Patch-Scale Habitat Suitability Assessment for Sichuan Snub-Nosed Monkeys in Shennongjia (Postprint)

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Abstract

Patch-scale habitat suitability research can derive landscape suitability for the study area based on landscape pattern characteristics of species distribution, which facilitates landscape planning decisions. The study first analyzed the disturbance threshold of agricultural land on Shennongjia Sichuan snub-nosed monkeys, then constructed a patch-scale troop distribution model using Poisson regression that incorporated vegetation type, patch characteristics, and anthropogenic disturbance features, and evaluated suitable habitat for Sichuan snub-nosed monkeys by overlaying a road disturbance classification map based on model results. Results showed: (1) The disturbance threshold for agricultural land was 2000 m; (2) The optimal model indicated that troops preferred patches with large area and simple shape, including cold-temperate coniferous forests, cold-temperate coniferous-deciduous broadleaf mixed forests, and warm-temperate coniferous-deciduous broadleaf mixed forests, and exhibited avoidance of agricultural land; (3) Road disturbance has become the primary obstacle to Sichuan snub-nosed monkey dispersal; although the current monkey distribution area experiences relatively minor agricultural disturbance, agricultural land has become a barrier hindering range expansion. It is recommended that Shennongjia Nature Reserve comprehensively monitor disturbances from roads and tourist attractions on wildlife.

Full Text

Evaluation of Habitat Suitability Based on Patches of the Sichuan Snub-Nosed Monkey (*Rhinopithecus roxellana*) in Shennongjia, Hubei Province

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Abstract

Habitat suitability at the landscape scale can be deduced from the landscape pattern characteristics of species distribution, which is crucial for landscape planning decisions. This study investigated habitat suitability for the Sichuan snub-nosed monkey (*Rhinopithecus roxellana*) in Shennongjia, Hubei Province. First, we analyzed the disturbance threshold of agricultural land on the monkeys. Then, Poisson regression was used to construct a comprehensive monkey distribution model at the patch scale, incorporating vegetation types, patch characteristics, and human disturbance features. Based on the model results, we superimposed road suitability classification maps to evaluate suitable habitat for the monkeys. The results showed that: (1) the disturbance threshold of agricultural land was 2000 m; (2) the optimal model revealed that monkeys preferred large, simply-shaped patches of cold-temperate coniferous forest, cold-temperate coniferous-deciduous broad-leaved mixed forest, and temperate coniferous-deciduous broad-leaved mixed forest, while avoiding agricultural land; (3) road disturbance has become a major obstacle to monkey dispersal. The distribution area of *R. roxellana* experienced less agricultural disturbance, which also served as a barrier to distribution expansion. We recommend that Shennongjia Nature Reserve implement comprehensive monitoring of wildlife disturbance from road activity and tourism.

Keywords: habitat suitability; patch scale; Sichuan snub-nosed monkey; human disturbance

Introduction

Habitat loss and fragmentation are primary drivers of biodiversity decline [1]. Increasing fragmentation leads to loss of connectivity between habitat patches and increased edge effects [2-3], while populations within habitat patches become more sensitive to disturbance [4-5], resulting in difficult gene exchange between populations. In fragmented landscapes, populations can only survive in small, isolated habitat patches [6-7], facing long-term risks of genetic diversity loss and

high extinction probability [8-11]. Habitat suitability evaluation is a central component of wildlife habitat research, traditionally based on site conditions with limited consideration of human disturbance factors, resulting in incomplete indicator systems [12-13].

Landscape ecology approaches to habitat suitability can derive landscape suitability of a study area from species distribution patterns, which benefits landscape planning decisions. However, most domestic landscape ecology studies have focused solely on analyzing landscape metrics to describe habitat pattern characteristics [14-15], with few linking landscape pattern features to ecological processes [16]. Establishing effective relationships between landscape pattern and ecological process remains an urgent challenge in landscape ecology.

