Factors affecting the efficacy of biodiversity conservation in tropical protected areas: a case study in Xishuangbanna, southwestern China

by

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Abstract

Protected areas have long been considered the backbone of biodiversity conservation strategies. However, whether protected areas are truly effective at conserving biodiversity remains an important question. Factors affecting the efficacy of biodiversity conservation in protected area are complex - human population density, policy enforcement, and local community attitudes towards conservation could all influence conservation outcomes. In this study, I measured how attitudes towards conservation and perception of law enforcement (based on 354 questionnaire surveys) in communities surrounding protected areas was associated with wildlife within the protected areas. I used motion-triggered camera traps (12,148 camera-trap days in total) and Bayesian hierarchical statistical models to estimate occupancy rates for four commonly hunted mammal species, as well as the species richness of medium- to large-sized mammals in six protected areas in Xishuangbanna, southern China, a diverse sub-tropical region with high hunting and land conversion pressures. I found that abundance of the large size species-wild boar (*Sus scrofa*) and small size Asian palm civet (*Paradoxurus hermaphroditus*), was positively correlated with park size. However, the villager-reported number of punishments the park meted out for law violations, and the villager-reported frequency of outreach by park staff to the local communities did not have significant effects on population size as well as richness of wildlife. Mammal diversity of mammal across parks was more correlated with villager-reported law enforcement effort than with outreach, even in parks surrounded by large human populations. My study highlighted the importance of reserve size, adequate habitat is the key of maintaining wildlife population in this area. My study provides insights that protected areas that have stricter enforcement as well as more frequent outreach activities could be more effective and our approach is applicable to assess effects of conservation actions on wildlife.

Lay Summary

Protected areas have long been considered the backbone of biodiversity conservation strategies. However, whether protected areas are truly effective at conserving biodiversity remains an important question. Factors affecting the efficacy of biodiversity conservation in protected area are complex - human population density, policy enforcement, and local community attitudes towards conservation could all influence conservation outcomes. In this study, I measured how attitudes towards conservation and perception of law enforcement (based on 354 questionnaire surveys) in communities surrounding protected areas was associated with wildlife within the protected areas. My study highlighted the importance of reserve size, adequate habitat is the key of maintaining wildlife population in this area. My study provides insights that protected areas that have stricter enforcement as well as more frequent outreach activities could be more effective and our approach is applicable to assess effects of conservation actions on wildlife.

Preface

This thesis is an original, unpublished work by Cheng Chen. The research project received research ethics approval from Human subject ethics committee of University of British Columbia (UBC BREB number: H15-01106, project name: Xishuangbanna biodiversity conservation project, July 17, 2015).

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Chapter 1: Introduction

Protected areas are defined as areas of land and/or sea especially dedicated to the protection and maintenance of biological diversity and natural and associated cultural resources, and managed through legal or other effective means (Dudley 2008). They have long been considered to be cornerstones of national and international conservation strategies (Dudley 2008). They act as refuges for species in fragmented landscapes and can maintain ecological processes that do not persist in areas with intensive land management by humans. In 2005 there were more than 100,000 protected areas worldwide, covering about 12% of the Earth's land surface (Chape et al. 2005). China, Earth's most populous country, has 2,538 nature reserves with a total area of 1.43 million km^2, or approximately 15.13% of its total land area (Wu et al. 2011).

The protected area strategy has focused on protecting 'pristine' landscapes from humans. However, human impacts are nearly ubiquitous in terrestrial and marine ecosystems, so it is problematic to try to separate "natural" system from human-influenced systems (Corlett 2015). In developing countries in particular, most protected areas are surrounded by human-altered landscapes and have human inhabitation within them. These external and internal anthropogenic threats can drive extinctions of vulnerable animal species in protected areas; for example, hunters are still able to access most of even large protected areas (Liu et al. 2001; Robbins et al. 2006; Corlett 2007), and strong "edge effects" from human disturbance permeate great distances into reserves (Olupot et al. 2009). Simply establishing parks without effectively managing them is not sufficient for conserving biodiversity (Schwartzman et al. 2000; Bruner et al. 2001).

Multiple lines of evidence have suggested that, for a variety of reasons, many protected areas are failing at effectively protecting key species (Gaston et al. 2008, Geldmann et al. 2013). In particular, two reviews, covering thousands of publications from hundreds of protected areas around the world, suggest that protected areas are usually effective at conserving forest habitat, but that they fail to protect many key animal species (Gaston et al. 2008; Geldmann et al. 2013). In tropical regions in particular, more than half of protected areas have experienced significant erosions of biodiversity (Laurance et al. 2012).

One of the main reasons for such low efficacy of parks is that many of them lack effective management. This is the well-known "paper park" syndrome (Bruner et al. 2001; Keane et al. 2008), whereby nominally protected reserves are subject to severe, illegal wildlife hunting (Corlett 2007). Proper law enforcement in parks has long been known to be essential for protected area management (Rowcliffe et al. 2004; Gibson et al. 2005), but is very expensive (Bruner et al. 2004). Anti-poaching action such as ranger patrols is the most commonly reported enforcement strategy (Geldmann et al. 2013). In Serengeti national park, for example, anti-poaching action halted declines in buffalo populations over a short period (Hilborn et al. 2006; Metzger et al. 2010). Moreover, the level of funding for anti-poaching activity is positively correlated with trends in abundance of African buffalo (*Syncerus caffer*), elephant (*Loxodonta africana*), and black rhino (*Diceros bicornis*) (Hilborn et al. 2006). Law enforcement has also been shown to be the best predictor of survival for Great Apes in Africa (Tranquilli et al. 2012). In a less guarded reserve in Costa Rica, densities of mammal species were 6-28% of what they were in more strictly guarded reserves (Carrillo et al. 2008). Pettorelli et al. (2010) found that carnivore biodiversity tended to be higher in national parks than in game reserves and forest reserves, and suggested that those differences could likely be explained by greater resources being allocated to protection of parks (Pettorelli et al. 2010). Evidence has shown that reducing enforcement level often increases the amount of poaching (Jachmann & Billiouw 1997; de Merode et al. 2007).

However, effective law enforcement is not the only answer—better outreach and interaction with local people are also critical. Conflicts of interest between protected areas and local forest-dwelling people are often reported (Weladji & Tchamba 2003; Minteer & Miller 2011). Park restrictions on access to natural resources can jeopardize the livelihoods of local people living in or near the protected area (Naughton-Treves et al. 2005). Furthermore, wildlife straying out of the protected areas can cause crop damage and livestock depredation or even threaten human lives (Weladji & Tchamba 2003). The negative attitudes towards protected areas that this generates among local people can undermine park efficacy and long-term biodiversity conservation (Schwartzman et al. 2000).

To address “people-park conflicts”, many conservation biologists emphasize the need for outreach to people living in and around protected areas, and the importance of integrated management that includes local communities in decision-making processes (Wells et al. 1992). Evidence suggests that protected area outreach is able to change attitudes towards conservation and to reduce illegal encroachment into protected areas (Holmes 2003; Kideghesho et al. 2007; Steinmetz et al. 2014). This represents a “bottom-up” conservation strategy that is distinct from the more “top-down” strategy of law enforcement.

While enforcement and outreach might both be important for protected area efficacy, it is critical to understand the relative benefits of these two strategies so that limited conservation resources can be allocated optimally. Which of the two approaches has a stronger influence on biodiversity conservation inside protected areas remains poorly known, and our understanding of the conditions under which protected areas succeed or fail to deliver conservation outcomes remain poor (Geldmann et al. 2013). Recent research in Thailand suggests that community outreach can be more effective than law enforcement at reducing poaching pressure in reserves (Steinmetz et al. 2014). The authors of this study argued that conservationists should treat outreach or community-based conservation as at least as important as law enforcement (Steinmetz et al. 2014). Community-based conservation also leads to more positive attitudes toward conservation among local residents than does state-led conservation (Brooks et al. 2006; Lepp & Holland 2006). Nevertheless, neither of these approaches is a panacea; variation in culture, norms, and conventions across different areas is high (Adams & Hulme 2001; Berkes 2007), so what works in one area may not be effective in another. Significant knowledge gaps remain in our understanding of how different types of management affect biodiversity in protected areas (Gaston et al. 2008).

This study aims to assess the degree to which law enforcement and community engagement affect megafauna in a suite of protected areas in southern China. My specific objectives are to: 1) assess the relationships between villager-reported law enforcement and villager-reported community engagement (outreach) with large mammal diversity and occurrence within 6 different protected areas, 2) estimate variation in mammal diversity and the relative abundance of several larger-bodied species across the protected areas, and 3) correlate animal diversity and abundance with abiotic and anthropogenic factors. There is an urgent need for more effective conservation practices in this area, which is a global biodiversity hotspot (Myers et al. 2000). My research is intended to inform future management strategies so as to reduce further biodiversity declines in existing protected areas.

Chapter 2: Do law enforcement and community outreach work? Measuring their success in wildlife conservation in a biodiversity hotspot in southwestern China

2.1 Introduction

Protected areas are at the forefront of global efforts to protect biodiversity in the "Anthropocene" and are the most important 'units' for in situ conservation (Chape et al. 2005). They are often intended to act as refuges for species in fragmented landscapes (Laurance et al. 2012), maintain critical ecological processes (Arcese & Sinclair 1997), and allow species to shift locations in response to changing climate (Hannah et al. 2007).

However, the success of protected areas at conserving biodiversity is often questioned (Rodrigues et al. 2004, Chape et al. 2005, Laurance et al. 2012). Most protected areas lack long-term monitoring, making it difficult to gauge their success at maintaining populations of threatened species or ecological processes (Parrish et al. 2003). Retrospective assessments of protected area efficacy have highlighted that most, particularly in tropical countries, have failed to halt illegal exploitation and the decline of wildlife populations (Gaston et al. 2008, Laurance et al. 2012, Geldmann et al. 2013).

A variety of reasons may account for the widespread failure of protected areas at conserving species (Gaston et al. 2008, Geldmann et al. 2013). Many are too small to support viable populations of large-bodied animals with low population densities (Brent Gurd et al. 2001). Small protected areas also have a high proportion of their area influenced by edge effects (Olupot et al. 2009). And even large protected areas may lose species through lack of connectivity to other parts of the landscape (Chape et al. 2005, Leverington et al. 2010, Brodie et al. 2015).

Aside from the size and location of protected areas, how they are managed can be a key determinant of their success. Lack of law enforcement has often been highlighted as a critical problem in protected areas, especially in developing countries that lack sufficient resources for effective on-the-ground management (Laurance et al., 2012). For example, Leader-Williams and

Albon (1988) show that the rate of decline of rhinos and elephants related directly to conservation effort and spending in South Luangwa Nation parks, Zambia. Indeed, reductions in enforcement level can lead to dramatic increases in poaching activity (Jachmann & Billiouw 1997, de Merode et al. 2007). But on the other hand, strong law enforcement can also generate negative attitudes towards the protected area among local people, leading to 'people-park' conflicts (Weladji & Tchamba 2003, Minteer & Miller 2011). In the long-term, it is difficult to achieve conservation goals without the support of local people (Berkes 2007). So we still lack a general understanding of how law enforcement levels affect protected area efficacy (Geldmann et al. 2013).

Besides "top-down" management strategies such as law enforcement, another non-mutually exclusive conservation strategy is to engage local communities via outreach (Wells et al. 1992). Such outreach can lead to significant changes in attitude towards conservation and reduce illegal encroachment into protected areas (Holmes 2003, Kideghesho et al. 2007, Steinmetz et al. 2014). But more research is needed to better understand how outreach ultimately affects biodiversity conservation (Mascia et al. 2003, Williams & Gordon 2015).

In this study, I assess how villager-reported community outreach and villager-reported law enforcement correlate with wildlife diversity and abundance in a suite of protected areas in the Xishuangbanna Region of southwestern China. This region is a global biodiversity hotspot (Myers et al. 2000) and holds most of the remaining habitat for several endangered or critically endangered megafauna in China such as the Asian elephant (*Elephas maximus*) and guar (*Bos gaurus*). I measured animal diversity and abundance in several nature reserves that have similar environment conditions but which vary in their management to try to understand how multiple factors, independently and interactively, affect the conservation effectiveness of the parks. I hypothesized that mammal diversity would be positively related to the strictness of villager-reported law enforcement within parks and the frequency of villager-reported community outreach activities conducted by park authorities. My general goal of this study was to understand the conditions under which parks succeed at supporting populations of large animals so as to help direct future conservation efforts.

2.2 Methods

2.1.1 Study sites

Xishuangbanna is in the Yunnan Province of southwestern China (Fig. 1). It is in the upper basin of the Mekong River and is a part of the Indo-Burma biodiversity hotspot (Myers et al. 2000). The total area of Xishuangbanna is 19,200 km^2, or 0.5% of China, but it holds over 16% (~5000 species) of the country's vascular plant species and 22% (102 species) of the mammals (Zhang & Cao 1995). Biodiversity in the region is threatened by habitat loss and fragmentation from large-scale rubber plantations (Li et al. 2007; Ziegler et al. 2009) as well as by direct exploitation such as hunting.

The Chinese Forestry Department established Xishuangbanna National Nature reserve (XNR) in 1958, composed of five independently managed sub-reserves with a cumulative area of 2417 km^2: Mengla Sub-reserve, Mengyang Sub-reserve, Shangyong Sub-reserve, Mangao Sub-reserve, and Menglun Sub-reserve (Fig. 1). All people and villages were relocated from core zone of the reserves. Human activities other than scientific research are forbidden in the cone zones of the reserves but allowed in surrounding buffer areas. Nabanhe National Nature Reserve (NNR), in the same region, was established to protect a small watershed. It was established in 1991 and became a national reserve in 2000, with 266 km^2 managed by the Environment Department. This reserve still has villages in the buffer zone and people there are allowed to collect forest products and to plant crops. Bulong County Natural Reserve (BNR) is a new county-level reserve that was established in 2009 with 353 km^2. It has two major sections: Bu Lang Shan section and Meng Song section. Among the five sub-reserves in XNR, Mangao Sub-reserve and Mengla Sub-reserve are considered to have moderate law enforcement, while Menglun Sub-reserve is considered to have relatively weak enforcement (Sreekar et al. 2015). Menglun Sub-reserve is also the smallest patch of forest among the different reserves, with 112 km^2. NNR has a good reputation for initiative in cooperating with local communities and having strict enforcement of regulations. Both sections of BNR are considered to have relatively weak enforcement (Sreekar et al. 2015). Research was conducted in six sites in XNR, NNR and BNR (Table 1).

2.2.2 Mammal sampling

I deployed camera-traps (Ltl Acorn®) in six reserves: Mengla, Menglun, Mangao sub-reserve of XNR, NNR, Mengsong, and Bulangshan from May to October in 2014 and 2015 (Fig. 1, Fig. 2). These traps used infrared and motion triggers and were set to medium sensitivity to reduce mis-triggers. Time interval between two trigger events was set to one minute and three photos were taken upon each trigger. Camera traps were installed along 5-10 km transects spaced 300-800m apart and were active 24 hours/day. Cameras were attached to the base of trees about 70-100cm above the ground. We selected trees that were 10-20 meters away from trails to avoid potential sabotage from local residents, and selected areas where light and slope conditions conferred high visibility. The transects covered the core zones of each nature reserve and straddled different forest types as much as possible. Each transect had at least eight camera traps. Consecutive photographs were considered to be independent detections if 1) they contained different species or clearly different individuals, 2) they were of the same species but separated by more than one hour, or 3) they were of the same species but with other species photographed in between (O'Brien et al. 2003, Yue et al. 2015). I calculated a simple relative abundance index (RAI) as the number of photographs of each species per 100 camera-trap days.

