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MAPPING VERTEBRATE BIODIVERSITY IN TAIWAN

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ABSTRACT

The worldwide decrease in biological resources has been the focus of much research. The first step in preserving the diversity is to characterize patterns of species distribution, thus providing the foundation for conservation.

Taiwan was once famous for its abundant wildlife. Due to lack of care, suitable wildlife habitats were destroyed and species either became extinct or were reduced to small ranges. In response, major efforts to study wildlife ecology in Taiwan began in the early 70's and data accumulated rapidly. Wildlife information, however, is sketchy and is in various formats that are unusable unless standardized.

We applied a computerized-database to document the vertebrate biodiversity in Taiwan. The aim of this data bank is promotion of data sharing among researchers, environmental educators, and decision-makers for better conservation of our environment. In the data bank, we included life history characteristics, spatial distribution, and available literature on Taiwan's wildlife. Life history ranges from taxonomic descriptions to macro- and micro-habitat information, as well as multimedia data such as calls and photos of the animals. Currently the data bank includes records on mammal and bird species from approximately 100 publications dating back as far as 1977. Further work will incorporate data on reptile, samphibians, freshwater fishes, and possibly invertebrates.

These data were linked with a relational database system under a GIS (PC Arc/Info). Wildlife distributions were recoded from locality data in published literature into a grid system, then converted into Arc/Info coverages. The grid is either about 700 ha for areas below 1,000 m in elevation or 2,800 ha for areas above 1,000 m. All references pertaining to particular wildlife species were cataloged. Microsoft Foxpro for Windows is used to link these attribute data and PC Arc/Info is the engine to display spatial distribution. Queries can be performed in Foxpro or in Arc/Info. Species richness patterns can be produced by overlaying the distribution maps of species in Arc/Info and the relationship between landscape pattern and biodiversity can be studied. An ecological monitoring system using vertebrates as indicators can be established through the linkage of wildlife habitat models with large-scale remote sensing data such as aerial photos or SPOT satellite images.

Key Words: GIS; Mapping; Taiwan; Wildlife distribution.

Introduction

The worldwide decrease in biological resources has been the focus of much research. Biological diversity is the term used to describe the variety of all living organisms on earth. Three levels have been identified: genetics, species, and ecosystem (Heyer et al., 1994). This paper focuses on biological diversity at the species level.

Taiwan, an island separated from the Chinese mainland by the Taiwan Strait and bordered on the north by the East China Sea, on the east by the Pacific Ocean, and on the south by the South China Sea, is famous for its rich fauna. Taiwan comprises a territory of about 36,000 km^2 and a population of nearly 20 million inhabitants. Approximately 55% of the land is covered by forests. Between sea level and about 2,000 m, tropical and subtropical broad-leaved forests abound. The abundant wildlife comprises about 62 species of mammals, over 400 species of birds, over 90 species of reptiles, 30 species of amphibians, over 140 species of freshwater fishes, and many unidentified invertebrate species (Patel and Lin, 1989). With its rapid economic development at the expense of environmental quality, this high species diversity is challenged by environmental degradation and destruction (Lee et al., 1994). Major efforts to study wildlife ecology in Taiwan began in the early 70's and data accumulated rapidly. Wildlife information, however, is sketchy and is in various formats that are unusable unless standardized.

Understanding the diversity of nature is a fundamental problem of ecological research. Questions such as "What are the patterns of diversity in nature?" are important in scientific studies and management implications. Understanding what regulates diversity is central to guiding strategies for habitat preservation, and for ecological restoration. Characterizing patterns of biodiversity is a critical first step in preserving that diversity, hence providing the foundation for conservation biology (Lubchenco et al., 1991).

A missing management element in Taiwan is a sound information base of the extent and diversity of the flora and fauna (Lee et al., 1992). It is hard to create a constituency for protection of wildlife among competing agenda when data on the status and even existence of that wildlife are sketchy. The creation of a biological inventory program and establishment of a spatial database of wildlife are necessary.

We document a method to map wildlife distribution in Taiwan with records from published literature using a geographic information system (GIS) approach. Specifically, we show the current status of data availability of mammal and bird species, and some initial analyses of these data.