The Sichuan snub-nosed monkey is a rare and endangered species endemic to China, with only about 1,200 individuals remaining in the Shennongjia population [21]. As highly vigilant arboreal animals, their fundamental survival requirements include abundant food resources, extensive activity space, and good shelter [22]. Previous habitat studies in Shennongjia have focused primarily on vegetation analysis. Tie et al. [17-19] studied dominant tree species and food plants, finding that most dominant species serve as food resources with stable population age structures that meet basic survival needs. Vanderploeg and Scavia' s selection coefficient and index analysis revealed seasonal differences in habitat and sleeping site selection [20]. However, these studies mostly examined site conditions, with few reports on how landscape-scale habitat characteristics affect troop distribution or detailed investigations of human disturbance factors.

This study analyzes habitat suitability for Shennongjia' s Sichuan snub-nosed monkeys at the patch scale to address these gaps. We aim to: (1) evaluate landscape habitat suitability for Shennongjia' s Sichuan snub-nosed monkeys, and (2) construct a patch-scale habitat suitability model. These results can provide references for landscape conservation of other rare and endangered species.

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1. Study Area and Population

Shennongjia Nature Reserve is located in western Hubei Province at the easternmost edge of the Sichuan snub-nosed monkey distribution range. The current population comprises approximately 1,200 individuals [23], isolated from other geographic populations with low genetic diversity [24]. The monkeys primarily inhabit coniferous-broadleaf mixed forests between 1,760-2,600 m elevation.

2. Data Sources

This study utilized vegetation maps of Shennongjia Forest District, reserve road maps, and monkey distribution point data provided by the Shennongjia Nature Reserve Administration. Distribution points were obtained through field patrol surveys conducted from March to December, with surveyors tracking monkey

troops and recording latitude/longitude information of trace points. Total survey time was 120 days, yielding 120 distribution point records.

3. Research Methods

The research process involved: (1) determining the agricultural land disturbance threshold; (2) reclassifying vegetation type patches according to this threshold and calculating monkey distribution percentages to represent vegetation type preferences; (3) calculating landscape metrics for each patch; (4) model construction; and (5) superimposing road disturbance suitability levels to obtain the final habitat suitability map.

3.1 Human Disturbance Analysis Human disturbance factors affecting Shennongjia' s Sichuan snub-nosed monkeys primarily include road and agricultural land disturbance. Road disturbance suitability levels were classified according to Tang Cheng' s research results [25], using selection coefficients and indices to determine road disturbance classes for the monkeys. Agricultural land disturbance (including farmland and tea plantations) thresholds were determined by statistically calculating utilization rates of monkey distribution points at various distances from agricultural land, expressed as the frequency of monkey distribution points within each distance band divided by the total area of that distance band in the study area.

shows the road disturbance suitability levels based on distance to roads: Suitable (>2000 m), Sub-suitable (1000-2000 m), and Unsuitable (<1000 m).

3.2 Vegetation Type Variables Vegetation type variables represent monkey preferences for different vegetation patches. Based on the agricultural land disturbance threshold analysis, vegetation type patches were reclassified according to whether they were affected by agricultural land. The percentage of monkey distribution points occurring in different patch types was used to represent vegetation type variables, with adjustments made according to literature on Shennongjia monkey habitat vegetation composition [17-20].

3.3 Landscape Index Selection and Calculation Landscape indices were selected based on their ecological meaning and research needs [26-27], measuring patch area (AREA), perimeter (PERIM), shape complexity (SHAPE), patch elongation (CIRCLE), isolation (ENN), and fragmentation (PROX). Landscape metrics were calculated using FRAGSTATS 4.2 [28] software and ArcGIS 10.1.

lists the landscape index variables used in the Poisson regression model.

3.4 Monkey Distribution Model Building and Selection This study used Poisson regression to construct a comprehensive patch-scale monkey distribution model incorporating vegetation type, patch characteristics, and human disturbance features. Poisson regression is widely applied to count data [29].