2.2.3 Questionnaire surveys

I conducted questionnaire surveys to assess local peoples' attitudes towards conservation (Appendix I, Part 1) and local peoples' self-reported perceptions of enforcement level and outreach frequency conducted by protected area staffs (Appendix I, Part 2) between 8:00 to 18:00 in May - October, 2015. To gauge the villager-reported level of government-sponsored law enforcement and outreach, Part 2 of questionnaires contained questions about the number of punishments the park meted out for law violations, the relationship between park staff and villagers, the rules of the protected area regarding hunting, and the rules of the protected area in terms of the collection of non-timber forest products. Questions in part 2 were asked right after the attitude-survey questionnaires (Part 1). I used data from the questionnaire about the number of punishments meted out for law infractions as a metric of people's perception of law enforcement activity for each area.

Ten attitude factors were extracted from the questionnaire survey data using Principal Component Analysis (correlation matrix) with Varimax rotation (Primmer & Karppinen 2010) (Table 2). Questions that had the strongest correlation or the largest loadings for each component were grouped together. 30 questions were grouped into ten attitude factors: 1) attitudes towards wildlife conservation (one question), 2) perceived behavioral control (an individual's perceived ease or difficulty of performing the particular behavior) (Ajzen 1991)(one question), 3) innate affinity for wildlife (one question), 4) innate affinity for wild plants (1 question), 5) attitudes about the benefits of plants and wildlife (two questions), 6) attitudes about the benefits of the protected area (two questions), 7) social norms about hunting and wildlife (two questions), 8) social norms about plants (five questions), 9) social norms about the protected areas (three questions), and 10) social norms about living near protected areas (two questions) (Table 2). For each question, the answer with agree, neutral, and disagree were given score by 1, 0, -1, respectively. For the attitude with more than one questions, the score was divided by question numbers.

The outreach frequency was calculated from Appendix part 2 question 1, answer that report 0, 1-2, 3-5, 5-10, 10-15, more that 15 times per year were coded as 0, 1.5, 4, 7.5, 12.5, 15. The number of punishments was calculated from Appendix part 2 question 2, answer that 0, 1-5, 5-10, 10-15, 15-20 and more than 20 punishments last year were coded as 0, 2.5, 7.5, 12.5, 17.5 and 20 people respectively. The relationship between park staff and villagers was calculated from Appendix part 2 question 3, the answer with very bad, bad, neutral, good and very good were given score by -2, -1, 0, 1, 2 respectively. The understanding of rules was measured based on multiply choose question - Appendix part 2 question 4 & 5. For example, the correct answers for question 4 are “Warning &get expel from PAs”, “Confiscation of plants & tools” and “Fine”. 0%, 33%, 66% or 100% mark were given to this question if responders circled 0, 1, 2 or all of the correct answers respectively.

The survey was a sample of people living near the administrative border of each reserve in Xishuanbanna (Fig. 1, Fig. 2). I selected at least four villages for each protected area, including one village for each of the three most common ethnic groups. The household of each village was selected by systematic sampling: I first arbitrarily chose one house and then visited all nonadjacent houses along a randomly chosen direction from the original house. Households without available respondent were skipped until 20% of the households in each village were sampled. Within a household, I surveyed one family member older than 16 years. I first introduced myself as a master student from University of British Columbia, Canada and Xishuangbanna Tropical Botanical Garden and I am doing a research in their village. I then obtained consent by asking responders whether they would like to answer some questions about their attitudes towards wildlife, wild plants and protected area. Respondents were asked to indicate the closest nature reserve and the time it took to get there. Fifteen questions, each on a 3-point scale, were used to measure attitudes towards hunting, plant exploitation, and the establishment of parks (five questions for each objective; Appendix 1, Part 1). A total of 30 villages were surveyed and 379 questionnaires collected.

Different ethnic groups of people in Xishuangbanna have different beliefs, and land use perspectives (Xu 2006) might affect their point view regarding use of natural resources (Ghorbani et al. 2012). For example, the most populous Dai people predominantly manage the fertile lowlands; the other groups such as the Hani and the Lahu have to live in the hills to earn a livelihood. Dai are Hinayana Buddhists; Hani are animist and worship their ancestors; Bulang have mixed beliefs of Buddhism, polytheism and ancestor worship (Xu 2006). Thus I collected socio-demographic data for each respondent (all self-reported) including age, gender, ethnicity, education level, number of family members, and annual income (yuan, 1 yuan = 0.15 USD). The surveys were conducted in Mandarin or translated into local languages (Dai, Hani) if the respondents did not speak Mandarin. At least one local resident was hired for guiding and translation during the interviews for each park. The consistency of translation was verified by multiple people (other guides or field assistants) who could speak both languages. A pre-test with 50 respondents was conducted to adjust questionnaires before they were used in real investigation. Some wording of questions was revised and the original five-point scale question was changed to three-point scale. The mean scores of the responses were used as a metric of the attitude towards conservation in each area. Questionnaire surveys were approved by the Human subject ethics committee of University of British Columbia (UBC BREB number: H15-01106).

2.2.4 Statistical analysis of factors affecting local abundance of key wildlife species

Hunting in Southeast Asia is known to affect numerous species, though some may be targeted particularly heavily (Harrison et al. 2016). I used Royle-Nichols latent abundance *N*-mixture models (Royle & Nichols 2003) to estimate how local abundance of 4 commonly hunted species varied across the parks: wild boar (*Sus scrofa*), northern red muntjac (*Muntiacus vaginalis*), Asian palm civet (*Paradoxurus hermaphroditus*), and masked palm civet (*Paguma larvata*) (Fig. 3). Wild boar and muntjac are large, terrestrial, and the most commonly hunted species, while Asian palm civet and masked palm civet are medium-sized, arboreal species that are less frequently exploited (Corlett 2007).

I modeled the latent abundance of a species at site *j* using a Poisson distribution of parameter λ:

$$\mathrm{N}_j \sim Poisson(\lambda_j)$$

The detection of a single individual at site *j* during sample period *k* (ω_{jk}) was considered to be a Bernoulli process of the detection probability of individual r_j:

$$\omega_{jk} \sim Bernoulli(r_j)$$

The relationship between detection probability of one site (p_{jk}) and detection probability of an individual (r_{jk}) can be stated as:

$$p_{jk} = 1 - (1 - r_{jk})^{N\,j}$$

Site covariates thought to potentially influence abundance were modeled as:

$$\log(\lambda_j) = \alpha 0_j + \alpha j_j * x_j$$

Factors potentially influencing detection probability were modeled as:

$$\mathrm{logit}(r_j) = \beta 0_j + \beta j_j * x_j$$

Factors potentially affecting mammal abundance ($\alpha j_j * x_j$ covariates in the log-link function) included: 1) the distance from each camera station to the closest boundary of the protected area, as an index of site accessibility, 2) an index of human population density for the area surrounding each camera station, 3) the size of the protected area, 4) villager-reported frequency of outreach by park staff to the local communities, and 5) villager-reported number of punishments the park meted out for law violations. Distance from camera trap to the boundary of protected area was calculated in QGIS. The relative human population density within 3 km of each camera station was calculated based on the China population map of 2010 (Gaughan et al. 2016).

For detection covariates ($\beta j_j * x_j$ in the logit-link function), I used the number of hours that each trap was active and a binary determination of whether cameras were installed at angles that conferred low visibility (cam_angle; Deploying cameras at angles was necessary in some instances to account for reduced visibility at a particular site due to, for example, micro-topography or tree-falls). All covariates were standardized to have a mean of 0 and variance of 1.

We ran 10 models with different combination of the covariates using the R package "unmarked" (Fiske & Chandler 2011). In order to compare the different models, I calculated the Akaike Information Criterion (AIC) for each, and ranked them by AIC weights. I also computed model-averaged predictions using the R package "AICcmodavg" (Mazerolle 2016) to estimate how occurrence would vary with the above factors.

Finally, correlation between villager-reported outreach, punishment was tested. The relationship between raw detection data of the four mammal – RAI: Relative abundance index (independent photos pre 100 camera trap days) of each park over park averaged frequency of villager-reported outreach, frequency of villager-reported punishment and size of protected area was examined.

2.2.5 Statistical analysis of factors affecting mammal species richness

I used community-level Bayesian hierarchical models to determine how villager-reported law enforcement and outreach affected overall mammal species richness. This multispecies occupancy model assumes that occurrences (Z) of observed species is represented by a Bernoulli process of the probability (Ψ) that species *i* occurs at site *j*, where Z = 1 when the species is present and 0 when absent. Detection ($Y_{i,j,k}$) is also a Bernoulli process of both occurrence ($Z_{i,j}$) and the probability of detection ($P_{i,j}$). In addition to those two levels, I used hierarchical estimation and data augmentation to estimate the number of species present in the community but not detected at any site (Royle & Dorazio 2008; Iknayan et al. 2014). These models assume that the occurrence state (W) of all partially observed species and unobserved species is a Bernoulli distributed random variable indexed by the parameter Ω. The detection of *n* species is augmented by *m* unobserved "pseudospecies" (Royle & Dorazio 2008; Iknayan et al. 2014). This process is completed by augmenting the data with an arbitrary number of undetected species with all-zero detection histories to represent species present in the study area but not detected. The number of species should be larger than the observed number (Royle & Dorazio 2008); for this project I augmented the 22 observed species with 25 unobserved.

$$Z_{i,j} \sim Bernoulli(W_i * \Psi_{i,j})$$

$$Y_{i,j,k} \sim Bernoulli(Z_{i,j} * \mathrm{P}_{i,j})$$

$$W_i \sim Bernoulli(\Omega)$$

Occupancy ($\Psi_{i,j}$) is governed by species-specific factors ($\alpha 0_i$) and relevant site covariates (αj_j) in the logit link functions:

$$logit(\Psi_{i,j}) = \alpha 0_i + \alpha 1_i * elevation_j + \alpha 2_i * population_j + \alpha 3_i * outreach_j + \alpha 4_j * punishment_j + \alpha 5_j * income_j$$

Similarly, detection probability is governed by species-specific covariates ($\beta 0_j$) and relevant site covariates (βj_j).

$$logit(\mathrm{P}_{i,j}) = \beta 0_i + \beta 1_j * camhour_j + \beta 2_j * cam\_angle_j$$

I considered elevation as a fundamental factor potentially affecting species occurrence in Xishuangbanna. Different forest types occur along the 665 to 1800 meters elevation gradient in this area, which may affect species distributions. In addition, I hypothesized that human disturbance may influence animal distributions. I used relative human population density and average income levels surrounding each protected area to index human disturbance. Human density within a 3 km buffer around each camera station was calculated based on the Chinese population map of 2010 (Gaughan et al. 2016). I hypothesized that villager-reported outreach frequency and villager-reported enforcement frequency would influence the occurrence of wild mammals. To quantify outreach and enforcement frequency, I calculated average villager-reported frequencies of outreach and punishment from questionnaires. Camera stations in the same park were assumed to have the same level of outreach and enforcement. Finally, I hypothesized that the duration of trapping and the visibility of each camera would influence the probability of a species being photographed (detectability).

The models used diffuse priors and random initial values and were run with a Gibbs sampler package "R2jags" (Su & Yajima 2012) in R, with 100,000 iterations after a burn-in of 70,000 and 20 iteration thinnings (Iknayan et al. 2014). Model convergence was checked by using Gelman-Rubin diagnostics where values <1.1 indicated convergence (Gelman et al. 2004), as well as through visual inspection of the trace, density, and autocorrelation plots. To estimate species richness at each site, I generated probability distributions of species richness for each camera location by summing up the number of estimated species (which $Z_i = 1$ at j site) in the occupancy matrix ($Z_{i,j}$) during each of the 100,000 iterations (Zipkin et al. 2010).

Finally, I compared the number of species detected at each protected area against villager-reported outreach, villager-reported punishment frequency and size of the park using linear regression analysis.

2.3 Results

The 115 camera stations yielded 12,148 camera-trap days and 1,213 independent detections of 22 medium- to large-sized mammal species, including two listed as Critically Endangered on the latest China Biodiversity Red List (Jiang et al. 2016), gaur (RAI = 0.187) and pig-tailed macaque (*Macaca nemestrina*; RAI = 0.203), and one listed as Endangered, dhole (*Cuon alpinus*; RAI = 0.008; Table 3). For the questionnaire survey, a total of 374 valid questionnaires were analyzed while five invalid ones were discarded. Among those invalid questionnaires, three were discarded because respondents did not fully understand the questions, for one it was determined that the respondent had been influenced by other people during the interview, and in the last case it turned out that the respondent's family member had already been interviewed. Demographic data summary of the questionnaire was listed in Table 4.

2.3.1 Assessing local people's attitude in the six study areas

Analysis with a Kruskal-Wallis H test showed that people living around the different protected areas varied significantly in six attitude factors (Table 5). Attitudes towards the benefit of plants and wildlife were significantly different among parks (Kruskal-Wallis $\chi^2 = 11.75$, DF = 5, p-value = 0.03); people near Nabanhe and Mengsong had positive mean attitudes while those near the other protected areas had negative mean attitudes. For the attitudes towards the benefits of the protected area, people near Nabanhe had the highest mean score (0.81, SD = 0.37) and those near Mengsong had the lowest (0.44, SD = 0.55).

People living near Mangao had the highest mean scores of social norms about hunting and wildlife (mean = 0.83, SD = 0.49), while people living around Mengsong had the lowest (0.33, SD = 0.82) (Table 6). Mean scores for social norms about plants were negative in all six parks, with Mengsong and Nabanhe having the lowest scores (-0.57 and -0.67, respectively) and Mangao having the highest scores (-0.002). Mean scores for social norms about protected areas were positive among people surrounding the six protected areas, although Bulangshan and Mengsong were significantly lower than the other parks. For the social norms about living near protected areas, people in Bulangshan and Mengla had negative mean scores while people near the other parks had relatively high positive scores.

Questionnaire analysis also indicated that education level was related to responders' conservation attitudes. Four attitude factors were significantly different among the education groups (Table 7). People with higher education levels had higher scores in perceived behavioral control, attitudes towards the benefit of plants and wildlife, and social norms about plants. People with a maximum education level of high school or secondary school had lower mean scores (0.41 and 0.40, SD=0.94 and 0.84, respectively) on attitudes towards wildlife conservation in general than did people who only went to middle school or less (0.84, SD=0.5).

Conservation attitudes also varied with ethnic group (Table 8). Attitudes toward the benefit of plants and wildlife, attitudes towards PA and three social norm factors (five factors in total) showed significant differences (using Kruskal-Wallis tests, see Table 8) among ethnic groups. Dai people had higher scores in all social norm factors. Bulang and Yi people had the lowest scores in attitudes towards the benefit of plans and /wildlife, social norms about protected areas, and living near protected areas.

2.3.2 Assessing villager-reported law enforcement and outreach levels in the six study areas

For the questions regarding park villager-reported enforcement, villager-reported outreach, local people's rating about their relationship with park staff and understanding of rules, mean score of each protected area is listed in Table 5.

