Acta Zoologica Taiwanica 8(2):??-?? (1998)

Distribution of the hairy-footed flying squirrel (*Belomys pearsonii*) in Taiwan, a GIS approach

Pei-Fen Lee

Department of Zoology
National Taiwan University
Taipei, Taiwan, R.O.C.

Abstract

I studied the distribution pattern of the rare hairy-footed flying squirrel (*Belomys pearsonii*) in Taiwan by integrating a field survey conducted at Chitou, an experimental forest of National Taiwan University, between September 1981 and June 1983 and wildlife distribution and ecological and environmental databases. Results indicate that the population size of *B. pearsonii* at Chitou was small. In the 20-mo survey, there were only 14 scattered sightings in both man-made and natural forest types. Large-scale distribution of *B. pearsonii* was extracted from a wildlife distribution database which was compiled from literature published between 1977 and 1995, and mapped using a geographic information system (GIS). Most of the distribution range of *B. pearsonii* in Taiwan overlapped those of two species of giant flying squirrels (*Petaurista* spp.). The spatial distribution of *B. pearsonii* roughly follows the north-south axis of the Central Mountain Range, but distribution records are scarce and scattered. Although the accuracy for predicting the presence of *B. pearsonii* using a logistic regression model is moderate (48%), the predicted probabilities of occurrence suggest a spatial pattern that resembles the known distribution. More inventory and monitoring studies are necessary to determine the conservation status of this species. The information in this report can serve as a foundation for protecting this rare squirrel.

Keywords: *Belomys pearsonii*, Flying squirrel, GIS, Species distribution map

Introduction

The hairy-footed flying squirrel (*Belomys pearsonii*) is one of three flying squirrel species which occur in Taiwan. It is distributed in large geographic areas across southeastern Asia, including Nepal, Sikkim, Assam, Burma, Thailand, Indochina, southern China, and Taiwan (Nowak, 1991; Corbet and Hill, 1992; Wilson and Reeder, 1993). Corbet and Hill (1992) recently synonomyzed this monotypic genus with *Trogopterus* based on its morphological similarity to *T. xanthipes*. However, this change was not adopted in Wilson and Reeder (1993). Reports on the distribution and ecology of the species are scattered and scarce (Lin et al., 1985). The squirrel is nocturnal and arboreal. Its life history is poorly known (Lin et al., 1985; Nowak, 1991). An adult squirrel is about 20 cm (range 18-26 cm) in head and body length (Nowak, 1991), and about 217 g in body weight (Lekagul and McNeely, 1977). *B. pearsonii* inhabits dense, temperate, broadleaf forests and is much less common in Taiwan than are the *Petaurista* spp. (Nowak, 1991). Other than this, little information is available for this species. It is officially classified as a rare and valuable species in Taiwan under the Wildlife Conservation Law and is included in the IUCN red list of threatened animals under the lower risk category (IUCN, 1996).

Recent efforts in documenting species distribution have focused on using a geographic information system (GIS) to produce species range maps (e.g., Miller, 1994; Csuti et al., 1997). Documentation of a species' distribution over the landscape is an important step towards its conservation and in-depth ecological and genetic/evolutionary studies (Krebs, 1994). Maps showing the distribution of wildlife species provide valuable information for research, conservation, and environmental planning. These maps link geography and ecology, and can be used to investigate the distribution characteristics of species.

During the last 20 yrs, there have been several surveys that reported the distribution of *B. perasonii*, and compiling these data provides a baseline for constructing a distribution map for this species in Taiwan. To better help in conserving this rare species, I investigated the distribution pattern of *B. pearsonii* in Taiwan using data extracted from a wildlife distribution GIS database (Lee et al., 1998). In particular, I documented field observations made at Chitou, an experimental forest of National Taiwan University, studied landscape features that characterize the spatial distribution of *B.*

pearsonii, and used a logistic regression model to predict its spatial distribution pattern in Taiwan.

Materials and Methods

Field observations

Detailed monthly nocturnal observations of flying squirrels were made between September 1981 and June 1983 at Chitou, Nantou County, central Taiwan. Chitou forest is located at the upper end of a precipitous mountain valley rimmed on the east by Phoenix Mountain (elevation 1669 m). Although most of the forests have been converted to coniferous plantations of Japanese fir *Cryptomeria japonica* since 1895, some stands of natural hardwood forests of Lauraceae and Fagaceae are preserved (see Lee et al., 1986 and 1993 for a detailed description). These spatially mosaic forests provide typical habitats for this nocturnal species. Three trails that cover areas from 1000 to 1400 m in elevation and both forest types were used to locate the squirrel.

Spotlighting was the major method used to locate squirrels during the night survey (see Lee et al., 1986 for details). Since I never heard the call of *B. pearsonii*, I relied on spotlighting to find the animal. When a squirrel was found, I recorded the location on a pre-surveyed map, as well as the forest type, tree species, and height in tree (in 5-m intervals) where the squirrel was spotted (Lee et al., 1993). I also recorded the behavior whenever possible.

