



# Relationship between Human Disturbance and Habitat Use by the Endangered François' Langur (*Trachypithecus francoisi*) in Mayanghe Nature Reserve, China

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## ABSTRACT

François' langur (*Trachypithecus francoisi*) is an endangered primate that has experienced a decline in population size and associated loss in habitat as a result of human disturbance (IUCN, 2020). We investigated human disturbance and habitat use of François' langur in Mayanghe Nature Reserve, Guizhou, China, by analyzing the effects of various types of human disturbance on habitat use using the spatial simultaneous autoregressive error model (SAR). We found that habitat use intensity of François' langur was positively correlated with slope and distance to roads but was negatively correlated with elevation and distance to bee-keeping locations and grazing locations. The effects of each different human disturbance type were consistently correlated with one another, except for distance to bee-keeping locations and grazing locations. Our results indicate that langurs are restricted to small areas along the rivers in Mayanghe Nature Reserve and area also used by small local roads. The ecological effect of the edge of a road "road-effect zone" was estimated to be 1400m, shorter than the maximum daily travel distance of the François' langur. Therefore, we suggest that an important conservation intervention for supporting the persistence of the species should involve controlling the expansion of road construction to minimize the impacts of human disturbances on the langurs.

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## Authors' Contribution

GL, JH, CZ and QZ conceived the project, which was led by GL, JH and CZ. JH, WB, YC conducted the analysis. JHn wrote the manuscript, with contributions from MW.

## Key words

François' langur, Human disturbances, Habitat use, Spatial simultaneous autoregressive error models, Road-effect, Mayanghe nature reserve

## INTRODUCTION

François' langur (*Trachypithecus francoisi*) (the langur) is an endangered colobine species, distributed from its southern extent at the Red River in Vietnam, across the Chinese border as far north as the Daming Hills in Guangxi and Xingyi in Guizhou (Brandon-Jones, 2002). It is estimated that François' langur has a global population of about 2,000 individuals (Zeng *et al.*, 2013). In China, the distribution of the langur was largely restricted to areas characterized by karst topography at elevations of

120 ~ 1,400 m in Guangxi, Guizhou and Chongqing (Ma, 1988; Ma *et al.*, 1989; Li, 1993; Li *et al.*, 2007). Due to habitat destruction, habitat fragmentation, and poaching, François' langur is locally extinct in Fangchen, Jingxi, Leye, Longzhou, Shanglin, and Tian'e county, Guangxi province (Li *et al.*, 2007). François' langur is listed as endangered on the International Union for Conservation of Nature Red List (IUCN, 2020) and is considered a first-grade protected species of wildlife in China (Li *et al.*, 2010; Wang *et al.*, 2011; Niu *et al.*, 2016).

Human activities threaten the long-term survival of many primate species, primarily through habitat loss and fragmentation (Guisan and Thuiller, 2005; Ashcroft *et al.*, 2011; Chang *et al.*, 2012) roads and railways alter habitats and reduce the interconnectedness of forest landscapes, resulting in habitat loss and fragmentation (Clauzel *et al.*,

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2013, 2015). This lack of connectedness reduces genetic exchange among populations (Way, 1977; Andrews, 1990; Carr *et al.*, 2002; Zhu *et al.*, 2010), causing population decline and decrease in genetic diversity (Chang *et al.*, 2012). Hunting may also have a significant impact on local population size (Huang *et al.*, 2002; Hu *et al.*, 2004), whilst logging and cultivation of domestic crops may further increase fragmentation and loss of forest habitats (Van Dyke *et al.*, 1986; Huang *et al.*, 2002).

To better understand how human disturbance has affected the langur and to help conservation managers design more effective protection plans, we investigated the relationship between distance to various agents of human disturbance, and habitat use intensity by François' langur in Mayanghe Nature Reserve, China.

