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A Preliminary Study on Integrating Geographic Information System and Multivariate Statistical Method to Model Muntjacs Habitat Use in Mountain Area of Southern Taiwan

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ABSTRACT

The ability to model habitat use and change in distribution of habitat is of considerable importance in wildlife management. In this study, Muntjac abundance obtained from auto-triggered cameras and habitat variables, such as elevation, aspect, slope, whole light sky space (WLS), forest cover type, forest cover type diversity, distance to river, and distance to road, were used to explain habitat selection and to identify areas of high use potential of Muntjac in natural forest of southern Taiwan. The model is based on the multivariate regression statistic coupled with Geographic Information System (GIS) technology to incorporate spatial correlation of wildlife-habitat relationship. Calculations were made with the GIS to generate spatial habitat variables and to produce a map containing habitat use potential that could not otherwise be identified by independent perusal of any single map layer. Confirmation of the accuracy of predictions of Muntjacs' habitat distribution was assessed with both survey data and expert's evaluation. Results shown that this technique is a useful tool for habitat mapping on a landscape scale.

Key words: GIS, habitat selection, Reeves' Muntjac, spatial distribution.

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1. INTRODUCTION

Chinese or Reeves' Muntjac (*Muntiacus reevesi*) are native to China and Taiwan (Sheng, 1992; McCullough, 1974). It is one of the small ungulates that occur in temperate to tropical forests (McCullough *et al.*, 2000). It is of interest because of their conservation and ungulate lineage importance. Research shows that it is predominantly forest dwelling and appear to be concentrate selectors for food items (Hofmann, 1985). However, little is known about Reeves' Muntjac in their native habitats because of the difficulties in long-term observation and trace in the wild (McCullough *et al.*, 2000).

Effective management of wildlife population largely depends upon understand and predicting their habitat needs (Buckland and Elston, 1993). Use of multivariate statistics and Geographic Information System (GIS) to assess habitat suitability has increased in recent years because the spatial characteristics and multi-dimensional nature of habitat limits use of simple univariate statistical techniques (Howell *et al.*, 2000; Brito *et al.*, 1999; Gros and Rejmanek, 1999; McKenney *et al.*, 1998; Buckland *et al.*, 1996; Clark *et al.*, 1993). In this study, Reeves' Muntjac abundance obtained from auto-triggered cameras and habitat variables obtained from digital terrain model (DTM) were used to explain habitat selection and to identify areas of high use potential of Muntjac in natural forest of southern Taiwan.

2. METHODOLOGY

The study area located at the mountain area of southern Taiwan including Shuang-Kuel-Hu Nature Protective Area, North Ta-Wu Nature Conifer and Hardwood Forest Protective Area, and Ta-Wu-Shan Nature Reserve (Fig. 1). Collectively, the 3 reserves consist of more than 234,000 acres of secondary hardwood and hardwood-conifer mixed forests. Primary vegetation includes species such as *Cyclobalanopsis morii*, *Adiandra lasiostyla*, *Cyclobalanopsis longinus*, *Persea japonica*, *Tsuga chinensis*, *Chamaecyparis formosana*, *Castanopsis carlesii*, *Alnus formosana*, and *Acer kawakamii*.

A total of 103 study sites were randomly allocated in the study area to conduct survey from 1992 to 2001 (Fig. 1). Each auto-trigger camera was installed 1.5 to 2.5 meters above ground and their locations were recorded using GPS receiver. Depending on the abundance of the animal and accessibility of study site, film and battery were collected and replaced every 2 to 4 weeks.

The relative abundance for Muntjac in each study site was represented by the Occurrence

Index (OI = the number of pictures taken per 1,000 camera working hour) (Pei, 1998; Pei *et al.*, 1997). Serial pictures belong to the same individual taken during a short period (usually within 30 minutes) will be considered only 1 picture in the calculation to prevent the over-representative of a lingering individual, hence, to reduce the possibility of over-estimation of the abundance. Camera working hours for each roll of film was calculated as the time span between the starting time of a new roll of film and the time recorded on the last picture or the time when the researchers arrived for collecting the film, which ever comes first.