Materials and Methods

A grid cell system (Figure 1 and 2), based on the current orthophoto maps (Council of Agriculture, 1983), was used as a basis for recording species distribution. In this system, a cell is either three minutes of arc square (approximately 2,800 ha, scale 1:10,000, for areas above 1,000 meters in elevation) or one and one-half minutes of arc square (approximately 700 ha, scale 1:5,000, for areas below 1,000 meters in elevation).

The distribution of mammal and bird species across the orthophoto map grid cells was recorded from published references with a GIS approach. Due to the nature of recording sighting data, we were unable to map exact location of wildlife distribution. Using the grid cell approach greatly reduces the difficulty associated with the coding problem. Although some detailed distributional information was lost in this process, we found this method is the best compromise that one can obtain. The reported data of previous references did not allow a specific site identification (i.e., within 100 m of range) of bird and mammal distribution. This is a compromise between precision and data availability. The distribution of species across the grid cell system was coded from published survey (see Yen, 1992 and Lin, 1987 for a recent compilation on bird and mammal bibliography respectively). This distribution database represents definite recordings within cells over a 17-year period (1977-1993). The maps produced will be refined when more detailed habitat information and vegetation data become available. These maps reveal a broad-scale pattern of wildlife distribution.

In order to display wildlife distribution spatially, we transpose the distribution database into a format that can be easily incorporated into PC Arc/Info GIS. A GIS is an integrated part of our system because it provides the analytic base for distribution data. Remote sensing and GIS have revolutionized mapping over the last two decades (National Research Council, 1993). GIS technology has become a necessary tool for wildlife inventory (Heyer et al., 1994).

Results

Current status

We create spatial distribution maps for each bird and mammal species in Taiwan. Our databases include wildlife data between 1977 and 1994 from over 100 published reports. Some areas were surveyed intensively at almost weekly intervals, while others were conducted only once. Over 400 bird and 58 mammal species are included in our system. Figures 1 and 2 show the current status of mammal and bird data. Clearly, these data cover varying geographic areas. Almost 17% of the grid cells (630 of 3,788) have been surveyed for bird data, and about 10% of the cells were covered by mammal data. Geographically, most of the western areas were covered, while the eastern received little attention. Wildlife distribution information is lacking for the higher elevations, except for the five national parks, some nature reserves, recreation areas, and some bird-watching hot-spots.

Certain high diversity areas are evident in these maps (Figures 1 and 2). The hot-spots of wildlife distribution show a cluster pattern. For the bird species, coastal areas have an abundance of migrants and mountainous areas have an abundance of residents. Some of the cells along the coast can have total number of species as high as 200 or more. Data on mammals in coastal areas are sketchy, but it is possible that most of the hot-spots are in higher elevation areas, especially in the range of 1,000 to 3,000 m, where small rodents are abundant.

