Rapid Assessment of Endemic Bird Areas in Michoacan, Mexico[1]

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Abstract—Non-sustainable land use practices in the state of Michoacan, Mexico, have perturbed endemic bird habitats for several decades. Endemic birds have a restricted geographic and ecological distribution. This feature makes them suitable to be used as indicators of biological diversity and environmental perturbation. Forty-one Mexican endemic species have been recorded in 11 temperate and 3 tropical vegetation types in Michoacan (59,000 km^2). This paper demonstrates the use of a geographic information system to locate and display spatially explicit endemic bird richness areas based on the potential distribution of individual endemic species in Michoacan . Relationships of endemic species with natural vegetation and altitudinal distribution were used as indicators of potential habitat. Low endemic bird richness areas (one to five species) totaled 1,558,417 ha with an almost random distribution throughout the state. Medium richness areas (six to 10 endemic species) summed 1,084,534 ha, most of them distributed in the Sierra Madre del Sur and along the southern escarpment of the Neovolcanic Belt. High richness areas (11 to 16 endemic species) include 1,864,117 ha concentrated in the less disturbed deciduous tropical forests of the Balsas Basin and in the highest coniferous forests of the neovolcanic belt. Conservation efforts must concentrate on these areas. However, areas with low or medium species richness can be of importance for the conservation of individual species and their habitats.

Wildlife species play a critical role in ecosystem functioning and are often indicators of ecosystem health. In Mexico and other Latin American countries, nonsustainable use of forests and rangelands has lead to local disappearances of many endemic and migratory species. Biological diversity in western Mexico is believed to be exceptionally high where a wide variety of vegetation types occurs within a limited geographical area (Ramamoorthy et al. 1993). Continued population declines of plant and animal species, especially those critical in food processing, insect pest control, ecosystem health, and medicine, may not only lead to a reduction in global diversity but also to a decline in health of forested ecosystems.

To maintain biological diversity resource managers need both fine-filtered (local level) and coarse-filtered (state or larger spatial level) information describing vertebrate species occurrences in different vegetation types. By analyzing regional patterns of species endangerment and endemism critical habitats can be identified and conserved. Species-rich habitats at the local level may not contribute greatly to regional biological diversity if these habitats are managed for common species and are unable to support and sustain populations of rare, endemic, or vulnerable species.

Rapid assessment sampling provides information that can be synthesized at different spatial scales to identify areas of high vertebrate species diversity and endemism, and to prioritize habitats in need of increased conservation efforts. Region-wide classification maps based on rapid assessment inventories are highly successful tools for identifying geographically important areas and for monitoring spatial and temporal changes in biological resources.

In the state of Michoacan, located in western Mexico, 492 bird species have been recorded, including 282 terrestrial birds (Villaseñor and Villaseñor 1994). Forty-one of these species are endemic to Mexico (American Ornithologists' Union 1998), and represent 40.6% of 101 species classified by Escalante et al. (1993) as true endemics to the country. All species have distribution limits that can be mapped. These limits are established by obvious factors such as: vegetation, climate, altitude, physical barriers, or soil types. Vegetation is one of the most reliable indicators of animal species distribution and their habitats. Animals respond to actual vegetation, not to the potential for vegetation presence. From a landscape approach, the dominant vegetation cover, represented as a successional phase or a climax community, will determine which animal species are present.

Distribution maps are essentially propositions about the probability of presence or absence of one species in one area. Distribution maps showing individual record localities can be used to predict the presence of a species in the gaps between records if the natural communities of which it is usually a member are present. Thus, mapped areas where no species records have been reported but where the community is similar to that of locality records can be considered potential habitat. To the degree which natural communities are represented by vegetation types, vegetation maps can be used as indicative of a species distribution (Csiuti 1994).

Knowing the distributional limits of a species and its habitat use patterns or associations with particular vegetation types makes it possible to use a geographic information system to create a large-scale or medium-scale distribution map. Because this process is not based solely on localities of specimen records, unexplored regions within the species range that have suitable habitat are included, whereas areas with unsuitable habit are excluded. Depending on the species habitat specificity, the map can be a very refined prediction about the distribution of a species (Scott et al. 1993, Csiuti 1994).

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Endemic species are more sensitive to changes in habitats than widespread species, and their local populations may react negatively to habitat perturbations by declining or going extinct. Because the distributions of endemic species are typically restricted, the species richness and abundance of endemics can be used as indicators of biological diversity status at a regional scale. Levels of avian endemism are positively correlated with levels of endemism of other life forms (Bibby et al. 1993), suggesting that birds may be useful predictors of overall patterns of biological diversity throughout a region.

The objective of this paper is to illustrate how managers can use a geographic information system to locate and demarcate areas of high bird species diversity based on the distribution of potential habitat of endemic birds in the state of Michoacan, Mexico. As indicators of potential habitat we used natural vegetation types with which endemic species are usually associated as well as altitudinal distributions of species.

