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Report

Initial Assessment on Large and Medium Sized Terrestrial Mammal Assemblage Using Camera Trapping in Nangunhe Nature Reserve in Yunnan, China

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Abstract: During surveys for wild felids in Nangunhe Nature Reserve, Yunnan province, China, we conducted a wider mammal survey of the core nature reserve area, using camera trapping techniques. Forty motion-triggered digital camera traps had been set in oldest forest tract of protected area to conduct a species inventory. The total camera trapping effort of 2460 camera trap nights yielded 232 digital photographs of mammals represented by 17 species in five orders. The species photographed include rare and elusive species and those that are of high conservation value, such as IUCN endangered species Asiatic elephant (*Elephas maximus*), and Phayre's leaf monkey (*Trachypit hecus phayrei*). In addition, IUCN vulnerable species including Asiatic black bear (*Ursus thibetanus*), sambar (*Rusa unicolor*), northern pig-tailed macaque (*Macaca leonine*), and marbled cat (*Pardofelis marmorata*), and more common species were found. All mammals were also listed as key protected wild animals by the State Forestry Administration of China. Of particular importance were the carnivores, with 7 different species recorded. Ungulates and other taxa forming a prey base for these predators,such as rhesus macaque (*Macaca mulatta*), red muntjac (*Muntiacus muntjac*), sambar, wild boar (*Sus scrofa*), and Chinese serow (*Capricornis milneedwardsii*), were found to be the most frequently photographed and most widespread species. Opportunities for local people to develop standardized monitoring designs for targeted species were identified by these initial assessment results. Local nature reserve staff lacked technical ability to produce standardized survey designs, yet a by product of this type of non-standardized data collection can be very informative and produce inventory information that gives a species richness analysis, as well as initial estimates for occupancy and detection probability for abundant species to drive future standardized survey designs and efforts.

Key words: species richness; species inventory; occupancy modeling

1 Introduction

An increase in habitat loss and degradation caused by human population growth and development has resulted in an appropriate concern for the conservation of biodiversity. Lack of baseline information about rare species occurrence and detailed spatial distribution data is a common problem facing many wildlife conservationists, especially in developing countries like China (Li 2010a). Many nature reserves in Yunnan Province are shown to perform poorly, representing only a part of Yunnan's biodiversity and subject to numerous pressures from economic development and human population growth (Zhang *et al*. 2012). Moreover, nature reserve management studies in Yunnan have shown inadequate research, monitoring, and lack systematic data collection, as well as lack current long term development plans for many nature reserves (Cao *et al*. 2014). Sustainable management requires knowledge of the mechanistic processes of key species within the ecosystem (Ordiz *et al*. 2013; O'Brien *et al*. 2010; Bengtsson 1998), especially to determine the community structure and sensitivity of certain species to habitat changes following fragmentation,

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knowledge which can contribute to halting fragmentation processes (Haag *et al*. 2010; Henle *et al*. 2004; Macdonald 1999). Mammal species composition and distribution information throughout protected areas in China remain incomplete, and understanding their patterns and underlying process are essential for conservation action and appropriate management.

There is an urgent need to implement rapid assessment non-invasive survey techniques in nature reserves to provide a reliable species inventory that can detect multiple species and give guidance for biodiversity management. One of the primary methods for surveying large and mid-sized mammals is camera trapping, which is effective at detecting large and medium-sized mammals (Manley 2006; Karanth and Nichols 1998). Small datasets from camera trapping surveys can provide a reliable species inventory, species richness information, estimate abundance, and give information regarding activity patterns of species (Suntaro *et al*. 2013; O'Brien *et al*. 2010; Kery 2010; O'Connell *et al*. 2010; Kelly 2008; O'Brien *et al*. 2003). Camera traps have been found to detect more species, be logistically easier, and collect more detailed capture information, such as activity patterns and species identification, compared with other survey methods such as sign surveys or DNA scat collection (Vanak and Gompper 2007; Karanth *et al*. 2006; Sanderson and Trolle 2005; Silveira *et al*. 2003; Foresman and Pearson 1998). Completing a species inventory via camera trapping can be further assessed by using a species richness curve to determine the sampling effort and number of species based on camera trap rate (Bernard *et al*. 2013; Carbone *et al*. 2001; Colwell *et al*. 2012), and the results can be used for determining future monitoring protocols (Li 2010a; Bailey *et al*. 2007).

Early camera trapping studies in Yunnan began in 1996 (Ma and Harris 1996). Previous camera trapping surveys were conducted in the past in Lincang Prefecture, within the Nangunhe Nature Reserve (Feng *et al*. 2006). One study was completed in Xishuangbanna Dai Autonomous Prefecture (Zhang *et al*. 2014). Camera trapping has been ongoing for nearly 20 years, yet published camera trap surveys within Yunnan province are relatively scarce in peer- reviewed literature.

This is a formal camera trapping study based on the mammalian ecology of the Nangunhe Nature Reserve, and builds on previous existing, yet unpublished knowledge, on mammals in southern Yunnan. Yunnan is estimated to have 52% of mammal species within China, 304 mammal species, compared with 581 mammal species in China overall (Pu *et al*. 2007). There are 26 mammal species designated as First Class national Chinese protection and are distributed only in Yunnan. Most of these protected species exist within narrow distributions of specific habitat. Yunnan is rich is species diversity (Tang *et al*. 2006; Li 2010a), but has a limited mammal community due to small protected habitat areas (Yang 2004b).

There is a paucity of knowledge about the community composition and mammal species richness throughout Lincang County where the Nangunhe Nature Reserve is located; despite the fact that it is recognized as a conservation priority area with high mammal species richness (Tang *et al*. 2006; Zhang *et al*. 2012; Sun *et al*. 2013). The majority of field research has been concentrated on Asian elephant (Feng *et al*. 2010). There are numerous threats posed by conversion of unprotected forest habitats to large scale monoculture plantations and agricultural zones (Zhang *et al*. 2012; Zhang *et al*. 2006). In addition, this area is shown to have high species richness and connectivity, with relatively low-medium levels of fragmentation compared with other areas in China (Li *et al*. 2010b), yet there is ongoing development pressure resulting in local habitat loss and fragmentation from city and road extensions in the county (Liu *et al*. 2014). It is important to acquire data on mammals in the remaining natural areas to develop a baseline understanding of the communities to prioritize conservation efforts. Acquiring this information is useful to the larger scientific community, regional and county management, as well as the human communities that live and work within the nature reserve system.

During the course of the study, problems for following camera trap data collection protocols, organization of equipment, and loss of equipment were endured. The resulting camera trapping dataset is characteristic of many datasets collected by local nature reserve staff, which can serve as guidance for future standardized monitoring efforts. While conducting preliminary surveys, small sample sizes in occupancy studies are commonly encountered in conservation projects for species; although, pilot study results can allow researchers to design a more intensive sampling effort for an occupancy survey that can to achieve a level of precision needed for results to be meaningful (Bailey *et al*. 2007; Guillera-Arroita *et al*. 2010).

This survey covered the core area of the Nangunhe Nature Reserve area and formed one part of a collaborative wildlife survey for a much larger wild felid conservation project that included areas within and outside of the nature reserve. The aim of our survey was to gather baseline data on mammal species richness and composition, as well as record other ecological information that might be useful for conservation management and monitoring. Here we (i) report the findings of a three month camera trap assessment on large and medium sized terrestrial mammal assemblages, and (ii) discuss species richness and composition, activity patterns, and issues surrounding biodiversity and conservation within the nature reserve.

2 Methods

2.1 Study area

The Nangunhe Nature Reserve is a 708 km^2 protected area located in western Cangyuan County, Yunnan Province, China (99°0.00′ E, 23°15.00′ N). Nangunhe is located in the northern most fringe of the Southeast Asian tropical zone, and situated in the middle of the Myanmar China border. It is one of China's priority conservation areas established in 1980. The nature reserve is divided into three functional zones: core, experimental, and buffer. This study focused on the largest tract of protected area within the 71 km^2 core zone, which was also the oldest core area of the nature reserve. Vegetation consisted of broadleaf evergreen forest, tropical rainforest, and shrub and grassland. The elevation ranges from 520 to 1747 m in the core area.