## MATERIALS AND METHODS

### Study area

The study area encompasses the Mayanghe Nature Reserve, located in Guizhou, on the border of Yanhe and Wuchuan Counties (Fig. 1). The total area of the reserve is 311.13 km<sup>2</sup>, with a core area of 105.43 km<sup>2</sup>. This reserve has typical karst geophysical features (Karst, terrain usually characterized by barren, rocky ground, caves, sinkholes, underground rivers, and the absence of surface streams and lakes. It results from the excavating effects of underground water on massive soluble limestone.) and occupies an altitude ranging from 280 m to 1441 m above sea level; with a mean annual temperature of 18.3°C, and a mean annual precipitation of 1139 mm (Chen, 2001). Forests cover about 64% of the total area of the reserve, including evergreen broadleaved forest, mixed evergreen deciduous broadleaved forest, and mixed conifer-broadleaved forests (Chen, 2001). As the known range of François' langur is concentrated along Mayanghe River and Hongduhe River of the reserve (Wang *et al.*, 2011; Zeng *et al.*, 2013; Niu *et al.*, 2016), the study area was initially defined by these two rivers, which also contains the most common human disturbance in the greater study area (including farmland, grazing location, road, households, and bee-keeping locations).

### Data collection and variable calculations

The period of the survey for recording both François' langur and the human disturbance activities in the Mayanghe Nature Reserve covered the period from October 2017 to August 2018, carried out over the area defined by 28°37'30"–28°54'20" N and 108°3'58"–108°19'45" E. Langur presence was determined via a variety of direct and indirect recordings (e.g., feces, evidence of feeding, sleeping sites, direct observations, and anecdotal records

from the reserve manager). In total during the survey period 229 locations were recorded with signs of langur. Based on the presence data, a density map for the langur was generated by using the kernel density analysis in ArcGIS v10.5 (ESRI, Redlands, USA), which was used to demonstrate the intensity of langur activity and habitat use in the study area. In addition, the location of human activities were recorded, including 30 bee-keeping sites, 16 grazing sites, 6 townships and 3 power stations each recorded using a global positioning system (GPS). The location of all roads, households and farmland was obtained from government maps and Google Earth (Google Inc., Mountain View, USA; Fig. 2). Based on these data, seven human disturbance variables were included in ArcGIS including distance from each langur location to the nearest road (roads included in this study were either county road or back roads), households, townships, farmland, grazing area, or bee-keeping area. For those sites where the langur was found to be present, three topographic variables were recorded including elevation, slope, and aspect.

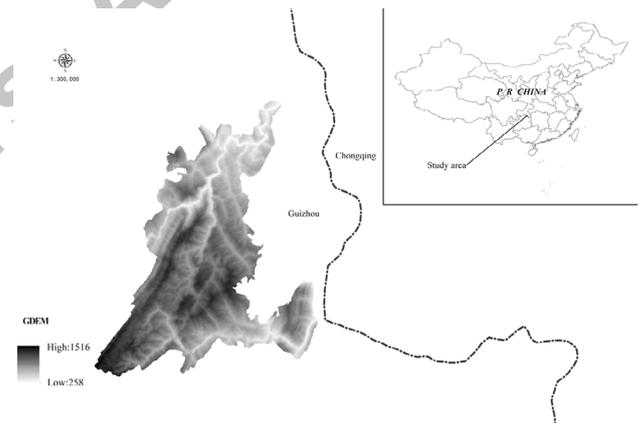


Fig. 1. Mayanghe Nature Reserve, established to protect the François' langur in Guizhou, provinces, China.

Finally, ten additional environmental variables were obtained (Table I) and the Pearson's correlation coefficient was applied to test the multicollinearities among these ten variables, some of which were subsequently excluded from the analysis (Hosmer and Lemeshow, 2000). The environmental variables with correlation values less than  $|\pm 0.7|$  were retained. All the variables except the distance to the nearest edge of residence area were included in the following analysis (Table II).