GIS databases

Squirrel distribution data were extracted from a wildlife databank in Taiwan (Lee et al., 1998). The data from this database were summarized from an extensive literature review. These published reports and articles on mammal distribution were sponsored by governmental agencies and the private sectors between 1977 and 1996. Since the locality information presents many difficulties, I positioned each locality record in a 2 x 2 km^2 grid system in a GIS, i.e., Arc/Info. These records were first mapped using the UTM coordinates and transferred onto the grid. A total of 56 mammal species and 1695 grids containing species richness information were established (Lee et al., 1998). Due to incompatibilities in the methods used among researchers, data on distribution were in presence/absence format. To ensure the data quality, the data-screening process included examining the distribution map and excluding species observations of doubtful authenticity based on my own field experience. There are 203 records for *B. pearsonii*. A record is defined as a single observation of a species at a geographic location that is about 200 m away from the any other observation.

An ecological and environmental GIS database for Taiwan (Lee et al., 1997) was used to investigate the landscape characteristics of the squirrel distribution. Based on my knowledge, I selected 21 environmental variables from the database (Table 1). These habitat and landscape variables include temperature, precipitation, and human development and topographic factors. Proximity to topographic and human-related features may play an important role in the ecological condition. A GIS is used to derive the following distance measurements: shortest distance to areas above 3000 m in elevation, rivers, major roads, major cities and coast lines (explained below). Most of the original map sources were at 1:100,000 or coarser resolution. Most of the data were first digitized in Arc/Info and rasterized or calculated using SAS or IDRISI (IDRISI, 1997). Area was used to weight the landscape variables when calculating the mean value to represent the grid.

Climatic variables were digitized from a publication of the Central Weather Bureau (1990). Warmth index was derived by subtracting 5 from each monthly mean temperature and summing the results (Liu and Su, 1983). Dry period precipitation was the sum of monthly precipitation from October to March and was used to represent the rainfall for the dry period in Taiwan. The ratio of precipitation between the dry period and annual total was calculated. The variable, total number of months short of water supply, was determined by calculating the water shortage condition in each month by comparing the monthly mean precipitation with the critical amount of rainfall, i.e., doubling the monthly mean temperature. A negative value means water shortage (coded as 1), whereas a positive value means abundance (coded as 0). Then, conditions for each month were summed.

Elevation contours were digitized in 100-m intervals from 1:50,000 topographic maps. The layers for the shortest distances (km) to areas above 3000 m in elevation, rivers, major roads (railway, highways, and freeways), coast lines, and major cities were derived with a raster-based GIS package, IDRISI. These features were rasterized and shortest distance measurements were calculated using the DISTANCE function in IDRISI. Urban development index was used to represent the development status of the areas and is based on the proportion of the number of people participating in different types of industries in a township. Lee et al. (1997) provided calculation methods. Naturalness index was derived from a vegetation map by subjectively assigning the wilderness condition to each forest type on a 0 (developed and highly disturbed) to 10 (undisturbed and highly natural) scale. Population data in 1994 within each township were extracted from the population census data set and converted to density (people/ha).

Data Analysis

The presence/absence data were used to investigate the distribution characteristics of *B. pearsonii* using the environmental datasets. Distribution probability was calculated by categorizing each of the variables and comparing the number of cells that have presence records with the total number of cells in their respective category. An χ^2 test (ter Braak and Looman, 1987) was applied to test whether the distribution probability of occurrence for a specified variable differed among the categories.

I applied a logistic regression to model the distribution using the environmental variables to make prediction areas where no survey data exists. All calculations were performed with SAS. The data set was randomly split into two nearly equal samples: training set and validation set. The training set was used to model the distribution in a stepwise approach, and the results were checked by the validation set. Since the output of the logistic regression model is in the range of 0 to 1, which is treated as the probabilities of occurrence for the species in the grid, presence is then estimated deterministically by choosing the highest estimated probability of occurrence. An approach suggested by Buckland and Elston (1993) was applied. This method suggests that the total number of grids in which a species is present equals the sum of all estimated probabilities, i.e., the cutting point for determining the presence of the squirrel is to sum all the probabilities, take the integer value (n), and select the n largest probabilities. The validated model was used to predict the potential distribution of *B. pearsonii* for all of Taiwan.

Results

Field observations

Compared to the relative high abundance of *Petaurista* species at Chitou (Lee et al., 1993), *B. pearsonii* was quite rare. There were only 14 sightings in a 20-mo period. Only one individual per sighting was recorded in each encounter. Eleven of these observations were made in conifer plantations (*Cryptomeria japonica*), while three encounters were in hardwood forest. Elevations of sightings were between 1100 and 1350 m. Four sightings were made when the squirrel was moving between branches. In other situations the squirrel was sitting on a branch. Trees which animals were observed include *C. japonica* (6 times), *Pinus morrisonicola* (2), *Cunninghamia konishii* (1), *Debregeasia edulis* (1), *Machilus japonica* (1), *Pasania kawakamii* (1), and *Turpinia formosana* (1). Similar to the *Petaurista* species, *B. pearsonii* was not disturbed by the flashlight. On one occasion, I was about 3 m away from an animal and it did not seem to be disturbed. Most sightings were made in trees of 5-10 m in height, about the height of the subdominant tree layer in the forests. Squirrels were not found in the canopy layer, which is at least 10 m in height. They are reported to go down to the shrub layer where they have been caught in a mesh-wired rodent cage at about 1.4 m high in *Cryptomeria japonica* plantations (S. P. Yo, National Chung-Hsin University, pers. comm.). No gliding behavior was observed.