Perceived outreach frequency was significantly different among protected areas (Kruskal-Wallis H test: $\chi^2 = 15.89$, DF = 5, p-value = 0.007). Nabanhe had the highest outreach frequency (Mean = 5.67 times/year, SD = 4.39) and Menglun the lowest (Mean = 2.23 times/year, SD = 1.20). The total villager-reported number of punishments across the six park was quite low but there was also a significant difference among parks in the villager-reported number of punishments (Kruskal-Wallis χ^2 test = 11.16, DF = 5, p-value = 0.048). Mengsong had the highest number of punishments (Mean = 1.25 times/year, SD= 1.71) and Mangao the lowest (Mean = 0.54 times/year, SD= 1.16).

2.3.3 Factors affecting mammal occurrence

For wild boar and muntjac, two models (*elevation + distance + park size + outreach + punishment)* and *(elevation + distance + park size + human population density + outreach + punishment*) received the highest AIC support. The AIC weight for these two models for wild boar was 0.71 and 0.29, respectively, and for muntjac 0.64 and 0.36, respectively. For the civet species, differences in AIC weight among the top five models were much smaller (Table 9).

Villager-reported enforcement level was a better predictor than villager-reported outreach level was for the local abundance of mammals (Fig. 4, Table 10). The estimated local abundance of wild boar was 1.5-fold higher in reserves that received five outreach activities per year than in those that received only two per year (Fig. 4). Wild boar abundance also increased rapidly after the villager-reported number of punishments exceed one per year, though the precision of these estimates was low (Fig. 4). Similarly, local abundance of muntjac was positively associated with villager-reported enforcement level (Fig. 4, Table 10). Model-averaging revealed strong edge effects (β = 0.390, 95% confidence interval, CI = 0.117 to 0.662) and association of park size (β = 0.756, CI = 0.360 to 1.153; Table 10) and wild boar local abundance. Local abundance of wild boar and muntjac was 3-fold higher 5 km from the edge of the park than at 1.5 km from the edge, and also 3-fold higher in reserves of 7500 ha than in those of 2500 ha (Fig. 4).

None of the villager-reported law enforcement or outreach variables were significantly related to the local abundance of civets. There was a significant elevation effect (95% confidence interval did not overlap zero) for common palm civets, but the effect size was weak, with only 0.1 more individuals predicted to occur at 1500 m elevation than at 650 m (Fig. 4).

In tests of correlation using parks as replicates (n = 6), the size of protected area is significantly correlate with RAI of wild boar (linear regression: R^2= 0.75, P-value= 0.03; Fig 5. I) and common palm civet (R^2= 0.81, P-value=0.01; Fig. 5 L). But, there is no significant correlation between frequency of villager-reported outreach and punishment (R^2= 0.29, P-value= 0.27). Moreover, although the RAI of wild boar and muntjac showed a trend toward being higher in parks that received more reported outreach (Fig. 5 A, B), the correlations were not significant (R^2=0.19, P-value = 0.39; R^2= 0.52, P-value = 0.1). Correlation between village-reported punishment and RAI of wild boar and muntjac were not statistically significant either. (R^2= 0.11, P-value = 0.53; R^2= 0.29, P-value = 0.27, Fig. 5 E, F). Nabanhe and Mengla have high wild boar and muntjac detection. No relationships were found between village-reported outreach/punishment and Masked palm civet/common palm civet (Fig. 5 C, D, G, H).

2.3.4 Factors affecting species richness

The Bayesian posterior predictive check of the multi-species occupancy model was 0.51, indicating that the model fit the data very well (Gelman et al. 2004). The total estimated species richness across the six reserves was 28 species (95% credible interval = 22 to 42), only slightly greater than the 22 species actually detected on the camera traps. Average (±SE) species richness of each camera site was 5.15 ± 1.44. Mammal richness was not significantly related to elevation (β=0.28, 95% Bayesian credibility Interval = -0.11 to 0.70; Fig. 6) or to the income levels of people living outside the reserves (β = 0.41, 95% CI = -0.08 to 0.85; Fig. 7; Table 11). The villager-reported frequency of outreach conducted by park staff was strongly positively related to mammal richness (β = 1.94, 95% CI = 0.91 to 3.12; Fig. 7; Table 11). The villager-reported number of punishments that parks meted out for law violations had the strongest association with mammal richness of any factor (β = 10.35, 95% CI = 4.93 to 15.87). Human density had a negative association with mammal richness (β = -1.45, CI = -2.78 to -0.41; Fig. 7; Table 11). Individually, the mean predicted effects of elevation, human density, villager-reported punishment frequency, villager-reported outreach frequency and annual income of local people were positive for 81.9%, 13.6%, 100%, 90.1% and 100% of species, respectively (Fig. 8).

Finally, there are positive but non-significant relationship between the number of species detected at each park and park size and villager-reported number of punishments/outreach (Fig. 9 A, B, C).

2.4 Discussion

Understanding how different management strategies affect biodiversity in protected areas is critical for tropical conservation. To my knowledge, this is the first study to measure the associations between outreach, law enforcement, animal populations, and protected area biodiversity using multi-species hierarchical models that account for imperfect detection of all species. We found adequate size of protected area are essential for maintaining animal population size, especially for species that has large home range (Woodroffe 1998). But contrary to my hypothesis, even though the analysis shows a positive trend between local abundance of large hunted species and park size and villager-reported park enforcement/outreach, the non-significant correlation between RAI and villager-reported enforcement/outreach frequency of each park means we cannot conclude whether abundance of large mammals are influenced by enforcement level and outreach frequency. Moreover, we found a trend toward positive effects of villager-reported law enforcement/outreach on wildlife richness of parks, but the relationship is not statically significant. The mammal abundance and diversity of protected areas are likely be affected by other abiotic factor (i.e. vegetation type) and/or interactions between factors. Increasing total amount of study sites and taking appropriate interactions between variables into account would improve this analysis.

The expected outcomes of conservation actions can be modeled using theories of change (Margoluis et al. 2013; Johnson et al. 2016). Theoretically, law enforcement that leads to increased warnings, fines, and arrests should reduce the frequency of illegal hunting. Community outreach, meanwhile, should lead to increased understanding of protected area regulations in local people. Both of those changes could result in mammal diversity and abundance levels that were higher than in areas with no outreach or enforcement (Fig. 10).

However, this result-chain barely illustrated all possible variables nor has been seldom tested on the ground (Pressey et al. 2015), particularly in highly diverse tropical countries. Because, the level of compliance of local people with Park regulations could also related to other factors. For instance, age of protected area is important. The older protected area might be more efficient than the newly established one because there is an assumption that the management will improve overtime (Belokurov et al. 2007). But, time alone might not necessarily result in improvement without proper implemented management (Belokurov et al. 2007; Andrade & Rhodes 2012). In my case, half of protected area were established in same year (Mangao, Mengla, Menglun in 1958) and old parks were not necessarily have more conservation effort that the other (i.e. locals in Nabanhe reported more outreach frequency by park staff than other parks). Different social taboos and traditional beliefs might also be "invisible" factors (Colding.J & Folke.C 2001). For instance, the dominant ethnic group - Dai nationality has both Polytheistic and Buddhist beliefs. They believe there is a holy hill close to their village where gods live. Any disturbance of the holy hill forest will be punished by gods. Hence, hunting, gathering and cutting are strictly prohibited in the holy hill forest (Liu et al. 2002). Likewise, level of local community participation in PA management seems to be a crucial of generating compliance (Andrade & Rhodes 2012). The inclusion of local communities in PA decision-making processes may promote a sense of ownership that make locals willing to regulate their own use of natural resources (Andrade & Rhodes 2012). Nabanhe reserve seems working close with locals in terms of decision making (Cheng 2012), but the locals' understanding of park regulations were not better than the other. Further studies are need to explore more factors that affecting level of local people's compliance with park regulation. Variables should be monitored overtime to evaluate the outcomes.

Nevertheless, my model results indicate that increasing levels of law enforcement, measured here as the villager-reported frequency of punishment, does relate positively to the local abundance of several large, hunted species, and was also associated with elevated overall mammal diversity. Conservation goals could be achieved by enhancing enforcement, at least in this tropical and relatively under-developed region where policy enforcement is often weak (Bruner et al. 2004).

I do note, however, the result should be interpreted carefully because these correlations might not be due to direct causality. It could be, for example, that parks strengthen their enforcement when they have more animal species to protect, or that increased animal diversity and abundance leads to higher hunting pressure, resulting in more villager-reported punishments. For example, Nabanhe protected area contains a threatened flagship species, the Gaur (*Bos gaurus*), leading to strict enforcement of hunting restrictions. However, most of protected areas were lacked data on animal populations and distributions. (Previous wildlife surveys in this region mostly used line transects that have less power than camera-trap surveys (Silveira et al. 2003)). This suggests that it is unlikely that the protected area in our study allocated management resources based on precise comparative wildlife data. Moreover, using suitable counterfactuals (controls) to assess conservation effectiveness is critical and appropriate BACI (Before/ After or Control/ Intervention) designs is demanded by conservation scientist (Ferraro 2009; Joppa & Pfaff 2010; Geldmann et al. 2013). The distribution of protected areas across landscapes is likely biased which affect the potential impact of protected areas on wild animal distribution. Adding collection of population time-series data in same exact area would be more adequate than just compare absolute numbers of animal between parks. This would require long term field monitoring inside and outside of PAs or historical animal population data which is normally costly. Camera-trap provided such opportunity for future long-term and rapid assessment of wildlife, although the initial costs is high (Silveira et al. 2003).

People living near the different protected areas in my study had significantly different attitudes about conservation. Dai people in Xishuangbanna had favorable conservation attitudes, especially related to social norms for wildlife and plants, whereas Hani and Bulang people had much more negative scores overall.

Education level was also related to perceived behavioral control and attitudes towards plants. Relatively well-educated people appeared to believe that they had more responsibility to protect wild animals, and showed more innate affinity for plants. Interestingly, people who went to high school and secondary school responded negatively to the statement “Protecting wild animals in the reserve nearby is good for the environment of Xishuangbanna.” One possible explanation for this attitude is that well-educated people may have been more worried about crop damage caused by wild animals and to consider such damage a negative effect of animals on the environment (C. Chen, pers. obs.).

Any human population is likely to have law-breakers, and our results indicate that as the human density surrounding a park increases, the local abundance of large-bodied species declines, as does overall mammal richness. Plus, local abundance of wild boar and muntjac was positively related to the distance from camera station to the edge of the park. I speculate that relocating local residents away from parks would have positive influences on wild animal. Studies have shown that, on the one hand, village relocation have benefits in terms of reducing human disturbance inside park (Rangarajan et al. 2009) as well as enhancing recover ability of prey and predator populations of parks (Karanth et al. 2006). On the other hand, relocation is not always accepted by the local residents (Xu et al. 2006). Arbitrary displacement without a care for the aspirations of those who are moved is not only ethically unacceptable, it also goes against the grain of a more effective approach to nature conservation (Rangarajan et al. 2009). Meanwhile, a comparison of standardized regression coefficients shows that human population density has a much weaker relationship with mammal richness than does villager-reported enforcement level. This suggests that, even in parks surrounded by large human populations, enforcement can still be an effective tool to protect wildlife. More research is needed to test to what extent human settlements around parks would affect wildlife biodiversity as well as conservation effect of parks.

My results also show that community outreach could be an effective tactic to maintain mammal diversity in parks. Outreach has been proposed as a conservation action by other studies (e.g. Steinmetz et al. 2014), due to its short-term effectiveness and its potential for cultivating conservation awareness, which may have long-term benefits for conservation (Keane et al. 2011). Nevertheless, largest regression beta coefficient of villager-reported law enforcement indicating the relationship between mammal diversity and villager-reported enforcement might be stronger than villager-reported outreach. One possible explanation for this is that the consequences of being caught hunting illegally are very high in this region. Illegal hunting is considered a criminal activity in China, subject to up to ten years imprisonment, fines, and confiscation of property. While both plant collection and hunting in protected areas are illegal, my data show that local communities understand the hunting restrictions better. But the ways by which outreach is conducted can also strongly influence its effectiveness (Jacobson et al. 2006). In this region, the most commonly reported outreach techniques that the parks use are to send out leaflets and post information banners, followed by occasionally hosting outdoor educational movies. Most of the leaflets and posters only include slogans, while some have warnings about restrictions on activities. In our assessment (C. Chen, pers. obs.), such literature has poor resonance with local people. Park staff and rangers often have limited training in outreach; enhanced skills in negotiation, consensus-building, and public communication could pay conservation dividends. Research also suggests that outreach programs should be designed based on psychological theory and the social conditions of the target villages in order induce the most behavioral changes (Steinmetz et al. 2014).

My analysis makes several assumptions that warrant mention. First, the models I used assumed that occupancy for all species was “closed” to births, deaths, and immigration (MacKenzie et al. 2006). The average sampling period was relatively short (three and half months) for large mammals, and there are no known migrations of mammals in this area that would violate the closure assumption, particularly since only a small section of the study area is directly connected to other forested areas. Most of the protected areas in Xishuangbanna are surrounded by monoculture rubber plantations and other land cover types that are unsuitable for most forest wildlife (Li et al. 2007). Second, I assumed that heterogeneity in the occupancy and detection functions was explained by the modeled parameters (MacKenzie et al. 2006). Although forest type varies among the protected areas in my study and is not explicitly modeled, it is very strongly associated with elevation in Xishuangbanna (Zhang and Cao 1995, Li et al. 2007). I included elevation as a variable to account for heterogeneity of habitat, though occurrence of only two species was significantly related to it (Chinese porcupine and common palm civet). Finally, as with most interview surveys, respondents' honesty was difficult to assess. Nevertheless, we have no reason to think that the honesty of responses would vary systematically across villages or parks, so the survey information should be relatively unbiased.

Objective evaluation of the efficacy of tactics such as law enforcement and community outreach is critical for enhancing conservation outcomes (Geldmann et al. 2013, Johnson et al. 2016). Results of this study suggest that maintaining the diversity and local abundance of large mammals could depend on significant and sustained law enforcement from parks and may also be enhanced by complementary activities such as community outreach. The methods used here link conservation actions to protected area biodiversity using multi-species hierarchical models (Zipkin et al. 2010) and could be widely applicable for park efficacy assessments and conservation monitoring around the world.

Chapter 3：Conclusion

Efficacy of protected areas is essential for biodiversity conservation. In this study, I found that the abundance of two mammals was strongly associated with the size of the park, suggesting that park size is more important than conservation actions by park staff in this area. The frequency of outreach by park staff to the local communities, and the villager-reported number of punishments the park meted out for law violations show a trend toward being related to population size of mammals and wildlife richness, but these relationships are not statistically significant. I still speculate, first, that the size of park is the most essential factor for maintaining large terrestrial animal populations. But, smaller protected areas could also be helpful for small arboreal species. Strict enforcement appears to be beneficial in terms of maintaining the abundance of large mammals as well as the richness of mammal species in general. Finally, complementary community outreach activities might further enhance the efficacy of protected area.

For local people's conservation attitudes, I demonstrated that people's attitudes towards different subject varies among different parks and nationality groups. Specific group people living in different area have specific attitudes towards wild animal, wild plants and protected area in general. I also showed that education might be an important factor to change people's idea about benefit of having wild animal and plants.

Looking towards the future of biodiversity conservation and conservation research in tropical forest ecosystems, I make several recommendations. First, authorities should prevent further habitat loss in existing protected areas to maintain parks that are as large as possible. Second, authorities should strengthen the detection and determent of rule violations via more frequent patrols combined with long-term, systematic monitoring. Third, I recommend enhanced community engagement with residents around parks. Fourth, conservation actions should be tailored to specific parks based on demographics and ethnic composition.