Based on a previous survey at Nangunhe, a total of 1885 seed plant species (including subspecies and varieties) and also 98 species of mammals were recorded (Yang and Du 2004). It is one of the only remaining regions in Yunnan that preserves tracts of primary and secondary forest for Asian elephant (*Elephas maximus*), with a population of approximately18-22 individuals (Zhang *et al*. 2006; Feng *et al*. 2010). Indo-Chinese tiger (*Pathera tigiris corbetti*) has been previously reported (Su and Zhang 2005; Yang *et al*. 2004; Lan and Dunbar 2000), yet present is unconfirmed at this time. Many mammal species have experienced drastic declines in distribution and population as a result of land use/land cover changes, deforestation, and hunting (Feng *et al*. 2010; Grueter *et al*. 2009).

2.2 Camera trapping

Camera trapping was conducted between January to May 2014. The dry season (Oct-May) was optimal for camera deployment, to avoid heavy rainfall. The team placed 40 automatic remote motion triggered digital camera traps (LTL Acorn 6210) within the core area of the nature reserve. One camera had been placed at each camera station and then marked using a GPS unit (Garmin eTrex). Camera settings were adjusted to high IR sensitivity to maximize night captures, and low sensitivity motion to avoid wind or insect photo capture. Cameras were synchronized for date and time and operated continuously throughout 24 hours. Cameras had attempted to be deployed throughout the nature reserve in a 1 km^2 grid formation. Camera placement was based on accessibility, minimizing risk of harm to researchers and wildlife, and information from skilled trackers who had little experience placing cameras, using GPS, or filling out routine field data collection forms. Cameras were placed to maximize animal captures at 50 cm above the ground, and put in areas thought to be travelled frequently by mammals, such as along animal trails, near animal tracks, and near streams. Danger in regards to elephant confrontation in the dense forest environment caused the team to adjust original placement plans. Many grid cells in close proximity to human settlements and plantations caused concern for disturbance or loss of cameras due to theft; therefore cameras were placed in adjacent grid cells.

The Wildlife Institute, an academic research unit at Beijing Forestry University that collaborated with nature reserve staff for this study, had conducted a three day training on a basic camera trapping protocol one month prior to this survey. The training covered camera trap use, as well as field orientation to minimize human error when setting cameras in the field, and to facilitate the standardization of camera trapping protocol.

2.3 Data analysis

At the end of the survey period, most cameras were retrieved. Camera trapping images were transferred to storage devices, and then uploaded and imported into Camera Base v1.6.1 (Tobler 2014) for data management and analysis. Animal species were identified with the aid of Smith and Xie (2008). The global and regional conservation status of each species was determined based on the IUCN Red List of Globally Threatened Species (IUCN 2014), as well as Chinese National key protected wild animal list (The State Council 1988).

To avoid sequences of photos of a particular individual a time period of 1 hour was used to differentiate the individual mammal photographs. Unfocused, incoherent, or photographs where only parts of the animal had been photographed were excluded from the analysis. Other photographs excluded from the analysis include many small mammals, including shrews, squirrels, and rats which were not possible for consistent positive species identification, along with all birds and domestic animals which were outside of the scope of the study. Common palm civet (*Paradoxurus hermaphroditus*), large Indian civet (*Veverricula indica*), small Indian civet (*Viverra zibetha*) and spotted Lincang civet (*Prionodon paricolor*) became hard to distinguish in the photographs; therefore these species were grouped as one species.

A species accumulation curve of the cumulative number of species recorded as a function of cumulative camera trapping days, was used to determine the adequacy of the sampling period. An abundance-based rarefaction (Format 4, Sample, Species, Abundance) using one set of replicated sampling units (i.e. based on the number of mammal photographs captured) with 95% confidence intervals was computed in EstimateS version 9.10 (Colwell *et al*. 2012) and based on 100 random iterations. For species richness, exact analytical methods are used to compute the expected number of species (with unconditional variance and confidence intervals) for each level of rarefaction (or accumulation) of the sample. The curve is a plot of species richness as a function of the number of individual photographs. In addition, the mean of four commonly used abundance-based species richness estimators (i.e. ACE, CHAO1, JACK1, and Bootstrap) were computed. Furthermore, the species accumulation curve was extrapolated using the Bernouilli product model to project the richness beyond the dataset to predict further species capture for 300 samples.

Activity patterns, for mammal species that were relatively frequently captured (>6 independent photographs), were represented by a percentage of the total number of photographs recorded during daytime and nighttime intervals. Based on the photographs automatic time stamp, photos grouped into either daytime (ranging from 06:00 to 18:00 hours) or nighttime (ranging from 18:00 to 06:00 hours). Then, categorized into three categories, diurnal, arrhythmic, and nocturnal based on the total percentage of daytime and nighttime photos.

2.4 Data modeling

Detection/non-detection data were used to model species occurrence data and assess environmental management for protected areas. Occupancy modeling is often used to inform questions of abundance, colonization and extinction. Despite imperfect detection during surveys, occupancy modeling methodology addresses this by incorporating detection probability (Mackenzie *et al*. 2002). The camera trapping data were inputted into program PRESENCE (version) as 1s and 0s indicating presence and absence, respectively. Occupancy modeling was conducted on detection/non-detection data for species with more than 20 independent detections including Chinese serow (*Capricornis milneedwardsii*), sambar (*Rusa unicolor*), wild boar (*Sus scrofa*), and rhesus macaque (*Macaca mulatta*). We used GIS (Geographic Information Systems) analysis (ArcGIS 10.1.0, ESRI, Redlands, CA) to calculate slope and elevation at each camera trap, and Akaike's Information Criterion. In addition, based on the detection probabilities from the pilot survey, Program GENPRES was used to provide optimal survey camera trapping intensity to suit a single season-single species occupancy model.

3 Results

3.1 Key species recorded by camera trapping

All 40 cameras had attempted to be deployed into the field within 2–3 weeks. Six cameras had been unable to be safely placed due to their proximity to elephant habitat, five went missing, one destroyed by an elephant, and an additional six cameras lacked final GPS coordinates. There had been a total of 27 stations which successfully recorded 30–100 camera trap nights of data in the field (Fig. 1).

The total camera trapping effort was 2460 camera trap nights. The average number of nights was 70 nights. In total, 16 553 digital photographs were captured, of which 237 were mammal photographs (Fig. 2), and a total of 17 mammal species representing 5 orders and 11 families (Table 1). The mean elevation of the camera stations was 881 m. The highest elevation was 1641 m, the lowest elevation was 541 m.

Of the species photographed there were several species that are of high conservation value, listed as endangered species under the IUCN (2009) – Asiatic elephant (*Elephas maximus*), and Phayre'sleaf monkey (*Trachypit hecus phayrei*). Three species were listed as IUCN vulnerable species: Asiatic black bear (*Ursus thibetanus*), sambar, northern pig-tailed macaque (*Macaca leonine*), and marbled cat (*Pardofelis marmorata*). There were three species listed as IUCN near threatened species: Assam macaque (*Macaca assamensis*), leopard (*Panthera pardus*), and Chinese serow. Eight species were listed as least concern.

The combined photographic capture rate of all species across all stations was 1.41 photographs/100 trap nights.

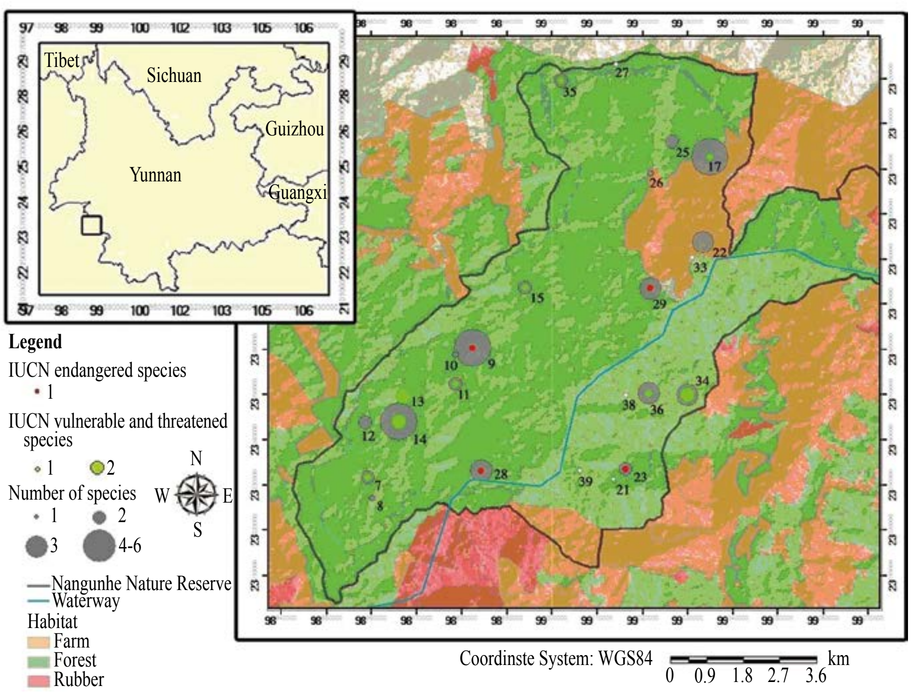

Fig. 1 Camera trap locations within Nangunhe Nature Reserve, southwest Yunnan, China. Symbolized capture information for each station for IUCN status and total number of species captured.

