Habitat characteristics or territory size: which is more important to composition and diversity of mammals in non-protect area?

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Abstract

The main strategy for animal diversity conservation is to increase the territory size but little consideration is given to habitat characteristics requirement, which lead to a decrease in effectiveness for protected areas. Marginal of protected areas are considered to have higher species richness due to the edge effect. Strategy in these sites are still adopts to increase territory size or pay no attention to needs of specific habitat characteristics that is an important topic for the planner and manager. In this study, camera traps was used to estimate composition, diversity and habitat characteristics of mammals in a non-protected area near Huangshan Mountains in Anhui Province, China. We ran 49 liner models with the relative abundance index and 13 habitat characteristic factors of 11 mammals. To answer the question of habitat characteristics or territory size: which is more important to composition and diversity of mammals in non-protect area? We hypothesized that: (1) Non-protected areas have more mammal species than protected areas with the edge effect. (2) Non-protected areas have more species associated with habitat characteristics. We predicted that the habitat characteristics should be firstly considered, territory size secondly in non-protected areas, would provide a last refuge for mammals. Cameras were operated from June 2017 to October 2019, for a total of 29 months, 2,212 independent photos, 9,485 trap-days, recorded 18 species of mammals more than any other protected areas confirmed first hypothesis 1. The model

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analysis results showed that, habitat characteristics of mammals were different and showed a significant correlation, supported hypothesis 2. In addition, most species are related to vegetation characteristics except to primates (*Macaca. thibetana*) and rodent (*Leopoldamys edwardsi*) confirmed our prediction. We suggested conservation policies in non-protected areas: Habitat characteristics should be concerned at first and then increasing protected areas to provide the last refuge for species conservation.

KEYWORDS: mammal diversity; camera traps; habitat characteristics; territory sizes; conservation management.

1 INTRODUCTION

The most effective strategy for species conservation is to protect all their territory areas. The common practice is building nature reserves or protected areas to protect original habitat characteristics for endangered species, that gives more opportunities for protected species to survive and reproduce in the most suitable habitat characteristics, and then achieve the goal of protecting the species (Astudillo-Scalia, & de Albuquerque, 2020; Burns, Johnston, & Schmitz, 2003). These protect areas has been paid more attention by scholars for its ecological, economic and research value (Brum et al., 2017). Although there are a large number of protected areas established, more or less faced with wildfires (Camargo et al., 2018), illegal hunting (Duporge, Hodgetts, Wang, & Macdonald, 2020), deforestation and other problems (Mekonen, 2020), thus reducing the protection value of protected areas and making the protected species not well protected.

However, with the implementation of the global biodiversity conservation plan, there is still a large area are not classified as protected areas, which has not attracted much attention of researches (McShea et al., 2009; Burns, Johnston, & Schmitz, 2003). Although these areas have been shown to have high species diversity, which may provide germplasm resources, gene flow, etc. for protected species in protected areas this accordingly achieved the important role of maintaining biodiversity (Yahner, 1988). Species diversity conservation in unprotected areas has always been faced with an important choice: Increase territory size or specifically protect the habitat characteristics of protected species (Bai et al., 2020). Increasing territory size there will be more investment in manpower and materials, and the final results may be far less than that in the protected area. Protecting habitat characteristics only needs to obtain the information of habitat and ecological characteristics for protected species and then establish a set of effective measures. This choice will be precisely found out the size of protect areas thereby reducing investment in manpower and materials.

Animals have potential for habitat selection, studies have shown that they can spread into unoccupied areas, most animals cannot fully monopolize their potential habitats (Bai et al., 2020; Sukma, Di Stefano, Swan, & Sitters, 2019; Wong et al., 2018). This means that they only select to live in some fixed habitat, which can meet their requirements of habitat characteristics (Huang et al., 2020). In addition, the difference of habitat characteristics (such as geography, food and the distribution of other species etc.) has an impact on animals' distribution (Huang et al., 2020). Therefore, the habitat characteristics of animal should be considered when undertaking animal protection strategy. Actually，many protected areas were created without consideration on habitat characteristics eventually lower the conservation effectiveness of nature reserves, such as animals population declines (Xu et al., 2014; Kolahi et al., 2013; Craigie et al., 2010; Scott et al., 2001).

Mammals are important components of forest, however, only few studies that provide information on the species composition and diversity of mammalian in non-protected area are available (Bogoni et al., 2016; Hagger, Fisher, Schmidt, & Blomberg, 2013; Wang, 1990). Most non-protected areas are not enough to attract much attention. For instance, conversion of forests into secondary forests does not always result in mammal species decline as some species thrive well based on forest mosaic, tree species composition, structure, type, age, and number of predators in forests (e.g., squirrels (*Callosciurus erythraeus*) and wild boar (*Sus scrofa*) (Meijaard & Sheil, 2007). Forest structure changes make the understory vegetation more open and the increase of herbaceous layer coverage is also beneficial to ungulates such as *Muntiacus reevesi*. In addition, mammals may also affect the structure and composition of forests by feeding on seeds and spreading them (Andresen, Arroyo-Rodríguez, & Ramos-Robles, 2018;

Fedriani & Delibes, 2009). Similarly, activities such as trampling, wallowing and digging, such as *Sus scrofa*, may physically alter the substrate and the vegetation structure (Barrios-Garcia & Ballari, 2012). The existence of some predators (e.g., *Neofelis nebulosa* and *Prionailurus bengalensis*) can also control the destruction of animal ecosystems caused by excessive growth of other small mammals (Chiang et al., 2014; Kolchin, 2018; Watanabe & Izawa, 2005). Therefore, it is necessary to understand the diversity, composition and habitat characteristics of mammals in non-protected areas.