Finally, while the need for long-term biodiversity monitoring in protected areas has often been discussed, I propose that it would also be extremely useful to monitor peoples' attitudes over time. It would be very useful, for example, to determine whether conservation actions led to changes in peoples' views of conservation. Studies that assessed hunting pressure through a combination of interview surveys and spatial analysis of wildlife distribution and abundance are strongly recommended. As my study demonstrated, research that can link conservation attitude assessments, animal population estimation, and hunting pressure assessments can reveal clearer patterns of conservation efficacy.

Table 1. Summary of sites information. Name of site, national reserve that site belong, size of the site, year of establishment, major minority group of site were listed.

Name of site	National reserve	Size(Ha)	Year of official establishment	Major minority group
Bulangshang	Bulong county level reserve	25000	2009	Bulang, Lahu
Mengsong	Bulong county level protected area	10333	2009	Hani
Nabanhe	Nanbanhe National reserve	26600	1991	Dai, Hani, Lahu
Mangao	Xishuangbanna Nation reserve	7870	1958	Dai, Hani, Lahu
Mengla	Xishuangbanna Nation reserve	92683	1958	Dai, Hani, Yao
Menglun	Xishuangbanna Nation reserve	1473	1958	Dai, Jinuo

Table 2. Attitude factors measured from questionnaire surveys. For each question, the answer with agree, neutral, and disagree were given score by 1, 0, -1, respectively. For the attitude with more than one question, the score was divided by question numbers. Questions grouped were based on principal component analysis result.

Factor	Question	Mean score (SD)
Attitudes towards wildlife conservation	1.1. Protecting wild animals in nearby reserves is good for the environment of Xishuangbanna.	0.82 (0.52)
Perceived behavioral control	1.2. Only the national government has the responsibility to protect wild animals in nearby reserves; it is not my own business.	0.30 (0.93)
Innate affinity for wildlife	1.5. Having many animals living in the forest nearby makes me happy.	0.85 (0.50)
Innate affinity for wild plants	2.3. Seeing trees, grass, and flowers in the nearby reserve makes me happy.	0.97 (0.23)
Attitudes towards the benefits of plants and wildlife	1.4. If there are no animals in the reserve, the quality of the forest in the reserve will decline. 2.2. If the forest nearby has one more or one fewer plant species, it will not have any impact on me.	0.00 (0.77)
Attitudes towards the benefit of protected areas	3.4. The actual effectiveness of protected areas nearby is low. 3.5. The protected area nearby is good for future generations.	0.64 (0.50)
Social norms about hunting and wildlife	4.1. If I go hunting, my friends will be against it. 4.2. If I go hunting, my family will be against it.	0.57 (0.70)
Social norms about plants	5.1. If I go to collect plants from the protected area, my friends will be against it. 5.2. If I go to collect plants from the protected area, my family will be against it. 5.3. Old people in our village always told us not to collect plants in the protected area. 5.4. When I was in school, my teachers always told us not to collect plants in the protected area. 5.5. People in my village are supportive of plant collecting in protected areas.	-0.31 (0.71)
Social norms about protected areas	6.1. My friends think that establishing protected areas is useless. 6.2. My family thinks that establishing protected areas is useless. 6.3.People in our village think that establishing protected areas is good.	0.73 (0.48)
Social norms about living near protected areas	6.4. My friends think that living close to a protected area is good. 6.5. My family thinks that living close to a protected area is good.	0.36 (0.81)

Table 3. List of mammal species detected in 6 protected areas in Xishuangbanna, including relative abundance index (RAI; number of detections per 100 trap-days) and the proportion of camera stations with at least one detection.

Common name	**Scientific name**	**Chinese Red-List status**	**IUCN Red-List status**	**RAI**	**Percent of stations with at least one detection**
Brush-tailed porcupine	*Atherurus macrouru*	Least Concern	Least Concern	0.041	2.61
Malayan porcupine	*Hystrix brachyura*	Least Concern	Least Concern	0.114	7.83
Chinese ferret-badger	*Melogale moschata*	Near Threatened	Least Concern	0.285	2.61
Hog badger	*Arctonyx collaris*	Near Threatened	Near Threatened	0.049	2.61
Crab-eating mongoose	*Herpestes urva*	Near Threatened	Least Concern	0.179	9.57
Rhesus Macaque	*Macaca mulatta*	Least Concern	Least Concern	0.236	9.57
Pig-tailed macaque	*Macaca leonina*	Critically Endangered	Vulnerable	0.203	8.7
Common palm civet	*Paradoxurus hermaphroditus*	Vulnerable	Least Concern	0.407	17.39
Yellow-throated marten	*Martes flavigula*	Near Threatened	Least Concern	0.073	6.96
Masked palm civet	*Paguma larvata*	Near Threatened	Least Concern	0.342	20
Small Indian civet	*Viverricula indica*	Vulnerable	Least Concern	0.008	0.87
Spotted linsang	*Prionodon pardicolor*	Vulnerable	Least Concern	0.008	0.87
Yellow-bellied Weasel	*Mustela kathiah*	Near Threatened	Least Concern	0.041	1.74
Southern red muntjac	*Muntiacus muntjak*	Near Threatened	Least Concern	3.53	56.52
Wild boar	*Sus scrofa*	Least Concern	Least Concern	2.611	58.26
Sambar	*Rusa unicolor*	Near Threatened	Vulnerable	1.147	20
Serow	*Capricornis milneedwardsii*	Vulnerable	Near Threatened	0.041	1.74
Chinese goral	*Naemorhedus griseus*	Vulnerable	Vulnerable	0.122	1.74
Gaur	*Bos gaurus*	Critically Endangered	Vulnerable	0.187	4.35
Asiatic black bear	*Ursus thibetanus*	Vulnerable	Vulnerable	0.098	7.83
Leopard cat	*Prionailurus bengalensis*	Vulnerable	Least Concern	0.138	10.43
Dhole	*Cuon alpinus*	Endangered	Endangered	0.008	0.87

Table 4. Demographic data summary of the questionnaire. Number (present) of questionnaire listed.

	Group	National reserve						Total (%)
		Bulangshang	Mangao	Mengla	Menglun	Mengsong	Nabanhe	
Gender	Man	49	44	70	34	43	57	297 (79.4%)
	Woman	2	13	12	18	14	18	77 (20.6%)
Age	< 30	21	10	17	6	14	12	80 (21.4%)
	30 - 50	21	33	50	29	33	46	212(56.7%)
33	50	9	14	15	17	10	17	82 (21.9%)
Nationality	Bulang	48	0	0	0	0	0	48 (12.8%)
	Dai	0	27	10	34	0	13	84 (22.5%)
	Han	0	0	7	0	0	0	7 (1.9%)
	Hani	0	10	24	0	57	22	113 (30.2%)
	Jinuo	0	0	0	18	0	0	18 (4.8%)
	Lahu	3	20	0	0	0	40	63 (16.8%)
	Yao	0	0	38	0	0	0	38 (10.2%)
	Yi	0	0	3	0	0	0	3 (0.8%)
Family Income(k yuan)	< 7.5 & 7.5	10	4	21	4	2	16	57 (15.2%)
	20	26	27	27	16	16	45	157 (42.0%)
	40	11	22	23	23	19	12	110 (49.4%)
	75 & > 75	4	4	11	9	20	2	50 (13.4 %)
Education level	None	8	12	17	5	3	27	72 (19.3%)
	Elementary school	26	26	24	27	20	32	155 (41.4%)
	Middle school	14	18	28	18	28	14	120 (32.1%)
	High school and higher	3	1	13	2	6	2	27 (7.2%)

Table 5. Estimated enforcement levels of six protected areas in Xishuangbanna, including mean (SD) annual frequency of outreach conducted by the park, the number of punishments the park meted out for law violations, the relationship between park staff and villagers, the rules of the protected area regarding hunting, and the rules of the protected area in terms of non-timber forest product collection. The outreach frequency was calculated from Appendix part 2 question 1, answer that report 0, 1-2, 3-5, 5-10, 10-15, more that 15 times per year were coded as 0, 1.5, 4, 7.5, 12.5, 15. The number of punishments was calculated from Appendix part 2 question 2, answer that 0, 1-5, 5-10, 10-15, 15-20 and more than 20 punishments last year were coded as 0, 2.5, 7.5, 12.5, 17.5 and 20 people respectively. The relationship between park staff and villagers was calculated from Appendix part2 question 3, the answer with very bad, bad, neutral, good and very good were given score by -2, -1, 0, 1, 2 respectively. The understanding of rules is correctness of multiply choose question - Appendix part2 question 4 & 5.

Protected area	**Mean villager-reported outreach Frequency (times/year)**	**Mean number of villager-reported punishments (times/year)**	**Mean villager-reported relationship**	**Mean understanding of rules regarding non-timber forest product**	**Mean understanding of rules regarding hunting**
Bulangshan	3.00 (3.03)	1.00 (1.89)	0.57 (0.76)	0.16 (0.21)	0.34 (0.23)
Mangao	2.94 (2.67)	0.54 (1.16)	0.98 (0.72)	0.23 (0.25)	0.41 (0.25)
Mengla	2.64 (2.79)	0.85 (2.53)	0.48 (0.69)	0.26 (0.31)	0.41 (0.30)
Menglun	2.23 (1.20)	0.47 (1.10)	0.62 (0.59)	0.17 (0.20)	0.39 (0.20)
Mengsong	3.14 (3.01)	1.25 (1.71)	0.55 (0.73)	0.15 (0.20)	0.93 (0.22)
Nabanhe	5.67 (5.23)	1.10 (2.63)	0.77 (0.55)	0.14 (0.18)	0.25 (0.18)

Table 6. Difference of peoples' attitudes toward conservation in different park (N = 374); differences in means compared with Kruskal-Wallis H tests; significant differences are indicated in bold and with an asterisk. Refer table 3 for questions used to evaluate the attitudes. For each question, the answer with agree, neutral, and disagree were given score by 1, 0, -1, respectively. For the attitude with more than one question, the score was divided by question numbers.

Factor	**Protected area**						**Kruskal-Wallis χ^2**	**P-value**
	Bulangshang (*N* = 51)	Mangao (*N* = 57)	Mengla (*N* = 82)	Menglun (*N* = 52)	Mengsong (*N* = 57)	Nabanhe (*N* = 75)		
Attitudes towards wildlife conservation	0.71 (0.61)	0.81 (0.55)	0.77 (0.59)	0.83 (0.51)	0.91 (0.34)	0.87 (0.45)	6.36	0.27
Perceived behavioral control	0.12 (0.99)	0.23 (0.95)	0.37 (0.92)	0.46 (0.9)	0.33 (0.93)	0.29 (0.94)	4.49	0.48
Innate affinity for wildlife	0.73 (0.67)	0.98 (0.13)	0.80 (0.55)	0.87 (0.49)	0.84 (0.49)	0.87 (0.47)	7.64	0.17
Innate affinity for wild plants	0.86 (0.49)	0.98 (0.13)	1 (0)	0.96 (0.19)	0.98 (0.13)	0.97 (0.23)	9.56	0.09
Attitudes towards the benefit of plants and wildlife	-0.26 (0.83)	-0.02 (0.67)	-0.01 (0.76)	-0.05 (0.8)	0.2 (0.76)	0.12 (0.78)	11.75	**0.03***
Attitudes towards the benefits of protected areas	0.62 (0.53)	0.46 (0.54)	0.68 (0.47)	0.78 (0.42)	0.44 (0.55)	0.81 (0.37)	31.77	**<0.01****
Social norms about hunting & wildlife	0.51 (0.78)	0.83 (0.49)	0.62 (0.61)	0.65 (0.6)	0.33 (0.82)	0.5 (0.75)	16.89	**<0.01****
Social norms about plants	-0.28 (0.8)	-0.02 (0.75)	-0.06 (0.74)	-0.33 (0.65)	-0.67 (0.55)	-0.57 (0.51)	44.94	**<0.01****
Social norms about protected areas	0.55 (0.58)	0.84 (0.43)	0.83 (0.38)	0.87 (0.35)	0.51 (0.56)	0.7 (0.44)	38.54	**<0.01****
Social norms about living near protected areas	-0.03 (0.89)	0.7 (0.69)	-0.18 (0.88)	0.79 (0.47)	0.56 (0.65)	0.49 (0.66)	72.65	**<0.01****

Table 7. Difference of attitudes toward conservation of people receive different education ($N = 373$). One questionnaire that reported temple-based education was discarded. Differences in means compared with Kruskal-Wallis H test; significant effects shown in bold and with an asterisk. Refer table 3 for questions used to evaluate the attitudes. For each question, the answer with agree, neutral, and disagree were given score by 1, 0, -1, respectively. For the attitude with more than one question, the score was divided by question numbers.

Factors	**Education level**					**Kruskal-Wallis χ^2**	**P-value**
	None (*N*=71)	Elementary (*N*=155)	Middle (*N*=120)	High (*N*=17)	Secondary School (*N*=10)		
Attitudes towards wildlife conservation	0.89 (0.36)	0.83 (0.48)	0.84 (0.5)	0.41 (0.94)	0.4 (0.84)	13.57	**<0.01****
Perceived behavioral control	-0.27 (0.96)	0.24 (0.95)	0.64 (0.75)	0.65 (0.79)	0.7 (0.67)	46.44	**<0.01****
Innate affinity for wildlife	0.86 (0.49)	0.85 (0.51)	0.85 (0.48)	0.88 (0.33)	0.6 (0.84)	1.80	0.77
Innate affinity for wild plants	0.93 (0.35)	0.96 (0.25)	0.99 (0.09)	0.94 (0.24)	1 (0)	3.40	0.49
Attitudes towards the benefit of plants and wildlife	-0.2 (0.7)	-0.04 (0.75)	0.07 (0.81)	0.44 (0.66)	0.85 (0.34)	24.24	**<0.01****
Attitudes towards the benefit of PA	0.69 (0.43)	0.65 (0.51)	0.63 (0.5)	0.47 (0.6)	0.45 (0.5)	4.26	0.37
Social norms about hunting/wildlife	0.49 (0.72)	0.55 (0.74)	0.63 (0.65)	0.56 (0.68)	0.75 (0.42)	2.47	0.65
Social norms about plants	-0.35 (0.65)	-0.33 (0.73)	-0.38 (0.68)	0.15 (0.75)	0.22 (0.66)	13.81	**<0.01****
Social norms about PA	0.79 (0.37)	0.66 (0.56)	0.73 (0.44)	0.86 (0.24)	1 (0)	7.01	0.14
Social norms about living near PA	0.3 (0.85)	0.36 (0.83)	0.35 (0.79)	0.62 (0.7)	0.65 (0.67)	4.46	0.34

Table 8. Difference of peoples' attitudes toward conservation of nationalities ($N = 363$); Differences in means compared with Kruskal-Wallis H test; significant effects indicated with an asterisk. Refer table 3 for questions used to evaluate the attitudes. For each question, the answer with agree, neutral, and disagree were given score by 1, 0, -1, respectively. For the attitude with more than one question, the score was divided by question numbers.