Methods

Study Area

Michoacan extent is 59,864 km^2. It is the fifth estate in Mexico with the highest bird species diversity (Flores-Villela and Gerez 1989). Two thirds of its territory are still covered by natural vegetation (SARH 1991, SDAF 1995). Altitudes range from sea level to 3,840 meters. There are two great physiographic provinces: the Neovolcanic Belt (temperate-cold climate), and the Sierra Madre del Sur, which includes the Balsas Basin (dry tropical climate) and the coastal area (INEGI 1995). Protected natural areas total six national parks, with a total of 25,000 ha, and one special biosphere reserve (Monarch butterfly reserve, 19,000 ha), all of which are distributed along the Neovolcanic Belt.

Bird Species

Of the 101 endemic species found in Mexico, 41 have been recorded in Michoacan (Villaseñor y Villaseñor 1994). In our study we included only 36 species, excluding extirpated or extinct species, such as the eared trogon (*Euptilotis neoxenus*) and the imperial woodpecker (*Campephilus imperialis*), regional migrants such as the thick-billed parrot (*Rhynchopsitta pachyryncha*), species with only one recorded locality in the estate like the white-fronted swift (*Cypseloides storeri*), and Strickland´s woodpecker (*Picoides stricklandi*) whose distribution is not well understood.

Information Sources

We used field verification as a primary source of information about species distribution by vegetation type, geographic locality, and altitude (e.g., García et al. 1998). To supplement our field surveys, we consulted bird collection data bases at the Facultad de Biologia at Universidad Michoacana de San Nicolas de Hidalgo (curator Laura Villaseñor) and Instituto de Biologia at Universidad Nacional Autonoma de Mexico (curator Patricia Escalante). A third information source was scientific publications reported by Michoacan authors who collected and observed birds from 1935 to the Present. The fourth information source was INEGI cartographic products: (1) land use and vegetation maps (1984, scale 1:500,000) and (2) digital elevation models, 1994.

Verification of Species Distribution

Point counts were used to determine presence and distribution of the species selected (Ralph et al. 1995). Five ten-minute point counts were conducted at a total of 130 sites selected using a stratified sampling scheme (García et al 1995, 1998). The sampling method was designed to sample both common and rare vegetation types and associated bird species. Each point count station was separated by 200 meters. From May to July 1994, 63 sites (315 point counts) were sampled. During the same months of 1995, 67 additional sites (335 point counts) were sampled.

Vegetation Map Verification

The INEGI land use and vegetation base map were verified at the micro scale (within a sampling site or particular vegetation type) and at the macro scale (among vegetation types or landscapes). In the first case, vegetation vertical structure and floristic composition were measured at the five point count stations of each sampling site (see Ralph et al. 1993 for methodology). More details are found in García et al. (1995, 1998). At the macro scale, black-and-white photographs (scale 1:25,000, 1990 and 1992), and a INEGI space-map (Espaciomapa MORELIA E-14-1, scale 1:250,000, generated from a 1993 Landsat TM image) were used to verify and update the vegetation map.

Processes to Generate Digital Maps

Data obtained from the sources specified above were grouped to form six sets of information used to generate predictive maps of the distribution of endemic bird species and species richness areas with a geographic information system:

1) A digitized map of vegetation types.
2) A digitized map of geographic entities (municipalities).
3) A digitized map of altitude ranges.
4) A data base assigning species presence or absence to each municipality.
5) A data base associating each species with vegetation types, and
6) A data base associating each species with altitude ranges.

All maps were digitized and processed with PC ARC/INFO ver. 3.5 and ArcView GIS ver. 3.1a. The altitude range map was generated from INEGI digital elevation models processed with IDRISI ver. 4.1.

Accuracy of the Digital Vegetation Map

To evaluate how closely the digital vegetation map corresponded to field-verified data, it was overlapped with a GPS sample-point digital map. Only 39% of the 1995 GPS points corresponded with the vegetation types assigned to each intersected polygon. The 1994 GPS coincided with 57.8% of intersected polygons. In both years 49.2% of GPS points coincided with their corresponding vegetation polygons. Field verification of vegetation was clearly valuable for improving accuracy of vegetation cover maps.

Procedure to Model Species Distributions and Endemic Species Richness Areas:

1. Generation of a Composite Digital Map.

The digital vegetation map, altitude map, and municipalities map were overlapped to generate a composite map. The resulting digital map contained 28,434 polygons, each one assigned to a vegetation type, an altitude range, and a municipality.

2. Attribute Allocation.

Using an automatic procedure each species was assigned to each polygon as an individual attribute.