The subtropical forest in Mt. Huangshan is among the most diverse anywhere and an important part of 32 priority areas of inland biodiversity protection in China (Huangshan- Huaiyu mountain area). Several studies focusing on mammals and birds communities in these forests exists (Fang, 2017; Liu et al., 2017; Wang et al., 2015). However, such studies are carried out in national nature reserves and provincial protected areas. There are few studies on the areas with a lower protection level around the reserve. In addition, most of these studies are tentative studies, lacking systematic and regular research efforts. Mammals constitute a key component of tropical and subtropical forest ecosystems (Wang, 1990). However, knowledge gaps in understanding variations in communities or assemblages in unprotected subtropical forests stationed as protected area boundaries is paramount.

Mammals portray a wide array in body size, behavior (e.g., arboreal, terrestrial, diurnal, and nocturnal), and home range size which makes it challenging to conduct standardized surveys on subtropical forests mammals. Several methods of sampling mammalian fauna have been tried and tested with limited success. Apparently, no single site approach technique has proven suitable for conclusively surveying the entire mammalian fauna (O'Connell, Nichols, & Karanth, 2011). Recently, camera traps method has become an important tool for terrestrial species surveys and mammal surveying in particular (Andresen et al., 2018; McShea et al., 2009; Srivastava & Kumar, 2018). The method has also been used to research human disturbance and environmental change on mammals (Vanthomme, Kolowski, Korte, & Alonso, 2013; Widness & Aronsen, 2018). Furthermore, this technique has been used in the conservation of species that are rare and endangered, animal monitoring in human landscapes, and the behavior study of non-human primates (Pebsworth & LaFleur, 2014; Rabinowitz & Nottingham, 1989; Saito & Koike, 2013), to document the use of specific habitats (Fiderer, Göttert, & Zeller, 2019; Granados, Crowther, Brodie, & Bernard, 2016)

Mammalian species composition and diversity show obvious spatio-temporal dynamic changes and are directly related to the spatial scale of the study. Heterogenous habitats influence species distribution and abundance patterns including temporal variation in environmental conditions (Bhattarai & Kindlmann, 2011; Blake & Loiselle, 2018; Saito & Koike, 2013; Vanthomme et al., 2013). Several studies that have employed the use of camera traps to survey mammalian communities cover vast land areas. However, most of these surveys are designed for some large and endangered species, and they may have strong migration ability. Therefore, most of these studies are large-scale monitoring (Meijaard & Sheil, 2007; Widness & Aronsen, 2018). These large-scale monitoring may ignore the impact of small-scale habitat environments on mammals activities (Mochizuki & Murakami, 2013). The spatial activity and distribution of mammals under small scale can reflect the habitat change and predation pressure under small scale.

From June 2017 to October 2019, the camera traps was used to estimate composition, diversity and habitat characteristics of mammals in a non-protected area near Huangshan Mountains Anhui province, China. With the objective to answer the question of habitat characteristics or territory size: which is more important to composition and diversity of mammals in non-protect area? We hypothesized that: (1) Non-protected areas have more mammal species than protected areas with the edge effect (Cheyne, Sastramidjaja, Muhalir, Rayadin, & Macdonald, 2016; Yahner, 1988). (2) Non-protected areas have more species associated with habitat characteristics (Bhattarai & Kindlmann, 2011; Blake & Loiselle, 2018). We predicted that the habitat characteristics should be firstly considered, the territory areas secondly in non-protected areas, this would provide a last refuge for mammals.

2 METHODS

2.1 Study sites

We study in the Niejiashan Research Base (NRB) Mt. Huangshan, Anhui province in east-central China (30°.12′ N, 118°27′ E, 250-650 m) founded by the International Collaborative Research Center for Huangshan Biodiversity and Tibetan Macaque Behavioral Ecology, Anhui University in 2017 (Figure 1). The aims were to monitor the biodiversity and Tibetan Macaque behavioral ecology in Mt. Huangshan including its surrounding areas. NRB is located adjacent to Mt Huangshan Tianhu Nature Reserve (a provincial nature reserve in Anhui province) and with a total area of 35.12 km^2. In 1990 this place was named a UNESCO World Heritage Site for being a site of scenic natural beauty. Huangshan was declared a national park by the government and now is a major developed tourist destination in China. It is an important area in the pilot area of the great Mt. Huangshan National Park. It is also an important part of the 32 priority areas of inland land biodiversity conservation (Mt. Huangshan-Huai Yu mountain) in China. The NRB is surrounded by mountains with steep slopes, the altitudes increase from Northwest to Southeast. The intermontane plain is located in the lowland. Tianhu mountain (1217 m) is the main peak. Due to inconvenience in transportation, the area is sparsely populated. A large and intact subtropical evergreen deciduous broad-leaved mixed forest is still remaining in the whole Mt. Huangshan-Huai Yu mountains.