Distribution

From a total of 174 articles published between 1977 and 1996, I found 69 reports containing distribution information on flying squirrels. Of these, only 17 studies reported sightings of *B. pearsonii*. Sixteen reports indicated that *B. pearsonii* was sympatric with *Petaurista petaurista* and/or *P. ablorufus*. Flying squirrels occurred in 666 grid cells (Table 2). Of these, *B. pearsonii* occurred in 174 cells. Compared to the 489 cells for *P. petaurista* and 544 for *P. alborufus*, distribution records for *B. pearsonii* are relatively scarce. The distribution pattern of *B. pearsonii* is similar to that of the *Petaurista* species. These three species coexisted in 22% of cells. In only three cells (0.5%) did this species exist with no occurrence record of either of the *Petaurista* species.

The spatial distribution of *B. pearsonii* is similar to an elliptical shape that roughly follows the north-south axis of the Central Mountain Range (Fig. 1). The distribution is scattered and discontinuous. Most of the known occurrence records are distributed above 1000 m in elevation. The species occurs in large patches of various forest types, including conifers (hemlock, spruce, and red cypress), cultivated conifer (*C. japonica*), and hardwoods.

Occurrence probability with various environmental factors showed distinct preference patterns (Fig. 2). The occurrence probabilities for *B. pearsonii* were lower than those of *Petaurista* species (P. F. Lee, unpubl. data). The areas where the animals were found with higher probabilities show the following landscape characteristics: higher elevation (above 1500 m), median- to high precipitation with high dry period season precipitation ratio, low temperature and warmth index, low urban development index, high naturalness index, and proximity to major roads and coast lines. All of the occurrence probabilities of the above landscape variables are significantly different at least at the 1% level.

The squirrel shows preference in its distribution (Fig. 3). Using 2 x 2 km grid representation, the current distribution ranges between 393 and 3217 m in elevation (mean = 1743 m, SD = 687). The average January temperature of these areas ranges from 2.5 to 15 °C, and that in July from 13 to 25 °C. The annual precipitation ranges from 1703 to 4081 mm. All signs indicate that less disturbed forest areas in Taiwan are suitable habitats for this species.

Prediction model

Although the accuracy for predicting the absence condition is high, the prediction of the logistic regression model (Table 3, $\chi^2 = 35.3$, $P = 0.006$) on the presence of *B. pearsonii* is only moderate. The max-rescaled R^2 value (a value similar to the R^2 in multiple linear regression models, but always far smaller even for a good fit) for the prediction model is 0.32. The overall accuracy of prediction is 87% (737/847), with the accuracy for presence in the grids being 48% (41/86), and for absence, 91% (696/761). Cohen's Kappa coefficient is 0.36 and range from 0.26 to 0.45, indicating the model does provide certain explanatory power. The predicted probabilities for a particular cell range from 0.0 to 0.59 with a mean of 0.07 and standard deviation of 0.11. Five landscape variables were included, in the order of the stepwise selection process: urban development index, indicator of eastern side of Taiwan, presence of forest cover, precipitation ratio of the dry period to annual total, and proximity to the coast line (Table 3). The coefficients of this model suggest that the occurrence of *B. pearsonii* is positively related with the presence of forest cover, precipitation ratio of the dry period to annual total, and proximity to the coast line, and negatively correlated with urban development index and indicator of eastern side of Taiwan.

The spatial distributions of *B. pearsonii* in Taiwan using predicted probabilities and predictive presence pattern are shown in Fig. 4A and 4B, respectively. Predicted probabilities (Fig. 4A) suggest the potential habitat for *B. pearsonii*. It roughly follows the Central Mountain Range and shows some potentially high-occurrence areas. Using the criteria suggested by Buckland and Elston (1993), cells with higher probabilities were selected (Fig. 4B). These predictive occurrences are clustered in two areas, in and around the Shei-Pa National Park and north of Yushan National Park. This map correctly predicts the occurrence of the animal at the center of its distribution range, but it fails to predict the occurrence in peripheral areas, especially in the southern part of the Central Mountain Range.

Protection status

Though *B. pearsonii* is listed as a conservation species and legally protected, no conservation plan exists. The current distribution of *B. pearsonii* is largely under the habitat protection umbrella of three large national parks (Shei-Pa, Taroko, and Yushan) and two nature reserves (Ta-Wu Mountain and Cha-Tian Mountain) (Fig. 4B). The distribution of *B. pearsonii* along the Central Mountain Range in areas between these three national parks, however, represents gaps in the conservation for this species.

Discussion

Understanding the distribution and abundance of a species is the first step in the design of a comprehensive conservation strategy (Krebs, 1994). This study summarizes the scattered reports on the distribution and field observation of a relatively little known species of flying squirrel. The combination of local observation and large-scale mapping gives a better view of the distribution and abundance of *B. pearsonii* in Taiwan. Local observation at Chitou provides detailed information on the habitat and vertical use in the forest, and relative population densities of the animals, while the large-scale approach gives a clue to the extent of the species' distribution range. My observations of this species support what Nowak (1991) indicated: that it is rare and confined to the forests.

The vertical distribution of *B. pearsonii* in Taiwan is between 393 and 3217 m and is concentrated in mid-elevation areas (Fig. 3). The elevation range is wider than those reported by Mitchell (1979) in the eastern Himalayas where *B. pearsonii* was found from 1500 to 2400 m. Corbet and Hill (1992), on the other hand, indicated that it can be found at 900 m elevation. The vertical distribution data presented in this paper should be interpreted with caution. Due to the highly complex topography in Taiwan, a 2 x 2 km^2 grid cell may contain areas that have elevation differences exceeding 1500 m. This will definitely cause some problems in defining the vertical distribution range using this grid representation.

