheasant was not detected below 2400 m and was detected proportionately more often in mature coniferous forest. Temminck's Tragopan was detected at a lower elevation and seemed to prefer broadleaved forest. Thus, we found both species in less diverse situations than those mentioned in these previous reports.

There were apparent differences in the social organization of the two most abundant species, as Blood Pheasants were observed in pairs or flocks much more often than Temminck's Tragopan. Both Blood Pheasant and Temminck's Tragopan are considered monogamous (Li 1996, Jia *et al.* 1999, 2004), but for Blood Pheasants, both single-sex and mixed-sex flocks were photographed, whereas for Temminck's Tragopan no adult groupings of more than a pair were photographed. We obtained several photographs of Blood Pheasants in multi-adult groups, as was previously reported in Wolong by Jia *et al.* (1999) and in Shiqu by Lu *et al.* (2006), but we obtained no photographs of such groups in Temminck's Tragopan. There is no published research on the sex ratio or population structure of Temminck's Tragopan in China, but a study on a closely related species, Cabot's Tragopan *Tragopan caboti*, estimated an even sex ratio within a population of 50 individuals (Zhang & Zheng 1990). A previous study of Blood Pheasant in Wolong (Jia *et al.* 1999) reported a sex ratio of 0.89 : 1.00, based on the observation of 70 individuals in four winter flocks, but we found male pheasants to be twice as abundant as female pheasants in the photographs for both species. Male-skewed adult sex ratios are common in birds (Donald 2007) but there are other factors that should be considered. One possibility is that males of both species may be detected more frequently than females because they spend more time patrolling and defending their territories (Zhang & Zheng 1999, Jia *et al.* 2003). A second possibility is that males are detected more often because they take the lead position when the pair or flock moves through the habitat, with the trailing animals being missed by the time-delayed camera.

Many studies using infrared-triggered cameras are primarily designed for large mammal research and the bird species detected during the sampling are considered 'bycatch' detections (Chan *et al.* 2005). There may be three important reasons for the lack of further application and analysis of camera data for bird species in these studies. First, camera settings for large mammals may not be suitable to detect terrestrial birds. For both the passive and the active camera units, cameras may be set at a height equivalent to the target animal's shoulder or chest. Therefore, cameras set for large mammals may not be triggered by passing pheasants. Secondly, phasianids cannot usually be individually identified in photographs, so mark–recapture approaches, which are widely applied in studies on large felids based on camera data (Karanth & Nichols 1998, Cutler & Swann 1999), are not appropriate for these phasianids. Thirdly, the relationship between camera photographic rate and animal density remains unclear (Carbone *et al.* 2001, Jennelle *et al.* 2002). These potential limitations do not preclude the incorporation of camera-trapping into phasianid surveys.

Although our field protocol was developed as a general survey of large- and medium-sized mammals, it was effective in recording phasianids in forested and remote areas. Our data demonstrate that a combination of cameras and use of occupancy models can be an effective approach for future phasianid studies. Occupancy analyses suggested that our survey protocol (30–50 cm above the ground and 3–5 m from the trail or focal point, and a 1-month sampling duration at each site) was sufficient to detect the presence of several phasianids. Given the relatively small home-range of phasianids (e.g. 8.7–31.9 ha for Blood Pheasant in the breeding season; Jia *et al.* 2004), we would recommend a higher camera density (3–4 cameras/km^2). We do not recommend using the photographic rate for direct comparison of the abundance of species because of species-specific differences in behaviour and population ecology (Hernandez *et al.* 1997, York *et al.* 2001, Moruzzi *et al.* 2002, Stephens *et al.* 2006, Rowcliffe *et al.* 2008), which may affect detection probability by infrared-triggered camera of any phasianids. Our analysis indicated that the occupancy rate of phasianids could be estimated using occupancy models and can be used as a robust index for phasianid monitoring projects. A standardized deployment of infrared-triggered cameras should be a reliable tool for comparing sites or time periods within a species, with minimal variation among researchers and areas. At its most basic level, the camera units provided information on species' natural history that was not obtainable using standard monitoring within these reserves and will enhance decision-making for reserve management and conservation activities.

This work was supported by the Smithsonian's National Zoological Park, Friends of the National Zoo, Peking University, World Wildlife Fund China, Sichuan Forestry Department, and China Wildlife Conservation Association. We thank Chen Youping, Jiang Shiwei, Huang Junzhong, Xu Haibin, Zhang Qingyu, Tang Hao and all the reserve staff who assisted with data collection. We also thank John H. Rappole, Pan Wenshi, Lu Zhi, Wang Hao, Shen Xiaoli, Liu Yang, and several reviewers for fruitful discussions and valuable comments on the manuscript.

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Received 28 March 2009;
revision accepted 23 October 2009.

APPENDIX 1

List of all non-phasianid avian species recorded during our survey in Wanglang National Nature Reserve and Wolong National Nature Reserve (2005–2007).

Order	Family	Scientific name	Common name	Wanglang		Wolong	
				# photographs	# sites	# photographs	# sites
Passeriformes	Corvidae	*Urocissa erythrorhyncha*	Red-billed Blue Magpie	–	–	2	1
	Paridae	*Parus monticolus*	Green-backed Tit	–	–	1	1
	Timaliidae	*Garrulax cineraceus*	Moustached Laughingthrush	1	1	–	–
		Garrulax lunulatus	Barred Laughingthrush	1	1	1	1
		Garrulax maximus	Giant Laughingthrush	1	1	2	3
		Garrulax ocellatus	Spotted Laughingthrush	–	–	3	1
		Garrulax elliotii	Elliot's Laughingthrush	3	3	2	3
		Garrulax affinis	Black-faced Laughingthrush	3	2	3	1
	Sittidae	*Sitta nagaensis*	Chestnut-vented Nuthatch	–	–	1	1
	Turdidae	*Myophonus caeruleus*	Blue Whistling Thrush	–	–	1	1
		Zoothera dixoni	Long-tailed Thrush	4	3	–	–
		Zoothera dauma	Scaly Thrush	2	2	3	1
		Turdus rubrocanus	Chestnut Thrush	2	2	4	1
		Turdus mupinensis	Chinese Thrush	7	5	3	1
	Muscicapidae	*Tarsiger indicus*	White-browed Bush Robin	1	1	–	–
		Tarsiger cyanurus	Red-flanked Bluetail	5	3	3	3
		Tarsiger chrysaeus	Golden Bush Robin	3	2	7	1
	Prunellidae	*Prunella immaculata*	Maroon-backed Accentor	2	1	–	–
	Fringillidae	*Fringilla montifringilla*	Brambling	2	1	–	–
		Carpodacus thura	White-browed Rosefinch	1	1	–	–
		Pyrrhula erythaca	Grey-headed Bullfinch	–	–	1	1

Name and taxonomy based on Gill and Wright 2006, *Birds of the World*.
The IUCN threat status of all species in Appendix I is Least Concern.