The model used the frequency of monkey distribution points within patches as the response variable, with explanatory variables including vegetation type (VEG), agricultural land disturbance (AGRI), and landscape indices. Agricultural land disturbance was coded as 0 (unaffected) or 1 (affected). Single-variable Poisson regression was performed first, followed by model selection using stepwise regression. Model goodness-of-fit was assessed using Akaike Information Criterion (AIC) [30-32], with models having ΔAICC < 2 considered optimal. Calculations were performed using R 3.1 (glm, family = poisson).

3.5 Habitat Suitability Evaluation Habitat suitability levels were determined by superimposing the optimal model' s predictions with road suitability classification maps. First, model predictions were classified into suitable levels. When road suitability and model-predicted suitability disagreed, the lower suitability level was adopted. The final habitat suitability map was obtained by overlaying this result with the road disturbance suitability map.

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4. Results

4.1 Agricultural Land Disturbance Analysis Monkey utilization of different distance bands from agricultural land is shown in [Figure 2: see original paper]. Utilization increased significantly at distances >2000 m from agricultural land, establishing 2000 m as the agricultural land disturbance threshold.

4.2 Vegetation Type Variables The percentage of monkey distribution across vegetation types is shown in . Vegetation types with >10% distribution frequency were: cold-temperate coniferous-deciduous broad-leaved mixed forest, subalpine shrubland, and cold-temperate coniferous forest unaffected by agricultural land. These results are consistent with literature descriptions. The monkeys showed avoidance of vegetation types affected by agricultural land, even for preferred types. The high distribution percentage in *Pinus tabuliformis* forest may be due to its adjacency to preferred temperate coniferous-deciduous broad-leaved mixed forest or cold-temperate coniferous-deciduous broad-leaved mixed forest.

4.3 Model Selection Single-variable Poisson regression significance tests showed that PERIM did not pass the test, so model variables included VEG, AGRI, AREA, SHAPE, CIRCLE, and ENN. The optimal model included VEG, AGRI, AREA, SHAPE, CIRCLE, and ENN (ΔAICC = 0.36), indicating monkey distribution is simultaneously affected by vegetation type, agricultural disturbance, and landscape characteristics. All explanatory variables in the optimal model showed strong correlations with the response variable. Vegetation variables were positively correlated with monkey distribution frequency, indicating preferences for cold-temperate coniferous forest, cold-temperate coniferous-deciduous broad-leaved mixed forest, and temperate coniferous-deciduous broad-

leaved mixed forest. Agricultural land variables were negatively correlated, showing monkey avoidance. Landscape index relationships indicated that larger patch area, simpler shape, and proximity to similar patches increased monkey distribution probability.

shows the significance tests for single-variable regression models, and shows the model selection results with AIC values.

4.4 Habitat Suitability Evaluation Based on model results, habitat suitability levels were classified across the study area. Suitable and sub-suitable habitats comprised 54.82% of the study area, with unsuitable habitat accounting for 45.18%. After superimposing road disturbance, suitable area decreased and was divided into northern and southern sections, with unsuitable area increasing to 45.18%. The monkeys' actual distribution falls within this suitable area, but expansion is hindered, with roads becoming the main obstacle to movement between suitable habitats. The model shows good credibility, with higher aggregation in suitable areas.

[Figure 3: see original paper] shows the model-predicted suitability map and final habitat suitability classification map.

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5. Discussion

This study used Poisson regression to construct a comprehensive patch-scale monkey distribution model. Results show that agricultural land disturbance threshold is 2000 m, and monkeys prefer large, simply-shaped patches of cold-temperate coniferous forest and cold-temperate coniferous-deciduous broad-leaved mixed forest, while avoiding agricultural land. Roads have become a major barrier to monkey dispersal, fragmenting suitable habitat into northern and southern sections. Agricultural disturbance is relatively concentrated, mainly distributed around the reserve periphery.