There are fewer distribution records of *B. pearsonii* than of the two giant flying squirrel species (*P. petaurista* and *P. alborufus*) in Taiwan. Although it can be found in several different forest types and adapts to plantation habitat, it has limited spatial distribution. The field survey conducted at Chitou suggests that the population of *B. pearsonii* is very rare. It id not a dominant species in the forests. Observations recorded from the 17 publications also confirm this point. The literature concerning other geographic ranges of *B. pearsonii* also indicate a similar pattern (van Peenen, 1969; Mitchell, 1979).

Several factors may affect the survival of this species. Forest habitat is essential to its survival. Increasing the number of open habitats (e.g., clear-cutting) at the local scale has a negative impact on populations of flying squirrel. Monkkonen et al. (1997) found that this kind of habitat loss has a significant impact on the survival of the flying squirrel (*Pteromys volans*) in Finland. Biologically, it may face some competition for food and nest sites from the nocturnal giant flying squirrel and diurnal tree squirrel species in Taiwan. Also, predation pressure from owls and arboreal snakes may be high. With its small body size, it is suspected that owls (e.g., Mountain Scops Owl, *Otus spilocephalus*) and snakes (e.g., Taiwan green snake, *Eurypholis major*) may be the major predators to this species.

Given the absence of regularly and systematically collected locality data across the whole of a species' range, information of habitat and landscape features can be used as a broad-scale predictor of its distribution (Romero and Real, 1996). The differences in habitat requirements reflect fundamental differences in individual species' life history requirements. A close association between life history requirements of a species and its environmental conditions is the prerequisite for all prediction applications. The logistic regression model does not predict the presence satisfactorily, but the variables included agree with the general trend observed in the macro-distribution pattern. The use of logistic regression to model the prediction of spatial distribution has been advocated by many researchers (e.g., Nicholls, 1989; Osborne and Tigar, 1992; Romero and Real, 1996). Logistic regression can be an appropriate method to analyze a broad range of internal complexities of distribution data. Logistic regression allows the identification which combination of variables is able to explain the internal complexities of the species distribution. With logistic regression the typical habitats of *B. pearsonii* are characterized. The species distribution pattern is suggested by the probability of occurrence. Although the prediction for *B. pearsonii* in the paper is only moderate, the variables included in the model agree with the occurrence probabilities and distribution of environmental range of this species. In the case of *B. pearsonii*, the predicted probabilities may be more informative than the presence/absence prediction.

Although some of the current distribution of *B. pearsonii* is protected by national parks and nature reserves in Taiwan, more attention should be focused on the species due to its low population size. Despite the fact that gathering population data for this species is rather difficult, without this information judging and classifying the conservation status will be seriously affected. More inventory and monitoring studies are necessary to determine the status of this species. Because this species is distributed in a wide geographic range, adoption of standard field methods (e.g., Wilson et al., 1996) should help in comparing data among studies conducted at local, national, and international levels.

ACKNOWLEDGMENTS

I thank C. L. Loh and Y. C. Chao for field assistance; J. E. Sheu, Y. C. Lee, W. C. Su, C. J. Hsieh, and C. C. Chen for database compilation; and T. S. Ding and C. Y. Liao for locating important literature. This paper was improved by the comments of two anonymous reviewers. This study was supported by the National Science Council (field survey) and the Council of Agriculture (database compilation), Republic of China. The preparation of this paper was supported by the National Science Council and the Ministry of Education.

References

Buckland, S. T. and D. A. Elston (1993) Empirical models for the spatial distribution of wildlife. J. Appl. Ecol. 30: 478-495.

Central Weather Bureau (1990) *Climatic atlas of Taiwan, the Republic of China*, Volume 1. Central Weather Bureau, Ministry of Communications, Taipei, 96 pp. (In Chinese)

Corbet, G. B. and J. E. Hill (1992) *The mammals of the Indomalayan region: a systematic review.* Oxford Univ. Press, Oxford, 488 pp.

Csuti, B., A. J. Kimerling, T. A. O'Neil, M. M. Shaughnesy, E. P. Gaines and M. M. P. Huso (1997) *Atlas of Oregon wildlife: distribution, habitat, and natural history.* Oregon State University Press, Corvallis, OR, 492 pp.

IDRISI. (1997) *IDRISI for Windows, version 2.0.* Clark University, Worcester, MA, 386 pp.

IUCN. (1996) *The 1996 IUCN red list of threatened animals.* IUCN, Cambridge, UK (WWW version).

Krebs, C. J. (1994) *Ecology: the experimental analysis of distribution and abundance*, 4th ed. HarperCollins College Publishers, New York, 801 pp.

Lee, P. F., C. Y. Liao, Y. C. Lee, Y. H. Pan, W. H. Fu and H. W. Chen (1997) *An ecological and environmental GIS database for Taiwan.* Council of Agriculture, Taipei, 90 pp. (In Chinese, English abstract)

Lee, P. F., D. R. Progulske and Y. S. Lin (1986) Ecological studies on the two sympatric giant flying squirrel species (*Petaurista petaurista* and *P. alborufus*) in Taiwan. Bull. Inst. Zool., Acad. Sinica 25: 113-124.