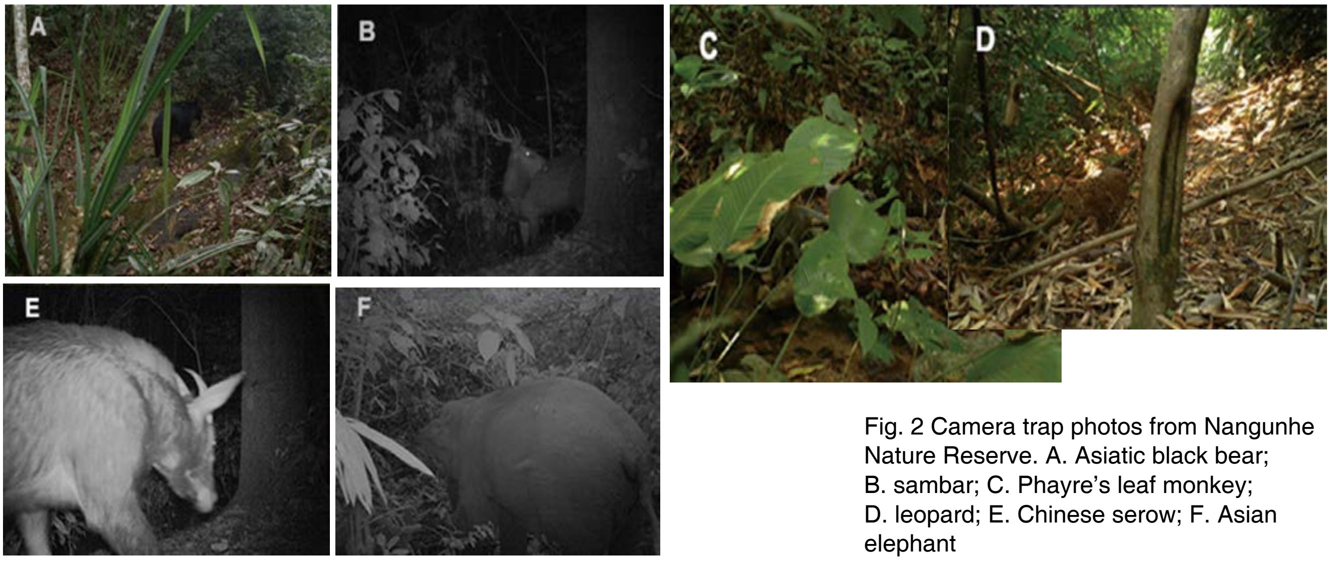

Fig. 2 Camera trap photos from Nangunhe Nature Reserve. A. Asiatic black bear; B. sambar; C. Phayre's leaf monkey; D. leopard; E. Chinese serow; F. Asian elephant

The species with the highest camera trap rate was rhesus macaque 0.30 photographs/100 trap nights, Malayan porcupine (*Hystrix brachyuran*) 0.19 photographs/100 camera trap nights, wild boar 0.18 photographs/100 trap nights, sambar 0.16 photographs/100 camera trap nights, Chinese serow 0.16 photographs/100 camera trap nights, red muntjac (*Muntiacus muntjac*) 0.13 photographs/100 camera trap nights. These 6 species combined together to account for 75% (of 237) of all mammal photographs.

Mammals captured by the most number of cameras, red muntjac (11 cameras), sambar (5 cameras), yellow-throated marten (*Martes flavigula*) (4 cameras), Asiatic black bear (4 cameras), rhesus macaque (4 cameras). These species did not necessarily all have the highest recorded photographic rates (Fig. 4). Several species had fewer than 4 photographs and represent the least number of species present including marbled cat (1 photograph), crab-eating mongoose (*Herpestes urva*) (1 photograph), leopard cat (*Prionailurus bengalensis*) (1 photograph), northern pig-tailed macaque (4 photographs), Assam macaque (4 photographs), Asian elephant (4 photographs).

Seven species of Carnivora in 5 families were recorded making it the most diverse order of mammals recorded during the survey. The order Artiodactyla was represented by 3 families and 4 species.

3.2 Estimation of species richness

The mean estimated species richness computed with EstimateS was 16.58 (ACE 16.04, CHAO1 16, JACK1, 17.98, Bootstrap 16.31), which resulted in a sampling completeness ratio of 0.96. This suggests that the sampling saturation of camera trapping survey was extremely high (Fig. 2). This represents the true species richness of the reference sample, including species not present in the sample. According to the jackknife estimator, we could have missed approximately two species. This suggests that the sampling saturation of camera trapping survey was extremely high with confidence intervals showing the potential to capture between 15 and 19 species (Fig. 3). The extrapolation shows a survey effort of 300 samples, or approximately doubling the number of samples, would potentially capture one more species, and up to four species according to the 95% unconditional confidence intervals (Fig. 4).

3.3 Activity patterns of major species

Researchers analyzed activity patterns of 9 mammals recorded with more than six photographs (Fig. 5). Two species were classified as diurnal (rhesus macaque and yellow-throated marten), five species were recorded as arrhythmic (red muntjac, wild boar, Asian elephant, Asiatic black bear, and sambar), and two species as nocturnal (civet spp., Parodoxurus hermaphroditus, and Malayan porcupine).

3.4 Occupancy modeling for selected species

For species with more than 20 samples, we used PRESENCE software to do an occupancy analysis. The results showed that when factoring in detection probability, there is a large discrepancy between naïve occupancy and the fixed probability model using occupancy, which highlights the need to account for imperfect detection when analyzing data (Gray *et al*. 2012). Since the sample size using camera trap days was too small to be used, we compressed each survey to represent one camera trap week; therefore, more precise occupancy estimates and detection probabilities were found using a weekly time period (Table 2).

Slope and elevation covariates derived from ArcGIS for each species were assessed (p_{elev}, p_{slope}) for potential influence on occupancy results (Table 3). Based on these

Table 1 Summary of animals photographed within the core area of Nangunhe Nature Reserve, Yunnan, China as part of SFA related biodiversity surveys 2014. NIP, number of independent photographs, SPR, photographic rate of species captured, i.e. NIP per 100 camera trap photos. SITE: indicates the camera stations where animals were photo captured. IUCN, Red List of globally threatened species status, EN= endangered, VU=vulnerable NT= near threatened, LC= least concern.