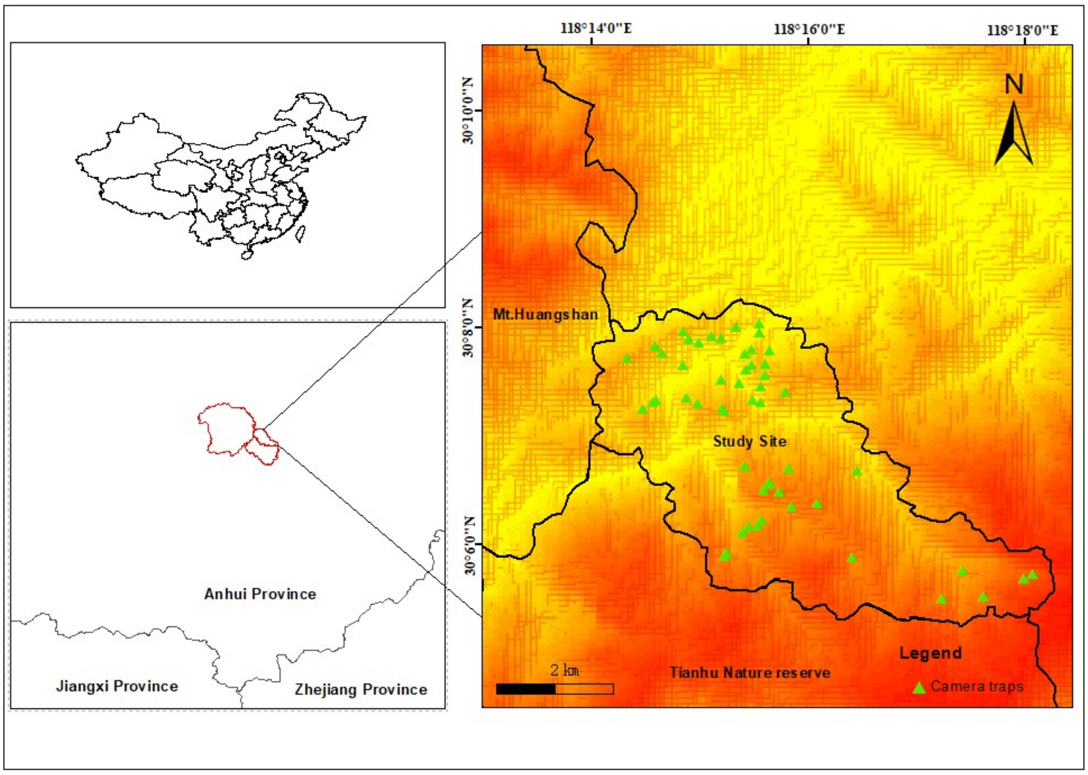

Figure 1 Study site and the distribution of camera traps in this study. The study site was situated at the boundaries of Huangshan Mountains and Tianhu Nature Reserve，triangle represents the effective monitoring points of the infrared camera.

This non-protected area situated in a subtropical monsoon climate zone. The annual rainfall during September 2018 to August 2019 was 2639.4 mm, the annual mean monthly rainfall 29.6-474.4 mm, and the mean temperature was 15.5 ℃ with the highest temperature in July (38.1℃) and the lowest in February (-13.1 ℃) (Figure 2) (Acquired by the automatic weather station(QS-3000) of NRB).

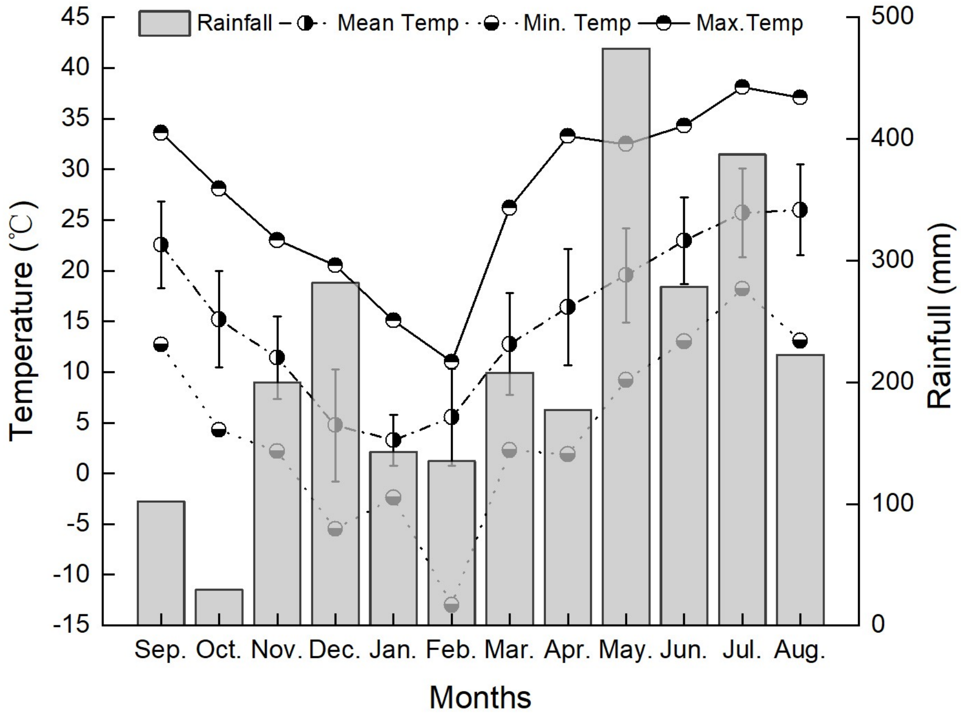

Figure 2 Monthly maximum, minimum, average temperature and rainfall at Niejiashan Research Base during the study periods

2.2 Data Collection

Camera traps

We first conducted the study in the higher altitude (range 750-1100 m) using six camera traps in the periods of June 2017- June 2018, and in July- October 2018, we added ten more camera traps in the nearby areas. From October 2018 to October 2019 we stopped checking those in the higher altitude areas while turning our monitoring efforts to lowland forest areas (Table 1)

Table 1 Characteristics of camera traps. Date refers to the time when the camera starts working, altitude and areas is determined by the camera's location, trap days is the total active time, species is the total species photographed by the camera.