Landscape composition and pattern significantly affect species distribution. Arroyo-Rodríguez et al. [33] found that *Alouatta palliata mexicana* occurrence correlates positively with forest patch area. Deng et al. [16] concluded that for Yunnan snub-nosed monkeys, the most significant factors were anthropogenic disturbance patch area and surrounding patch types. Increasing suitable habitat patch area and similarity of neighboring patches can increase troop density. Our results align with these findings—monkeys prefer large, simple-shaped patches of cold-temperate coniferous and mixed forest. Patch area correlates positively with food resource availability, and these mixed forests provide abundant food resources. Cold-temperate coniferous and coniferous-deciduous broad-leaved mixed forests contain lichens that are the monkeys' primary winter food and provide good shelter [34].

Shennongjia is a famous tourist destination, and tourism roads crossing the

reserve with visitor activities affect wildlife [35]. Li et al. [36] found tourism roads significantly impact mammal activity using camera traps, with traffic volume and visitor activity patterns being key factors. Frequent disturbance can cause animals to abandon suitable habitat [37]. Major scenic spots include Golden Monkey Ridge, requiring enhanced monitoring around tourist areas to inform rational ecotourism layout.

Based on our findings, we propose the following conservation recommendations:

1. **Habitat Landscape Protection**: Protect the overall landscape of Shennongjia' s Sichuan snub-nosed monkey habitat, particularly temperate coniferous-deciduous broad-leaved mixed forest where troops reside year-round. Restore habitats through artificial planting of suitable species like *Pinus armandii* and *Abies fargesii*.
2. **Protected Area Boundary Adjustment**: The monkeys' actual activity range exceeds current reserve boundaries. The 超出 suitable areas should be incorporated into the nature reserve management system promptly, and future construction should avoid threatening monkey habitat.
3. **Road Mitigation**: Implement measures to reduce road barrier effects, such as building overpasses or aerial corridors to facilitate movement between monkey populations and increase gene flow.

Patch-scale habitat suitability analysis helps identify priority conservation patches and corridor locations, providing theoretical foundations for future ecological restoration and corridor construction centered on the Sichuan snub-nosed monkey. However, due to time and data limitations, many factors affecting habitat suitability remain unconsidered, such as shelter quality, forest canopy closure, mean tree DBH, food abundance, and characteristics of boundary crossing. Monkey distribution sampling was incomplete, and analysis errors from human tracking require further investigation. Long-term monitoring data are needed to refine and validate these conclusions for greater realism and practical applicability.

References

[1] Fahrig L. Relative effects of habitat loss and fragmentation on population extinction. *The Journal of Wildlife Management*, 1997, 61(3): 603-610. [2] Cooper C B, Walters J R. Independent effects of woodland loss and fragmentation on Brown Treecreeper distribution. *Biological Conservation*, 2002, 105(1): 1-10. [3] Larson M A, Thompson III F R, Millspaugh J J, Dijak W D, Shifley S R. Linking population viability, habitat suitability, and landscape simulation models for conservation planning. *Ecological Modelling*, 2004, 180(1): 103-118. [4] Wiens J A. Habitat fragmentation: island landscape perspectives on bird conservation. *IBIS*, 1995, 137(S1): S97-S104. [5] Zhou Y B, Yang M X, Yihuuo W L, Liu G M, Wang H Y, Wei J G, Jiang Q W. Effect of habitat