Order	Family	Scientific Name	English Name	NIP	SPR	# Cameras	SITE	IUCN	Protection in China
Proboscidea	Elephantidae	*Elephas maximus*	Asian elephant	4	0.02	3	CL23, CL29, CL28	EN	l
Primates	Cercopithecinae	*Macaca assamensis*	Assam macaque	4	0.02	3	CL23, CL09, CL34	NT	l
		Macaca leonina	Northern pig-tailed macaque	4	0.02	1	CL34	V	
		Macaca mulatta	Rhesus macaque	49	0.30	4	CL09, CL34, CL17, CL28	LC	ll
		Trachypit hecus phayrei	Phayre'sleaf monkey	1	0.01	1	CL09	EN	l
Rodentia	Hystricidae	*Hystrix brachyura*	Malayan porcupine	31	0.19	1	CL15	LC	
Carnivora	Felidae	*Pardofelis marmorata*	Marbled cat	1	0.01	1	CL35	V	l
		Prionailurus bengalensis	Leopard cat	1	0.01	1	CL22	LC	l
		Pathera pardus	Leopard	3	0.02	3	CL13, CL14, CL34	NT	l
	Viverridae	*Paradoxurus hermaphrodites* and *Paguma larvata*	Palm civet	17	0.10	3	CL09, CL 14, CL17	LC	
	Herpestidae	*Herpestes urva*	Crab-eating mongoose	1	0.01	1	CL30	LC	
	Ursidae	*Ursus thibetanus*	Asian black bear	6	0.04	4	CL11, CL13, CL07, CL17	V	ll
	Mustelidae	*Martes flavigula*	Yellow-throated marten	9	0.05	4	CL26, CL22, CL25, CL34	LC	ll
Artiodactyla	Suidae	*Sus scrofa*	Wild boar	29	0.18	9	CL07, CL08, CL12, CL14, CL17, CL22, CL25, CL28, CL36	LC	
	Cervidae	*Muntiacus muntjac*	Red muntjac	21	0.13	11	CL12, CL07, CL23, CL08, CL28, CL14, CL34, CL17, CL29, CL36, CL11	LC	
		Rusa unicolor	Sambar	27	0.16	5	CL14, CL15, CL29, CL34, CL36	V	ll
	Bovidae	*Capricornis milneedwardsii*	Chinese serow	25	0.15	3	CL09, CL15, CL35	NT	
	Total	17 spp.		233	1.41				

initial assessment results, AIC (Akaike Information Criterion) was used to rank the models based on elevation and slope. From these results, a new survey along an elevational gradient targeting sambar would be appropriate. As an IUCN vulnerable species, and considering there are higher elevations in the nature reserve that were not surveyed, this could be a useful study for future design. Unfortunately, the survey was incomplete for these covariates, and upon investigation the c-hat statistic found in the model outputs, there results conclude a lack-of-fit where the c-hat statistics resulted in a 0 value, this indicates that the data were under-dispersed (Bailey *et al*. 2007). However, these results show basic occupancy analysis from non-systematic surveys may be indicative of future science driven environmental monitoring questions currently not addressed or answered in the scientific literature or explored by local staff.

The occupancy estimates were not robust for each species, with low detection probabilities. To determine how many cameras and survey days would be required for future surveys we used program GENPRES to run simulations using the detection probabilities from Table 3.

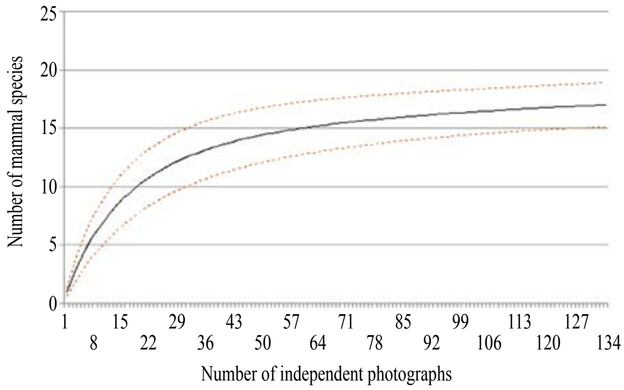

Fig. 3 The species curve (-) and 95% Confidence Intervals (…) for mammal species in the core area of Nangunhe Nature Reserve conditional is based upon the 134 individual-based mammal abundance sample with 100 randomization runs (Colwell *et al*. 2012).

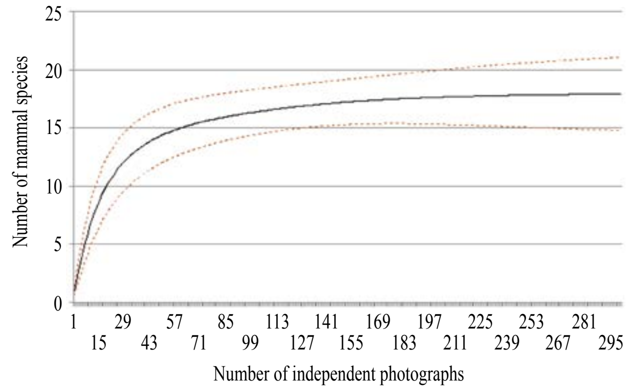

Fig. 4 Extrapolated species curve (-) and 95% Confidence Intervals (…) for mammal species is based upon a 300 individual-based mammal abundance sample with 100 randomization runs (Colwell *et al*. 2012).

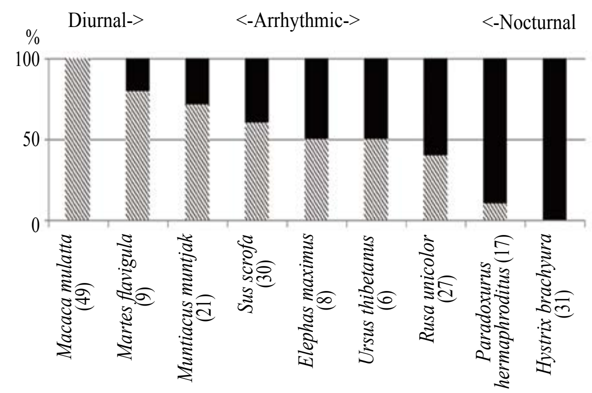

Fig. 5 Activity patterns for 9 species, listed by scientific name with number of photos in parentheses, in the core area of Nangunhe Nature Reserve, Yunnan, China. All species have n>6 photos. The pattern bar indicates percent frequency of photographs taken during the day time (06:00–18:00 hours); black bar indicates percent frequency taken during the night time. Species are listed in order of decreasing diurnal activity.

The simulations were based on the camera trapping weekly survey, and varying numbers of camera trapping stations to find appropriate numbers of camera traps during a 10 week survey to yield higher occupancy estimates (Table 4).

Since the economic and logistical constraints of camera trapping studies are often an issue, we ran 100 simulations to achieve an occupancy estimate of 0.75. For sambar, 60 camera traps over a 10 week period would be required for an occupancy estimate of 0.75 ±0.24; as it appears that with less cameras, for example 40 cameras, the standard deviation drastically increases and the occupancy estimate is 0.78 ± 25.08. The other species showed that varying levels of camera traps increased the AIC, and also lowered the standard deviation for the occupancy estimate, which shows high variability for future surveys. For species in which a single season, single species model is not appropriate, a multi-season model would be considered on the single species to increase sample size.

Although local staff lacked technical capacity and the logistics were compromised, using a small camera trapping dataset from a rapid three to four month survey can provide a species inventory, and guide future standardized surveys from the preliminary occupancy and detection probability outputs.

3.5 Comparison with historical records

There are several other large and medium sized mammals, which are found during previous surveys in 2003 (Liu and Liu 2003), and historically recorded (Yang *et al*. 2004; Smith and Xie 2008), but not detected by our surveys (Table

Table 2 Occupancy (Ψ) and detection probability (P) for the five selected species with data grouped into camera trap weeks. AIC: Akaike Information Criterion.

	Ψ estimate	SD	P	SD	AIC	-2log_(likelihood)
Chinese serow	0.1196	0.0658	0.1239	0.0463	69.5643	65.5643
Wild boar	0.3674	0.179	0.0454	0.024	92.552	88.552
Sambar	0.4693	0.2819	0.0316	0.0209	86.1084	82.1084
Rhesus macaque	0.2014	0.1061	0.0644	0.0331	72.3144	68.3144

Table 3 Ranking of models which assess the influence of elevation and slope covariates on occupancy rated according to difference in AIC.

	AIC	ΔAIC	AIC wqt	Model likelihood	No.Par	-2log_(likelihood)
Macaque						
p(),psi (elev)	176.76	0	0.5048	1	2	172.76
p(),psi ()	177.22	0.57	0.3797	0.752	2	173.33
p(),psi (slope)	179.71	2.95	0.1155	0.2288	2	175.71
Chinese Serow						
p(),psi()	150.88	0	0.712	1	2	146.88
p(),psi (elev)	152.97	2.09	0.2504	0.3517	2	148.97
p(),psi (slope)	156.76	5.88	0.0376	0.0529	2	152.76
Sambar						
p(),psi (elev)	180.48	0	0.9998	1	2	176.48
p(),psi()	198.51	18.03	0.0001	0.0001	2	194.51
p(),psi (slope)	198.51	18.03	0.0001	0.0001	2	194.51
Wild Boar						
p(),psi (elev)	206.26	0	1	1	2	202.26
p(),psi ()	230.83	24.57	0	0	2	226.83
p(),psi (slope)	230.83	24.57	0	0	2	226.83

Notes: p is probability of detection; psi is proportion of plots occupied; ΔAIC is the relative difference in AIC values between each model and the currently top-ranked model; AIC wqt is the AIC weight which is a measure of support for which is the best model; No. Par is the number of parameters used in the model.