Date	Camera traps	Altitude	Areas	Trap days	Species
201706-201806	6	724-1100m	4.12km^2	1231	12
201807-201810	16	449-1020m	10.8km^2	3467	13
201810-201910	30	250-780m	11.15km^2	4787	18

In this study, a total of 36 infrared cameras (EREAGLE TRAIL CAMER POWER: DC 6 ~ 17V LENS: 7.45mm E1) were used to cover 52 cameras traps location, and the interval between each camera was not less than 500m (Figure 1). It should be noted that each cameras traps location was only equipped with 1 camera, fixed on a thicker tree with a belt of 50-60cm high. Infrared camera was set to take 3 pictures and a 10 second video at 0.05s intervals. Camera continuous monitoring work started from June, 2017 until October, 2019, and each effective camera traps location works for at least 30 days. The same sampling points were used every month. We checked the camera every month, to confirm whether the camera has been working because the camera may be damaged by some large animal, such as *Macaca thibetana* and *M. mulatta*. The working time of each camera was calculated according to their actual working time, excluding the time of failure due to battery and other factors.

Habitat characteristics

We used stratified random sampling to divide forest and habitats into 3 different forest types or levels. A total of 52, 20m * 20m plots (area: 11.15 km^2) were set up according to the camera location. Among them, 20 plots were planted in evergreen broad-leaved forests, 10 plots were planted in deciduous broad-leaved forests, and 22 plots were planted in mixed forests. Since we used 30 infrared cameras to conduct a comprehensive periodic survey of the low-altitude area from October 2018 to October 2019, we investigated the habitat characteristics at 30 camera points in the low-altitude areas (Table 2)

Table 2 Definition and category of habitat characteristics in 52 camera traps location

Habitat characteristics	Definition	Category
Altitude	Location of camera traps	_
Aspect of slopes	Via an electronic compass E = east = 45°-135°; S = south = 135°-225°; W = west = 225-315°; N= north =315-360° and 0°-45°	E, S, W, N

Slope position	Different parts of the mountains	upper, middle, lower positions
Slope-gradient	Gentle slope (≤30°); slight slope (30°-60°); steep slope (≥60°)	gentle slope, slight slope, steep slope
Distance from water source	Near (≤50 m), mid-distance (50 m-100 m), and far (≥100 m)	near, mid-distance, far
Forest types	Evergreen broad-leaved forests; deciduous broad-leaved forests;; mixed forests	-
DBH	diameter at breast height	≤15 cm, ≥30 cm, 15–30 cm
Tree canopy	Coverage degree of tree crown	≤25%, 25%-50%, 50%-75%, ≥75%
Tree density	Number of all trees with DBH≥5cm	-
Tree height	Actual height of the tree as perceived	-
Shrub coverage	coverage degree of shrub crown	≤5%, 5%~10%, 10%~15%
Shrub height	actual height of the tree as perceived	0-1m, 2-3m, 3-4m, 5-6m, ≥7m
Herb coverage	coverage degree of herb crown	≤2%, 2%~4%, and 4%~5%

2.3 Data analyses

After collected field survey data, species identification was conducted on photos and videos, the classification system of mammal species was referred to *China's mammal diversity (2nd edition)* (Jiang, Liu, Wu, Jiang, & Zhou, 2017). Species of the IUCN Red List assessment level with reference to ("IUCN, 2017. IUCN Red List of Threatened Species. http://www.iucnredlist.org.,"). All photos and videos at intervals of 30min (small-sized mammals) or 60min (larger-sized mammals have strong mobility) for each effective monitoring site were combined as a valid statistic (effective detection or independent photos) for the species. The relative abundance index (RAI) was counted on the effective detection of each species (Burton et al., 2015; O'Connell et al., 2011). Individual species RAI is calculated as follows: RAI = (Independent photos/total number of traps days)×100 (Blake & Loiselle, 2018). We used the species accumulation curve to assess the sampling effort (Colwell & Elsensohn, 2014). Species richness gradually stabilized with increasing numbers of traps and traps day, nearing 18 species.

A chi-square goodness-of-fit test was used to test relationship between habitat characteristics and our measures of different mammal species relative abundance index (including 11 species, with more than 10 individual photos of each species). Linear model was used to create the Global Model, including camera traps location habitat characteristics (Altitude, aspect of slopes, slope position, slope-gradient, distance from water source, forest types, DBH , tree canopy, tree density, tree high, shrub coverage, shrub high, herb coverage Table 2). We compared support for total 49 models of mammal species relative abundance index, including a null (intercept-only) model for all analysis. Because the information-theoretic framework (an information criterion corrected for small sample size) makes up for many defects in the use of conventional stepwise regression analysis. Based on the AIC determination method, model selection and multimodel inference were used to explore the determinants of the diversity and composition of mammals (Burnham & Anderson, 2002; Palmer & Koprowski, 2015). Before logistic regression analyses, independence tests were conducted using a nonparametric Spearman rank correlation of habitat characteristics data. All factors related to habitat characteristics (N=13) were selected into the model during the model construction of each species. The function glmulti in glmulti package was used to screen all possible models and select the optimal model. If Δ AICc > 2 choose end model, namely the optimal model for the first model, or for all the models using MuMIn in lm model average function model, to lists all the possible models. Analyses were carried out in R for windows version 3.3.0 (The R Foundation for Statistical Computing, 2016). The significance level was set at p =0 .05.