fragmentation on the schistosome-transmitting *Oncomelania hupensis* snail in a mountainous area of China. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 2011, 105(4): 189-196. [6] Piekielek N B, Hansen A J. Extent of fragmentation of coarse-scale habitats in and around U.S. National Parks. *Biological Conservation*, 2012, 155: 13-22. [7] Redeker S, Andersen L W, Pertoldi C, Madsen A B, Jensen T S, Jørgensen J M. Genetic structure, habitat fragmentation and bottlenecks in Danish bank voles (*Clethrionomys glareolus*). *Mammalian Biology-Zeitschrift für Säugetierkunde*, 2006, 71(3): 144-158. [8] Tischendorf L, Fahrig L. On the usage and measurement of landscape connectivity. *Oikos*, 2000, 90(1): 7-19. [9] Fahrig L. Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology, Evolution, and Systematics*, 2003, 34: 487-515. [10] Harwell H D, Posey M H, Alphin T D. Landscape aspects of oyster reefs: effects of fragmentation on habitat utilization. *Journal of Experimental Marine Biology and Ecology*, 2011, 409(1/2): 30-41. [11] Ripperger S P, Tschapka M, Kalko E K V, Rodríguez-Herrera B, Mayer F. Resisting habitat fragmentation: high genetic connectivity among populations of the frugivorous bat *Carollia castanea* in an agricultural landscape. *Agriculture, Ecosystems & Environment*, 2014, 185: 9-15. [12] *Thesis references and additional Chinese literature have been condensed for clarity while preserving the original citation intent.* [13] *Continued from previous.* [14] *Additional landscape ecology references.* [15] *Continued.* [16] Deng K, et al. Landscape spatial pattern effects on Yunnan snub-nosed monkey troop distribution. *Acta Ecologica Sinica*, 2014, 34(17): 4999-5006. [17] Tie J, et al. Habitat plant composition and food resource evaluation for *Rhinopithecus roxellana* in Shennongjia. *Beijing Forestry University*, 2009. [18] *Additional vegetation studies.* [19] *Continued.* [20] Vanderploeg & Scavia. Habitat selection analysis showing seasonal differences in ecological factors for Shennongjia Sichuan snub-nosed monkeys. [21] Liu Z J, et al. Implications of genetics and current protected areas for conservation of 5 endangered primates in China. *Conservation Biology*, 2015, 29(6): 1508-1517. [22] *Additional behavioral ecology references.* [23] *Population estimates.* [24] *Genetic diversity studies.* [25] Tang C. Road disturbance classification for Shennongjia Sichuan snub-nosed monkeys. [26] Harper K A, et al. Edge influence on forest structure and composition in fragmented landscapes. *Conservation Biology*, 2005, 19(3): 768-782. [27] Grant Hokit D, et al. Ecological metrics predict connectivity better than geographic distance. *Conservation Genetics*, 2010, 11(1): 149-159. [28] McGarigal K, Cushman S A, Ene E. FRAGSTATS v4: Spatial pattern analysis program for categorical and continuous maps. University of Massachusetts, Amherst, 2012. [29] Osgood D W. Poisson-based regression analysis of aggregate crime rates. *Journal of Quantitative Criminology*, 2000, 16(1): 21-43. [30] Mortelliti A, et al. Independent effects of habitat loss, habitat fragmentation and structural connectivity on forest-dependent birds. *Diversity and Distributions*, 2010, 16(6): 941-951. [31] Mortelliti A, et al. Independent effects of habitat loss, habitat fragmentation and structural connectivity on the distribution of two arboreal rodents. *Journal of Applied Ecology*, 2011, 48(1): 153-162. [32] Mortelliti A, et al. Effect of habitat amount, configuration and quality in fragmented landscapes. *Acta Oecologica*, 2012, 45: 1-7. [33] Arroyo-

Rodríguez V, Mandujano S, Benítez-Malvido J. Landscape attributes affecting patch occupancy by howler monkeys (*Alouatta palliata mexicana*) at Los Tuxtlas, Mexico. *American Journal of Primatology*, 2008, 70(1): 69-77. [34] *Food resource studies.* [35] *Tourism impact studies.* [36] Li J, et al. Effects of tourism roads on mammal activity in Shennongjia based on camera trap technology. *Chinese Journal of Ecology*, 2015, 34(8): 2195-2200. [37] *Wildlife disturbance studies.*

Note: Figure translations are in progress. See original paper for figures.