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Habitat Suitability for the Yunnan Snub-nosed Monkey *Rhinopithecus bieti* (Milne-Edwards, 1897) (Primates: Cercopithecidae) Based on the MaxEnt Model

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Abstract: The Yunnan snub-nosed monkey *Rhinopithecus bieti* is an endangered species distributed in a narrow strip of land extending from the north side of the Qinghai–Tibet Plateau of China. To better understanding the Yunnan snub-nosed monkey's distribution and ecology, this study recorded the winter activity of the monkeys using infrared cameras and then employed MaxEnt modelling with six factors to analyse the habitat suitability for the species in the most critical season for its survival. The results showed that the main ecological factors affecting the habitat suitability of this species were aspect, altitude and distance from roads and rivers. The model identified low coverage of highly suitable (1.89 % of the entire reserve) and medium suitable (6.48 % of the entire reserve) habitats. The most suitable habitats were on the eastern and north-eastern slopes, at altitudes of 3100–3400 m a.s.l. The study revealed that the protection of primary forests, including the connectivity among areas of suitable habitats, is of great significance to the survival of this species.

Key words: winter, infrared camera, ecological factors

Introduction

Habitat is an important ecological resource for wildlife populations (Ma et al. 2003). Habitat suitability directly affects the reproductive success and survival rates of individuals, thus affecting population dynamics and species distributions (Gaillard et al. 2010). With the development of society and the intensification of human activities, the areas of habitats with high quality for the wild species are decreasing and, in the long term, wild species will face risk of loss of genetic diversity and extinction (Harwell et al. 2011, Ripperger et al. 2014).

The study of wildlife habitat suitability can contribute to a better understanding of the relationship between species and environmental factors. Such information can be used to predict the potential distribution of species and to carry out effective wildlife protection and management plans. At present, the most often employed models for evaluating wildlife habitat suitability are EnFA (Engler et al. 2010) and MaxEnt (Merow & Silander 2014). MaxEnt is widely used as a tool for analysing the contributions of the variables in the model, especially for making predictions from incomplete information. Example applications include studies of forest musk deer (Luo et al. 2011), the Sichuan snub-nosed

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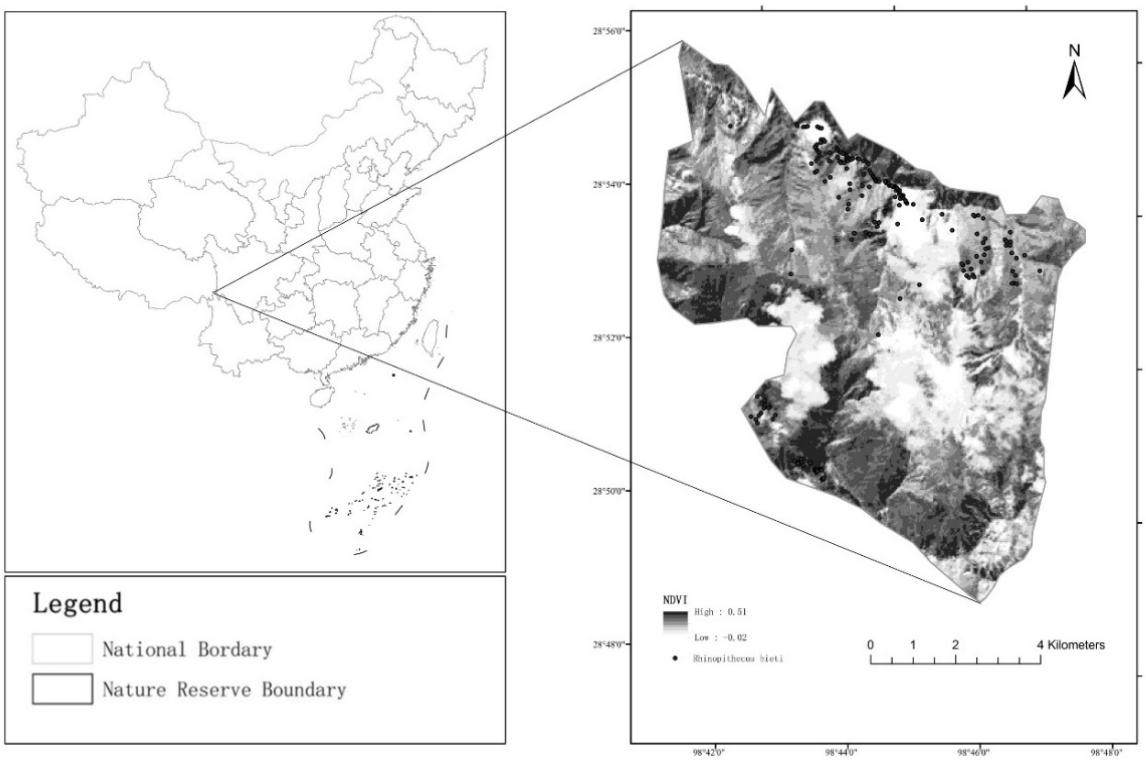

Fig. 1. An overview of the Bamei Yunnan Snub-nosed Monkey Nature Reserve, Yunnan Province, China

monkey (Bai et al. 2021), the black muntjac (Chen et al. 2021) and red deer (Wu et al. 2016).