There were total of 8 explanatory variables used to model Muntjacs' habitat selection. The geographical variables, i.e. elevation, slope, and aspect, were measured at study site. The landscape statistics, i.e. distance to river, distance to major road, land-use type, cover diversity, and whole light sky space (WLS), were calculated with 40 meter resolution using GIS database, the DTM, and the land use map. Stream and road networks were obtained from the 1:25,000 terrain maps and proximity zone maps were generated from those, hence the data layers of distance to major road and distance to river. We used the Land-use map from the 3rd national resources inventory conducted in 1994, which used aerial photo to identify land use type within national forests. Using moving window function of GIS, the number of different land use types within a 9*9 matrix of 40-m cells (12.9ha) surrounding the center cell was assigned to that center cell to obtain a measure of cover diversity. For example, if land-use type 1, 2, 4 were found in the 9*9matrix, then center cell will be assigned the cover diversity of 3. This matrix size corresponded to the core area of a Muntjac (Chapman *et al.*, 1994, McCullough *et al.*, 2000). WLS indicates the potential sunlight radiation denoted by percentage of open sky. Its value was calculated from DTM data and algorithm written in C language (Cheng *et al.*, 2002). Finally, a layer of moist regimes was generated from Mesic to Xeric through reclassification of aspect map according to Whittaker (1960). The moisture gradient were classified as： (1) Mesic – streams, (2) Submesic -- N, NE, NNE, ENE, and NNW slopes, (3) Subxeric – E, NW, ESE, WNW, SE, and W slopes, (4) Xeric – SSE, WSW, S, SW, and SSW slopes.

All variables were then tested for normality and correlation. The Pearson Correlation Coefficient matrix was generated to test the correlation of covariates. A stepwise multiple regression models was used to determine which of the 8 landscape variables accounted for the greatest amount of variation in Muntjacs abundance (OI value). K-S goodness-of-fit test and stepwise elimination process with $P<0.05$ was performed to understand habitat use by Muntjac by individual map layers (forest type, elevation, slope, aspect, and cover diversity). Results of the stepwise elimination process were used to generate a multivariate model. The multivariate model was expanded to generate Reeves' Muntjacs' habitat distribution map of the whole study area. Model accuracy was examined by comparing study site observations with model predictions.

3. RESULT AND DISCUSSION

For the 103 camera sites, frequencies of elevation and slope were equally distributed between the rages of 400 meter to 2,900 meter and 0 to 50 degrees, respectively. WLS ranges from 32% to 82%,however, extreme poor or abundant of sunlight radiation potential were less. Aspect was classified into moisture regime in a descending manner with class 1 as mesic and class 4 xeric. Cover diversity showed most camera sites were located in continuous land use patches instead of fragmented land use patch. Pearson correlation coefficient showed all continuous variables were independent to each other, which indicated the selection of each variable did not affect the contributions of other variables.

Among the 103 camera sites, 80 sites (= 77.67%) have recorded Muntjac. Among the 8 variables, 2 of them, i.e. land-use type and moisture regimes, were categorical while all the rest of the covariates were continuous. The result of stepwise process eliminated covariate distance to river and distance to road at the significant level of $p<0.05$. The result of Analysis of variance (ANOVA) showed that the categorical variables were not significantly correlated excepted for moisture regime. The submesic site which neither too dry nor too humid seems to be significantly correlated with Muntjac OI value. Therefore, with all covariates and their transformations, 5 variables, including one categorical variable of moisture regime, were selected for the multiple regression model with $R^2=0.39$. The final selected covariates for the habitat model were elevation, slope, moisture regime (class 1, 2, 3, and 4), cover diversity, and WLS was selected for the model. The multivariate regression equations obtained for the study area showed that Muntjacs were more abundant in lower elevation, flatter slope, with higher land use diversity and medium WLS. Subxeric to submesic appears to be most suitable moisture class to Muntjacs (Table 1).

The stepwise multiple regression model was applied to the whole landscape with existing DTM data and GIS technology (Figure 1). The estimated Muntjac distribution showed a relatively higher Muntjac abundance in lower elevation and flatter slope area. In higher elevation, the Muntjac abundance was usually lower except for area of more Mesic environment, such as area around lakes.