3. Species Presence/Absence Assignation.

Two relational data bases are required: one to indicate associations among species and vegetation types, and another one to indicate their altitudinal distribution. The data bases format is a matrix with the species arranged as rows, and vegetation types or altitudinal ranges arranged as columns. Using the four information sources, we filled in matrices with "0"s to indicate species absence and "1"s to indicate presence (Table 1). Polygons in the composite map were coded interactively according to features defining each species distribution.

The result was a single composite digital map with each attribute being a bird species linked to each polygon. This

Table 1.—Distribution of endemic bird species by general vegetation types in the estate of Michoacan, Mexico. Secondary and primary successional phases are lumped together. Cells are filled with "1" to indicate presence, an "0" to indicate absence. Common English names and scientific names follow the AOU (1998) classification.

Species	Vegetation Types[1]											
	1	2	3	4	5	6	7	8	9	10	11	12
West Mexican Chachalaca (*Ortalis poliocephala*)	1	1	1	0	0	0	0	0	0	0	0	0
Long-tailed Wood-partridge (*Dendrortyx maccroura*)	0	0	0	1	1	1	1	1	0	0	0	0
Banded Quail (*Philortyx fasciatus*)	0	1	0	0	0	0	0	0	0	0	0	0
Lilac-crowned Parrot (*Amazona finschi*)	1	1	0	0	0	0	0	0	0	0	0	0
Balsas Screech-owl (*Otus seductus*)	0	1	1	0	0	0	0	0	0	0	0	0
Dusky Hummingbird (*Cynanthus sordidus*)	0	1	1	0	0	0	0	0	0	0	0	0
Bumblebee Hummingbird (*Atthis heloisa*)	0	0	0	1	0	0	1	1	0	0	0	0
Citreoline Trogon (*Trogon citreolus*)	0	1	1	0	0	0	0	0	0	0	0	0
Gray-crowned Woodpecker (*Piculus auricularis*)	1	1	0	0	0	0	0	1	0	0	0	0
Golden-checked Woodpecker (*Melanerpes chrysogenys*)	1	1	0	0	0	0	0	0	0	0	0	0
White-striped Woodcreeper (*Lepidocolaptes leucogaster*)	0	0	0	1	1	1	1	1	1	0	0	0
Flammulated Flycatcher (*Deltarhynchus flammulatus*)	0	1	1	0	0	0	0	0	0	0	0	0
Pileated Flycatcher (*Xenotriccus mexicnus*)	0	0	1	0	0	0	0	0	0	1	0	0
Pine Flycatcher (*Empidonax affinis*)	0	0	0	0	1	0	1	1	0	0	0	0
Gray-barred Wren (*Camylorhynchus megalopterus*)	0	0	0	1	1	0	1	1	1	1	0	0
Spotted Wren (*Camylorhynchus gularis*)	0	0	0	0	0	0	1	1	1	1	0	0
Sinaloa Wren (*Thryothorus sinaloa*)	1	1	1	0	0	0	0	0	0	0	0	0
Happy Wren (*Thryothorus felix*)	1	1	1	0	0	0	0	0	0	0	0	0
Blue Mockingbird (*Melanotis caerulescens*)	0	0	0	1	0	1	1	1	1	0	0	0
Rufous-backed Robin (*Turdus rufopalliatus*)	1	1	1	0	1	0	0	1	1	1	0	0
Golden Vireo (*Vireo hypochryseus*)	1	1	1	0	0	0	0	0	0	0	0	0
Dwarf Vireo (*Vireo nelsoni*)	0	0	0	0	0	0	1	1	1	1	1	0
Red Warbler (*Ergaticus ruber*)	0	0	0	1	1	0	1	1	0	1	0	0
Black-polled Yellowthroat (*Geothlypis speciosa*)	0	0	0	0	0	0	0	0	0	0	0	1
Red-headed Tanager (*Piranga erithrocephala*)	0	0	0	1	0	0	0	1	0	0	0	0
Green-striped Brush -finch (*Buarremon virenticeps*)	0	0	0	1	1	1	0	1	0	0	0	0
Rufous-capped Brush-finch (*Atlapetes pileatus*)	0	0	0	1	0	0	1	1	1	1	0	0
Rusty-crowned Ground-sparrow (*Melozone kieneri*)	0	0	0	0	0	0	1	0	1	1	1	0
Black-chested Sparrow (*Aimophila humeralis*)	0	1	1	0	0	0	0	0	0	0	0	0
Red-breasted Chat (*Granatellus venustus*)	1	1	1	0	0	0	0	0	0	0	0	0
Orange-breasted Bunting (*Passerina lechlanlerii*)	1	1	1	0	0	0	0	0	0	0	0	0
Collared Towhee (*Pipilo ocai*)	0	0	0	1	1	1	1	1	0	0	0	0
Striped Sparrow (*Oriturus superciliosus*)	0	0	0	0	0	0	1	0	0	0	0	0
Yellow-winged Cacique (*Cacicus melanicterus*)	1	1	0	0	0	0	0	0	0	0	0	0
San Blas Jay (*Cyanocorax sanblasianus*)	1	1	0	0	0	0	0	0	0	0	0	0
Russet Nightingale-trush (*Catharus occidentalis*)	0	0	0	1	1	1	1	1	1	1	0	0
Total	12	18	13	11	9	6	14	16	9	9	2	1