The Yunnan snub-nosed monkey, a rare and endangered species endemic to China, is primarily distributed in the Yunling Mountains of Yunnan and Tibet (Nian 2004). Due to environmental changes and the natural migration of populations, some habitats of the Yunnan snub-nosed monkey overlap with human settlements, causing suitable area to diminish and habitat fragmentation; thus, the population of the Yunnan snub-nosed monkey has decreased dramatically (Li et al. 2018). Therefore, the study of habitat quality and suitability for the Yunnan snub-nosed monkey is important for protecting habitat diversity and the species conservation (Zhu et al. 2022). At present, studies of the Yunnan snub-nosed monkey generally focus on feeding habits (Li et al. 2011), activity rhythms (Li et al. 2015) and reproduction (Xia et al. 2016). However, there are no reports concerning habitat suitability for this species. Furthermore, the winter is the most critical season for the survival of the Yunnan snub-nosed monkey due to bad weather conditions and lack of food. Thus, locating the areas with high habitat suitability in the most critical period is crucial for the survival of this monkey.

This study used the MaxEnt model to examine winter habitat suitability for the Yunnan snub-nosed monkey in the Deqin BaMei Yunnan Snub-nosed Monkey Nature Reserve. The results can be used to identify the main environmental factors affecting the species and to predict the distribution of suitable habitats, thereby providing a basis for its effective management.

Materials and Methods

Study area

Our study was carried out from 2020 to 2022 in the Deqin Bamei Yunnan Snub-nosed Monkey Nature Reserve. It located in an area of 65 km^2 of virgin forests north-east of Bamei Village, Foshan Township, Deqin County (28°54′N, 98°43’E) at an altitude of 3000–4700 m a.s.l. (Fig. 1). The protected area has a plateau cold temperate mountain monsoon climate, with an annual average temperature of 9°C, average annual rainfall of about 550 mm and sunshine of 1980.7 h/year for a sunshine percentage of 4.5 %. The Nature Reserve is rich in animal and plant resources, including 174 species of plants, 47 species of mammals and 215 species of birds.

Design of the camera traps survey

According to the topography, vegetation type, animal traces and living habits of Yunnan snub-nosed monkeys, infrared cameras traps (LtlAcorn-6210) were

Fig. 2. Installation of infrared cameras and captured pictures of Yunnan snub-nosed monkey

arranged following the sample line method. Totally, 80 infrared cameras were installed with a monitoring time from November to January during 2020–2022. The cameras were generally fixed on large trees and shrubs with clear traces of animal activity, such as dung or animal paths. The cameras were set at about 0.5–0.8 m from the ground with a distance between each camera of about 200 m (Luo et al. 2019). The infrared cameras were set in hybrid shooting mode (photo + video) with continuous shooting (three pictures), 3-s time interval and medium sensitivity of the trigger sensors. We used a handheld GPS (Garmin GPSmap 60csx) to record the geographic coordinates of the camera deployment locations. We checked and updated the SD cards and batteries every two weeks. The camera positions were changed once a month. Yunnan snub-nosed monkeys were photographed at 187 sites (Fig. 2).

Acquisition of environmental variables

The terrain data were downloaded from the international scientific data service website (https://www.datamirror.csdb.cn) as a digital elevation model (DEM) with 30 m resolution. Elevation, aspect and slope were extracted from DEM. A normalised vegetation index (Normalised Difference Vegetation Index, NDVI) was calculated from remote sensing images of the protected land at 30 m resolution as the raster data were retrieved from the geospatial digital cloud platform Landsat 8 OLI_TIRS satellite digital products using ENVI 5.0. The vector layers for rivers and roads were downloaded first through the OSM data platform (https://www.openstreetmap.org) and were used to generate 30 m Euclidean distance rasters from them using ArcGIS 10.6.

In ArcGIS 10.6, all environment layers were set to WGS 1984 geographic coordinate system and with the same spatial range. At the end, all environmental variable layers were converted to ASCII raster format as required by the MaxEnt modelling software.

Statistical analysis

The Yunnan snub-nosed monkey distribution data and the environmental variables were imported into MaxEnt modelling software (MaxEnt3.4.4, www.cs.princeton.edu/~schapire/maxent); 75 % of the distribution points were randomly selected for the establishment of the model, while the remaining 25 % of the points were used for model validation. The Jackknife method was selected to test the importance of environmental factors. The correlation between the presence of the Yunnan snub-nosed monkey and environmental factors was tested by a response curve using ten permutations and the prediction results were output in Logistic format (Behdarvand et al. 2014). The receiver operating characteristic curve (ROC curve) was used to interpret the results from the permutations. The AUC value range is from 0 to 1, while the evaluation criteria used were: 0.5–0.6 as unsuitable, 0.6–0.7 as poor, 0.7–0.8 as medium, 0.8–0.9 as good and 0.9–1.0 as excellent (Yu et al., 2020). The permutation with the largest AUC value was selected as the prediction result. According to previous research results and field studies, the prediction results were reclassified into four grades in ArcGIS 10.6 as non-suitable area (0–0.1), area with low suitability (0.1–0.3), area with medium suitability (0.3–0.6) and area with high suitability (0.6–1.0) (Yang et al. 2013).