### Statistical analysis

Spatial simultaneous autoregressive error models (SAR) were used to investigate the relative effect of human disturbance variables and topographic variables on the

**Table I. Definition and description of habitat variables in Mayanghe National Nature Reserve, China.**

Class	Variable	Description
Topographic variable	Elevation (ELE)	Elevation of the location above sea level
	Slope (SLO)	Degree of the slope at the locations ranging from 0° to 90°
	Aspect (SLA)	Aspect of the slope at the locations ranging from 0° to 360°
Human disturbance	Distance to households (DHO)	Distance from the locations to the nearest edge of the residence area
	Distance to road (DRO)	Distance from the locations to the nearest road
	Distance to farmland (DFA)	Distance from the locations to the nearest edge of the farmland
	Distance to bee-keeping location (DBK)	Distance from the locations to the nearest bee keeping site
	Distance to grazing location (DGR)	Distance from the locations to the nearest grazing site
	Distance to power station (DPO)	Distance from the locations to the nearest power station
	Distance to township (DTO)	Distance from the locations to the nearest township

**Table II. The values (right-upper triangle) and corresponding significance (left-lower triangle) of pearson correlation coefficients between the ten selected variables.**

	Elevation	Aspect	Slope	Distance to road	Distance to power station	Distance to farmland	Distance to bee-keeping	Distance to grazing location	Distance to township
Elevation		0.074	0.016	0.248	0.54	0.27	-0.399	-0.497	0.301
Aspect	ns		0.139	-0.051	0.018	-0.035	-0.007	-0.047	0.082
Slope	ns	*		0.194	-0.087	0.134	-0.106	-0.098	0.305
Distance to road	***	ns	**		0.234	0.634	-0.147	-0.365	0.634
Distance to power station	***	ns	ns	***		0.334	-0.329	-0.346	-0.093
Distance to farmland	***	ns	*	***	***		-0.301	-0.324	0.279
Distance to bee-keeping location	***	ns	ns	*	***	***		0.47	-0.319
Distance to grazing location	***	ns	ns	***	***	***	***		-0.352
Distance to township	***	ns	***	***	ns	***	***	***	

\*\*\* P<0.001; \*\* P<0.01; \* P<0.05; ns, not significant.

habitat use of the langur. To address the study question, four SAR models were run based on different combinations of predictor variables. The combinations were: 1) a model only including intercept, 2) a model including all the topographic variables, 3) a model including all the human disturbance variables and 4) a full model including all the variables. The Akaike information criterion (AIC) was used for model selection, and the lowest AIC score and highest Akaike weights were used to select the most parsimonious best-fit models (Anderson, 2008).

The purpose of the test was to determine whether the intensity of habitat use increased as distance from human

disturbance increased. We used a liner model, polynomial model, and logarithmic model to visualize the relationship between distance from human disturbance and habitat use intensity. We divided the study region into 300 m<sup>2</sup> patches and established transects in each square such that the survey sites were distributed uniformly throughout the study area. We calculated habitat use intensity in region *i* of width 300 (GHI<sub>*i*</sub><sup>300</sup>) as  $N_i/A_i$ , where  $N_i$  is the number of signs of François' langur in region *i* (m<sup>2</sup>),  $A_i$  was the area of region *i* (m<sup>2</sup>).

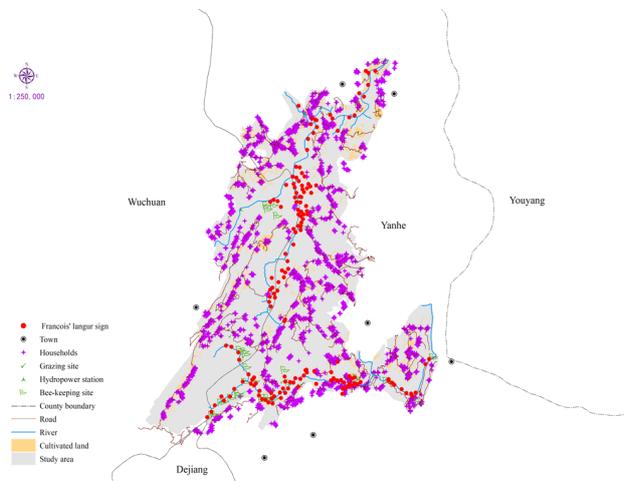


Fig. 2. The locations of François' langur signs and human disturbance in the study area.