Lee, P. F., D. R. Progulske and Y. S. Lin (1993)

Spotlight counts of giant flying squirrels (*Petaurista Petaurista* and *Petaurista alborufus*) in Taiwan. Bull. Inst. Zool., Acad. Sinica 32: 54-61.

Lee, P. F., K. Y. Lue, C. C. Hsieh, Y. C. Lee, Y. H. Pan, H. W. Chen, T. C. Pan and T. S. Ding (1998) *A wildlife distribution database in Taiwan*. Council of Agriculture, Taipei, 406 pp. (In Chinese, English abstract)

Lekagul, B. and J. A. McNeely (1977) *Mammals of Thailand*. Association Conservation Wildlife, Sahakarnbhat Co., Bangkok, 758 pp.

Lin, Y. S., D. R. Progulske, P. F. Lee and Y. T. Day (1985) Bibliography of Petauristinae (Rodentia, Sciuridae). J. Taiwan Mus. 38(2): 49-57.

Liu, T. R. and H. J. Su (1983) *Forest ecology*. Sangwu Publisher, Taipei, 462 pp. (In Chinese)

Miller, R. I., ed. (1994) *Mapping the diversity of nature*. Chapman & Hall, London, 218 pp.

Mitchell, R. M. (1979) The Sciurid rodents (Rodentia: Sciuridae) of Nepal. J. Asian Ecol. 1: 21-28.

Monkkonen, L. P. Reunanen, A. Nikula, and J. Inkeroinen. 1997. Landscape characteristics associated with the occurrence of the flying squirrel *Pteromys volans* in old-growth forests of northern Finland. Ecography 20: 634-642.

Nicholls, A. O. (1989) How to make biological surveys go further with generalized linear models. Biol. Cons. 50: 51-75.

Nowak, R. M. (1991) *Walker's mammals of the world*, 5th ed. John Hopkins Univ. Press, Baltimore, MD, 1: 1-642, 2: 643-1629.

Osborne, P. E., and B. J. Tigar (1992) Interpreting bird atlas data using logistic methods: an example from Lesotho, Southern Africa. J. Appl. Ecol. 29: 55-62.

Romero, J. and R. Real (1996) Macroenvironmental factors as ultimate determinants of distribution of common toad and natterjack toad in the south of Spain. Ecography 19: 305-312.

ter Braak, C. J. F., and C. W. N. Looman (1987) Regression. In *Data analysis in community and landscape ecology*, R. H. G. Jongman, C. J. F. ter Braak, and O. F. R. van Tongeren, eds. Cambridge Univ. Press, Oxford, pp. 29-77.

van Peenen, P. F. D. (1969) *Preliminary identification manual for mammals of South Vietnam*. Smithsonian Institution Press, Washington, D.C., 310 pp.

Wilson, D. E. and A. E. Reeder, ed. (1993) *Mammal species of the world: a taxonomic and geographic reference*, 2nd ed. Smithsonian Institution Press, Washington, D.C., 1206 pp.

Wilson, D. E., F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster, ed. (1996) *Measuring and monitoring biological diversity: standard methods for mammals*. Smithsonian Institution Press, Washington, D.C., 409 pp.