Factors	**Nationality**								**Kruskal-Wallis χ^2**	**P-value**
	Bulang (*N*=48)	Dai (*N*=83)	Han (N=7)	Hani (*N*=113)	Jinuo (*N*=18)	Lahu (*N*=63)	Yao (*N*=38)	Yi (N=3)		
Attitudes towards wildlife conservation	0.69 (0.62)	0.89 (0.38)	0.86 (0.38)	0.91 (0.34)	0.78 (0.65)	0.73 (0.63)	0.66 (0.75)	1 (0)	12.62	0.08
Perceived behavioral control	0.15 (0.99)	0.15 (0.98)	0.71 (0.76)	0.41 (0.9)	0.44 (0.92)	0.40 (0.89)	0.18 (0.98)	1 (0)	9.47	0.22
Innate affinity for wildlife	0.71 (0.68)	0.95 (0.26)	1 (0)	0.83 (0.52)	0.67 (0.77)	0.92 (0.37)	0.76 (0.59)	1 (0)	11.08	0.09
Innate affinity for wild plants	0.85 (0.5)	0.98 (0.15)	1 (0)	0.99 (0.09)	1 (0)	0.95 (0.28)	1 (0)	1 (0)	10.21	0.17
Attitudes towards the benefit of plants and wildlife	-0.24 (0.84)	-0.08 (0.77)	0 (1)	0.25 (0.71)	-0.25 (0.69)	0.03 (0.75)	-0.07 (0.76)	-0.67 (0.58)	21.40	**<0.01****
Attitudes towards the benefit of PA	0.61 (0.53)	0.7 (0.45)	0.71 (0.49)	0.61 (0.5)	0.92 (0.35)	0.63 (0.53)	0.57 (0.53)	0 (0)	15.28	**0.03***
Social norms about hunting/wildlife	0.48 (0.8)	0.75 (0.53)	0.86 (0.38)	0.46 (0.77)	0.83 (0.42)	0.53 (0.72)	0.53 (0.67)	0.67 (0.58)	12.51	0.08
Social norms about plants	-0.3 (0.81)	0.04 (0.69)	-0.31 (0.63)	-0.46 (0.65)	-0.73 (0.51)	-0.55 (0.58)	-0.12 (0.74)	-0.2 (1.04)	47.51	**<0.01****
Social norms about protected areas	0.55 (0.58)	0.92 (0.31)	0.9 (0.25)	0.63 (0.53)	0.83 (0.4)	0.68 (0.44)	0.85 (0.39)	0.44 (0.69)	42.20	**<0.01****
Social norms about living near protected areas	-0.02 (0.9)	0.62 (0.68)	0.29 (0.76)	0.39 (0.77)	0.67 (0.54)	0.54 (0.71)	-0.21 (0.88)	-0.67 (0.58)	44.36	**<0.01****

Table 9. Top five candidate models, ranked by AIC, for assessing the factors affecting local abundance of 4 hunted mammal species. Detection probability (r) functions for all models were structured by the number of hours that each camera was active and by camera visibility. The local abundance (λ) functions were structured by the combinations of covariates listed.

Model	Δ AIC	AIC Weight
Wild boar		
r(camhour+cam angle) *λ(elevation+distance+park size +outreach+punishment)*	0.00	0.710
r(camhour+cam angle) *λ(elevation+park size+distance+density of human+outreach+punishment)*	1.80	0.289
r(camhour+cam angle) *λ(elevation+distance+density of human+outreach+punishment)*	13.46	0.001
r(camhour+cam angle) *λ(elevation+distance+outreach+punishment)*	14.83	<0.001
r(camhour+cam angle) *λ(elevation+distance+park size)*	29.67	<0.001
Muntjac		
r(camhour+cam angle) *λ(elevation+distance+park size +outreach+punishment)*	0.00	0.642
r(camhour+cam angle) *λ(elevation+park size+distance+density of human+outreach+punishment)*	1.17	0.358
r(camhour+cam angle) *λ(elevation+distance+outreach+punishment)*	33.97	<0.001
r(camhour+cam angle) *λ(elevation+distance+density of human+outreach+punishment)*	34.62	<0.001
r(camhour+cam angle) *λ(elevation+distance+park size +density of human)*	57.33	<0.001
Masked palm civet		
r(camhour+cam angle) *λ(elevation+distance+park size +outreach+punishment)*	0.00	0.360
r(camhour+cam angle) *λ(elevation+distance+outreach+punishment)*	1.21	0.196
r(camhour+cam angle) *λ(elevation+distance+density of human+outreach+punishment)*	1.28	0.189

Model	Δ AIC	AIC Weight
r(camhour+cam angle) *λ(elevation+park size+distance+density of human+outreach+punishment)*	1.30	0.188
r(camhour+cam angle) *λ(elevation+distance+park size +density of human)*	5.19	0.027
Common palm civet		
r(camhour+cam angle) *λ(elevation+distance+outreach+punishment)*	0.00	0.441
r(camhour+cam angle) *λ(elevation+distance+density of human+outreach+punishment)*	1.49	0.210
r(camhour+cam angle) *λ(elevation+distance+park size +outreach+punishment)*	1.51	0.207
r(camhour+cam angle) *λ(elevation+park size+distance+density of human+outreach+punishment)*	3.49	0.077
r(camhour+cam angle) *λ(elevation+distance+park size)*	4.57	0.045

Table 10. Model-averaged parameter estimates (mean and 95% confidence intervals) of factors related to the local abundance of four hunted species in six nature reserves in Xishuangbanna. Significant effects indicated by asterisk.

Species	λ (elevation)	λ (park size)	λ (distance)	λ (density of human)
Wild boar	-0.09 (-0.38, 0.20)	**0.76 (0.36, 1.15) ***	**0.390 (0.12, 0.66) ***	-0.06 (-0.34, 0.21)
Muntjac	0.30 (-0.02, 0.60)	**1.33 (0.78, 1.88)***	-0.01 (-0.29, 0.26)	0.19 (-0.20, 0.59)
Masked palm civet	0.15 (-0.41, 0.70)	-0.42 (-0.95, 0.10)	0.47 (-0.18, 1.13)	0.21 (-0.14, 0.56)
Common palm civet	**0.83 (0.16, 1.51)***	0.12 (-0.35, 0.60)	-0.53 (-1.10, 0.03)	-0.08 (-0.63, 0.47)

Species	λ (outreach)	λ (punishment)	r (camhour)	r (cam angle)
Wild boar	**0.44 (0.06, 0.8) ***	**2.95 (0.35, 5.54) ***	0.067 (-0.09, 0.22)	0.317 (-0.19, 0.82)
Muntjac	**0.68 (0.26, 1.11)***	**4.64 (0.98, 8.31)***	-0.035 (-0.14, 0.07)	**1.10 (0.56, 1.63)***
Masked palm civet	0.27 (-2.46, 3.00)	0.27 (-2.46, 3.00)	6.50 (-145.61, 158.60)	10.29 (-105.28, 125.86)
Common palm civet	-8.01 (-16.37, 0.34)	5.60 (-2.19, 13.40)	36.84 (-16886.56, 16960.24)	-1.10 (-3.84, 1.65)

Table 11. Mean and 95% credibility intervals (CIs) of the Beta coefficients of factors potentially related to occupancy (α) and detection (β) of mammals in six reserves in Xishuangbanna. Parameters with a significant effect (95% CI that does not include zero) indicated with an asterisk.

Parameter	Mean estimate	95% credibility interval
$\alpha1_i$ elevation	0.28	-0.11, 0.7
$\alpha2_i$ human population density	-1.45	**-2.78, -0.41***
$\alpha3_i$ villager-reported number of punishment	10.35	**4.93, 15.87***
$\alpha4_i$ villager-reported outreach frequency	1.94	**0.91, 3.12***
$\alpha5_i$ income	0.41	-0.08, 0.85
$\beta1_i$ camhour	0.35	**0.08, 0.73***
$\beta2_i$ camangle	0.26	-0.32, 0.92

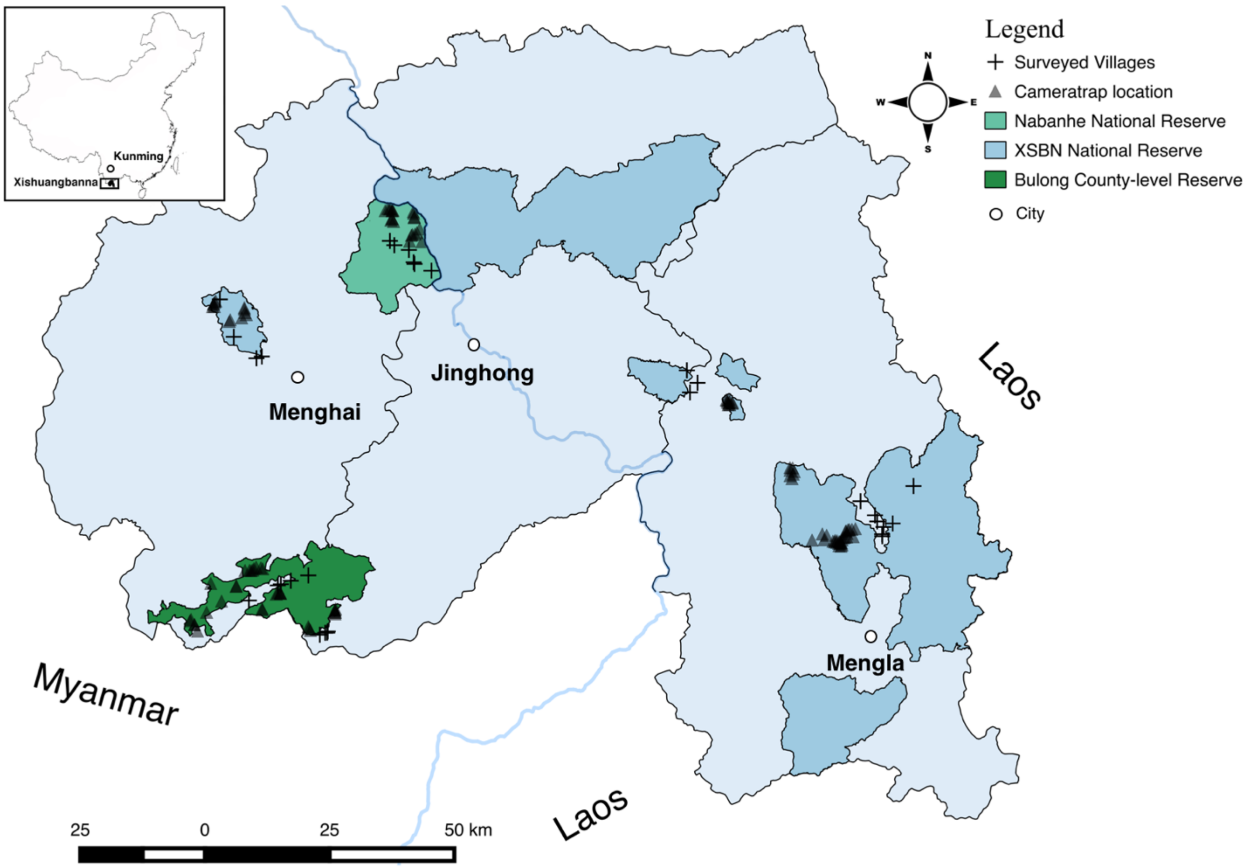


Figure 1. Camera locations and surveyed villages in six nature reserves in Xishuangbanna.

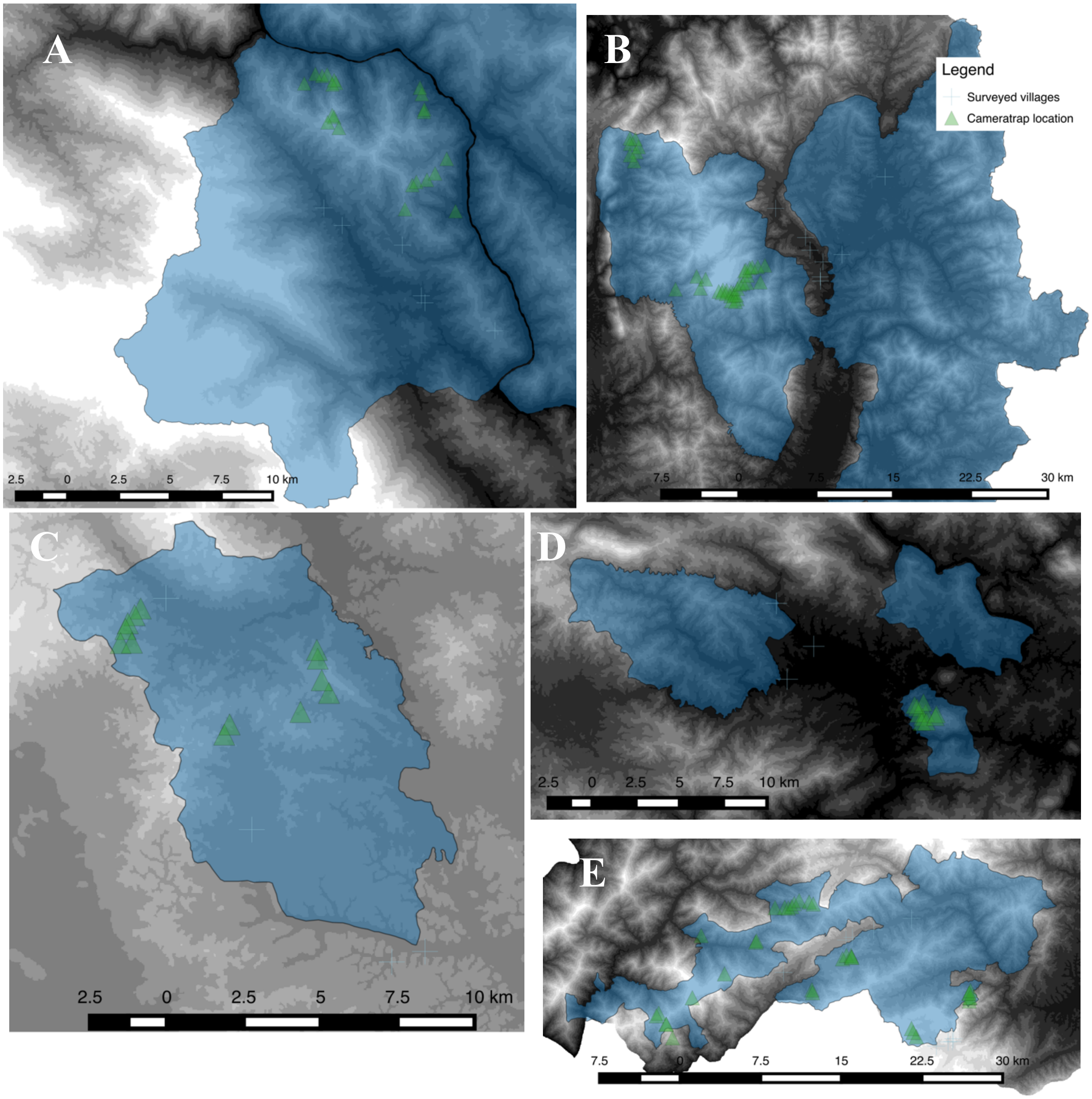


Figure 2. Topographic map of each protected area in Xishuangbanna with camera locations and surveyed villages indicated. Elevation gradient is from 475 m (black) to 2430 m (white). Protected areas include (A) Nabanhe National reserve, (B) Mengla sub-reserve of Xishuangbanna National Nature Reserve, (C) Mangao sub-reserve of Xishuangbanna National Nature Reserve, (D) Menglun sub-reserve of Xishuangbanna National Nature Reserve, and (E) Bulong section and Mengsong section of Bulangshan national reserve.

Figure 3. Species photo. A. wild boar (*Sus scrofa*), B. northern red muntjac (*Muntiacus vaginalis*), C. Asian palm civet (*Paradoxurus hermaphroditus*), D. masked palm civet (*Paguma larvata*).