3 RESULTS

3.1 Species composition and diversity

We collected a total of 2,212 independent photos of mammal species, representing a total of 18 species, over 9,485 trap days. According to the red list of IUCN species, there were 1 endangered species (*Muntiacus crinifrons* [RAI = 0.03]), 3 near-endangered species (*M. thibetana* [RAI = 2.58], *Arctonyx collaris* [RAI = 1.14], and *Capricornis sumatraensis* RAI = 0.05). Together, they accounted for 22.2% of the total species. Four species (*Leopoldamys edwardsi* [RAI = 10.97], *M. reevesi* [RAI = 8.04], *M. thibetana* [RAI = 2.58], and *M. mulatta* [RAI = 2.38] showed higher abundance-activity indices. Species scoring over 2% were deemed dominant. For *Niviventer niviventer*, *A. collaris*, *Melogale moschata*, *Sus scrofa, Paguma larvata, Callosciurus erythraeus,* and *Tamiops maritimus*, the RAI for each accounted for more than 0.1, and thus they were considered common species. *Mustela sibirica*, *C. sumatraensis*, *Martes flavigula*, *Lepus sinensis*, *M. crinifrons*, *Erinaceus europaeus*, and *Meles meles* each accounted for less than 0.1, for which they were considered as rare species (Table 3). The relative abundance index of Rodentia and Artiodactyla were the highest, followed by Carnivora (Figure 3). The camera traps differed in relative abundance index (RAI) of species richness (chi-square goodness-of-fit test: df = 10, χ^2 =119.77, P = 0.000).

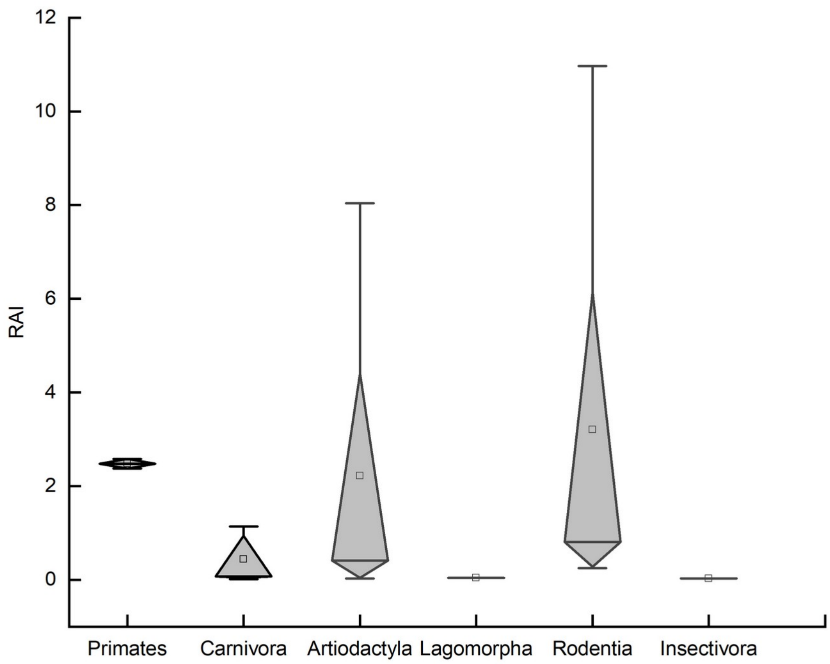

Figure 3 The relative abundance index (RAI) of different taxa. The RAI was the sum of different species in different taxa, which consisted of 18 terrestrial mammal species The camera traps differed in relative abundance index (RAI) of species richness (chi-square goodness-of-fit test: df = 10, $\chi 2$ =119.77, P = 0.000).

Table 3 Composition, threatened level and relative abundance index of mammal species in non-protected areas during Jun. 2017–Oct. 2019, the photos were the total number of independent records (2,212), trap-days were given by all the normal days (9,485).

Mammals	(IUCN, 2017)	RAI
Primates		
Cercopithecidae		
Macaca thibetana	NT	2.58
Macaca mulatta	LC	2.38
Carnivora		
Mustelidae		
Martes flavigula	LC	0.04
Mustela sibirica	LC	0.07
Melogale moschata	LC	0.94
Meles leucurus	LC	0.01
Arctonyx collaris	NT	1.14
Viverridae		
Paguma larvata	LC	0.61
Artiodactyla		
Suidae		
Sus scrofa	LC	0.77
Cervidae		
Muntiacus reevesi	LC	8.04
Muntiacus crinifrons	VU	0.03
Bovidae		
Capricornis sumatraensis	NT	0.05
Lagomorpha		
Leporidae		

Lepus sinensis	LC	0.04
Rodentia		
Muridae		
Leopoldamys edwardsi		10.97
Niviventer niviventer		1.30
Sciuridae		
Tamiops maritimus	LC	0.25
Callosciurus erythraeus	LC	0.31
Insectivora		
Erinaceidae		
Erinaceus europaeus		0.03

3.2 Habitat characteristics needs between different mammals

We characterized the habitat of where mammals were found at 30 camera trap sites with 13 habitat characteristics. Univariate analyses revealed the trap sites were significant differences in 13 habitat characteristics ($P=0.000$).There was significant correlation between species richness（the total number of species ）and altitude ($Rs = 0.628$, $p = 0.000$),slope position ($Rs = -554$, $p = 0.000$)，distance from water source ($Rs = 0.162$, $p = 0.015$)，tree density ($Rs = 0.338$, $p = 0.000$)，tree coverage ($Rs = -0.504$, $p = 0.000$) ，DBH ($Rs = -0.318$, $p = 0.000$), tree high ($Rs = -0.278$, $p = 0.000$),shrub coverage ($Rs = -0.442$, $p = 0.000$), shrub high ($Rs = -0.159$, $p = 0.016$) in different camera traps sites.