Results

Tests of prediction results

The evaluation result of the ROC curve of the model is shown in Figure 3. The prediction result of the MaxEnt model was classified as excellent (AUC = 0.925). The result indicated that the model was a valuable reference for the prediction of potential suitable habitats for the Yunnan snub-nosed monkey.

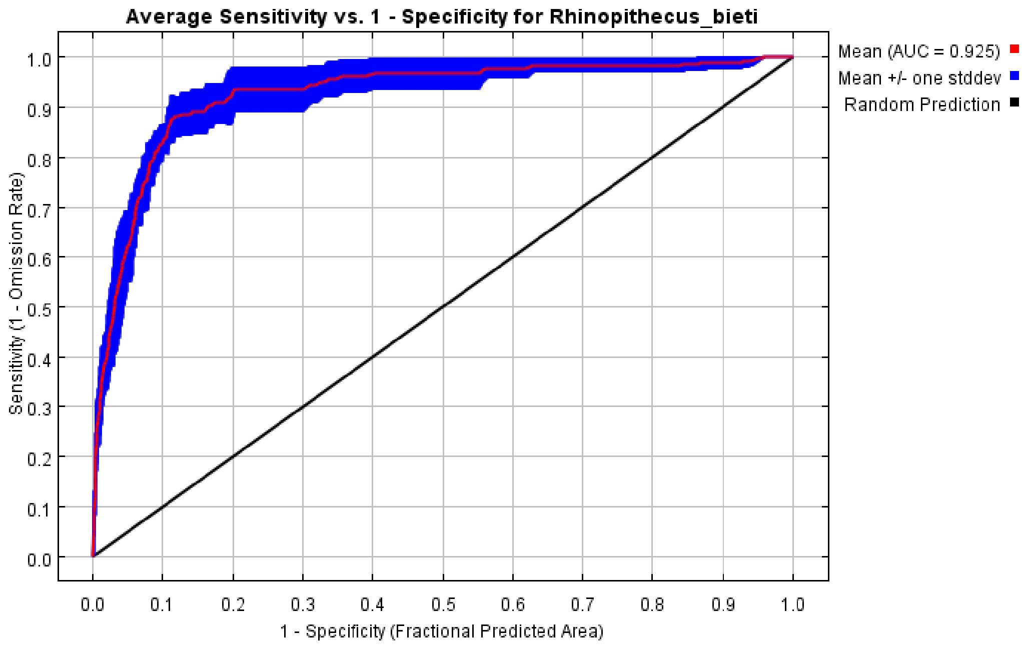

Fig. 3. ROC curve for *Rhinopithecus bieti* from the MaxEnt model

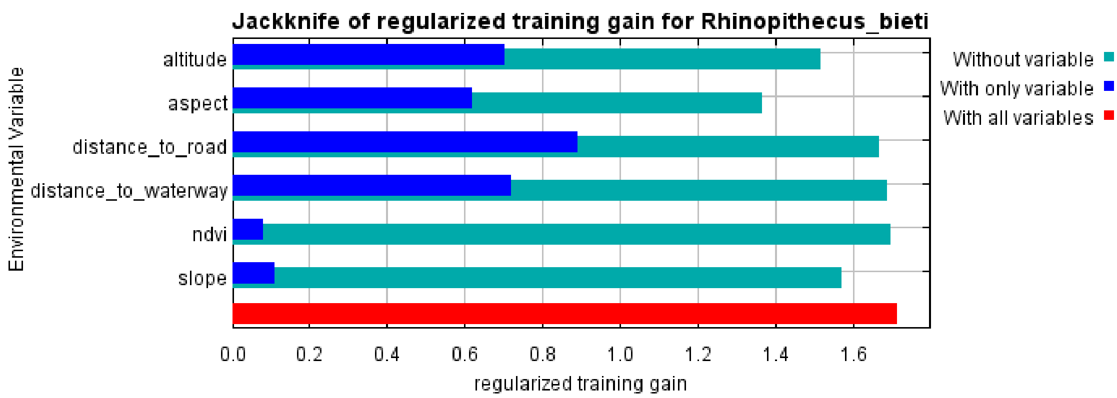

Fig. 4. Variable importance from the jackknife test in training data

Evaluation of the importance of environmental variables

As shown in Fig. 4, aspect, elevation, distance from the nearest road and distance from the nearest river had the strongest effects on the gain of the model, showing high importance with contributions of 32.9 %, 28.74 %, 23.5 % and 7.9 %, respectively, for a cumulative contribution rate of 93.04 %. The results showed that these were the main environmental factors affecting the distribution of the Yunnan snub-nosed monkey. For the contribution and importance values of the six environmental variables, see Table 1.

Table 1. Permutation importance of variables affecting the distribution of the Yunnan snub-nosed monkey

Variable	Percent contribution (%)	Permutation importance (%)
Aspect	32.9	48.3
Altitude	28.7	13.2
Distance to road	23.5	16.4
Distance to waterway	7.9	13.9
Slope	6.2	7.8
NDVI	0.9	0.4

Response curve of major environmental variables

According to the importance analysis results from the Jackknife test, four factors (aspect, altitude, distance from the nearest road and distance from the nearest river) were selected to analyse the influence of environmental variables on potential habitat suitability for the Yunnan snub-nosed monkey via the ecological factor response curve.