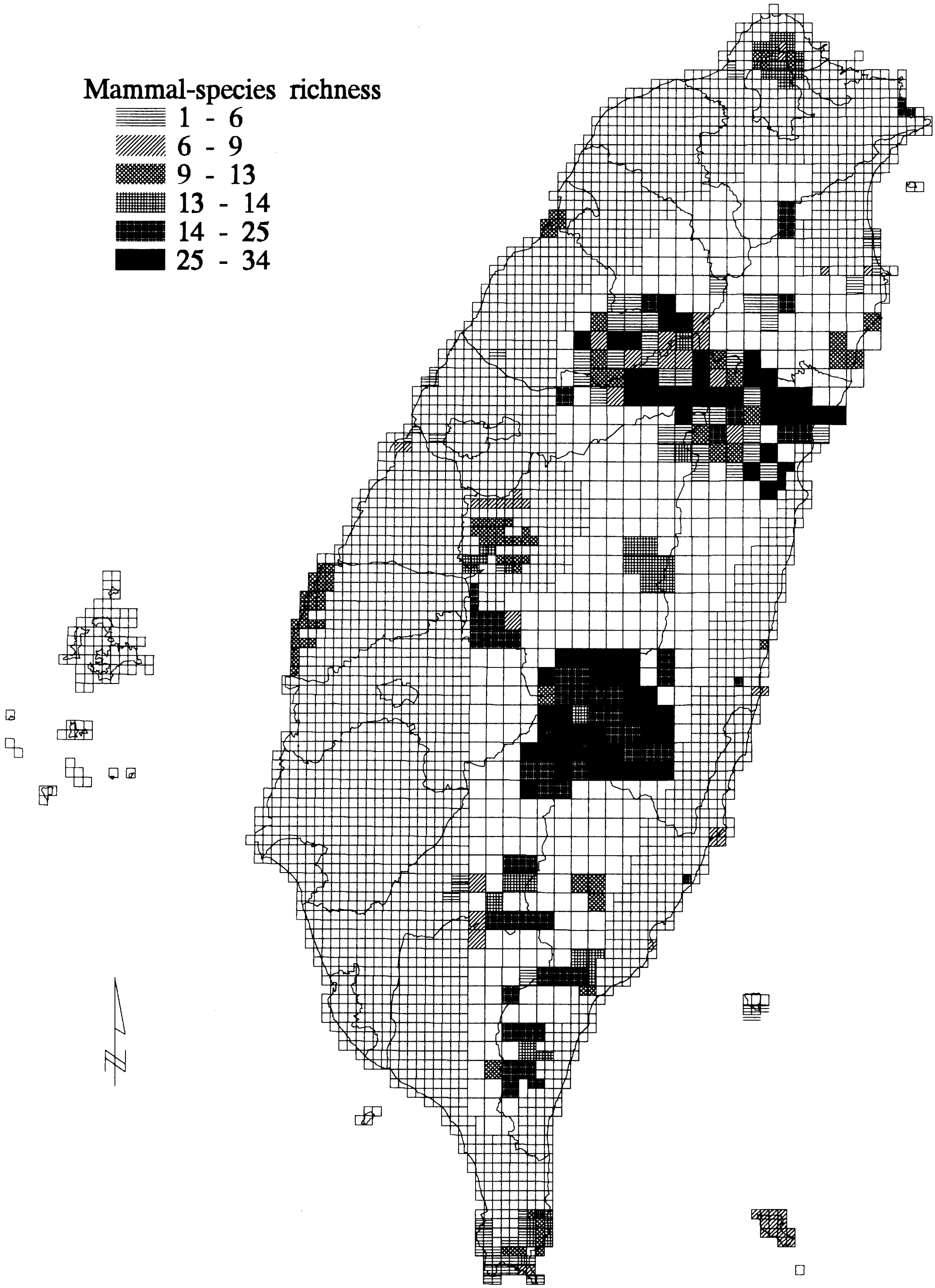

Figure 1. Availability and species richness of mammals in Taiwan based on published inventory references between 1977 and 1993. Distribution data were overlaid with the nature reserve system (national parks, nature reserves, and wildlife protection areas). See text for description of the grid cell system used.