The simple matching coefficient showed that the predicted and observed values agreed for 78% ((75+5)/103=0.78) in the model (Table 2). However, since the logistic predicts the OI values which gives the distribution of suitability of habitat instead of the absent/present of

Muntjac, if the distance to observed OI value was to be used, the matching coefficient increased to 84% (Table 3).

Overall, the multivariate model of Reeves' Muntjac agrees with field survey and field experience, therefore, provides good estimation of habitat distribution. In this study, landscape variables are proofed to be useful explanatory variable for Muntjac distribution model. Part of the reason for the high prediction rate of using landscape variables only may because of Muntjac is a more common species that is not very selective for their habitat. If habitat use of other species were to be assessed, other explanatory variables such as vegetation species and vegetation structure may have to be included.

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Table 1. Results of stepwise multiple regression of landscape and vegetation effects on Reeves' Muntjac distribution in Shuang-Kuel-Hu Nature Protective Area, North Ta-Wu Conifer and Hardwood Forest Protective Area, and Ta-Wu-Shan Nature Reserve in Taiwan

Covariate, X	estimate	t-test	P-value
Elevation (m)	-0.01192	-5.15	0.0001
Slope (°)	-0.23364	-2.54	0.0126
Moisture region 3	8.74757	2.10	0.0381
Cover diversity	2.97776	1.63	0.1055
WLS (%)	0.29595	2.38	0.0191

R2=0.3901; F=7.52, P=0.0001

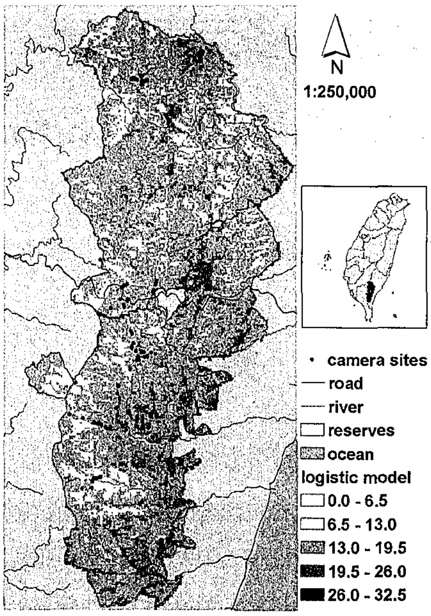

Figure 1. Estimated Reeves' Muntjac distribution and camera sites in Shuang-Kuel-Hu Nature Protective Area, North Ta-Wu Conifer and Hardwood forest Protective Area, and Ta-Wu-Shan Nature Reserve in Taiwan

Table 2. Matching counts of logistic model : a method to assess the matching of predicted sample and observed sample

Observation	Prediction		Total	Matching coefficient
	Present	Absent		
Present	75	5	80	96%
Absent	18	5	23	43%

Simple matching coefficient = (75+5)/103=0.78

Table 3. Matching counts of differences between predicted sample and observed sample for logistic model

Differences	Prediction		Total
	Under estimate	Over estimate	
10 – 20	4	9	13
>20	4	0	4
Total	8	9	
<=10		86	

Simple matching coefficient = 86/103=0.84

*: 5 samples were matched exactly

整合地理資訊系統及多元迴歸模式推估台灣南部山區山羌棲地選擇之初探

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摘要

本研究應用多變值統計迴歸分析之原理，建立台灣南部山區山羌（*Muntiacus reevesi*）之棲地分布模式。使用自動照相設備收集山羌的野外調查資料，並利用數值地形資料庫與土地利用圖，產生棲地變數，以多元迴歸分析建立研究區域之山羌棲地模式，並利用此一模式推估全區之山羌棲地分布。以樣點所在位置之模式預測值檢測，可達 84%之準確率。依此棲地模式推估所得之山羌棲地分布圖顯示，在低海拔平緩坡地，山羌的族群密度相對較高，而在高海拔地區之平緩潮濕地區，則山羌也可達到一定之族群密度，此一結果與以往之觀察研究結果吻合。研究結果顯示，使用多變值統計迴歸分析結合地理資訊系統可以了解山羌對棲地之選擇，有效地建立山羌之棲地模式，並進而推估山羌之空間分布。

關鍵詞：棲地模式、地理資訊系統、空間分布、山羌

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