We ran liner models with the relative abundance index and 13 habitat characteristic factors of 11 mammals. The model showed that each mammal had different habitat characteristics selected (Table 4), and each species showed a significant correlation with its own habitat characteristics (Table 5). Species that were involved in topographic features (altitude, slope, slope position, slope gradient, distance from water sources) were *M. thibetana* (slope gradient: $\beta \pm SE = 2.00 \pm 0.94$, $t = 2.13$, $p= 0.04$) preferred steep hill, *M. mulatta* (altitude: $\beta \pm SE = 0.02 \pm 0.01$, $t = 2.51$, $p= 0.02$) preferred higher mountains, *M. reevesi* (altitude: $\beta \pm SE = 0.03 \pm 0.02$, $t = -2.20$, $p= 0.04$; slope: $\beta \pm SE = -0.35 \pm 1.37$, $t = -2.81$, $p= 0.01$; slope gradient: $\beta \pm SE = -7.92 \pm 1.52$, $t = -5.22$, $p< 0.001$)

preferred higher mountains with gentle sunny slopes, *T. maritimus* (slope position: β ± SE = -0.37 ± 0.12, t = -3.04, p= 0.005; water: β ± SE = -0.24 ± 0.10, t = -2.461, p= 0.02) preferred lower slope with long distance water sources, *S. scrofa* (slope position: β ± SE = -0.52 ± 0.20, t = -2.68, p= 0.01) preferred lower slope, *A. collaris* (slope position: β ± SE = -0.67 ± 0.33, t = -2.01, p= 0.06) preferred lower slope, *L. edwardsi* (slope gradient: β ± SE = -4.85 ± 2.73, t = -1.78, p= 0.06) preferred gentle hill. Species that were involved in forest features (forest types, tree canopy, density, height, DBH, shrub height and coverage, herb coverage) were *M. mulatta* (forest types: β ± SE = 1.24 ± 0.56, t = 2.21, p= 0.036) preferred deciduous broad-leaved forest, evergreen and deciduous broad-leaved forest, *N. niviventer* (shrub coverage: β ± SE = -1.52 ± 0.39, t = 3.94, p<0.001) prefer lower degree of shrub coverage usually≤ 5%, *S. scrofa* (tree density: β ± SE = 0.05 ± 0.001, t = 5.68, p<0.001; tree canopy: β ± SE =-0.82 ± 0.28, t =-2.88, p<0.001; shrub coverage: β ± SE =0.58 ± 0.16, t =3.70, p<0.001) preferred many trees with lower canopy and higher shrub coverage, *M. reevesi* (tree density: β ± SE = 0.40 ± 0.08, t = 5.05, p<0.001; shrub height: β ± SE = -3.52 ± 1.46, t = -2.41, p = 0.02; herb coverage: β ± SE =3.08 ± 1.18, t =2.62, p=0.02) preferred many trees with lower shrub height and higher herb coverage, *P. larvata* (forest types: β ± SE = 0.39 ± 0.23, t = 1.70, p<0.10; shrub height: β ± SE = -0.66 ± 0.26, t = -2.60, p = 0.02) preferred deciduous broad-leaved forest with lower shrub height. *M. moschata* (tree canopy: β ± SE = -1.29 ± 0.65, t = -1.98, p=0.06; DBH: β ± SE = 0.20 ± 0.12, t = 1.68, p = 0.11) , *A. collaris* (tree density: β ± SE = 0.04 ± 0.02, t = 2.22, p = 0.04; herb coverage: β ± SE = 1.10 ± 0.25, t = 4.37, p < 0.001) preferred many trees with higher herb coverage, *C. erythraeus* (tree density: β ± SE = 0.02 ± 0.01, t = 2.05, p = 0.05; tree canopy: β ± SE = -1.67 ± 0.26, t = -4.53, p < 0.001; shrub coverage: β ± SE = -0.20 ± 0.12, t = 1.7, p = 0.10) preferred many trees with lower canopy and shrub coverage (Table 5).

Table 4 Model selection and measures for models using logistic regression to explain different needs of habitat characteristics between different 11 mammal species in non-protected areas. Models were ranked in order of increasing AICc values, K was number of parameters; AICc was Akaike's Information Criterion values; ΔAICc was difference between the specified model and the optimal model; AICcWt was relative strength of support for each model; W_i was AICc model weight.

Model	K	Log likelihood	AICc	ΔAICc	AICcWt	Wi
Macaca thibetana						
slope + slope gradient	4	-82.25	174.11	0	0.32	0.32
slope gradient	3	-83.69	174.3	0.19	0.29	0.61
Null	2	-84.98	174.41	0.3	0.27	0.88
slope	3	-84.59	176.09	1.98	0.12	1
Macaca mulata						
altitude + forest types	4	-69.98	149.56	0	0.65	0.65
altitude	3	-72.48	151.88	2.31	0.2	0.85
forest types	3	-73.12	153.17	3.61	0.11	0.96
Null	2	-75.32	155.09	5.52	0.04	1
Paguma larvata						
forest types + shrub height	4	-42.36	94.32	0	0.46	0.46
shrub height	3	-43.89	94.7	0.38	0.38	0.84
Null	2	-46.43	97.31	2.99	0.1	0.94
forest types	8	-45.7	98.32	4	0.06	1
Melogale moschata						
tree canopy + DBH	4	-53.57	116.74	0	0.34	0.34
DBH	3	-55.05	117.02	0.29	0.3	0.64
Null	2	-56.73	117.91	1.17	0.19	0.83
tree canopy	3	-55.6	118.12	1.38	0.17	1
Arctonyx collaris						
tree density + slope position + herb coverage	5	-48.6	109.7	0	0.55	0.55
tree density + herb coverage	4	-50.77	111.13	1.44	0.27	0.82
tree density + slope position	4	-51.2	112.01	2.31	0.17	0.99
tree density	3	-55.45	117.82	8.12	0.01	1
Sus scrofa						
tree density + slope position + tree	6	-27.21	70.08	0	0.82	0.82

