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ASSESSING CONSERVATION PRIORITIES IN MEGADIVERSE MEXICO: MAMMALIAN DIVERSITY, ENDEMICITY, AND ENDANGERMENT

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Abstract. The identification of areas of high priority for conservation is becoming a major endeavor for conservation biologists. Regions of high species richness and high concentrations of endemic and endangered species have been considered a priority for conservation. In this paper we use information about the species richness, composition, and distribution of mammals from Mexico for selecting priority areas for conservation. All species of terrestrial mammals were characterized by geographic range size, body mass, and conservation status, and their distributions were overlaid on a $2° \times 2°$ grid to detect areas of high concentrations of species richness, endemicity, and endangered species. We focused our analyses at both species and biogeographic levels.

At the species level we examined differences among endangered, endemic, and non-endemic species in ecological characteristics correlated with vulnerability to extinction. There were significant differences between endangered and non-endangered species, and between endemic and non-endemic mammals in body size and geographic range size. At the biogeographic level simple correlation analyses were carried out to determine the relation between latitude, total species richness, number of endemic species, and number of endangered species. We found a very low correspondence among areas of high diversity, high endemicity, or high number of endangered species. The distribution of many species with restricted geographic ranges, including endemic and non-endemic species, did not coincide with areas of high species richness, endemicity, or endangerment.

We suggest a conservation strategy that gives priority to areas of high concentration of endangered species and of non-endangered species with restricted distributions. Among endangered species a higher priority should be given to endemic taxa vs. non-endemic species, and to restricted species over widespread taxa in these two groups.

Key words: biological diversity; conservation of mammalian diversity; distribution patterns; endangerment; endemicity; Mexican mammals; rarity and conservation priorities; species distribution trends.

Introduction

One of the major global environmental problems is the loss of biological diversity as a result of human activities. Extinction rates have sharply increased in recent decades, so conservation efforts have broadened in emphasis, moving from single species to also focusing on whole habitats and ecosystems, as a way of maximizing the number of protected species, and of maintaining the structure and function of biological systems (Margules et al. 1988, WCMC 1992, Dobson et al. 1997). In a wide range of organisms, including birds and mammals, the risk of extinction increases with increasing body mass and specialization, and decreasing geographic range and population density (Terborgh and Winter 1980, Rabinowitz 1981, Lawton 1993, Brown 1995). In mammals, rare species tend to be of high body mass, high specialization, low population density, and/or restricted geographic range. Given their restricted geographic ranges, endemic species are generally considered more prone to extinction than widespread species (Rabinowitz 1981, WCMC 1992). Ecological and biogeographical patterns of species distribution have been used to determine priorities at global, national, and regional scales (ICBP 1992, WCMC 1992, Sisk et al. 1994, Ceballos and Brown 1995, Caldecott et al. 1996). Areas with high priority for conservation have been selected because of their species diversity, habitat heterogeneity, and ecosystem processes, among other factors (Noss and Harris 1986, Myers 1988, McNelly et al. 1990, Franklin 1993).

Specifically, an important trend in determining conservation priorities has been to identify regions with both high species richness and high concentrations of endemic and endangered species. A low correspondence among areas with high diversity and high concentration of endemic species has frequently been found, however (Prendergast et al. 1994, Kershaw et al. 1995). Few studies have evaluated the correspondence between areas of either high diversity or endemicity, and areas with high concentrations of endangered species (Woinarski and Braithwhite 1990, Ceballos and Rodríguez 1993, Rodríguez and Rojas-Suárez 1996, Dobson et al. 1997). We focus on Mexico as a case

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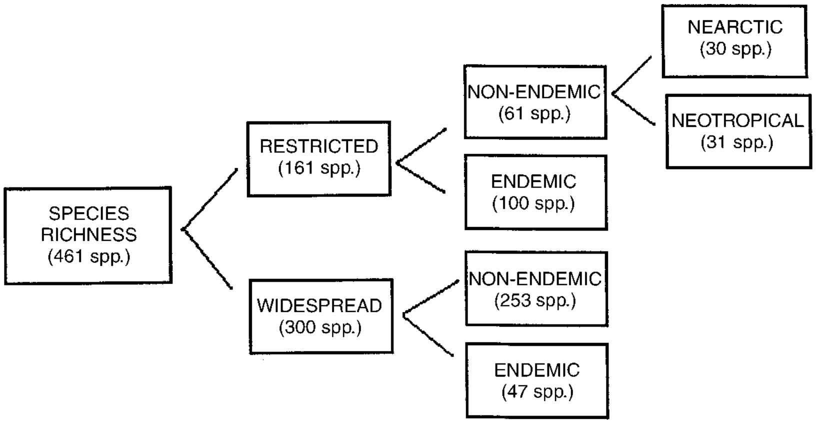

FIG. 1. Classification of the mammal species from Mexico according to their geographic distribution. "Restricted" species occupied <50 000 km^2.