Figure 1

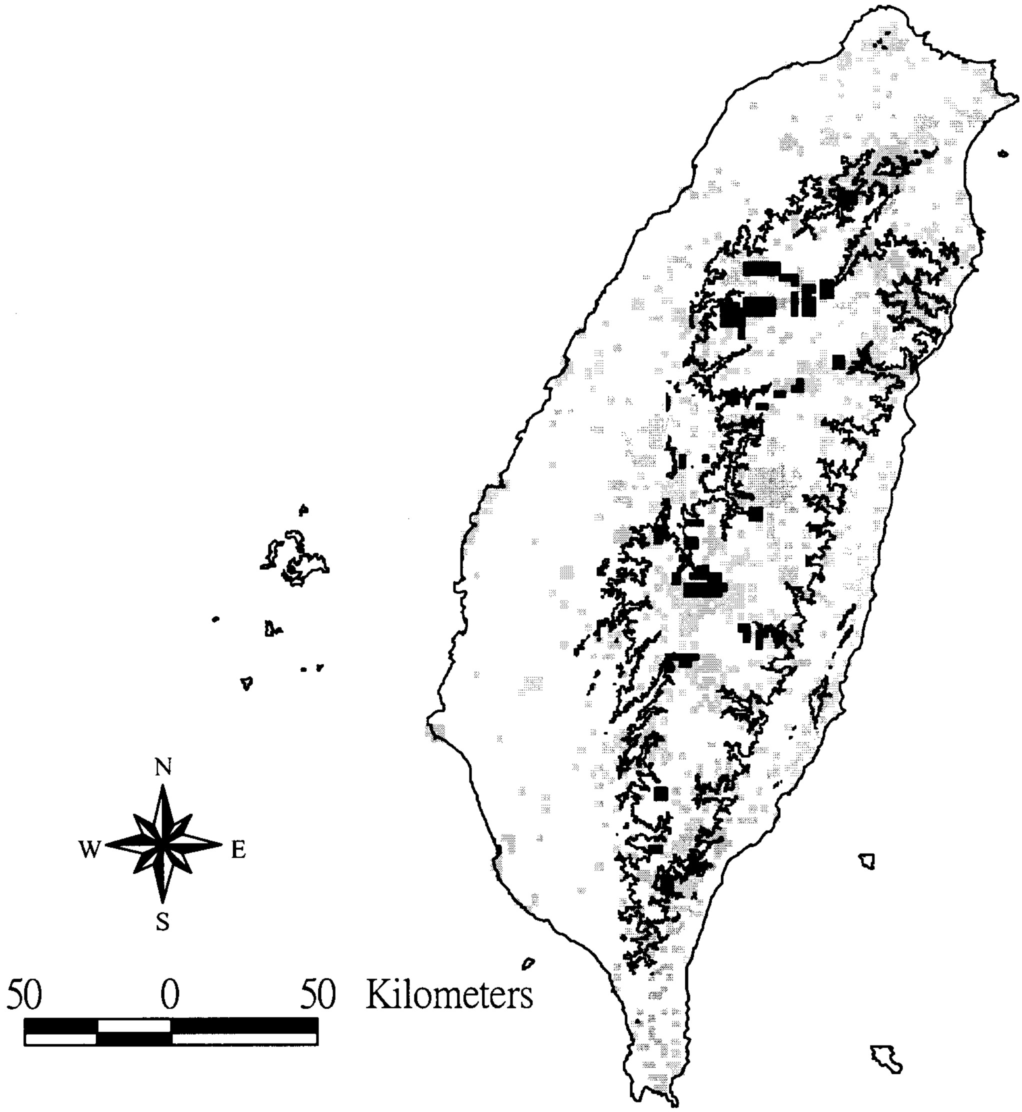

Figure 1. Distribution patterns of the hairy-footed flying squirrel (*Belomys pearsonii*) in Taiwan. Gray portions show areas that were surveyed but had no occurrence record, and black areas indicate the presence of *B. pearsonii*. Blue contour lines correspond to 1000 m in elevation.

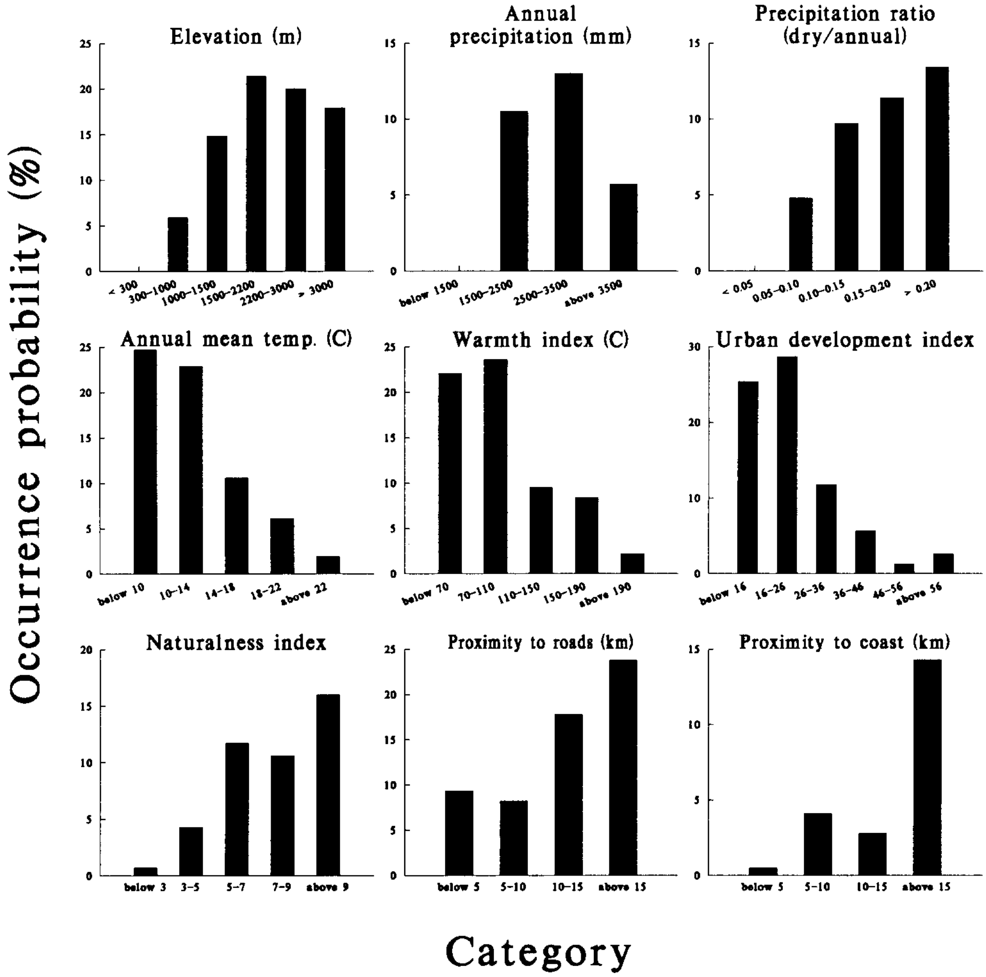

Figure 2. Occurrence probabilities of the hairy-footed flying squirrel (*Belomys pearsonii*) for various types of environmental variables.