Table 4 GENPRES output for simulations that were run (100 simulations) using varying number of sites based on the detection probability from the weekly occupancy outputs found in Table 3.

	Camera stations	Surveys	Ψ estimate	SD	AIC	SD
Sambar	40	10 weeks	0.785415	25.003958	91.3225	20.23504276
	60	10 weeks	0.76336	0.2420279	136.4493	27.25062072
	80	10 weeks	0.778152	0.2292443	184.7521	30.73261783
Chinese serow	20	10 weeks	0.784961	0.1647334	124.8498	19.8221799
	40	10 weeks	0.772332	0.1305176	245.2097	34.11948202
Wild boar	20	10 weeks	0.743502	0.2915573	61.9267	18.47503743
	40	10 weeks	0.75352	0.2358524	120.5014	25.89983757
	60	10 weeks	0.738603	0.2372163	182.3131	31.03578637
Rhesus macaque	20	10 weeks	0.786661	0.2346569	78.9424	16.75056014
	40	10 weeks	0.761304	0.1891341	156.3481	28.68018757
	60	10 weeks	0.766527	0.1906579	235.0489	37.94665836

5). Of the nineteen species listed, twelve were partially arboreal or primarily nocturnal, which may have resulted in low detection probabilities due to the ground level camera trap methodology that was used. In addition, most of the species on the list are IUCN critically endangered, endangered, or vulnerable species, which implies rarity, meaning they persist at low densities or are not widely distributed. White-handed gibbon (*Hylobates lar*), presumed to be locally extirpated based on previous surveys (Grueter *et al*. 2009).

4 Discussion

Our results highlight the value for conservation in Nangunhe Nature Reserve, Yunnan, China for terrestrial mammals. We demonstrate the efficiency of camera trapping for large and medium-sized terrestrial mammal inventories and how species richness accumulation curves perceive sampling efficacy, as well as yield useful occupancy and detection probability estimates for species with sufficient samples to guide future survey efforts. Six globally IUCN endangered or vulnerable species were recorded which suggests this mammal community still retains a high amount of species richness. The populations of Asian elephants, leopards, Asiatic black bear and other medium sized carnivores may be seen as particularly significant due to extensive regional declines and lack of recent records from many adjacent

Table 5 Summary of mammals not detected within the core area of Nangunhe Nature Reserve, southwest Yunna, China. IUCN, Redlist of globally threatened species status. EN= endangered, VU=vulnerable, NT= near threatened, LC= least concern

Order	Family	Scientific name	English name	IUCN	Partially arboreal	Primarily nocturnal
Carnivora	Felidae	*Panthera tigris*	Indo-Chinese Tiger	EN		Yes
		Neofelis nebulosa	Clouded leopard	VU	Yes	Yes
		Felistem mincki	Asian golden cat	NT		Yes
		Felis chaus	Jungle cat	LC		
	Mustelidae	*Lutral utra*	Eurasian otter	NT		Yes
	Canidae	*Canis lupus*	Gray wolf	LC		
		Nyctereutes procyonoides	Racoondog	LC		Yes
		Cauon alpinus	Dhole	EN		
	Viverridae	*Arcticti binturong*	Binturong	NT	Yes	
	Ailuridae	*Ailurus fulgens*	Red panda	VU	Yes	
Primates	Lorisidae	*Nycticebus coucang*	Slow loris	VU	Yes	Yes
	Cercopithecidae	*Macaca arctoides*	Stump-tailed macaque	VU	Yes	
		Macaca nemestrina	Southern pig-tailed macaque	VU	Yes	
		Hylobates lar	White-handed hibbon	EN	Yes	
Pholidota	Manidae	*Manis pentadactyla*	Chinese pangolin	CR		Yes
Artiodactyla	Cervidae	*Eleaphodus cephalophus*	Tufted deer	NT		
		Axis porcinus	Indian hog deer	EN		
		Moschus berezovskii	Chinese forest musk deer	EN		
		Naemorhaedus goral	Chinese goral	NT		
Total		19			7	7

nature reserves in Yunnan. On-going research work to estimate species populations using non-invasive capture-recapture techniques (for Asian elephant, leopard, Asiatic black bear), and line distance sampling transects and camera trapping for globally threatened large ungulates for example sambar and Chinese serow, can further aide in highlighting conservation significance for large mammals in the area (Gray *et al*. 2012).

4.1 Species inventory in Nangunhe Nature Reserve

To produce a thorough species inventory, researchers need to consider of the number of camera trap stations, survey duration, and sampling bias (O'Brien *et al*. 2003). Previous studies on camera trapping on a small trail system with high density of cameras has been shown produce a reliable species inventory, where total area covered and camera spacing have little impact on survey results (Tobler *et al*. 2008a, 2008b). Camera trapping is also more useful compared to track or line census techniques for a period of more than 30 days (Silveria *et al*. 2003). Camera trap methodology can be limited for rare species' due to elusive behavior, territoriality, size and habitat preferences, in which case it is advised for long term camera deployment to capture all species (Cheyne and MacDonald 2011). Previous studies have found 90% of species in less than 1000 camera trap days and comprehensive inventory at 8700 camera trap days (Si *et al*. 2014), and for rare species more than 3000 camera trap days (Tobler *et al*. 2008a, 2008b).

A key consideration in the design of species richness and inventory surveys is that all species have the potential to be detected (Karanth *et al*. 2004). EstimateS computes species richness information for camera trap data, illustrated by a rarefied species accumulation curve useful to calculate the average number of species given the sampling intensity, which also shows potential for number species not detected during camera trap surveys. In addition, non-parametric jackknife estimators resulted in species richness estimation which was also computed using EstimateS 9.1.0. We can conclude that there were very few species that had zero probability of detection due to the sampling intensity or layout.

The survey may not represent the full range of species present in the entire nature reserve beyond the core zone, especially within the experimental zone which represents a different high elevation habitat and forest succession. There are several ungulate species including Chinese forest musk deer (*Moschus berezovskii*), tufted deer (*Elaphodus cephalophus*), Chinese goral (*Naemorhedus griseus*) (He and Hu 1989; Liu and Liu 2003), thought to persist in elevations higher than 2000m which was outside of the scope of this project. It would be interesting to see if the secondary forest area was colonized by the mammal species from the old growth forest, and if the decision to protect this area with corridors was successful.

Camera trapping at ground level also is not as effective for the mammal species which are be partially arboreal, where further surveys using camera traps in the trees (Di Cerbo and Biancardi 2013), spotlight or radio collar would allow for recording of those individuals (Lynam *et al*. 2013; Kays and Allison 2001). There were several partially arboreal species not recorded by this survey, which may be due to the low detection probability for camera trap methods, including Binturong (*Arctictis binturong*), red panda (*Ailurus fulgens*), stump-tailed macaque (*Macaca arctoides*), southern pig-tailed macaque (*Macaca nemestrina*), white-handed gibbon (*Hylobates lar*)(Yang *et al*. 2004).

Several rare species of carnivores in Southwest China, including clouded leopard (*Neofelis nebulosa*), and Indo-Chinese tiger, which have been previously recorded. Previous camera trapping in Nangunhe Nature Reserve, conducted from January – June 2005, recorded clouded leopard (Feng and Jutzeler 2010). The Nangunhe Nature Reserve also previously had Indo-Chinese tiger (Su and Zhang 2005; Yang *et al*. 2004; Lai 2000), and there are ongoing monitoring efforts. Here, we did not capture either of these two rare species during our survey, which adds evidence that the species has disappeared from the core area of the nature reserve, aside from transient individuals. We had considered baiting camera traps specifically for clouded leopard, but Asiatic black bear and leopard response to the bait was unknown; furthermore, the disturbance effects of sympatric species on potential clouded leopard distribution was also unclear, so bait was not used. Recovery of populations will rely on a commitment by dedicated park management and community support. There were a number of photos that provided strong evidence that poaching and disruptive activities were occurring (such as the presence of humans with guns, domesticated dogs, and livestock). Setting clear goals for management is critical (Yang *et al*. 2004).