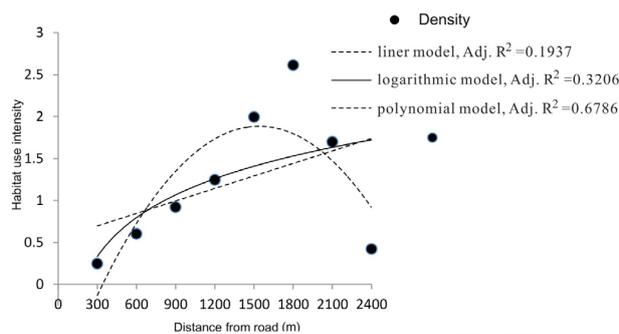


Fig. 3. Line- and curve-fitting analysis of the relationship between the François' langur habitat use intensity and distance to households.

## RESULTS

### SAR models

According to the SAR models, the full model including all the variables outperformed the remaining three models, with the lowest AICc value of 699.999. The results indicated that both topographic and human disturbance factors were important in determining habitat use by the langur (Table III). However, only four of the nine variables in the full model have a significant effect on habitat use of François' langur (Table IV). Specifically, distance from the observation locations to the nearest road and the slope of the location both have positive effect on the activity intensity of the langur, with influence coefficients of 0.415 and 0.153 respectively. Conversely, distance from the observation locations to the nearest beehive and distance from the locations to the nearest grazing location both have negative effect on the activity intensity of the

langur, with influence coefficients of -0.632 and -0.483 respectively.

**Table III. Model comparison for the four spatial simultaneous autoregressive error models (SAR) based on different combinations of predictor variables. The best model with the lowest AICc was highlighted in bold. df: number of parameters; AICc: Akaike's Information Criterion for finite sample size;  $\Delta$ AICc: difference of AICc from the lowest AICc; wAIC: model weight.**

Model	df	log likelihood	AICc	$\Delta$ AICc	wAIC
Null	3	-370.657	747.314	47.315	< 0.001
TOP	6	-363.217	738.434	38.435	< 0.001
HD	9	-354.353	726.706	26.707	< 0.001
Full	12	-337.999	699.999	0	0.999

**Table IV. The output of spatial simultaneous autoregressive error models (SAR) that included all the variables.**

	Estimate	Std. error	z value	Pr (> z )
Distance to road	0.415	0.173	2.396	0.017*
Distance to power station	0.173	0.172	1.004	0.315
Distance to farmland	-0.14	0.121	-1.158	0.247
Distance to bee-keeping location	-0.632	0.172	-3.667	<0.001***
Distance to grazing location	-0.483	0.152	-3.178	<0.001***
Distance to township	-0.005	0.193	-0.025	0.980
Alope	0.153	0.068	2.266	0.023*
Elevation	-0.609	0.109	-5.596	<0.001***
Aspect	-0.102	0.063	-1.625	0.104

### Human disturbance effect zones

Line and curve-fitting was used to analyze each of the human disturbances, with the results indicating that only distance to roads had a strong fit with habitat use intensity. In addition, the polynomial model was a better fit for distance to road (Fig. 3), compared to the linear model or the logarithmic model ( $R^2 > 0.6$ ). The polynomial model showed a significant increase in habitat use intensity at distance <1,400m to road.

## DISCUSSION

Our results suggest that seven human disturbance and three topographic variables define the best-fit model (composed of 10 variables). It indicated that both human disturbance and topographic variables had substantial effects on the langur activity. As many previous studies have shown, both habitat and human disturbance predict wildlife abundance and distribution (Morrison, 2001; Bhattarai and Kindlmann, 2013). The habitat selection processes and the habitat requirements of the langur have been studied thoroughly (Zhou *et al.*, 2010, 2011, 2018; Hu, 2011; Zeng *et al.*, 2013), as have the relationships between the langur and local human attitudes and perceptions (Niu *et al.*, 2019).