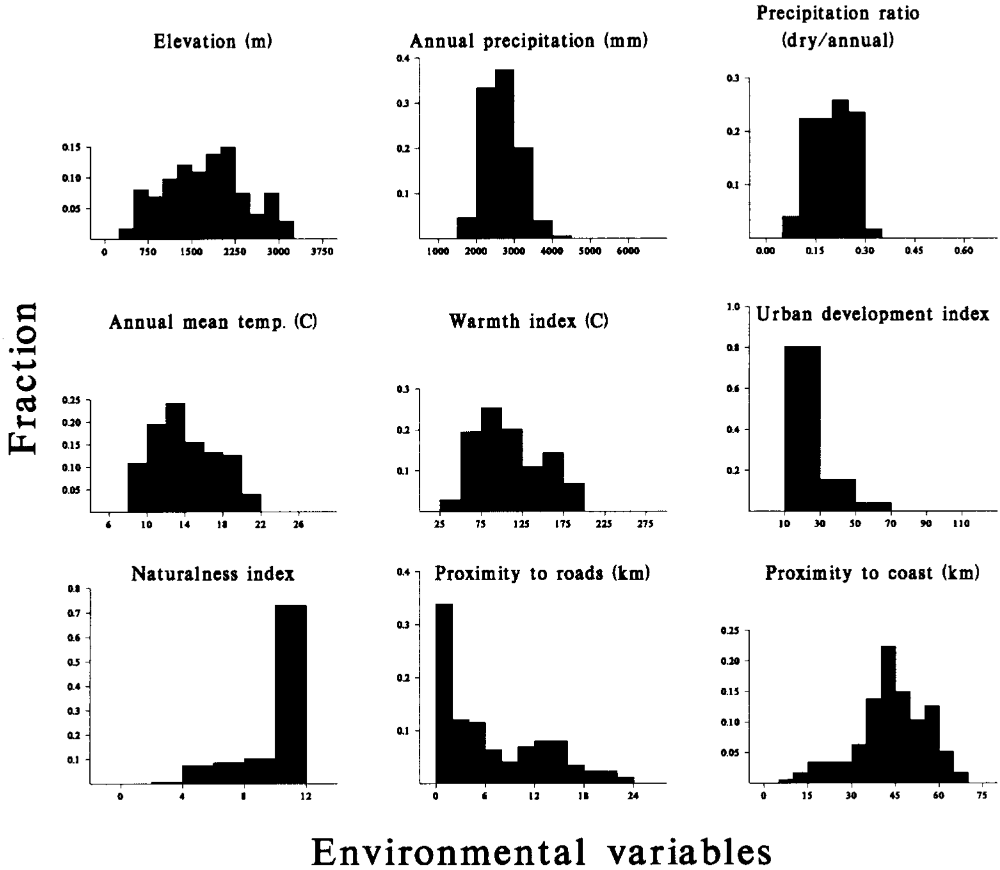

Figure 3. Distribution characteristics of the hairy-footed flying squirrel (*Belomys pearsonii*) in Taiwan by environmental variables. The X-axis in each graph shows the whole range of the environmental variable in Taiwan.