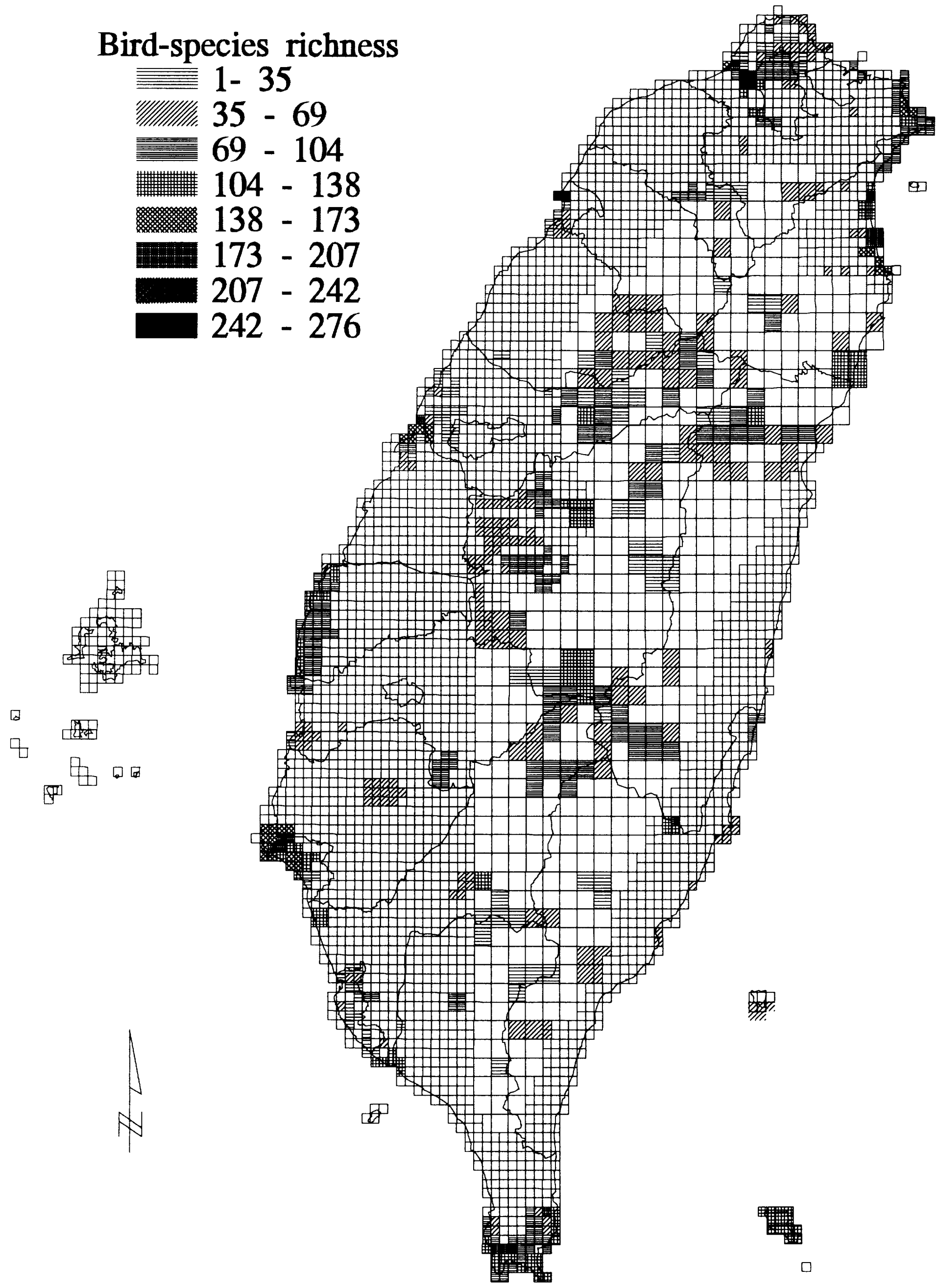

Figure 2. Availability and species richness of birds in Taiwan based on published inventory references between 1977 and 1993.

Nature reserve system versus wildlife distribution

Although wildlife information is very limited for many birds and mammals in Taiwan, the available data on their distribution and abundance nonetheless show some evident trends. These data, coupled with the amphibian and reptile data bank (Lue, 1992), should provide an invaluable source for conservation planning in Taiwan. Figure 3 shows the distribution of a bird species, Swinhoe's blue pheasant (*Lophura swinhoii*), which is endangered in Taiwan. We can see clearly that the current protection system does not cover all of the possible distribution of this species. It is also clear that the distribution of Swinhoe's blue pheasant is not continuous. With the overlay of other factors such as land use pattern, elevation, and vegetation, we can identify the habitat characteristics of this species and the potential barrier to dispersal. Similar analyses of other rare and endangered species can be conducted to reveal detail trends.

Environmental assessment versus wildlife distribution

Data on the distribution of rare and endangered species are readily available from our system. It is easy to generate maps showing the sighting data of certain rare species. With the species richness maps shown in Figures 1 and 2, one can overlay proposed new construction, such as highways, to see how the project influences the local wildlife spatial patterns. Specifically, one can also use maps similar to Figure 3 to determine if the project has adverse impact on the rare and endangered species.