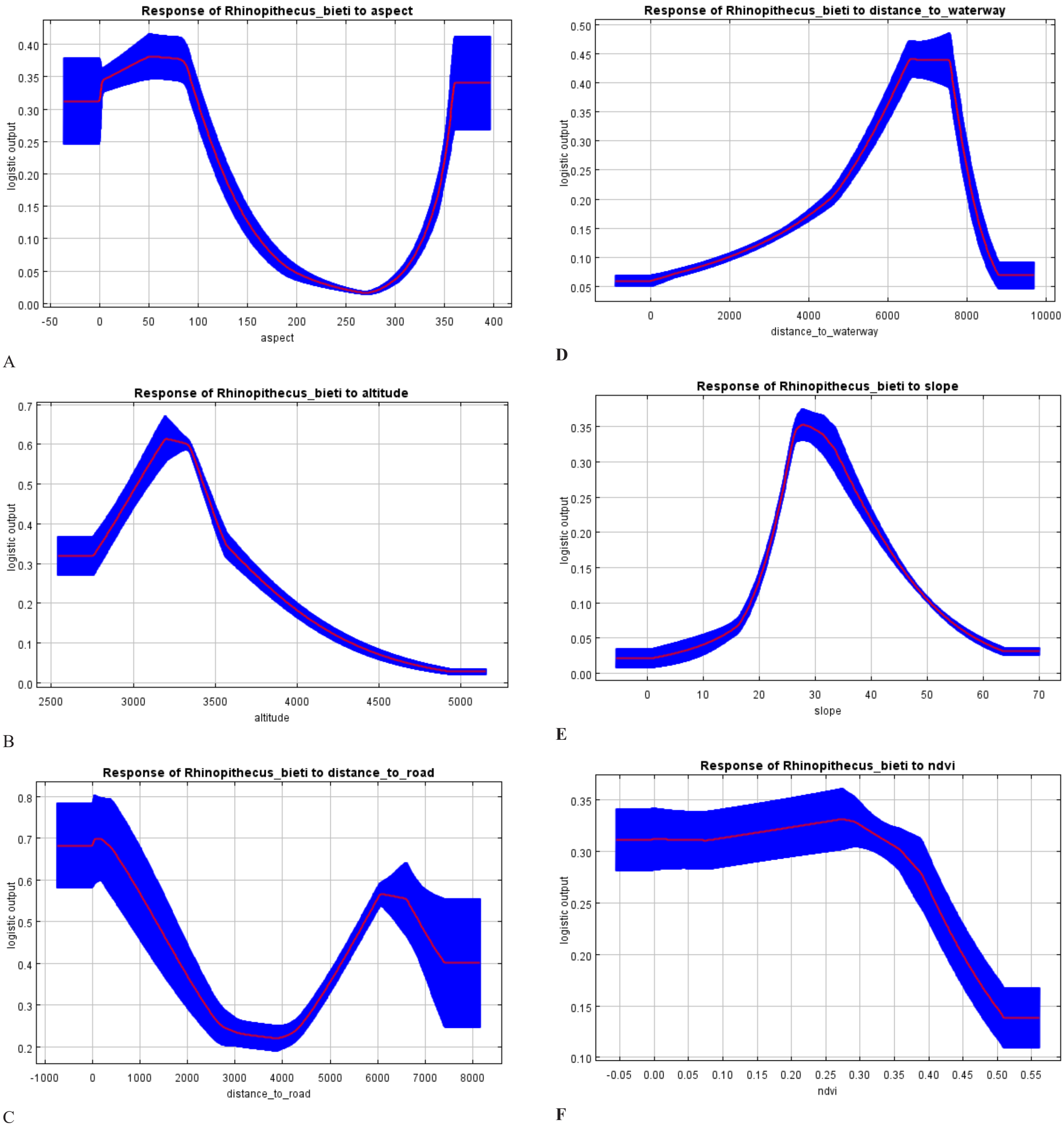

Fig. 5 Response curves of environmental variables

As shown in Fig. 5, the probability of occurrence of the Yunnan snub-nosed monkey was higher on the eastern and north-eastern parts (40°–90°), reaching a peak at approximately 3200 m a.s.l. and gradually decreasing from 3100 to 3500 m a.s.l. The probability of occurrence of the species decreased continuously at 0–4 km from the nearest road, reaching the lowest value at 4 km and, thereafter, showing an upward trend. The probability of occurrence of the Yunnan snub-nosed monkey was highest at 6–8 km from the nearest river.

Potential habitat suitability for the Yunnan snub-nosed monkey

The estimate of the area of highly suitable habitats for the Yunnan snub-nosed monkey (Fig. 6) was 1.34 km^2, accounting for 1.89 % of the entire reserve. The medium suitable habitat area estimate was 4.60 km^2, accounting for 6.48 % of the reserve area. Most of the reserve was predicted by the model to be unsuitable (76.87 % of the reserve, 54.55 km^2) or with low suitability (14.75 % of the reserve, 10.47 km^2).