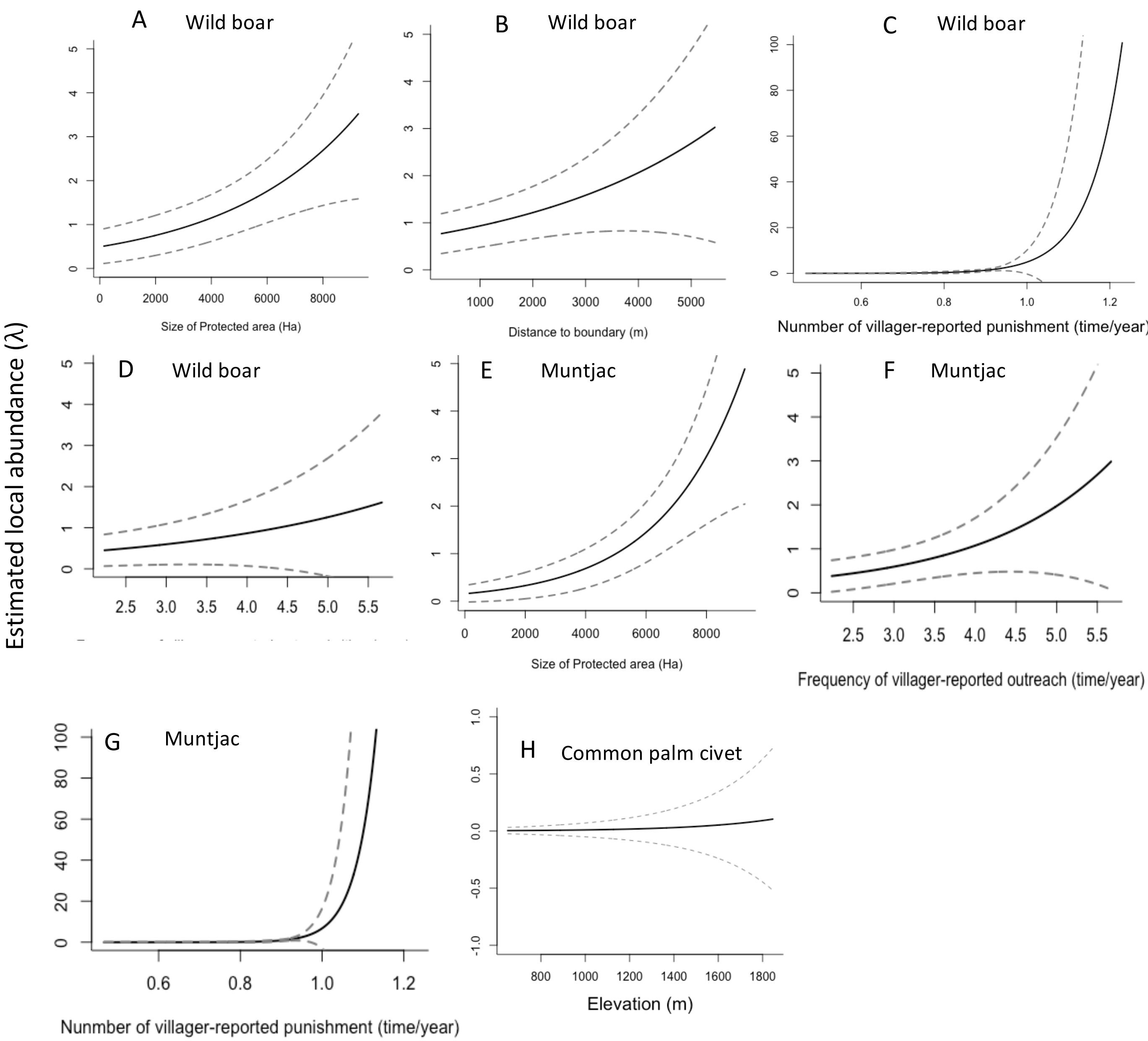
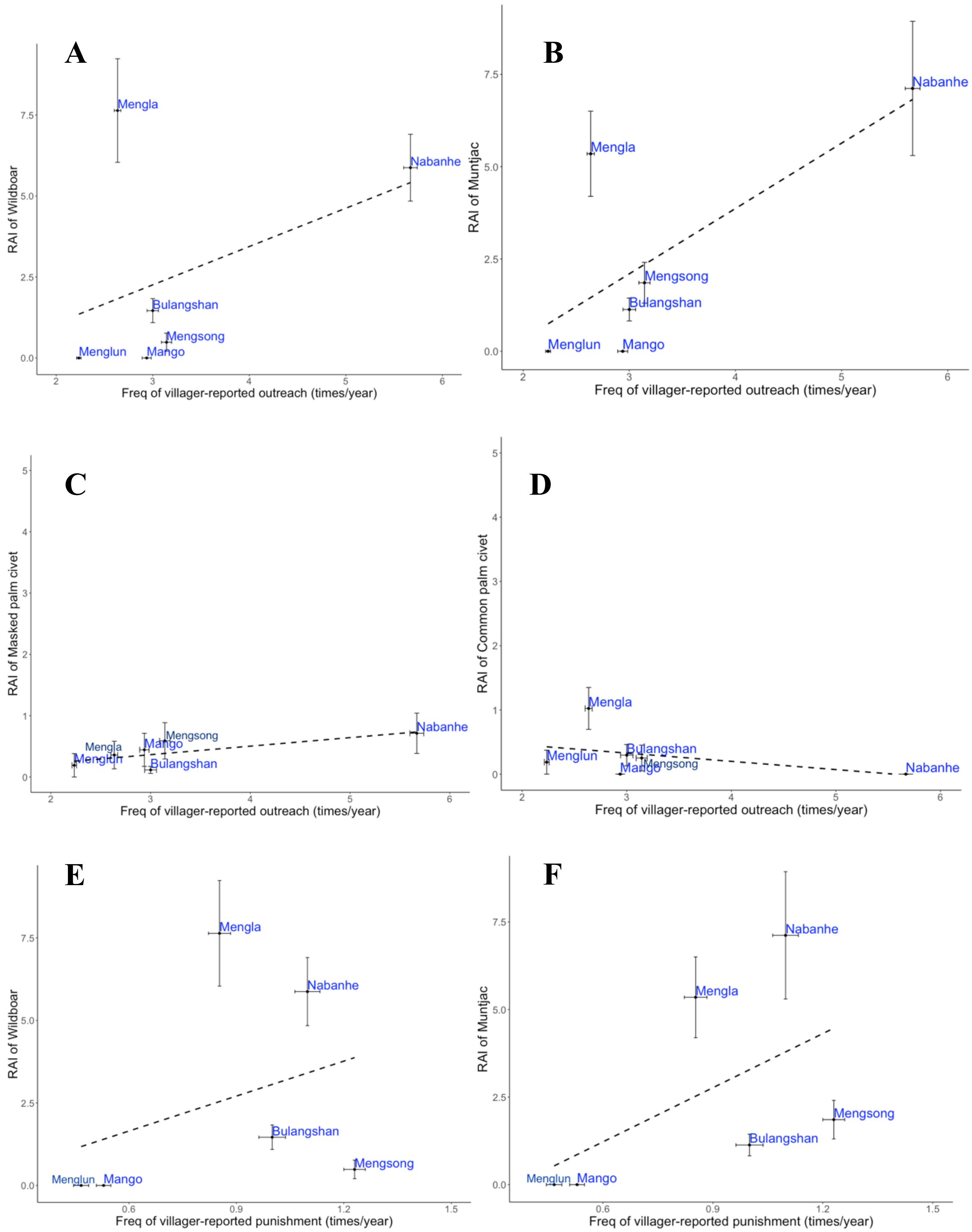


Figure 4. Model-averaged estimates of factors related to the local abundance (λ) of wild boar, muntjac, and common palm civets. Dotted lines indicate the 95% confidence interveals.


A
RAI of Wildboar
Freq of villager-reported outreach (times/year)
Mengla
Nabanhe
Bulangshan
Mengsong
Menglun
Mango
B
RAI of Muntjac
Freq of villager-reported outreach (times/year)
Nabanhe
Mengla
Mengsong
Bulangshan
Menglun
Mango
C
RAI of Masked palm civet
Freq of villager-reported outreach (times/year)
Nabanhe
Mengla
Mengsong
Mango
Menglun
Bulangshan
D
RAI of Common palm civet
Freq of villager-reported outreach (times/year)
Mengla
Menglun
Bulangshan
Mango
Mengsong
Nabanhe
E
RAI of Wildboar
Freq of villager-reported punishment (times/year)
Mengla
Nabanhe
Bulangshan
Mengsong
Menglun
Mango
F
RAI of Muntjac
Freq of villager-reported punishment (times/year)
Nabanhe
Mengla
Mengsong
Bulangshan
Menglun
Mango

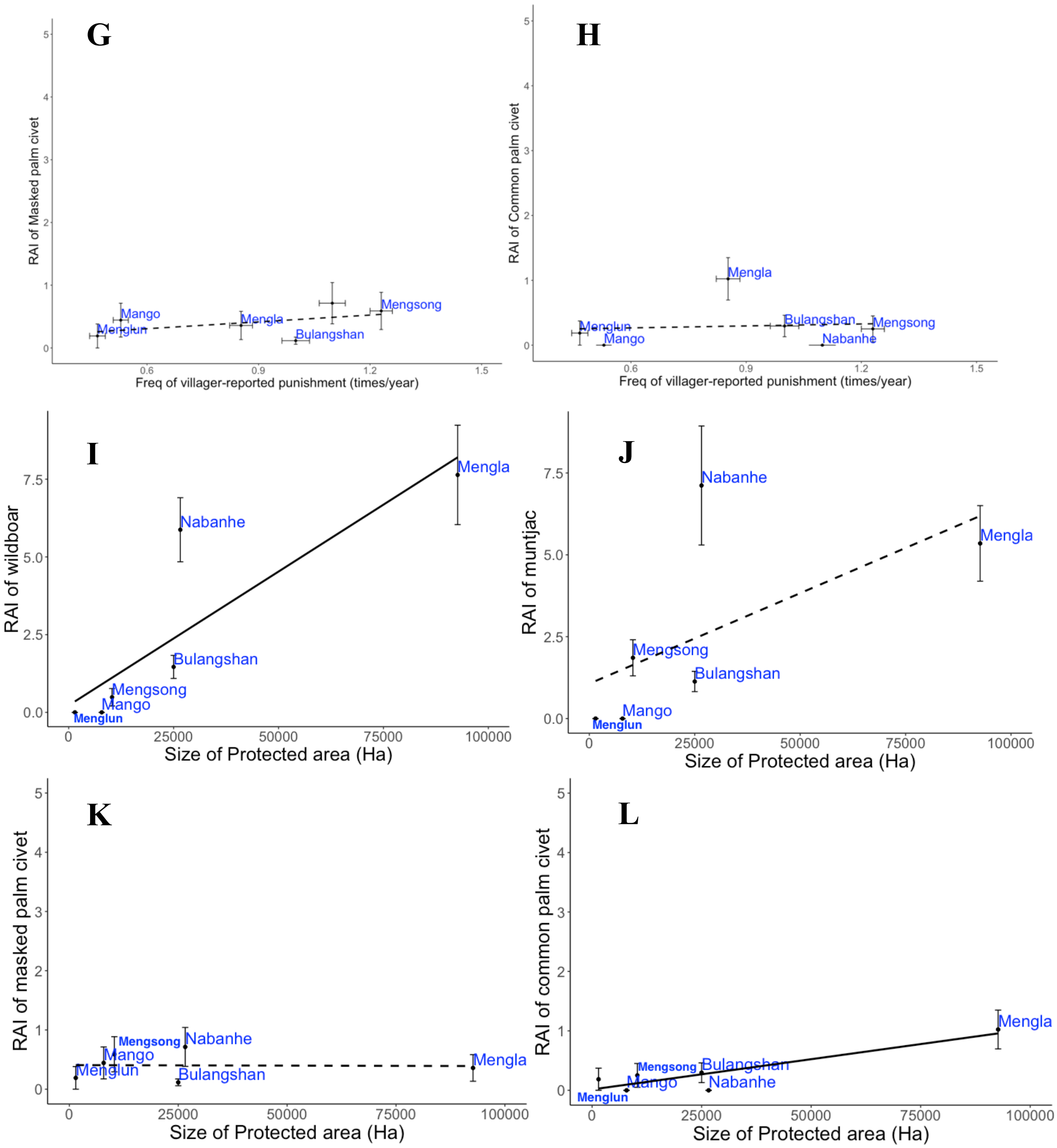


Figure 5. The mean RAI (detection per 100 trap days) and SE of four mammals in each park over park averaged villages-reported outreach and punishment frequency.

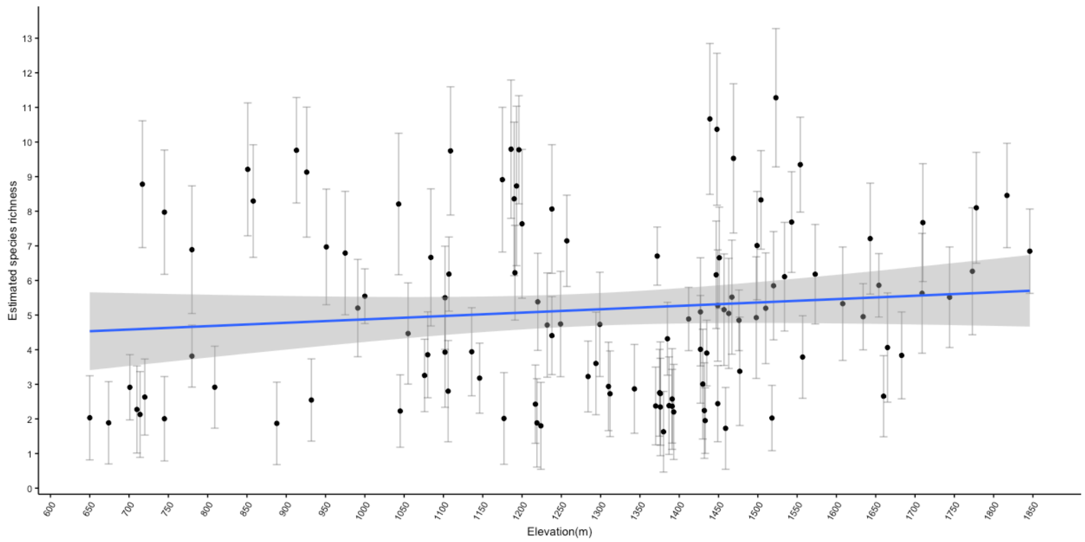


Figure 6. Mean and SD of site-specific estimates of overall species richness over site elevation (m). The blue line and gray region are trend line and 95% confidence interval.