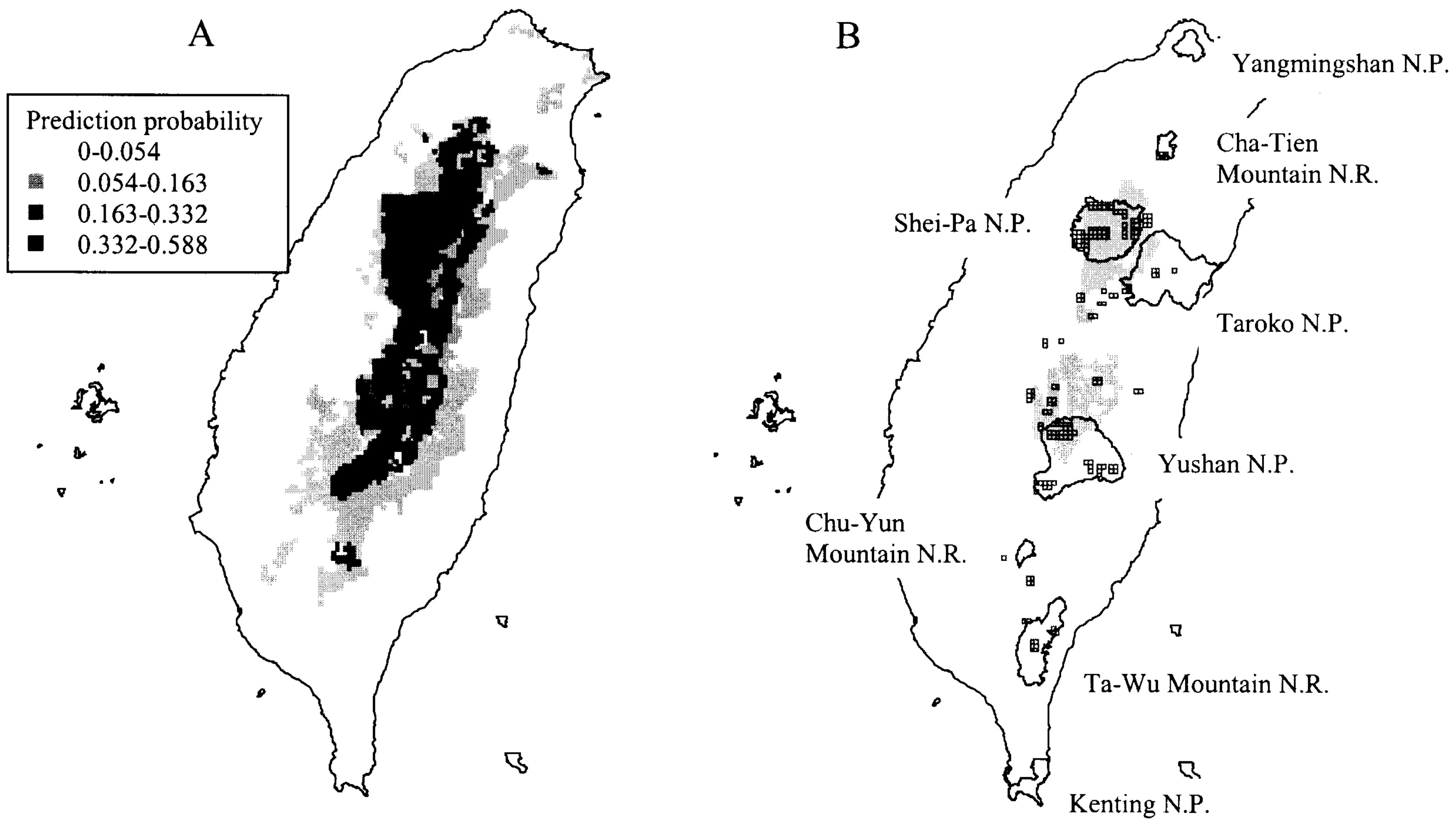

Figure 4. Distribution prediction for the hairy-footed flying squirrel (*Belomys pearsonii*) in Taiwan using a logistic regression model, (a) occurrence probability (by different shadings), (b) predictive presence and absence (gray and white areas, respectively), known distribution (red squares), and location of the five national parks (N.P.) and three large nature reserves (N.R., contours).

Acta Zoologica Taiwanica 8(2):??-?? (1998)

Table 1. Habitat and landscape variables used in the analysis

Environmental variables
Temperature
Annual mean (℃)
January mean (℃) - minimum monthly temperature
July mean (℃) – maximum monthly temperature
Warmth Index (℃)
Precipitation
Annual total (mm)
Total precipitation (mm) in the dry period, October-March
Precipitation ratio of the dry period to annual total
Ecological and topographic factors
Proximity to areas above 3000 m in elevation (km)
Proximity to rivers (km)
Proximity to major roads (km)
Proximity to coast lines (km)
Proximity to major cities (km)
Urban development index
Elevation (m)
Maximum elevation (m) in the grid
Minimum elevation (m) in the grid
Population density (people/ha) as in 1994 survey
Naturalness index
Vegetation cover
Presence of forest cover
Indicator of eastern side in Taiwan

Table 2. Occurrence statistics in the grid cells of three flying squirrel species (*Belomys pearsonii*, *Petaurista petaurista*, and *P. alborufus*) in Taiwan

Presence	Number of grid cells	Percentage
Three species	149	22.4
Only *Belomys pearsonii*	3	0.5
Only *Petaurista petaurista*	107	16.1
Only *P. alborufus*	155	23.3
Belomys pearsonii and *P. petaurista*	12	1.8
Belomys pearsonii and *P. alborufus*	19	2.9
P. petaurista and *P. alborufus*	221	33.2

Table 3. Summary of the final logistic regression model. The data presented are regression coefficients with their standard error.

Variable	Coefficient	Standard error	Wald Chi-square	P^+	Standardized Estimate
Precipitation ratio	8.13	2.13	14.6	***	0.364
Proximity to coast line	0.000032	0.000013	5.7	*	0.312
Urban development index	-0.06	0.01	25.8	***	-0.656
Presence of forest	1.48	0.49	8.9	**	0.330
East side of Taiwan	-0.81	0.39	4.4	*	-0.217
Constant	-3.93	1.06			

[+] Significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Acta Zoologica Taiwanica 8(2):??-?? (1998)

以地理資訊系統探討臺灣地區小鼯鼠(*Belomys pearsonii*)之分布

李培芬

國立臺灣大學動物學系

摘要

本研究利用地理資訊系統探討小鼯鼠(*Belomys pearsonii*)於台灣之分布情形。野外調查於 1981 年 9 月至 1983 年 6 月於台大實驗林溪頭營林區內進行，小鼯鼠全島之分布，則利用彙整發表於 1977～1995 年間之野生動物研究報告，配合生態與環境因子資料庫，進行分析，並以 logistic regression 推估其可能的分布範圍。結果顯示小鼯鼠在溪頭地區之數量甚低，在 20 個月的調查中，僅有 14 次發現紀錄，這些發現均出現於森林內，但出現於針葉人工林之次數遠高於闊葉天然林。小鼯鼠之出現區域，大多與大赤鼯鼠和白面鼯鼠之出現區域重疊，但整體之出現量較少；小鼯鼠之分布與中央山脈之走向一致。利用 logistic regression 之建立之預測模式，顯示此模式僅能正確地預測 48%小鼯鼠之出現，但就預測機率之空間分布而言，則與已知之分布情形類似。有關小鼯鼠之保育工作，建議以更多之資源調查與監測計畫，建立更完善之資訊，以為決策之基礎。

關鍵詞：小鼯鼠、飛鼠、地理資訊系統、動物分布圖