4.2 Lessons learnt from occupancy modeling

This study also implies the significance of low detection probability for species with arboreal or nocturnal habit using camera trap methodology. Since detection probability is an issue for abundance calculation, and our ability to detect individual species is arguably always imperfect (Kery and Schmidt 2008), using occupancy estimates can provide estimates for detection probability that can minimize detection bias (Royle and Nichols 2003; Gray *et al*. 2012). However, this survey was not standardized for a systematic occupancy analysis due to logistical considerations. In the future, a more systematic sampling for specific species can be designed and implemented based on these initial results and trials (TEAM Network 2008; Ahumada *et al*. 2011). Systematic sampling for of rare or threatened species for density and occupancy would be more useful than the presence/absence data presented in this study because it provides managers with estimations that are comparable over time and throughout space (Kitamura *et al*. 2010). The non-systematic occupancy analysis shown in this paper is to share initial assessment results to guide future efforts based on a preliminary species inventory, and from this a more thorough species specific standardized and systematic survey can be designed.

4.3 Limitations of camera trap deployment

Camera traps are a reliable method to evaluate biodiversity and used by wildlife managers and policy makers who can use camera trapping datasets to make decisions regarding conservation and management of mammal populations. Although camera trapping is seen as more expensive in terms of initial investment, considering the incurring costs for loss of cameras, there are tradeoffs to consider for considering future monitoring goals within the nature reserve. During this study, there were limitations for efficiently using the camera traps, including placement within the areas of the nature reserve inhabited by elephants, placement in areas with high amounts of vegetation which trigger the cameras unnecessarily, high rainfall within the reserve which results in blurry incoherent photographs, loss of cameras from dense forest areas, and loss of data cards which reduced the number of camera trap days. Being aware of these limitations, the Nangunhe Nature Reserve can work towards further standardization of their camera trap efficiency to detect species within the reserve using occupancy methods, and work towards improving technique since the nature reserve staff is relatively new to deploying camera traps independently.

4.4 Benefits of regional conservation management

The role of Nangunhe Nature Reserve, a small reserve, to protect rare species and species richness is likely not adequate, as it is a small fragmented area in various levels of forest succession. The nature reserve surrounding area has increasingly become regionally deforested and fragmented (Feng *et al*. 2010). Small nature reserves can play a supportive role yet require connectivity and larger scale action planning (Shafer 1999). Mammals are generally more sensitive to forest disturbance than plants, invertebrates and birds, and better information about minimum amount of forests required to retain species richness in human dominated landscapes is needed (Sodhi *et al*. 2010). Habitat loss and fragmentation can influence the genetic structure of biological populations, for example, leopard (Dutta *et al*. 2012). Large wide-ranging mammal species, can face increased extinction risk in smaller patches, which can be mitigated by maintaining landscape connectivity and corridors to enhance gene flow among populations (Di Minin *et al*. 2013; Cushman *et al*. 2013). To protect the nature reserves top predators, leopard and Asiatic black bear, regional ecosystem management is called for at a larger scale than the protected area boundaries. Leopards have shown a home range of 30–50 km^2 (Odden and Wegge 2005; Simcharoen *et al*. 2008), Asiatic black bear also have shown home ranges of 30–50 km^2 (Hwang *et al*. 2010). In addition, this area alone is also not suitable to support a large elephant population (Leimgruber *et al*. 2003). Protected areas are important for conservation, but the quality of the surrounding landscape land use matrix also matters to achieve protection landmarks, because wide-ranging species, for instance tigers, are more vulnerable in this matrix (Sharma *et al*. 2013). Researchers argue that monitoring prey-rich habitat patches, as small as 300 km^2 set in a larger landscape of various land use categories, should be central to tiger recovery in Asia (Nyhus and Tilson 2004). Most protected areas are too small to maintain viable populations of large animals because they are effected by outside land use changes and anthropogenic disturbances (DeFries *et al*. 2010), and only by extending the habitat beyond park boundaries can viable tiger, elephant, and large carnivore populations be maintained over a long period of time (Nyhus and Tilson 2004).

Conservation action based on the combined knowledge of local people and conservation biologists might more effectively target root causes of mammal declines and be better understood and supported by local stakeholders (Steinmetz *et al*. 2006). The management of the Nangunhe Nature Reserve system has yet to adopt an ecosystem services framework to manage trade-offs between local people and biodiversity, despite recent efforts to assess and value the current provision of ecosystem services in the area (Whitham *et al*. 2015). Current management plans mention balancing ecotourism, development, and biodiversity conservation (Yang and Du 2004), yet clear action planning based on a comprehensive ecosystem services framework has yet to be designed. The nature reserve network plays a principal role of biodiversity monitoring and conservation in China (Li *et al*. 2010a), although in China there continues to be an ongoing debate to the ethics of social conservation vs. nature conservation. Tensions arise where nature reserves are seen to take priority over poverty alleviation (Xu and Melick 2000; Zhou and Grumbine 2011) or ecotourism over biodiversity conservation (Xu and Melick 2000; Xu *et al*. 2012; Wang *et al*. 2012; Zhou *et al*. 2013). In addition, researchers have linked human density to declining wildlife populations, mainly due to hunting and poaching of natural resources (Woodroffe 2000; Harcourt *et al*. 2001), and vulnerability to hunting causes drastic declines in prey species that are important for large carnivores (Gray *et al*. 2011; O'Brien *et al*. 2003). There are no simple formulae for combining conservation objectives with local community needs, yet studies have shown that inclusion of local communities is the determinant of the level of compliance with the strategies (Andrade and Rhodes 2012). Efforts should be made in connecting the nature reserve to adjacent nature reserves, and examining landscape connectivity in the trans-boundary area between Myanmar and China. Conservation of ecosystem services requires a landscape scale perspective, where biodiversity can be maintained in complex landscapes with remnant forest that maintains original communities and species across managed systems (Sodhi *et al*. 2010).

5 Conclusions

The results from this survey show that non-systematic camera trapping within 3–4 months can produce large and medium-sized terrestrial mammal species richness and composition information to inform environmental management of conservation at local and regional scales. This survey accomplished an important step in making a registry database for species information in Nangunhe Nature Reserve, Lincang County, Yunnan, and engaging local staff in deploying and demonstrating camera trap methods.The sampling saturation was very high, and obtained records of 17 medium to large sized terrestrial mammals, including several species of conservation concern. The use of camera trapping also allowed us to detect elusive rainforest mammals, which otherwise would have been difficult to detect via tracking or trapping. Of particular interest were the carnivores, which represented by 7 species, including Asiatic black bear and leopard, the nature reserves top predators. Furthermore, we explored basic occupancy analysis and detection probability of five abundant species to design future survey efforts, to gauge the survey effort required for robust single species, single season occupancy analysis.The information from the survey can be useful for developing conservation management programs into the future, and also decide which species may possibly be for monitored over the long term. To maintain viable populations of mammal species within the nature reserve, and encourage the recovery of populations of keystone species such as tiger and clouded leopard, effective management is necessary. Standardizing future camera trapping data management and operating procedures is essential to further inform us the species currently within and outside the reserve so as to meet various conservation challenges.

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References

Ahumada J, C Faresin, K Gajapersad, *et al*. 2011. Community structure and diversity of tropical forest mammals: Data from a global camera trap network. *Philosophical Transactions of the Royal Society of London Series B: Biological Sciences*, 366: 2703-2711.

Andrade G, J Rhodes. 2012. Protected areas and local communities: An inevitable partnership toward successful conservation strategies? *Ecology and Society*, 17(4): 14.

Bailey L L, J E Hines, J D Nichols, *et al*. 2007. Sampling design trade-offs in occupancy studies with imperfect detection: Examples and software. *Ecological Applications*, 17: 281-290.

Bengtsson J. 1998. Which species?? What kind of diversity? Which ecosystem function? Some problems in studies of relations between biodiversity and ecosystem function. *Applied Soil Ecology*, 10: 191-199.

Bernard H, A Ahmad, J Brodie, *et al*. 2013. Camera-trapping surveys of mammals in and around Imbak canyon conservation area in Sabah, Malaysian Borneo. *The Raffles Bulletin of Zoology*, 61(2): 861-870.

Cao H, Tang M, Deng H, Dong R. 2014. Analysis of management effectiveness of nature reserves in Yunnan Province, China. *International Journal of Sustainable Development and World Ecology*, 21(1): 77-84.

Carbone C, S Christie, K Conforti, *et al*. 2001.The use of photographic rates to estimate densities of tigers and other cryptic mammals. *Animal Conservation*, 4, 75-79.