The impact of roads on wildlife distribution, abundance, and population interconnectedness has also been well studied (Andrews, 1990; Carr *et al.*, 2002; Anderson and Raza, 2010; Clauzel *et al.*, 2015). However, most previous studies have assessed the impact of linear infrastructure on wild animals, and typically show that distribution decreases as road density increases (Eigenbrod *et al.*, 2009; Clauzel *et al.*, 2013, 2015). Roads likely act as barrier to wildlife movements (Forman and Deblinger, 2000; Trombulak and Frissell, 2000; Coffin, 2007; Zhu *et al.*, 2011). Thus, roads might have substantial (negative) impact on the langur activity and distribution. In the best-fit model identified in this study, distance from roads was positively correlated with the intensity of langur activity. The length of back roads in the greater study locality has increased rapidly over the past 10 years. The study area includes a small stretch of county road along the Mayanghe River. Local residents frequently report spotting François' langurs either crossing this road or foraging nearby. This indicates that the langur have become accustomed to the road in these areas, despite the danger the road presents. However, the most preferred areas inhabited by François' langur were far from the road, as areas near the road tend to be occupied by buildings e.g. households and farms, with intense human activity, and contribute to fragmenting the langurs habitat landscape. Thus, François' langur typically avoided these areas.

Several studies have focused on the impact of farmland on wildlife habitat selection (Schmitt and Seitz, 2002; Rodriguez and Delibes, 2003; Li *et al.*, 2007; Zhou *et al.*, 2010, 2018; Huang *et al.*, 2017) as many wild animals avoid such agricultural areas (Liu *et al.*, 1999). In the best-fit model in our study, the intensity of langur activity was not significantly correlated with distance to cultivated land. As the slope of the areas of cultivated land was gentle, this area was suitable for cultivation, but was not as suitable for François' langur, as sleeping sites and food resources

were insufficient. Therefore, the langur typically avoided these areas, although we found that the langur did forage in farmland, for feed including corn, sweet potatoes, and other crops, especially in summer. This finding was consistent with previous studies (Hu, 2011; Wang *et al.*, 2011; Zeng *et al.*, 2013; Niu *et al.*, 2016).

The study suggests that habitat use intensity was generally higher when langur locations were closer to both bee-keeping locations and grazing locations. For other animals, livestock grazing is often a significant human disturbance (Zhang *et al.*, 2007, 2017; Hull *et al.*, 2011). Grazing locations are often far from cultivated land and residential buildings, and the slope of locations tends to be steep, with less human disturbance. As a result, these grazing areas are suitable for the langur. In the study area, human inhabitants placed bee barrels at the bottom or the middle of cliffs, so as to protect the barrels from the rain. The sleeping site of the langur was often observed on top of bee barrels. Thus both grazing and beekeeping can be considered as non-fixed disturbances, and may have limited effect on langur distribution.

It has been shown that animals may tolerate human disturbances at a certain distance (Huggett, 2005; Luck, 2005; Groffman *et al.*, 2006; Zhao *et al.*, 2017). Here, the relationship between the intensity of langur activity and the distance to roads was represented by a polynomial regression. Although it was difficult to determine the inflection points, we can use these regression curves to provide a model that suitably illustrates the effect of road on the intensity of langur habitat use. From this study the effect zone of road was estimated as being 1400 m, shorter than the maximum daily travel distance of the François' langur (Hu *et al.*, 2018). Although many previous studies have investigated the relationship between distance to human disturbance and François' langur distribution, our study is the first to define the size of the zone within which François' langur habitat use is affected by human disturbances.

## CONCLUSION

Many humans live within the study area and within the boundaries of the Mayanghe Nature Reserve, with thousands of households and large areas of farmland distributed around or embedded within the François' langur range. The langur is thus restricted to a limited area within the Mayanghe Nature Reserve. Our study focused on how the type of disturbance and its distance to the langurs, affected François' langur distribution. It is our recommendation that protected area management institutions should strictly control both road and household construction, in order to reduce the impact on

the endangered langur. Our findings may provide useful data for management institutions attempting to improve François' langur conservation and guide areas of focus for further prioritization of conservation interventions.

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#### Conflict of interest

The authors have declared no conflict of interest.

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