1.- Vegetation codes: 1.- Medium tropical subdeciduous forest; 2.- Low tropical deciduous forest; 3.- Low tropical thorn forest; 4.- Mesophylous montane forest; 5.- Fir forest; 6.- Fir-pine forest; 7.- Pine forest; 8.- Pine-oak forest; 9.- Oak-pine forest; 10.- Oak forest; 11.- Subtropical scrub; 12.- Highland marsh procedure avoided the creation of several separated maps, one for each species. Using the geographic information system the modeled distribution of each species can be displayed individually or used in tabular format. Moreover, adding new attributes to the composite map in any desired combination of species can be used to determine species richness in each polygon. Although this approach works well for common species, it tends to overestimate the distributions of rare species or those with highly fragmented distributions which are more difficult to predict. In these cases is more useful to use points to indicate individual records.

4. Estimation of Species Richness for Each Polygon.

This procedure is relatively simple. Species richness (i.e., number of species) for each polygon was calculated adding all values of "1" for each species present in the polygon. The resulting value was assigned as an attribute.

5. Cartographic Output.

An endemic bird areas map was composed and produced using ArcView GIS. This map depicts richness areas from 1 to 16 species.

Table 2.—Enemic bird species richness values (numbers of species) in 15 undisturbed vegetation types in the state of Michoacan, Mexico. Secondary successional phases are not included.

Vegetation Type	Richness
Low tropical deciduous forest	16
Pine-oak forest	14
Pine forest	12
Medium tropical subdeciduous forest	12
Thorn tropical forest	11
Mesophylous montane forest	11
Fir forest	8
Oak-pine forest	8
Oak forest	6
Fir-pine forest	5
Subtropical scrub	2
Highland marsh	1
Grassland	1
Chaparral	0
Halophylous vegetation	0

Results

Extent of area occupied by each vegetation type and land use category was calculated directly from maps. Areas devoid of natural vegetation (agriculture, water bodies and urban areas) occupied a third of the state surface (29%). The remaining 71% of Michoacan was covered by 14 vegetation types and their different successional stages. The non-disturbed pine-oak forest had the greatest extent (700,986 ha), followed by non-disturbed low deciduous tropical forest (679,453 ha). Our results are based on the assumption that avian species richness in Michoacan is proportional to vegetation availability or extent.

Endemic bird species richness values within each polygon varied from a minimum of 1 species to a maximum of 16 species (Table 2). As indicated above, vegetation types having greater extent showed highest species richness values. The non-disturbed low deciduous tropical forest had highest richness of endemic species (16 species), followed by non-disturbed pine-oak forest (14 species) and pine forest (12 species). Exceptions to this pattern were vegetation types with a small extent in Michoacan: the mesophylous montane forest ("cloud forest") with 8,127 ha and a richness of 11 species, and the medium deciduous tropical forest with 12 species.

Conclusions

Prediction of species presence at the stand scale (a few hectares) is subject to natural patterns of environmental heterogeneity (Csuti 1994). The methods outlined in this paper are better suited to predicting species occurrences in general vegetation types at the landscape level (Morrison et al. 1998).

The areas with the highest values of endemic bird species richness were located in two main regions: the pine-oak forests of the southern escarpment and the Purepecha Range in the Neovolcanic Belt, and the tropical deciduous forests of the Balsas Basin in the municipalities of Arteaga and Tumbiscatio. Calculating mean endemic species richness by vegetation type at a specific locality rather than throughout the extent of the type, however, would produce a higher value in mesophylous montane forest than in low deciduous tropical forest and pine or pine-oak forests (e.g., García 1998). In other words, the influence of forest extent on species richness values must be compensated for when prioritizing conservation areas. We recommend that areas of high biological diversity identified in this paper become the focus of major conservation efforts and also be identified as potentially sensitive to human perturbation caused by land use changes. However, areas with low values of species richness can be critical to breeding and survivorship of endangered individual species, such as the black-polled yellowthroat (*Geothlypis speciosa*), found only in highland marshes in central Mexico, which showed a richness value of 1 (Table 1). Such areas must also be protected because each endangered species contributes to regional biological diversity even though local diversity of the area used by the endangered species may be low.

Finally, it should be noted that predictions of potential bird species distributions and species richness areas are not an end, but rather are the first steps toward prioritizing areas requiring more intensive studies, surveys, and conservation efforts.

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