Cheyne S M, D W MacDonald. 2011. Wild felid diversity and activity patterns in Sabangau peat-swamp forest, Indonesian Borneo. *Oryx*, 45: 119-124.

Colwell R, Chao A, N Gotelli, *et al*. 2012. Models and estimators linking individual-based and sample-based rarefaction, extrapolation and comparison of assemblages. *Journal of Plant Ecology*, 5:1 3-21.

Cushman S, B McRae, FAdriaensen, *et al*. 2013. Biological corridors and connectivity. In: Macdonald D W and K J Willis (Eds.). Key Topics in Conservation Biology. John Wiley & Sons, Ltd, 384-403.

DeFries R, K K Karanth, S Pareeth. 2010. Interactions between protected areas and their surroundings in human-dominated tropical landscapes. *Biological Conservation*, 143: 2870-2880.

Di Cerbo A R, C M Biancardi. 2013. Monitoring small and arboreal mammals by camera traps: Effectiveness and applications. *Acta Theriologica*, 58: 279-283.

Di Minin E, L Hunter, G A Balme, *et al*. 2013. Creating larger and better connected protected areas enhances the persistence of big game species in the Maputaland-Pondoland-Albany biodiversity hotspot. *PLos ONE*, 8(8): 1-14.

Dutta T, S Sharma, J E Maldonado, *et al*. 2012. Fine-scale population genetic structure in a wide-ranging carnivore, the leopard (*Panthera pardus fusca*) in central India. *Diversity and Distributions*, 19(7): 760-771.

Feng L M, Wang Z S, Lin L, *et al*. 2010. Habitat selection in dry season of Aisan elephant (*Elephas maximus*) and conservation strategies in Nangunhe National Nature Reserve, Yunnan, China. *Acta Theriologica Sinica*, 30(1): 1-10. (in Chinese)

Feng L M, Wang Z S, Yang S B. 2006. Automatic infrared sensor camera app in nature reserve wildlife surveys and monitoring. The Third National Symposium on Wildlife Ecology and Conservation Abstract Book. (in Chinese)

Feng L M, E Jutzeler. 2010. Clouded leopard. *Cat News (Special Issue)*, 5: 34-36.

Foresman K R, D E Pearson. 1998. Comparison of proposed survey procedures for detection of forest carnivores. *The Journal of Wildlife Management*, 62:1217-1226.

Gray T, C Phan, C Pin, S Prum. 2012. Establishing and monitoring baseline for threatened ungulates in eastern Cambodia. *Wildlife Biology*, 18 (4): 406-413.

Gray T, C Phan. 2011. Habitat preferences and activity patterns of the larger mammal community in Phnom Prich wildlife sanctuary, Cambodia. *The Raffles Bulleting of Zoology*, 59(2): 311-318.

Grueter C, Jiang X, R Konrad, *et al*. 2009. Are *Hylobates lar* extirpated from China? *International Journal of Primatology*, 30(4): 553-567.

Guillera-Arroita G, B J T Morgan, M S Ridout, M Linkie. 2011. Species occupancy modeling for detection data collected along a transect. *Journal of Agricultural, Biological and Environmental Statistics*, 16(3): 301-317.

Haag T, A S Santos, D A Sana, *et al*. 2010. The effect of habitat fragmentation on the genetic structure of a top predator: Loss of diversity and high differentiation among remnant populations of Atlantic forest jaguars (*Panthera onca*). *Molecular Ecology*, 19(22): 4906-4921.

Harcourt A H, S A Parks, R Woodroffe. 2001. Human density as an influence on species/area relationships: Double jeopardy for small African reserves? *Biodiversity Conservation*, 10:1011-1026.

He X, Hu J. 1989. A report on mammals from Yunxian and Jingdong, the middle reaches of the Lancang River, Yunnan. *Journal of Yunnan Univeresity*, 11(2). (in Chinese)

Henle K, K F Davies, M Kleyer, *et al*. 2004. Predictors of species sensitivity to fragmentation. *Biodiversity Conservation*, 13: 207-251.

Hwang M, D Garshelis, Wu Y, Wang Y. 2010. Home ranges of Asiatic black bears in the Central Mountains of Taiwan: Gauging whether a reserve is big enough. *Ursus*, 21(1): 81-96.

IUCN. 2014. Thered list of threatened species (Version 2014.3). www.iucnredlist.org. [2014-04-08]

Karanth K U, J D Nichols, N S Kumar. 2004. Photographic sampling of elusive mammals in tropical forests. In: Thompson W L (Ed.). Sampling Rare or Elusive Species. Washington, D.C.: Island Press, 229-247.

Karanth K U, J D Nichols, N S Kumar, *et al*. 2006. Assessing tiger population dynamics using photographic capture-recapture sampling. *Ecology*, 87(11): 2925-2937.

Karanth K U, J D Nichols. 1998. Estimation of tiger densities in India using photographic captures and recaptures. *Ecology*, 79: 2852-2862.

Kays R, A Allison. 2001. Arboreal tropical forest vertebrates: Current knowledge and research trends. *Plant Ecology*, 153: 109-120.

Kelly M. 2008. Design, evaluate, refine: Camera trap studies for elusive species. *Animal Conservation*, 11: 182-184.

Kery M, B R Schmidt. 2008. Imperfect detection and its consequences for monitoring and conservation. *Community Ecology*, 9(2) 207-216.

Kery M. 2010. Species richness and community dynamics: A conceptual framework. In: O'Connell A F, J D Nichols, U K Karanth (Eds.). Camera Traps in Animal Ecology: Methods and Analyses. Tokyo: Springer.

Kitamura S, S Thong-Aree, S Madsri, P Poonswad. 2010. Mammal diversity and conservation in a small isolated forest of southern Thailand. *The Raffles Bulletin of Zoology*, 58(1): 145-156.

Lai Q. 2000. Community forestry and conflict management: A case in Nangun River Nature Reserve, Yunnan, China. www.mekonginfo.org/mrc_en/doclib.nsf/0/6017CDBE3CFDD122472568E1001397B1/$FILE/FULLTEXT.html [2015-02-02].

Lan D, R Dunbar. 2000. Bird and mammal conservation in Gaoligongshan Region and Jingdong County, Yunnan, China: Patterns of species richness and nature reserves. *Oryx*, 34(4): 275-286.

Leimgruber P, J B Gangon, C Wemmer, *et al*. 2003. Fragmentation of Asia's remaining wildlands: Implications for Asian elephant conservation. *Animal Conservation*, 6: 347-359.

Li S, Wang D, Gu X, *et al*. 2010a. Beyond pandas, the need for a standardized monitoring protocol for large mammals in Chinese nature reserves. *Biodiversity and Conservation*, 19:3195-3206.

Li T, F Shilling, J Thorne, *et al*. 2010b. Fragmentation of China's landscape by roads and urban areas. *Landscape Ecology*, 25: 839-853.

Liu S, Dong Y, Deng L, *et al*. 2014. Forest fragmentation and landscape connectivity change associated with road network extension and city expansion: A case study in the Lancang River Valley. *Ecological Indicators*, 36 160-168.

Liu S, Liu L. 2003. Studies on the species diversity of mammals in southern Hengduanshan: Spatial patterns of species richness of mammals in nature reserves in southern Yunnan. Zhejiang University Dissertation. (in Chinese)

Lynam A, E Jenks, N Tantipisanuh, *et al*. 2013. Terrestrial activity patterns of wild cats from camera-trapping. *The Raffles Bulletin of Zoology*, 61(1): 407-415.

Ma S L, R B Harris. 1996. Use of remote camera systems to document wildlife species presence in forested areas of Yunnan. *Zoological Research*, 17(4): 360-370. (in Chinese)

Macdonald D W, G Mace, G R Barretto. 1999. The effects of predators on fragmented prey populations: A case study for the conservation of endangered prey. *Journal of Zoology*, 247(04): 487-506.

MacKenzie D I, J D Nichols, G B Lachman, *et al*. 2002. Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, 83: 2248-2255.

Manley P, B Van Horne, J Roth, *et al*. 2006. Multiple species inventory and monitoring technical tuide. Gen. Tech. Rep. WO-73. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office, 204.

Nyhus P, R Tilson. 2004. Agroforestry, elephants, and tigers: Balancing conservation theory and practice in human-dominated landscapes of Southeast Asia. *Agriculture, Ecosystems and Environment*, 104:87-97.