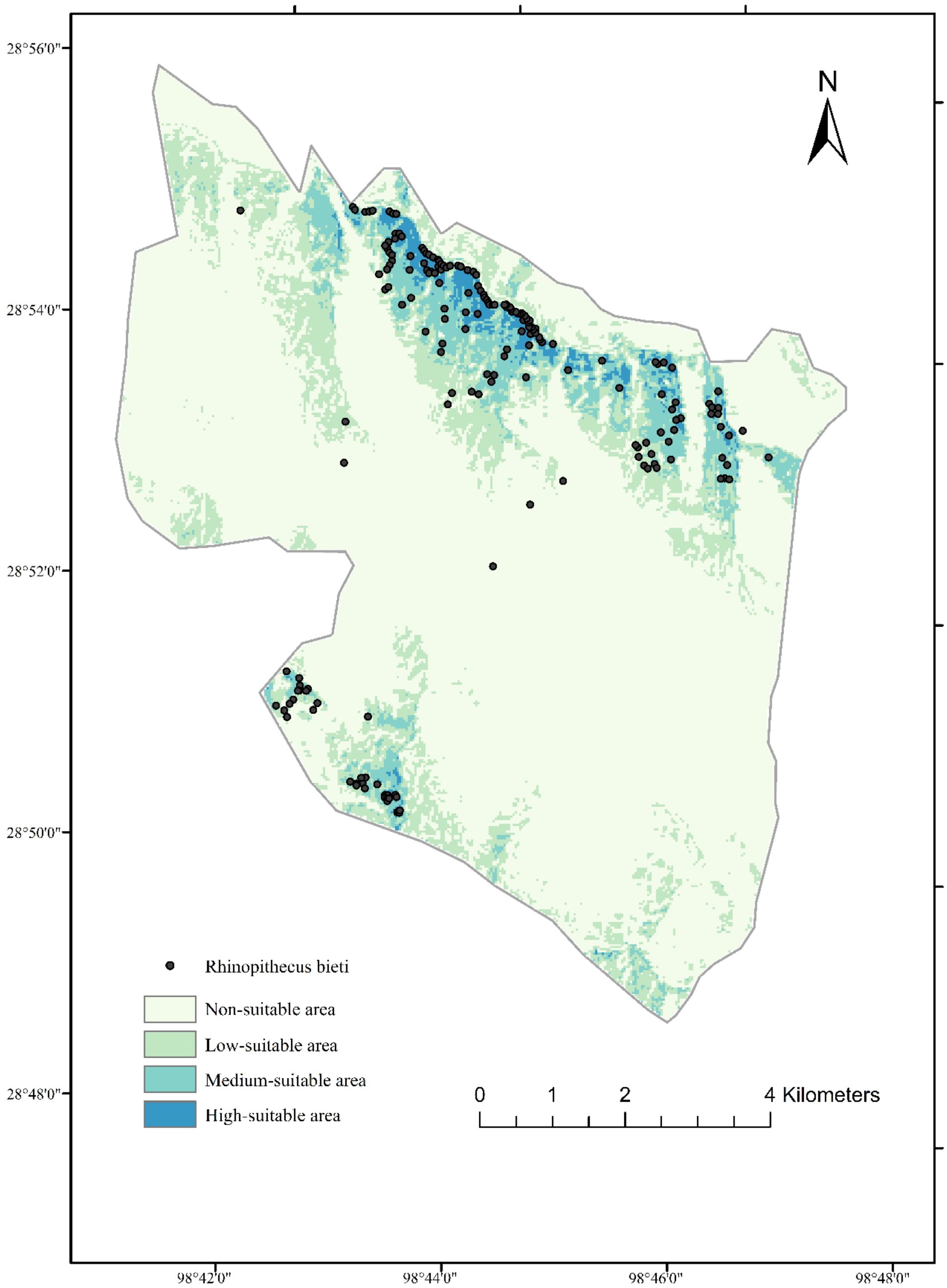

Fig. 6. Potential habitat and occurrence of the Yunnan snub-nosed monkey

Discussion

The MaxEnt model has two advantages in the study of suitable habitat for endangered species. On the one hand, the maximum entropy principle of the model can ensure that all the environmental variable information is used to produce the results (Yan et al. 2015). On the other hand, the model can maintain high prediction accuracy (Phillips & Miroslav 2008, Elith et al. 2011) when the species record sample size is small.

From the model simulation results of this study, aspect was the main factor affecting the suitability of habitat for the Yunnan snub-nosed monkey in winter. The aspect of suitable distribution area comprised eastern and north-eastern slopes, because the Yunnan snub-nosed monkey prefers areas with higher temperature in winter provided by the rising sun in the morning hours. Additionally, the light do not only provide sufficient heat but also supports plant growth and, thereby, provide more adequate food. This result is consistent with the choice of slope direction by the Yunnan snub-nosed monkey that also prefers the eastern slopes of the Gaoligong Mountains Range (MEYER et al. 2017).