Discussion

Trends for the 21st century

Until recently, most research biologists have ignored the spatial representation issue of wildlife data. Mapping wildlife distributions has become a worldwide trend with the introduction of GIS (National Research Council, 1993; Slater and Noble, 1991; Scott et al., 1993). Many agencies have developed GIS to handle wildlife data. They include the Nature Conservancy (Scott et al., 1993), Australian National Park Service (Slater and Noble, 1991), the World Conservation Monitoring Centre, etc. The newly established National Biological Survey of US also proposed a standard procedure for processing flow in species distribution mapping (National Research Council, 1993). In Taiwan, the National Geographic Information System (NGIS) is proposed, following the initial suggestion by Botkin (1986). Nine databases are expected to be established. The mapping of biological diversity discussed in this paper will fit into the ecological database of NGIS.

The spatial approach can be of great use to scientific research and policy making. Recent findings in Britain showed that species-rich areas are not necessarily the areas for endangered species and that a limited number of areas do not guarantee effective conservation for rare and restricted wildlife (Prendergast et al., 1993). Such findings should become available as soon as we collect more data on other categories of wildlife. Without spatial information, previous surveys are useless in this aspect.

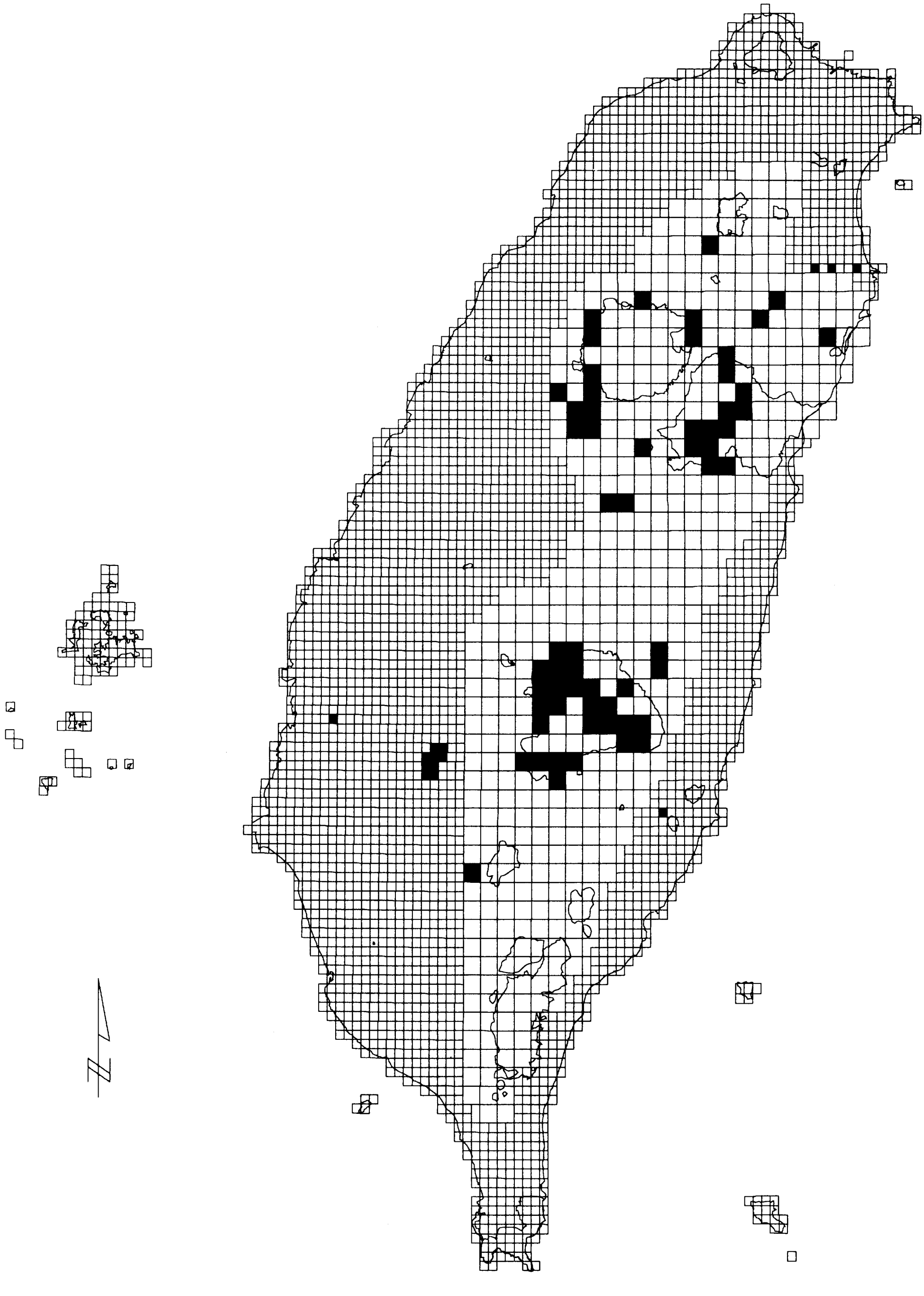

Figure 3. Distribution of Swinhoe's blue pheasant (*Lophura swinhoii*) with reference to the nature reserve system in Taiwan.

Future developments

The results presented above are the initial summary of our database. Many areas remain unknown. Complete inventories of species and their distributions is an impossible dream, even on a small island like Taiwan. The cost in time and money are prohibitive. To fill this gap, wildlife empirical distribution will be extrapolated using several statistical and modeling methods. We expect to enhance our records of wildlife distribution by incorporating species distributions from our data bank (Lee et al., 1994), museum collections, and lists from bird clubs'.

Future developments will include refinements of the wildlife-habitat relationship models by using intensive field data, such as those by Ding (1993). Using rule-based modeling, logistic regression, geostatistics (discussed in next section), and other generalized linear models (Buckland and Elston, 1993; Nicholls, 1989), we will develop better wildlife distribution models to estimate the areas that are not covered by the current survey data. Remote sensing of vegetation using multistage approaches, including SPOT satellite, airborne multispectral scanner (MSS) images, and aerial photos, will be conducted to delineate a complete vegetation distribution map for Taiwan, which can be used as a base map for wildlife prediction (Scott et al., 1993).