O'Brien T G, M F Kinnaird, H T Wibisono. 2003. Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Animal Conservation*, 6(2): 131-139.

O'Brien T, M Kinnaird, Wibisono H. 2010. Estimation of species richness of large vertebrates using camera traps: An example from an Indonesian rainforest. In: O'Connell AF, J D Nichols, U K Karanth (Eds.). Camera Traps in Animal Ecology: Methods and Analyses. Tokyo: Springer.

O'Connell A F, J D Nichols, U K Karanth (Eds.). 2010. Camera traps in animal ecology: Methods and analyses. Tokyo: Springer.

Odden M, P Wegge. 2005. Spacing and activity patterns of leopards Panthera pardus in the Royal Bardia National Park, Nepal. *Wildlife Biology*, 11: 145-152.

Ordiz A, R Bischof, J Swenson. 2013. Saving large carnivores, but losing the apex predator? *Biological Conservation*, 168: 138-133.

Pu Y, Zhang Z, Pu L, Hui C. 2007. Biodiversity and it's fragility in Yunnan, China. *Journal of Forestry Research*, 18(1): 39-47.

Royle J A, J D Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. *Ecology*, 84(3): 777-790.

Sanderson J, M Trolle. 2005. Monitoring elusive mammals. *American Scientist*, 93(2): 148-155.

Shafer C. 1999. National park and reserve planning to protect biological diversity: Some basic elements. *Landscape and Urban Planning*, 44: 123-153.

Sharma S, Dutta T, Maldonado J E, *et al*. 2013. Forest corridors maintain historical gene flow in a tiger metapopulation in the highlands of central India. *Proceedings of the Royal Society B*, 280: 20131506.

Si X, R Kays, Ding P. 2014. How long is enough to detect terrestrial animals? Estimating the minimum trapping effort on camera traps. *PeerJ*, 2:e374. DOI: 10.7717/peerj.374.

Silveira L, A Jacomo, J Aleandra, *et al*. 2003. Camera trap, line trasect census and track surveys: A comparative evaluation. *Biological Conservation*, 114: 351-355.

Simcharoen S, A Barlow, A Simcharoen, J Smith. 2008. Home range size and daytime habitat selection of leopards in HuaiKhaKhaeng Wildlife Santuary, Thailand. *Biological Conservation*, 141: 2242-2250.

Smith A and Xie Y. 2008. A guide to the mammals of China. Princeton, New Jersey: Princeton University Press.

Sodhi N, P Kohn, R Clements, *et al*. 2010. Conserving Southeast Asian forest biodiversity in human-modified landscapes. *Biological Conservation*, 143: 2375-2384.

Steinmetz R, W Chutipong, N Seuaturien. 2006. Collaborating to conserve large mammals in Southeast Asia. *Conservation Biology*, 20(5): 1391-1401.

Su T, Zhang E. 2005. A preliminary survey on the presence of Indo-Chinese tiger (*Panthera tigris corbetti*) in Yunnan Province, China. *Cat News*, 42: 9-12.

Sun G, Qu Y, Tang M, *et al*. 2013. Priority conservation plans of ecological function areas for terrestrial endangered mammals in China. *Biodiversity Science*, 21(1): 47-53.

Suntaro S R, A Mohamed, M Kelly. 2013. Camera trapping for the study and conservation of tropical carnivores. *The Raffles Bulletin of Zoology*, 28: 21-42.

Tang Z, Wang Z, Zheng C, Fang J. 2006. Biodiversity in China's mountains. *Front Ecology and Environment*, 4(7): 347:352.

TEAM Network. 2008. Terrestrial vertebrate protocol implementation manual (v. 3.0). Tropical Ecology, Assessment and Monitoring Network, Center for Applied Biodiversity Science, Conservation International, Washington DC, 56.

The State Council. 1988. National key protected wild animal list. People's Republic of China Ministry of Forestry (1989), Ministry Agriculture (1989). (in Chinese)

Tobler M W, S E Carrillo-Percastegui, R L Pitman, *et al*. 2008b. Further notes on the analysis of mammal inventory data collected with camera traps. *Animal Conservation*, 11:187-189.

Tobler M. 2014. Camera base. San Diego, USA: San Diego Zoo Institute for Conservation Research.

Tobler MW, S E Carrillo-Percasegui, R L Pitman, *et al*. 2008a. An evaluation of camera traps for inventorying large- and medium-sized terrestrial rainforest mammals. *Animal Conservation*, 11: 169-178.

Vanak A T, M E Gompper. 2007. Effectiveness of non-invasive techniques for surveying activity and habitat use of the Indian fox *Vulpes bengalensis* in southern India. *Wildlife Biology*, 13: 219-224.

Wang G, J L Innes, Wu SW, *et al*. 2012. National park development in China: Conservation or commercialization? *AMBIO*, 41:247-261.

Whitham C, Shi K, P Riordan. 2015. Ecosystem service valuation assessments for protected area management: A case study comparing methods using different land cover classification and valuation approaches. *PLoS ONE,*10(6): e0129748. DOI: 10.1371/journal.pone.0129748

Woodroffe R. 2000. Predators and people: Using human densities to interpret carnivore declines. *Animal Conservation*, 3: 165-173.

Xu J, Zhang Z, Liu W and P McGowan. 2012. A review and assessment of nature reserve policy in China: Advances, challenges and opportunities. *Oryx*, 46: 554-562.

Xu J, D RMelick. 2000. Rethinking the effectiveness of public protected areas in Southwestern China. *Conservation Biology*, 21(2): 318-328.

Yang Y, Du F (Eds.). 2004. Nangun River National Nature Reserve of China. Kunming: Yunnan Science and Technology Press. (in Chinese)

Yang Y, Tian K, Hao J, *et al*. 2004. Biodiversity and biodiversity conservation in Yunnan, China. *Biodiversity and Conservation*, 13: 813-826.

Zhang L, Ma L, Feng L. 2006. New challenges facing traditional nature reserves: Asian elephant (*Elephas maximus*) conservation in China. *Integrative Zoology*, 1: 179-187.

Zhang M, Chang R, Cao L, *et al*. 2014. Camera trap survey of animals in Xishuangbanna Forest Dynamics Plot, Yunnan. *Biodiversity Science*, 22 (6): 830-832.

Zhang M, Zhou Z, Chen W, *et al*. 2012. Using species distribution modeling to improve conservation and land use planning of Yunnan, China. *Biological Conservation*, 153: 257-264.

Zhou D, E Grumbine. 2011. National parks in China: Experiments with protecting nature and human livelihoods in Yunnan Province, Peoples' Republic of China (PRC). *Biological Conservation*, 144: 1314-132.

Zhou Y, C Buesching, C Newman, *et al*. 2013. Balancing the benefits of ecotourism and development: The effects of visitor trail-use on mammals in a protected area in rapidly developing China. *Biological Conservation*, 165: 18-24.

云南南滚河自然保护区大中型陆生哺乳动物初步调查

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摘　要：在云南省南滚河自然保护区进行猫科动物调查的同时，我们采用红外相机技术，在保护区核心区内进行了哺乳动物调查。我们在该保护区林地内架设了40台数字红外相机，旨在进行大中型哺乳动物调查评估。在2460个红外相机工作日内，拍到5目17种哺乳动物照片共计232张。调查记录到的这些物种不仅展示了该区较高的物种多样性，也包括了许多珍稀物种以及具有很高保护价值的物种，如IUCN红色名录濒危物种亚洲象（*Elephas maximus*）和菲氏叶猴（*Trachypit hecus phayrei*）。此外，也发现了亚洲黑熊（*Ursus thibetanus*）、水鹿（*Rusa unicolor*）、豚尾猴（*Macaca leonine*）、云猫（*Pardofelis marmorata*）等IUCN红色名录易危物种。所有这些哺乳动物都是国家重点保护野生动物，其中包括7种重要的食肉动物。有蹄类和其他一些猎物物种为记录最多的类群，分布也更为广泛，包括猕猴（*Macaca mulatta*）、赤麂（*Muntiacus muntjac*）、水鹿、野猪（*Sus scrofa*）、中华鬣羚（*Capricornis milneedwardsii*）等。这些初步的调查结果为当地开展科学规范的物种监测和保护提供了重要信息和可参考案例。

关键词：物种丰富度；物种名录；占有模型