Altitude was the second most important factor affecting the habitat suitability for the Yunnan snub-nosed monkey. The altitude associated with suitable distribution area in the Deqin Bamei Yunnan Snub-nosed Monkey Nature Reserve was about 3200 m a.s.l., thus avoiding human interference. These results confirmed the ones of Wu (2006), who performed a large-scale study based on 3S technology and found that the Yunnan snub-nosed monkey preferred the habitat at an altitude of 3217.8–3471.4 m a.s.l.

Snub-nosed monkeys are timid and extremely sensitive (Hu et al. 1980). Habitat loss, shortage of food resources, human activities and roads disturbance lead to stress responses of the animals (Agnes et al. 2011, Mumby et al. 2013, Viljoen et al. 2015, LI et al. 2016). In this study, the suitability of habitat for the Yunnan snub-nosed monkey was significantly positively correlated with the distance from the road and negatively correlated with the availability of food resources. In winter, the lack of food resources is the main stressor for the Yunnan snub-nosed monkey, while human activities such as vehicles and farming are less important and the level of human interference is weak. Closer to the road there are fewer human activities, such as grazing and logging, and there are more abundant food resources in the reserve. In this study, food resources were relatively rich within 1 km from the road, meaning higher suitability for the Yunnan snub-nosed monkey. At four km distance, the food resources were getting very scarce.

Animals cannot survive without water and having a water source is an important factor, which is expected to affect the distribution of suitable habitats for the Yunnan snub-nosed monkey (Wang 2014). There is a serious lack of food in the Deqin Bamei Yunnan Snub-nosed Monkey Nature Reserve in winter. Therefore, abundant food resources near the rivers will attract animals to come to feed, resulting in competition and a higher risk of predation. Choosing areas far from the river can effectively reduce the risk of predation in Yunnan snub-nosed monkeys. In the protected area, there is abundant rain and snow in winter, temporary stagnant water bodies can be formed in places far from the river as an alternative to meet the water needs of the species. Studies found that snub-nosed monkeys also feed on snow to meet their water needs.

In addition, slope and NDVI also affected (although not significantly) the habitat suitability distribution for the Yunnan snub-nosed monkey. In this study, Yunnan snub-nosed monkeys tended to choose areas with a moderate slope of 25–35°, because although the monkeys are forest animals, they often feed and drink water on the ground. A steep slope will increase additional energy consumption (Wang 2014). This result was similar to those for the Sichuan snub-nosed Monkey (Li et al. 2018, Bai et al. 2021), as well as to those of sun ungulates like the musk deer (Sun et al. 2020), roe deer (Xiang et al. 2021) and other hoofed species having the same preference for slope. Zhou et al. (2021) point out that the number of Yunnan snub-nosed monkeys increases with the increase of vegetation coverage but the results of our study showed that the NDVI range of suitable habitat for the Yunnan snub-nosed monkey was between 0.25 and 0.3, indicating that the species prefers areas with moderate vegetation cover. This choice for moderate vegetation cover in the reserve might be of a complex nature: as an effect of the higher altitude with less vegetation, which is preferred by the species in order for it to be away from humans and their activities.

Our study showed that the non-suitable habitats for the Yunnan snub-nosed monkey in the reserve were prevailing (76.87 %), while the percentage of suitable habitats was relatively low and highly fragmented. The distribution range of the highly suitable area for the Yunnan snub-nosed monkey was largely in the northern part of the protected area, in the core of the protected area. In this area, the primary vegetation was abundant, providing rich food resources and good hiding places for the monkeys. In winter, the food resources are scarce due to the severe cold climate, with large areas of deciduous plants and withered fruits and, thus, the Yunnan snub-nosed monkey are forced to migrate for foraging to the coniferous and broad-leaved mixed forests and broad-leaved forests at relatively low altitudes.

Conclusion

Based on the results of this study, our suggestions for habitat protection of the Deqin Bamei Yunnan snub-nosed monkey are as follows. (1) According to the ecological characteristics of the snub-nosed monkey, shrubs should be properly cut down to increase the proportions of coniferous forests and coniferous and broad-leaved mixed forests. This would improve the food resources for the snub-nosed monkey and turn part of the woodlands into suitable habitats. (2) Access to the mountains should be restricted in order to cultivate forests. (3) Regular patrol monitoring should be carried out in order to reduce the impact of human activities on the habitat of snub-nosed monkey. This will prevent suitable areas from turning into unsuitable areas.

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References

Agnes J., Jean-Paul L. & Joly P. 2011. Beyond occurrence: Body condition and stress hormone as integrative indicators of habitat availability and fragmentation in the common toad. Biological Conservation 144(3): 1008–1016. doi: 10.1016/j.biocon.2010.12.009.

Bai Y. L., Li Y. H., Zheng W. C., Chen W. L., Zhan L. M., Li D. Y. & Hu J. 2021. Habitat suitability assessment of *Rhinopithecus roxellana* in Tangjiahe National. Acta Ecologcia Sinica 41(11): 4460–4468. doi: 10.5846/stxb201910082078.

Behdarvad N., Kaboli M., Ahmadi M., Nourani E., Mahini A. S. & Aghbolaghi M. A. 2014. Spatial risk model and mitigation implications for wolf-human conflict in a highly modified agroecosystem in western Iran. Biological Conservation 177: 156–164. doi:10.1016/j.biocon.2014.06.024.