study for these issues. It is considered a megadiverse country because estimates indicate that it maintains ~10% of all living organisms on earth (Mittermeier 1988, Toledo 1988, Dirzo and Sarukhán 1992). Its mammalian fauna ranks second in species richness at a global level, and ~32% of all its mammals are endemics. Additionally, geographic trends in alpha diversity (Ceballos and Navarro 1991, Fa and Morales 1993, Ramírez-Pulido and Castro-Campillo 1993, Arita et al. 1997), beta diversity (Rodríguez 1997), and endemicity (Ramírez-Pulido and Mudespacher 1987, Ceballos and Rodríguez 1993) are well established. Finally, a large number of species are at risk of extinction—either globally, i.e. facing total extinction, or locally, i.e. facing eradication from Mexico. In this paper we analyze information on species richness, endemism, and endangerment of the mammals from Mexico, to determine species distribution trends for selecting priority areas for conservation. We focused our analyses at the species and biogeographic levels to evaluate two important issues in ecology and conservation: (1) the similarities in ecological characteristics between endangered and non-endangered species, and endemic and widespread species, and (2) the degree of correspondence among areas of high diversity, high endemicity, and high number of endangered species. We consider the implications of our results for the conservation of the mammalian diversity of Mexico.

METHODS

The composition and number of species of terrestrial mammals (i.e., excluding marine species) from Mexico was based on the checklists of Wilson and Reeder (1993) and Arita and Ceballos (1997). Each species was characterized by its geographic range size, body mass, and conservation status. Geographic ranges were calculated by digitizing maps from Hall (1981), which were modified according to published literature from 1981 to 1993; they do not reflect recent changes in geographic range due to human activities. Species were classified as "restricted" (with a distribution <50 000 km^2) or "widespread," considering only their geographic range in Mexico; therefore, for all non-endemic species the classification does not reflect their total geographic range (Fig. 1). Restricted species were then either classed as non-endemic or endemic to Mexico; finally, non-endemic species were then classified as Nearctic or Neotropical, if their geographic distribution reaches its northern or southern limit in Mexico, respectively. Widespread species included also both endemic and non-endemic species. Body masses were obtained from Eisenberg (1981) and Ceballos and Rodríguez (1993). The list of endangered species included all species classified as vulnerable, endangered, critically endangered, or recently extinct (Ceballos and Navarro 1991, SEDESOL 1994). Briefly, a qualitative description of these categories, following IUCN (Baillie and Groombridge 1996), is as follows: a *vulnerable* species is facing a very high risk of extinction in the wild in the medium-term future; an *endangered* species is facing a very high risk of extinction in the wild in the near future; finally, a *critically endangered* species faces an extremely high risk of extinction in the wild in the immediate future.

Data analysis and hypotheses

To detect areas of high concentrations of species richness, endemicity, and endangered species, distribution maps of terrestrial species were overlaid on a grid of 2° × 2° (latitude and longitude) quadrants. The occurrence of all species in a quadrat was recorded. Simple correlation analyses were carried out to determine the relation between latitude, total species richness, number of endemic species, and number of endangered species. Quadrats occupied by <15% of Mexico's territory were excluded from the analysis. We tested three major conservation-related hypotheses. At the species level, we tested the hypothesis that both endangered and endemic species were non-random samples of the total number of species in terms of ecological traits (i.e., body mass

TABLE 1. Species richness, endemicity, and species at risk in the orders of land mammals from Mexico. Species at risk include only critically endangered, endangered, and vulnerable species.

Orders	Species richness	Endemic species	Species at risk
Didelphimorphia	8	1	2
Insectivora	23	11	5
Chiroptera	137	15	8
Lagomorpha	14	7	3
Rodentia	228	110	51
Xenarthra	4	0	2
Primates	3	0	3
Carnivora†	33	3	17
Artiodactyla	10	0	4
Perissodactyla	1	0	1
Total	461	147	96

† Excludes marine (pinniped) species.

and geographic range) that are correlated to extinction vulnerability. We specifically predicted that endangered species, including both endemic and non-endemic species, would be of higher body mass and smaller geographic range sizes than non-endangered species. At a biogeographic level our hypothesis were the following: (a) there would be a low correspondence between areas of high diversity and high endemicity, and (b) there would be a high correspondence in the patterns of species distribution between the total number of species and endangered species, but a low correspondence between endemic and endangered species. Finally, we used our results to assess conservation priorities at species and regional levels.

RESULTS

Species richness, endemicity, and endangered species

The contemporary mammalian fauna of Mexico includes 461 land species and 43 marine species. Rodents comprised the most diverse order, followed by bats, carnivores, insectivores, and other orders (Table 1). Endemism of mammals from Mexico is high at the species level and low at the generic level: there were 147 (32%) endemic species and 11 (7%) endemic genera (Table 1). Most endemic species were rodents (110, 75%), followed by bats, and insectivores. The contribution of endemic species to the species richness in three orders—rodents, lagomorphs, and insectivores—was high (>40%), while in the others it was comparatively low (<13%). At least 96 species, representing 21% of all land mammals, were endangered (Table 1). Additionally, eight species from three orders have disappeared from Mexico in recent times. Five extinct rodents represent global extinctions because they were endemic to Mexico. Rodents and carnivores had the higher number of endangered species. When considering the proportion of species at risk from the order's total, however, higher percentages were found in orders with few species (e.g., Perissodactyla and Primates). Among the endemic genera, five of the monotypic ones (*Megasorex, Musonycteris, Romerolagus, Zygogeomys,* and *Xenomys*) were at risk. Some species in three additional genera (*Megadontomys, Nelsonia,* and *Pappogeomys*) were considered either vulnerable or fragile. The rest (*Hodomys, Neotomodon,* and *Osgoodomys*) were, apparently, relatively common.