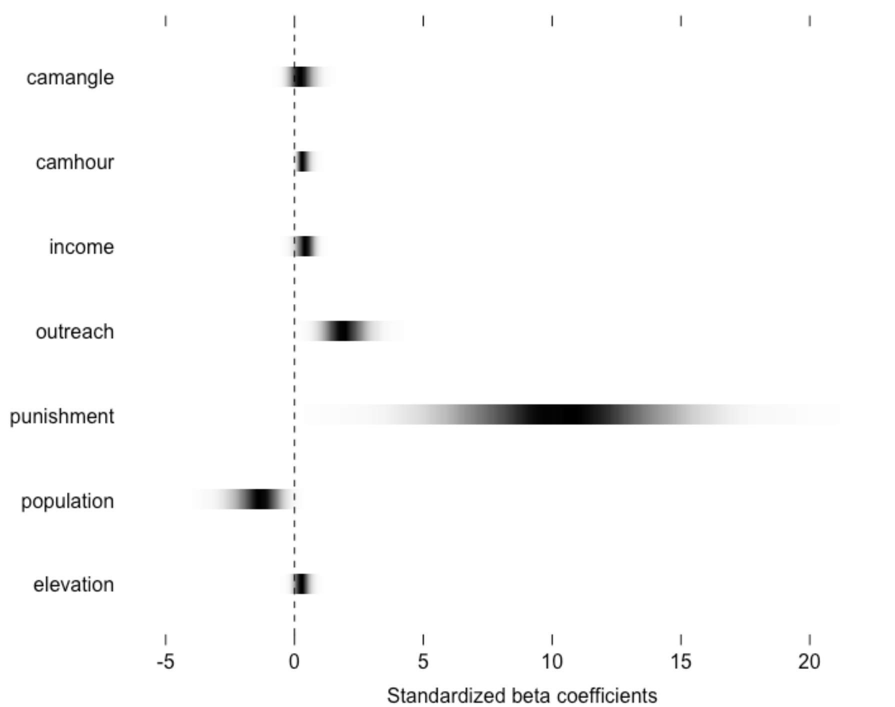
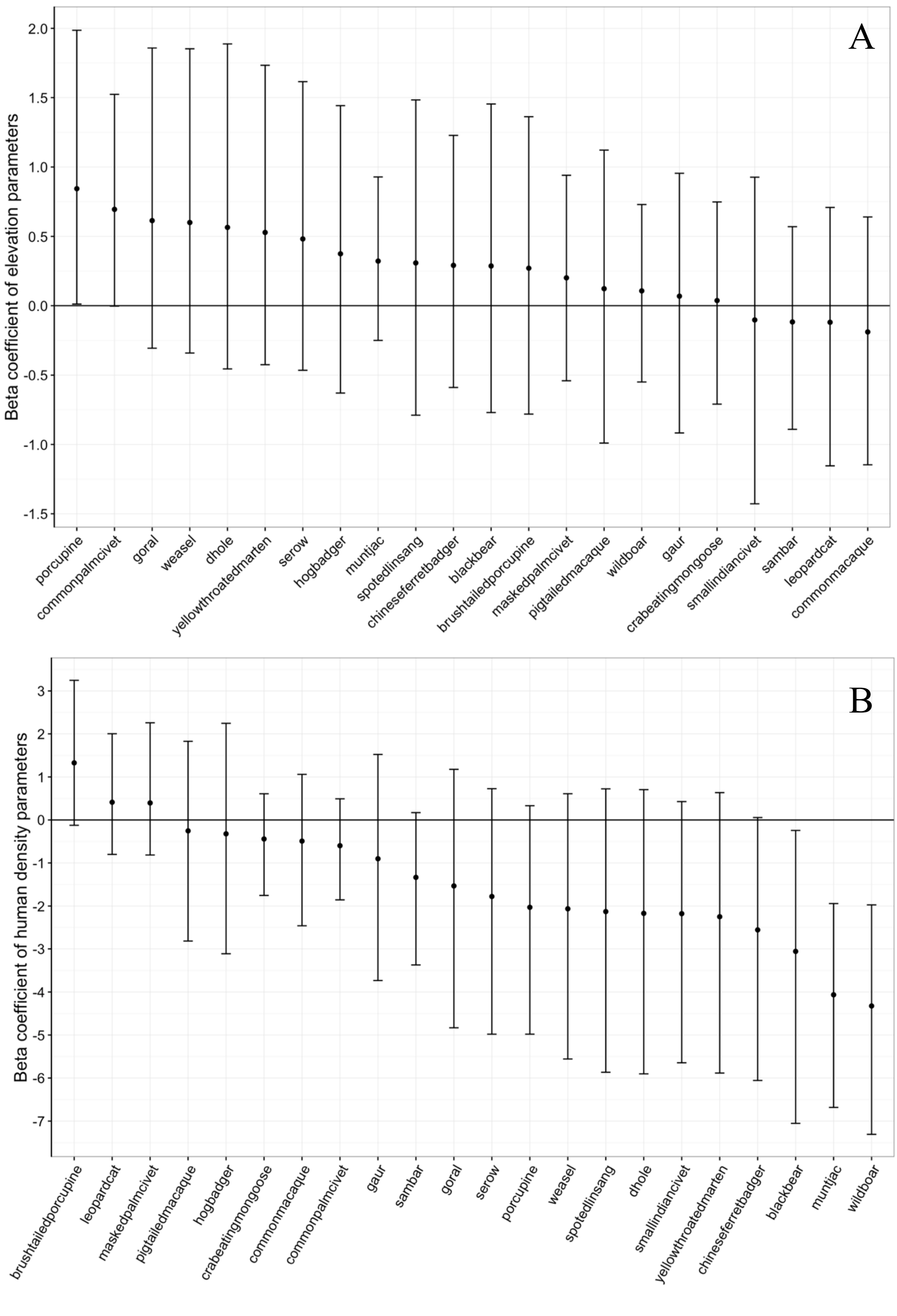
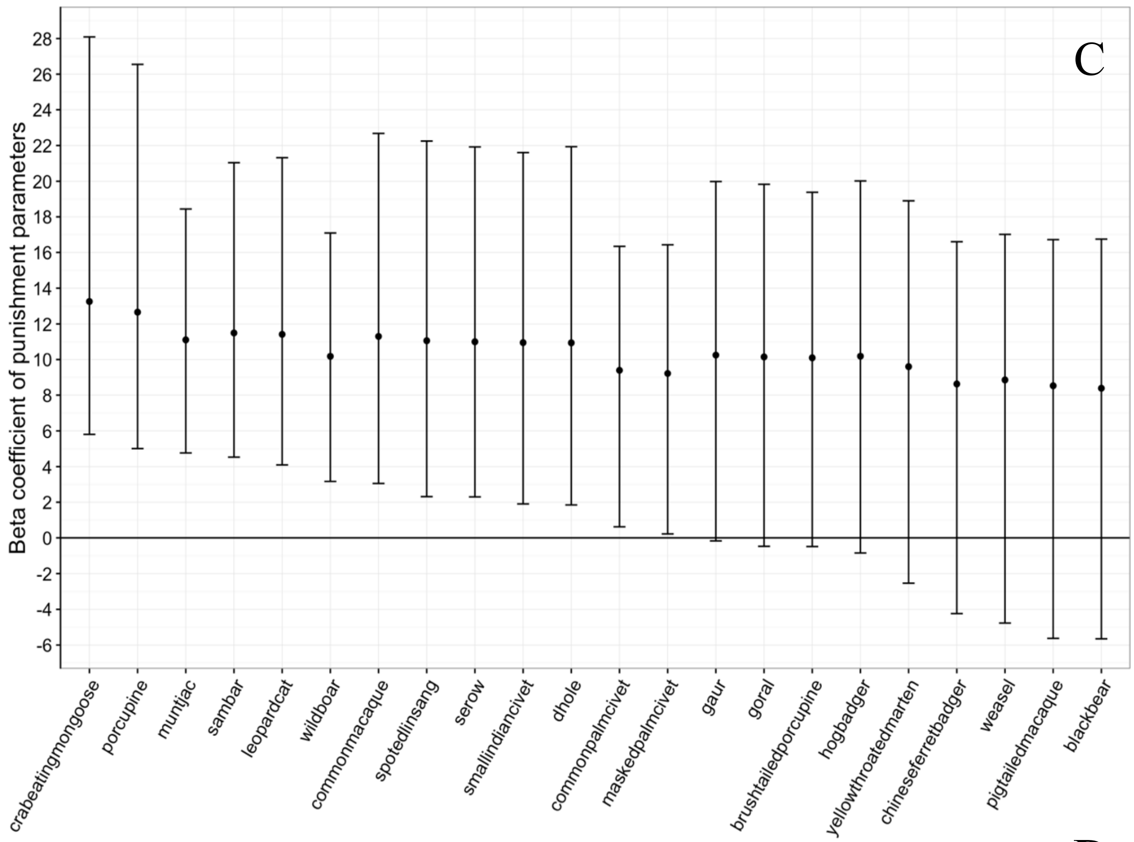
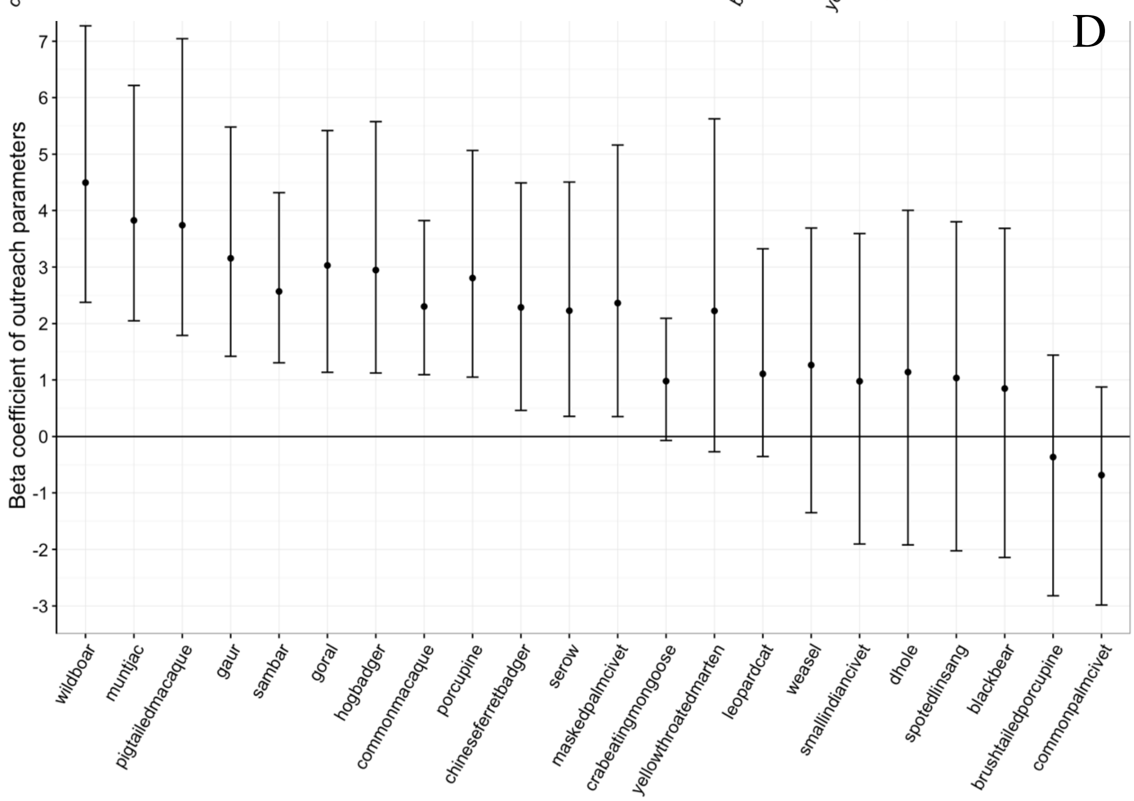


Figure 7. Beta coefficients for factors related to mammal species richness. Posterior distributions shown from high (dark) to low (light) probability.


A
Beta coefficient of elevation parameters
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
porcupine
commonpalmcivet
goral
weasel
dhole
yellowthroatedmarten
serow
hogbadger
muntjac
spotedlinsang
chineseferretbadger
blackbear
brushtailedporcupine
maskedpalmcivet
pigtailedmacaque
wildboar
gaur
crabeatingmongoose
smallindiancivet
sambar
leopardcat
commonmacaque
B
Beta coefficient of human density parameters
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
brushtailedporcupine
leopardcat
maskedpalmcivet
pigtailedmacaque
hogbadger
crabeatingmongoose
commonmacaque
commonpalmcivet
gaur
sambar
goral
serow
porcupine
weasel
spotedlinsang
dhole
smallindiancivet
yellowthroatedmarten
chineseferretbadger
blackbear
muntjac
wildboar


C
Beta coefficient of punishment parameters
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
crabeatingmongoose
porcupine
muntjac
sambar
leopardcat
wildboar
commonmacaque
spotedlinsang
serow
smallindiancivet
dhole
commonpalmcivet
maskedpalmcivet
gaur
goral
brushtailedporcupine
hogbadger
yellowthroatedmarten
chineseferretbadger
weasel
pigtailedmacaque
blackbear


D
Beta coefficient of outreach parameters
7
6
5
4
3
2
1
0
-1
-2
-3
wildboar
muntjac
pigtailedmacaque
gaur
sambar
goral
hogbadger
commonmacaque
porcupine
chineseferretbadger
serow
maskedpalmcivet
crabeatingmongoose
yellowthroatedmarten
leopardcat
weasel
smallindiancivet
dhole
spotedlinsang
blackbear
brushtailedporcupine
commonpalmcivet

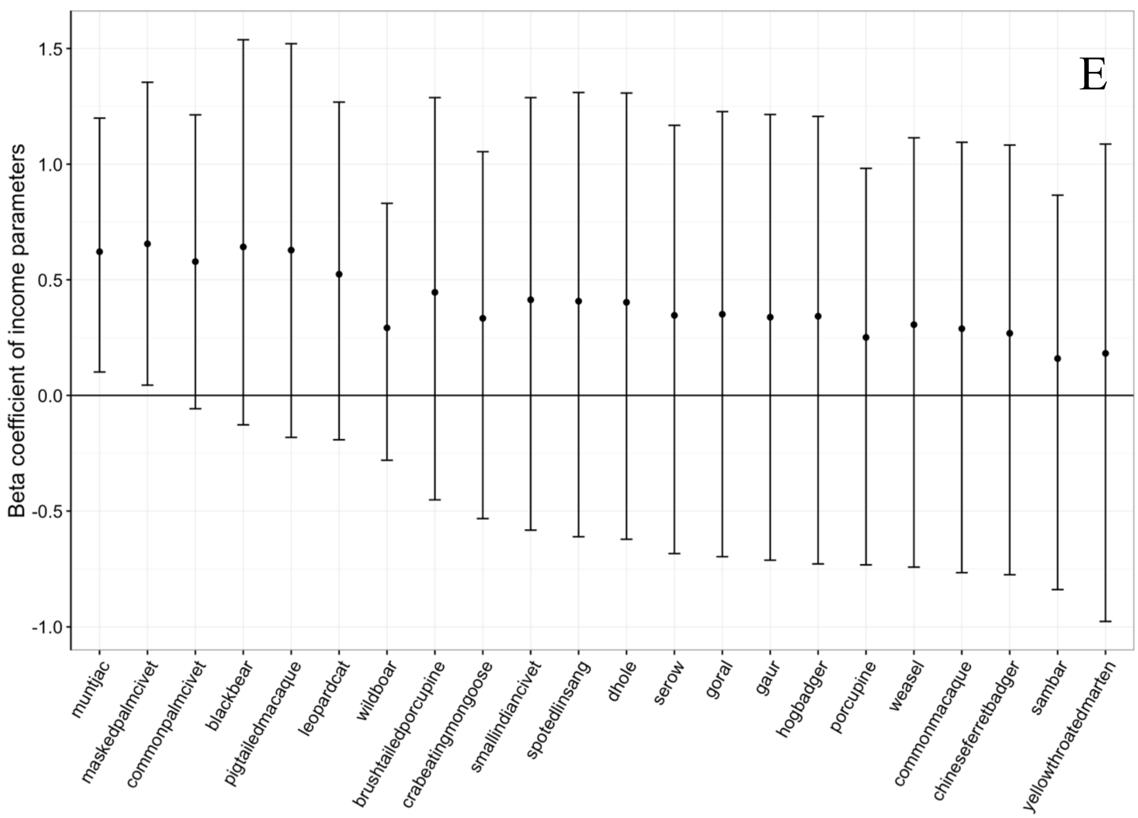
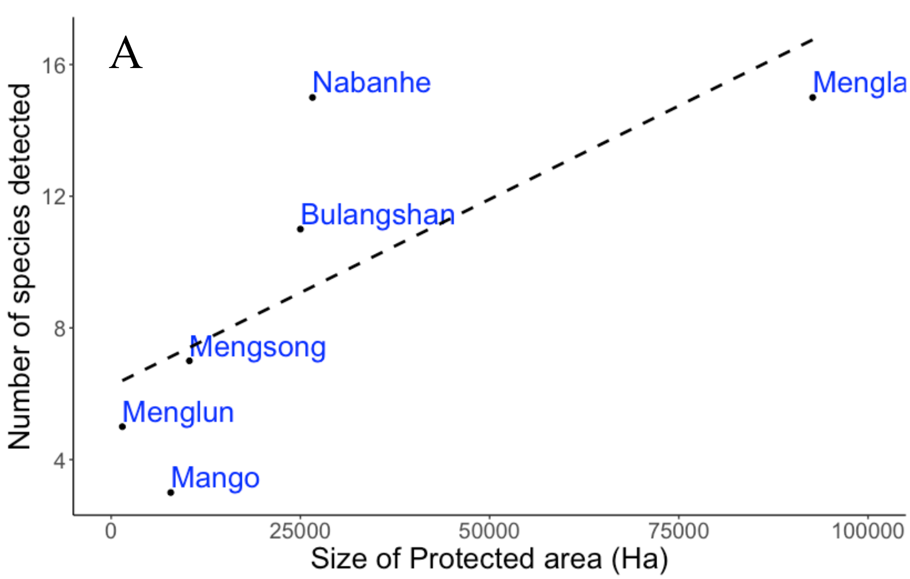