canopy + shrub coverage						
tree density + tree canopy + shrub coverage	5	-31	74.5	4.42	0.09	0.91
tree density + slope position + tree canopy	5	-31.52	75.45	5.46	0.05	0.96
tree canopy + shrub coverage	4	-34.06	77.72	7.65	0.02	0.98
tree density + tree canopy	4	-35.17	79.94	9.87	0.01	0.99
slope position + tree canopy +shrub coverage	5	-33.76	80.02	9.94	0.01	1
Muntiacus reevesi						
altitude + slope + slope gradient + tree density + shrub height + herb coverage	8	-91.31	205.47	0	0.42	0.42
slope + slope gradient + tree density + shrub height + herb coverage	7	-94.17	207.43	1.96	0.16	0.58
altitude + slope+ tree density + shrub height + herb coverage	7	-94.69	208.46	2.99	0.09	0.67
slope + tree density + shrub height + herb coverage	6	-96.86	209.38	3.9	0.06	0.73
altitude + slope gradient + tree density + shrub height + herb coverage	7	-95.23	209.54	4.07	0.05	0.78
altitude + slope + slope gradient + shrub height + herb coverage	7	-95.73	210.54	5.07	0.03	0.81
slope + slope gradient + shrub height + herb coverage	6	-97.45	210.56	5.09	0.03	0.84
slope gradient + tree density + shrub height + herb coverage	6	-97.63	210.92	5.45	0.03	0.87
altitude + slope gradient + shrub height + herb coverage	6	-97.69	211.03	5.56	0.03	0.9
slope gradient + shrub height + herb coverage	5	-99.38	211.27	5.8	0.02	0.92
Tamiops maritimus						

water + slope position	4	-15.72	41.03	0	0.74	0.74
water	3	-18.75	44.43	3.39	0.14	0.88
Null	2	-20.45	45.34	4.31	0.09	0.97
slope position	3	-20.12	47.16	6.13	0.03	1
Callosciurus erythraeus						
tree density + tree canopy + shrub coverage	5	-25.13	62.75	0	0.42	0.42
tree canopy + shrub coverage	4	-26.69	62.98	0.23	0.37	0.79
tree density + shrub coverage	4	-27.38	64.36	1.61	0.19	0.98
shrub coverage	3	-31.03	68.99	6.23	0.02	1
Niviventer niviventer						
shrub coverage	3	-63.77	134.46	0	1	1
Null	2	-70.38	145.21	10.57	0	1
Leopoldamys edwardsi						
slope gradient	3	-117.12	241.16	0	0.59	0.59
Null	2	-118.72	241.88	0.72	0.41	1

Table 5 Results of the linear model examining whether, relative abundance index of 11 mammal species significantly predicted their habitat characteristic needs.

Habitat characteristic	Estimate	SE	t	p
Macaca thibetana				
Intercept	-5.09	3.44	-1.48	0.15
slope gradient	2	0.94	2.13	0.04*
slope	1.47	0.89	1.64	0.11
Macaca mulatta				
Intercept	-7.05	2.69	-2.63	0.01*
altitude	0.02	0.01	2.5	0.02*
forest types	1.24	0.56	2.21	0.04*
Paguma larvata				
Intercept	2.18	0.94	2.31	0.03*
forest types	0.39	0.22	1.7	0.1
shrub height	-0.66	0.26	-2.6	0.02*
Melogale moschata				
Intercept	2.96	3.02	0.98	0.34

tree canopy	-1.29	0.65	-1.98	0.06
DBH	0.2	0.119	1.675	0.11
Arctonyx collaris				
Intercept	-1.38	1.49	-0.92	0.37
slope position	-0.67	0.33	-2.01	0.06
tree density	0.04	0.02	2.22	0.04*
herb coverage	1.1	0.25	4.37	0.000***
Sus scrofa				
Intercept	0.53	1.31	0.40	0.70
tree density	0.046	0.01	5.68	0.000***
slope position	-0.52	0.2	-2.68	0.01*
tree canopy	-0.82	0.28	-2.88	0.008**
shrub coverage	0.58	0.16	3.7	0.001**
Muntiacus reevesi				
Intercept	34.5	10.59	3.26	0.003**
altitude	-0.03	0.02	-2.2	0.04*
slope	-3.85	1.37	-2.81	0.01*
slope gradient	-7.92	1.52	-5.22	0.000***
tree density	0.4	0.08	5.05	0.000***
shrub height	-3.52	1.46	-2.41	0.02*
herb coverage	3.08	1.18	2.62	0.02*
Tamiops maritimus				
Intercept	1.35	0.36	3.8	0.001***
water	-0.24	0.1	-2.46	0.02*
slope position	-0.37	0.12	-3.04	0.005**
Callosciurus erythraeus				
Intercept	4.53	1.20	3.77	0.000***
tree density	0.02	0.01	2.05	0.05*
tree canopy	-1.17	0.26	-4.53	0.000***
shrub coverage	-0.2	0.12	-1.69	0.1
Niviventer niviventer				
Intercept	5.82	1.17	4.96	0.000***

shrub coverage	-1.52	0.39	-3.94	0.000***
Leopoldamys edwardsi				
Intercept	22.13	6.77	3.27	0.002**
slope gradient	-4.85	2.73	-1.78	0.09

4 DISCUSSION

4.1 Composition and diversity in non- protected area

Our data showed that more mammals were present in this non-protected area, we found 18 mammal species captured by 36 cameras in a span of two years, which were more than the numbers of species reported in Mt. Huangshan (14 species) (Liu et al., 2017), Anhui Jiulongfeng Provincial Nature Reserve (10 species) (Wang et al., 2015), Anhui Guniujiang National Nature Reserve (12 species) (Fang, 2017), and Anhui Qingliangfeng National Nature Reserve (9 species) (Li et al., 2017). Although the study site size, the number of infrared cameras, and duration of monitoring had some influence on mammal diversity, the area ($35.12km^2$) was monitored for 2 years thus revealing that this non-protected area was inhabited by more mammal species than protected areas.