With the vegetation cover map of Taiwan from SPOT images, we can relate habitat requirements of wildlife and vegetation map to create better wildlife distributions. With a rule-based model, we overlaid elevation, vegetation map, stream distribution, and wildlife habitat preference in a GIS. Figure 4 shows an example of the potential distribution of Formosan weasel (*Mustela sibirica taivana*) within a grid near Wuling of Shei-Pa National Park using this approach. This method can greatly increase the accuracy of our grid cell system approach by excluding unsuitable habitat areas within the range outline and pinpoint the potential habitats of studied species.

A GIS will be used to store the predicted spatial data and field work will be conducted to check the validity of these predictions. Critical areas of high species richness can be located from the distribution data by overlaying them with a GIS. We will also examine the biogeographic affinities of birds and mammals to seek correlation between wildlife distribution patterns and environmental variables, such as temperature, elevation, rainfall, etc.

Geostatistical analysis to cover no-data areas

Many geostatistical tools are now available for wildlife distribution studies (Rossi et al., 1992). Geostatistics brings novel tools to ecological studies for the interpretation of spatial patterns of wildlife. Formerly used for predicting the location of mines, geostatistics can be used to provide estimates for unrecorded areas of certain wildlife. In addition, we expect to use these methods to extrapolate the wildlife distribution of areas not covered by the current survey.

Summary

Our work reveals only certain aspects of biological diversity in Taiwan. A complete program of biological inventory in Taiwan is needed, not only to catalog and map the major distributions of spe-

Figure 4. A potential distribution (shaded areas) of Formosan weasel (*Mustela sibirica taivana*) in an orthophoto map near Wuling of Shei-Pa National Park. The data were based on the habitat preferences of Formosan weasel, overlayed with elevation (lines) and vegetation cover (polygons).

cies and species association, but also to link the pattern of distribution of species and habitat with natural and anthropogenic processes that affect biological diversity. These data will help when establishing conservation and management programs for rare and endangered species. Compared to other countries, Taiwan is small. With a unique combination of geographic locality, geologic history, and high species diversity, it provides a great opportunity to study the wildlife patterns that is unavailable in other areas.

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