Figure 8. Species-specific beta coefficients for (A) elevation, (B) human population density, (C) villager-reported outreach frequency, (D) villager-reported number of punishments, and (E) annual income of local people. Error bars show 95% credibility intervals.



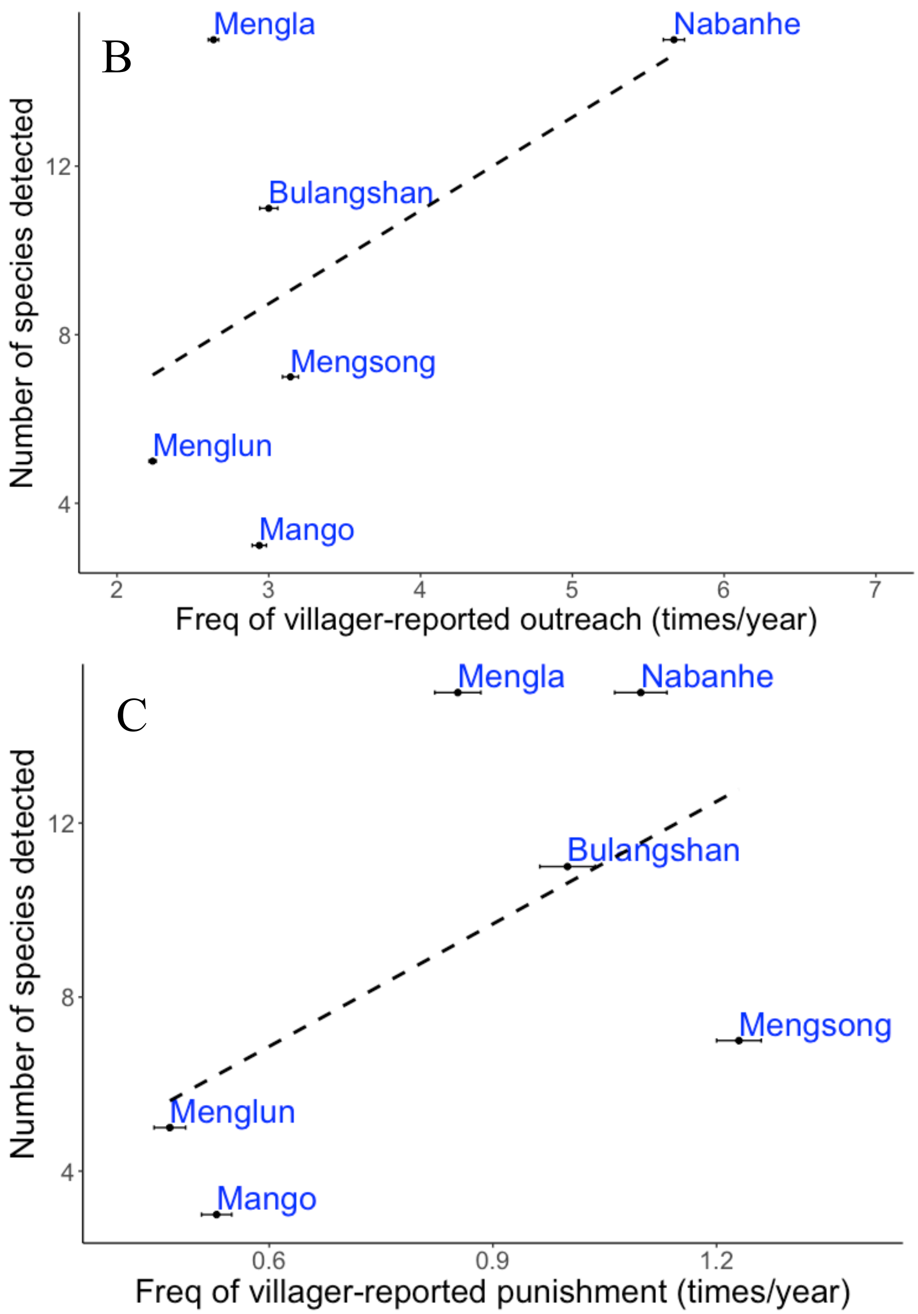


Figure 9. Relationship between (A) size of protected area, (B) frequency of villager-reported outreach, (C) frequency of villager-reported punishment and species counts across protected areas.

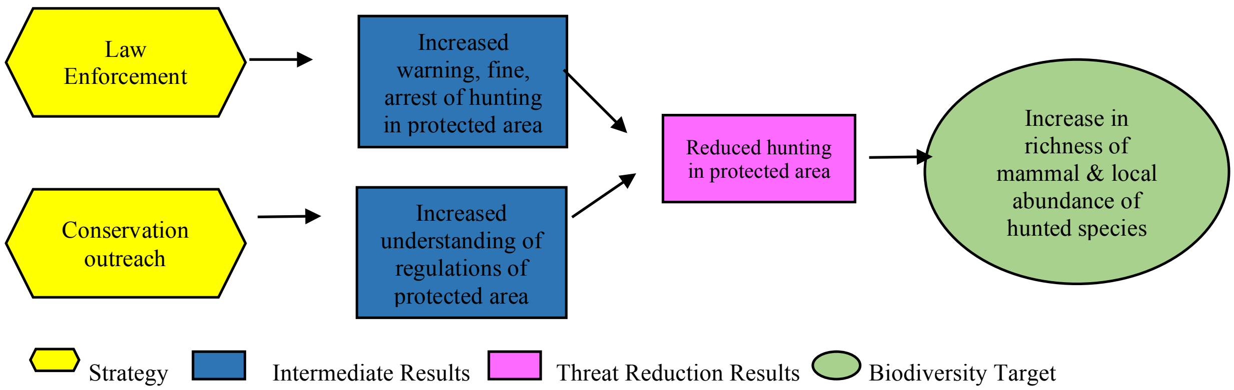


Figure 10. “Theory of change” diagram (Margoluis et al. 2013, Johnson et al. 2016) that illustrates how law enforcement and conservation outreach could lead to reduced hunting and increased mammal diversity in protected areas.

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Appendices

Appendix A: Questionnaire about attitudes towards wildlife and protected area

"I understand the terms and purpose of this research. I agree to participate in this study."

Part 1.Please check the box

	Agree	Neutral	Disagree
1.1. Protect the wild animal in reserve nearby are good for the environment of Xishuangbanna.			
1.2. Only the country has the responsibility to protect the wild animal in reserve nearby, it is not my own business.			
1.3. Any animal that damaged our crops should be killed.			
1.4. If there are no animal in the reserve, the quality of forest in the reserve will decline.			
1.5. Many animals living the forest nearby makes me happy.			
	Agree	Neutral	Disagree
2.1. Wild plants such as edible vegetable will not run out, we can collect it as much as we can.			
2.2. The forest nearby has one more or one less plant species will not have any impact on me.			
2.3. Seeing tree, grass and flowers in the nearby reserve makes me happy.			
2.4. We should not spend time to protect plants that we cannot use.			
2.5. Nearby reserves are built to protect animal but not to protect plants.			
	Agree	Neutral	Disagree
3.1. The protected area nearby has no benefits for me.			
3.2. The protected area nearby successfully protected wild animals and plants.			
3.3.The protected area nearby affect the income of my family.			
3.4. The actually effectiveness of protected areas nearby is low.			
3.5. The protected area nearby is good for our future generation.			
	Agree	Neutral	Disagree
4.1. If I go hunting, my friends will against it.			
4.2. If I go hunting, my family will against it.			
4.3. Old people in our village always told us to abstain from killing animals.			
4.4. When I was in the school, my teachers always told us to protected wild animal.			
4.5. People in my village are being supportive in terms of hunting.			
	Agree	Neutral	Disagree
5.1. If I go to collect plants from protected area, my friends will against it.			
5.2. If I go to collect plants from protected area, my family will against it.			

5.3. Old people in our village always told us do not collect plants in protected area.			
5.4. When I was in the school, my teachers always told us do not collect plants in protected area.			
5.5. People in my village are being supportive in terms of plant collection in protected area.			
	Agree	Neutral	Disagree
6.1. My friends think establish a protected area is useless.			
6.2. My family think establish a protected area is useless.			
6.3.People in our village think establish a protected are is good.			
6.4. My friends think living close to a protected area is good.			
6.5. My family think living close to a protected area is good.			

Part 2. Please circle the correct answer.

1. How many times that you noticed the **staffs of protected areas** came to you village for **outreach** such as send out leaflets and posters?						
Don't know	**0 times/year**	**1-2 times/year**	**3-5 times/year**	**5-10 times/year**	**10-15 times/year**	**15 times/year and more**
2.How many people that you noticed be punished by protected area of **last year**(including fine and detention)?						
Don't know	**0**	**1-5 people**	**5-10 people**	**10-15 people**	**15-20 people**	**20 people and more**

3.How do you rate **relationship** between protected area staffs and your villagers?					
Don't know	**Very bad**	**Bad**	**Neutral**	**Good**	**Very good**
4. What kind of punishment will someone receive if protected area staffs caught him/her collecting plants inside protected areas? (**Multiply choices**)					
Don't know	**No Punishment**	**Warning &get expel from PAs**	**Confiscation of plants & tools**	**Fine**	**Detention**
5. What kind of punishment will someone receive if protected area staffs caught him/her hunting inside protected areas? (**Multiply choices**)					
Don't know	**No Punishment**	**Warning &get expel from PAs**	**Confiscation of animals & guns**	**Fine**	**Detention**

Part 3. Personal information.

Nationality		Gender		Age		Education level	
Number of family members							
Estimation of Annual income of you family	5 K and less	5-10K	10-20K	30-50K	50-100K	100-150K	150 K and more
Village			Closest protected area				
The approximately time you need to get to protected area from you village (and How?)							

Appendices B: Questionnaire about attitudes towards wildlife and protected area (in simplified Chinese)

请先勾选同意参加研究：

“我了解该研究和问卷的内容和目的。我同意参加该研究，填写问卷。” ☐

问卷 1. 请勾以下选项。

	同意	中立	不同意
1. 保护附近保护区里的野生动物对西双版纳的环境没有好处			
2. 保护附近保护区的野生动物是国家的事，和我个人没关系			
3. 破坏庄稼的野生动物应该被消灭			
4. 如果附近保护区的动物没有了，保护区的森林会慢慢变坏			
5. 如果村子附近的林子里有很多种动物，会让我很愉快			
	同意	中立	不同意
1. 附近保护区里的野菜等植物可以无限制采集，永远采不完			
2. 附近保护区的林子里多一种植物，少一种植物对我个人没什么影响			
3. 附近保护区的林子中有各式各样的花草，会让我心情愉快			
4. 没有用处的植物，就不应花时间保护			
5. 附近的保护区是保护动物的，不是保护植物的			
	同意	中立	不同意
1. 附近的保护区对我个人没有好处			
2. 附近保护区成功的保护了许多野生动物、植物			
3. 国家在我家附近建立保护区，影响了我们家收入			
4. 国家在我家附近建立保护区，真实的保护效果并不好			
5. 附近的保护区对我们子孙后代有好处			
	同意	中立	不同意
1. 如果我上山抓野生动物，我老根会反对			
2. 如果我上山抓野生动物，我家人不会反对			
3. 村里的老人经常教育我们不要杀生			
4. 上学的时候，老师曾教育我们要保护野生动物			
5. 村里的人对大家上山抓动物野生动物挺支持的			
	同意	中立	不同意
1. 如果我去保护区采野菜，我老根会反对			
2. 如果我去保护区采野菜，我家人会反对			

3. 村里的老人经常教育我们不要进保护区采植物			
4. 上学的时候，老师教育我们不要去保护区采东西			
5. 村里的人对大家上山采集野菜挺支持的			
	同意	中立	不同意
1.我老根们都觉得，建保护区没有用			
2.我家人都觉得，建保护区没有用			
3.村里人都觉得，建保护区很好			
4.我老根们都觉得能够住在保护区旁边很好			
5.我家人都觉得能够住在保护区旁边很好			

问卷 2. 请圈出以下问题的正确答案。

1.在你印象中保护所的人、护林员一年来村里**发传单、贴海报，宣传教育几次**？						
不清楚	0 次/年	1-2 次/年	3-5 次/年	5-10 次/年	10-15 次/年	15 次/年以上
2.你印象中你们村**过去一年**有多少人被**保护所处罚的（罚款或者拘留）**的？						
不清楚	0 人	1-5 人	5-10 人	10-15 人	15-20 人	20 人以上
3.保护区保护所、管理站的工作人员**和村民关系**怎么样？						
不清楚	非常不好	不好	一般	好	非常好	
4.你知道如果有人在保护区采集**野菜、草药**被保护区工作人员碰到了，会怎么处理？**（多选）**						
不清楚	不处理	警告、驱逐出保护区	没收采到的东西、采集工具	罚款	拘留	
5. 你知道如果有人在保护区**打猎**保护区工作人员碰到了，会怎么处理？ **（多选）**						
不清楚	不处理	警告、驱逐出保护区	没收猎物、枪支	罚款	拘留	

问卷 3. 个人信息

民族		性别		年龄		教育程度	
家庭成员数							
家庭年平均收入估计	5 千以下	5 千-1 万	1-2 万	3-5 万	5-10 万	10-15 万	15 万以上
现居住村名		离你住地最近的保护区					
从你住地到最近保护区需要的大致时间（交通工具）							