Carpenter G., Gillison A. N. & Winter J. 1993. Domain: a flexible modelling procedure for mapping potential distributions of plants and animals. Biodiversity and Conservation 2(6): 667–680. doi:10.1007/BF00051966.

Chen Z. Q., Zhao Z. H., Wang Y. F., Wei L., Ding G. H. & Lin Z. H. 2021. Analysis of activity rhythm and prediction of potential suitable distribution of black muntjac (*Muntiacus crinifrons*) based on the ITCT and MaxEnt model. Acta Ecologcia Sinica 41(9): 3535–3547. Available from http://qikan.cqvip.com/Qikan/Article/Detail?id=7104871313.

Elith J., Phillips S. J., Hastie T., Dudik M., Chee Y. E. & Yates C. J. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distributions 17(1): 43–57. doi:10.1111/j.1472-4642.2010.00725.x.

Engler R., Guisan A. & Rechsteiner L. 2010. An improved approach for predicting the distribution of rare and endangered species from occurrence and pseudo-absence data. Journal of Applied Ecology 41(2): 263–274. doi:10.1111/j.0021-8901.2004.00881.x.

Gaillard J. M., Hebblewhite M., Loison A., Fuller M., Powell R., Basille M. & Moorter B. V. 2010. Habitat-performance relationships: finding the right metric at a given spatial scale. Philosophical Transactions of the Royal Society B: Biological Sciences 365(1550):2255–2265. doi:10.1086/321003.

Harwell H. D., Posey M. H. & Alphin T. D. 2011. Landscape aspects of oyster reefs: Effects of fragmentation on habitat utilization. Journal of Experimental Marine Biology and Ecology 2011 409(1): 30–41. doi:10.1016/j.jembe.2011.07.036

Hu J. C., Deng Q. X., Yu Z. ., Zhou S .D. & Tian Z. X. 1980. Study on ecology and biology of Giant Panda, Snub-nosed monkey and other rare animals. Journal of Nanchong Normal University (Natural Science Edition) (2): 125–132. doi:10.16246/j.issn.1673-5072.1980.02.001.

Li D. Y., Ren B.P., He L. M., Hu G., Li B. G. & Li M. 2011. Diet of *Rhinopithecus bieti* at Xiangguqing in Baimaxueshan National. Acta Theriologica Sinica 31(4): 357–371. doi: 10.1080/0144929X.2011.553739.

Li H, Li L,Wu G. S., Zhou Y., Li W. W. & Mei Z. W. 2018. Analysis of habitat landscape connectivity of Yunnan Snub-nosed monkey based on circuit theory. Acta Ecologica Sinica 38(6): 2221–2228. doi:10.5846/stxb201706031022.

Li Y. D., Luo Y., Zhao H. T., Wang C. L. & Du J. 2018. Study on the suitable habitat of *Rhinopithecus roxellana* in Jiuzhaigou National using MaxEnt model. Sichuan Journal of Zoology 37(05): 585–591. doi:10.11984/j.issn.1000-7083.20170152.

Li Y. W., Li D. Y., Ren B. P., Yan X. H., Feng H., Li Y. H. & Hu J. 2015. Daily Activity rhythm of an Over-large Yunnan snub-nosed monkey group (*Rhinopithecus bieti*) in Baimaxueshan National. Journal of China West Normal University (Natural Science) 36(3): 221–227. doi:10.3969/j.issn.1673-5072.2015.03.001.

Li Y. Z., Dong X. & Liu X. H. 2016. Habitat pattern dynamics of the Snub-nosed monkey in Baihe, Minshan Mountains, China, over the past 40 years. Acta Ecologica Sinica 36(7): 1803–1814. doi:10.5846/stxb201409231885.

Luo C., Xu W. H., Zhou Z. X., Ou-Yang Z. Y. & Zhang L. 2011. Habitat prediction for forest musk deer (*Moschus berezovskii*) in Qinling mountain range based on niche model. Acta Ecologica Sinica 31(5): 1221–1229. Available from https://d.wanfangdata.com.cn/periodical/stxb201105004.

Luo H, Xiao X, Li Y. J., Hou J., Dong X., Zhang J. D., Bai W. K. & Li C. 2019. Establishment of PAE coding system and ethogram of *Rhinopithecus roxellana* using infrared camera. Sichuan Journal of Zoology 38(6): 646–656. doi:10.11984 /j.issn.1000-7083.20180394.

Ma J. Z., Zhou H. F. & Zheng G. G. 2003. The Status and development trends of wildlife and habitat conservation in China. Review of China Agricultural Science and Technology 5(4): 3–6. doi:10.3969/j.issn.1008-0864.2003.04.001.

Merow C. & Silander J. A. 2014. A comparison of Maxlike and Maxent for modelling species distributions. Methods in Ecology and Evolution 5(3): 215–225. doi:10.1111/2041-210X.12152.