From the species perspective, there were more mammal species (18 species in this study). But it also showed some characteristics of marginal areas situated at the boundaries of protected areas. For example, the absence of large carnivorous wildlife, decrease in the number of rare and endangered species, and increase of single species of small mammals. No large carnivorous animal was found in this study (Such as: *Ursus thibetanus* and *Neofelis nebulosa*). They may have been extinct in the 1980s due to excessive hunting, abuse of rodenticide, and habitat degradation (Wang, 1990). Even the small cat (*Prionailurus bengalensis*) that was recently found in Mt. Huangshan (Liu et al., 2017) may have gone extinct in this area. We only found some small carnivores, and the main mammal species were Mustelidae and Viverridae. Predatory mammals can result in detrimental effects on other species survival. Loss of such predators can then have a variety of catastrophic effects (Chiang et al., 2014; Kolchin, 2018; Watanabe & Izawa, 2005). In this study , the highest rates recorded for *L. edwardsi* (capture rates = 10.97) was hundreds of times more than rare and endangered species, *M. crinifrons* (capture rates = 0.03). This may be related to the reduction of forest heterogeneity caused by human disturbance (Bhattarai & Kindlmann, 2011; Cheyne et al., 2016). In our study area, with the implementation national policy of return the grain plots to forestry and economic development, habitat destruction caused by destructive grazing and logging has been gradually replaced by ecotourism resulting in forest restoration over time. In addition, the higher relative abundance index of *L. edwardsi* and *N. niviventer* provided evidence for forest restoration. Finally, higher relative abundance index of *M. reevesi* also confirmed that the forest structure in these areas is slowly recovering. Previous studies reported that gradual decrease in forest cover and increase in herbaceous cover could benefit ungulate species (Barrios-Garcia & Ballari, 2012; Fedriani & Delibes, 2015; Vanthomme et al., 2013). In addition, mammals are important seed dispersal agents, seed predators, and herbivores therefore impacting on forest structure and composition through these activities (Andresen et al., 2018; Fedriani & Delibes, 2015). The higher relative abundance index of *S. scrofa* also provided evidence for this.

4.2 Importance of habitat characteristics

Furthermore, models showed that each mammal had different habitat characteristics selected (Table 4), and each species showed a significant correlation with its own habitat characteristics (Table 5). But we could also find surprising results, there was no strongly habitat dependency of these species, and no single species was associated with all the characteristics. At the most, there are only 6 related factors (such as *M. reevesi*), most of which were concentrated at 1-3 habitat characteristics. These habitat characteristics are mostly natural habitat properties including altitude, slope, slope position, slope gradient, are thought to be hard to destroy (Badgley, 2010; Qian, Badgley, & Fox, 2009). But there were some species associated with forest habitat characteristics (tree, shrub, herb), such as *S. scrofa* they preferred to live in forest with higher tree density, lower tree canopy and higher shrub coverage. The vulnerability of forest and their importance to animals have been demonstrated in many studies (Bai et al., 2020; Barr & Biernat, 2020; Blake & Loiselle, 2018; McShea et al., 2009; Tédonzong et al., 2019), provided more evidence for the establishment of many protected areas (increase the size of territory areas). In this study, increase the size of territory areas may effectively protect species such as *M. reevesi* and *S. scrofa* which were highly dependent on the habitat characteristics. It was also found in this study, some species such as primates (*M. thibetana*) and rodents (*L. edwardsi*) has a high adaptability to different kinds habitat, even in anthropogenic place(Klass, Van Belle, & Estrada, 2020; Mekonen, 2020). In some studies it has been shown that the most important factors affecting the population decline of these species are illegal trade and excessive capturing and slaughtering. It is less important to focus on habitat characteristics for the conservation of these species. Therefore, we believed that composition and diversity of mammal conservation in non-protected areas should be considering the habitat characteristics at first and then to increase the area of the protected area.

5 CONCLUSION

The establishment of protected areas with increase territory size of protected species is a challenge to ensure the long-term survival of many native species. For protected areas planners and managers, the key is to know which habitat characteristics are important for the species occurring within their habitat and being able to make a better decision for increasing territory size or the pertinent species protective measures. Our study highlights the importance of habitat characteristics in the establishment of protected areas for animals in non-protected areas. Without a specifically focus on the habitat characteristics of different species, potentially resulting in unsuccessful or increase the cost of establishing a protected area.

Specifically, the importance of habitat characteristics of other species cannot be neglected for the conservation of an important species. Because different species have different needs for habitat characteristics, conservation strategies that only for key species may cause populations to decline of other sympatric species. Recognising habitat characteristics requirements of different species will be important for conservation of mammal species.

According to the results of this study, in order to effectively protect the diversity of mammals in this area, protected areas planners and managers should consider protecting species such as *P. larvata*, *M. moschata*, *A. collaris*, *S. scrofa*, *M. reevesi* that are associated with the vegetation characteristics of their habitats. Appropriately increase protected areas, provide the last refuge for this species.

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CONFLICT OF INTEREST

We have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

All data are available in the open figshare repository, and the link to the data is https://doi.10.6084/m9.figshare.13271714.

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