Meyer, D., Momberg, F., Matauschek, C., Oswald, P., Lwin, N., Aung, S. S., ... & Roos, C. 2017. Conservation status of the Myanmar or black snub-nosed monkey *Rhinopithecus strykeri*. Fauna & Flora International, Yangon, Myanmar and German Primate Center, Göttingen. Available from: https://www.fauna-flora.org/app/uploads/2018/01/Conservation-status-of-the-Myanmar-snub-nosed-monkey.pdf

Mumby H. S., Courtiol A., Mar K. U. & Lummaa V. 2013. Climatic variation and age-specific survival in Asian elephants from Myanmar. Ecology 94(5): 1131–1141. doi:10.1890/12-0834.1.

NIAN B. 2004. Habitat suitability evaluation and landscape planning of Yunnan Snub-nosed monkey based on RS and GIS. Yunnan Normal University. Available from https://d.wanfangdata.com.cn/thesis/Y656950.

Phillips S. J. & Miroslav D. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 31(2): 161–175. doi:10.1111/j.0906-7590.2008.5203.x.

Ripperger S. P., Tschapka M., Kalko E. K. V., Rodriguez-Herrera B. & Mayer F. 2014. Resisting habitat fragmentation: High genetic connectivity among populations of the frugivorous bat *Carollia castanea* in an agricultural landscape. Agriculture Ecosystems and Environment 185(3):9–15. doi:10.1016/j.agee.2013.12.006.

Sun J., Zhao C., Meng D. H., Mi S. H., Li Z. Z., Teng L. W. & Liu Z. S. 2020. Winter habitat selection of alpine musk deer (*Moschus chrysogaster sifanicus*) in Helan Mountain. Chinese Journal of Wildlife 41(3): 573–579. doi: 10.19711/j.cnki.issn2310-1490.2020.03.004.

Viljoen J. J., Ganswindt A., Reynecke C., Stoeger A. S. & Langbauer W. R. 2015. Vocal stress associated with a translocation of a family herd of African elephants (*Loxodonta africana*) in the Kruger National Park, South Africa. Bioacoustics 24(1): 1–12. doi:10.1080/09524622.2014.906320

Wu R. D. 2006. Habitat analysis for Yunnan Snub-nosed monkey (*Rhinopithecus bieti*) based on 3S technologies. Southwest Forestry College 2006. Available from https://www.zsdocx.com/p-118217.html

Wu W., Li Y. H., Hu Y. M., Chen L., Li Y., Li Z. M., Nie Z. W. & Chen T. 2016. Suitable winter habitat for *Cervus elaphus* on the southern slope of the Lesser Xing'an Mountains. Biodiversity Science 24(1): 20–29. doi:10.17520/biods.2015177.

Wang Y. 2014. Habitat recognition of Sichuan Snub-nosed Monkey in Shennongjia in different seasons based on MaxEnt model. Huazhong Agricultural University. Available from https://d.wanfangdata.com.cn/thesis/Y2566056.

Xia F., Zhu P. F., Li M. P. 2016. Mating behavior of Yunnan snub-nosed monkey (*Rhinopithecus bieti*) at Xiangguqing in Baimaxueshan National, Yunnan, China. Acta Theriologica Sinica 36(1): 1–14. Available from http://qikan.cqvip.com/Qikan/Article/Detail?id=667733511.

Xiang R. W., Da Z., Wu J. Y., Bu X. L., Wang J., Lu Q. B., Hao Y. H., Sheng Y. & Meng X. X. 2021. Summer habitat preference of roe deer (*Capreolus pygargus*) in mountainous areas around Beijing. Chinese Journal of Ecology 40(10): 3252–3258. doi:10.13292/j.1000-4890.202109.015.

Yu J. P., Chen X. N., Yu H. S., Le Z. F., Shen X. L. & Cao M. C. 2020. Habitat assessment of black muntjac (*Muntiacus cirnifrons*) in the Gutianshan National based on MaxEnt modeling. Acta Theriologica Sinica 40(2): 143–151. doi:10.16829/j.slxb.150258.

Yan W. B., Wang Q. & Wang C. 2015. Evaluation of potential breeding habitat distribution with Maxent model for crested ibis in the Qinling-Bashan region. Chinese Journal of Zoology 50(2): 185–193. Available from https://d.wanfangdata.com.cn/periodical/dwxzz201502004.

Yang H. L., Li D. Q., Cheng. G., Duo H. R.,, Zhang Y. G. & Wang X. L. 2013. Habitat suitability evaluation for *Rhinopithecus brelichi* in Fanjing Mountain, Guizhou Province. Journal of Anhui Agricultural Sciences 41(8): 3403–3406. doi:10.13989/j.cnki.0517-6611.2013.08.008

Zhou Q. G., Li J., Meng H. B., Zhang X. Y. & Pang M. 2021. Evaluation of important Ecological Space quality in Chongqing based on remote Sensing interpretation. Soil and Water Conservation Research 28(6): 292–300. doi:10.13869/j.cnki.rswc.2021.06.023.

Zhu S. X., Li L., Xing L., Wu G. S., Guo H. Y., Wang X. & Bao G. J. 2022. Impact of the villages on habitat quality of Yunnan snub-nosed monkey in northwest Yunnan. Acta Ecologica Sinica 42(3): 1213–1223.

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