TABLE 2. Geographic range size and body mass of the mammals from Mexico. Comparisons among groups of species include endemic and non-endemic species, restricted and widespread species, and endangered and non-endangered species.

Group	*N*	Average geographic range size (km^2)	Average body mass (g)
All species			
Endemic species	147	64 561	287
Non-endemic species	314	427 183	9393
Total	461	428 407	9404
Restricted species			
Endemic species	100	8463	235
Non-endemic species	61	11 461	9270
Total	161	10 090	624
Widespread species			
Endemic species	47	181 843	262
Non-endemic species	253	525 187	11 465
Total	300	474 732	11 149
Endangered species			
Endemic species	49	9495	411
Non-endemic species	47	325 365	32 701
Total	96	159 199	24 734
Non-endangered species			
Endemic species	98	117 659	220
Non-endemic species	267	485 199	2256
Total	365	397 812	1764

Geographic range sizes and body masses

Our results showed that there were significant differences among endangered, endemic, and non-endemic mammals in all the ecological characteristics evaluated. Both endemic and endangered species were nonrandom subsets of the total number of species. As expected, both endemic and non-endemic endangered species, had smaller geographic ranges and larger body masses than taxa at low risk (Table 2).

Body mass.—The frequency distribution of body masses for all mammals was highly skewed (Fig. 2); the average body mass was 9404 ± 40 777 g (mean ± 1 SD). Most species (66%) had small body masses (<100 g), and include insectivores, bats, marsupials, and rodents. A smaller number of species (27%) had intermediate body masses (101 g to 10 kg); this category was represented by carnivores, lagomorphs, edentates, primates, and rodents. Finally, large-bodied species (>10 kg) were represented by only 31 (7%) species, including perissodactyls, artiodactyles, and carnivores.

Endangered species had a significantly larger body mass than non-endangered taxa; non-endemic endan-

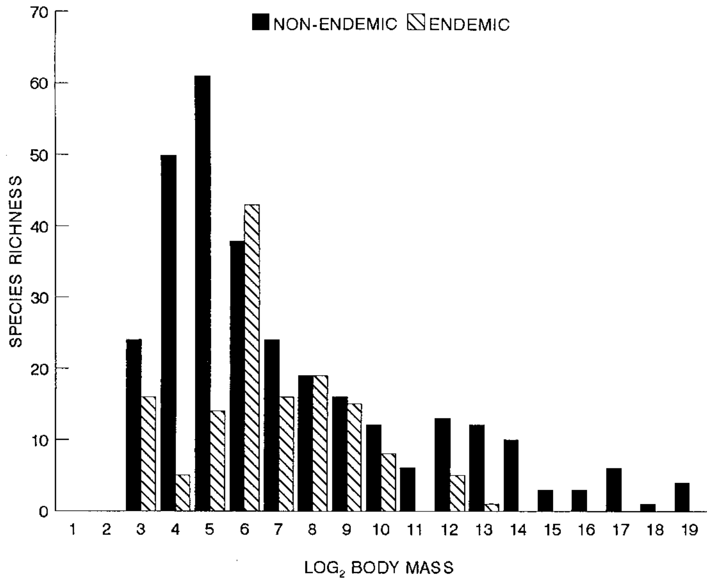

FIG. 2. Frequency distribution of body masses (in grams) for endemic and non-endemic mammals of Mexico (all mammals = sum of both columns).

gered species, however, showed the largest values within these groups (Table 2). Similarly, endemic species were significantly smaller than non-endemic species ($t = 2.78$, $P < 0.006$), and their average body mass was two orders of magnitude lower (Fig. 2, Table 2).

Geographic range sizes.—There were significant differences in geographic range size and percentage of restricted species between endemic and non-endemic species (Fig. 3; Table 2). The average range size of all the mammals from Mexico was 428 407 km^2, and the frequency distribution of such ranges was strongly skewed, because most species had relatively small ranges (Fig. 3).

The average range size was an order of magnitude larger in non-endemic species (Table 2), and the difference was statistically significant ($t = 8.570$, $P < 0.0001$), even though the ranges of those species are underestimated because only their distribution in Mexico is considered. Most non-endemic species had widespread distributions, and a few like the mountain lion (*Puma concolor*) were distributed throughout the country. Of these species only 61 (20%) both Nearctic and Neotropical species had restricted distributions (<50 000 km^2); a few, including *Microtus pennsylvanicus*, had geographic ranges <10 km^2. In contrast, 90% of endemic species had restricted ranges, equivalent to or smaller than 20% of the territory of Mexico (Fig. 3). At least 23 and 51% of such species occupied areas <100 km^2 and 10 000 km^2, respectively. Species known only from the type locality (e.g., *Orthogeomys lanius*

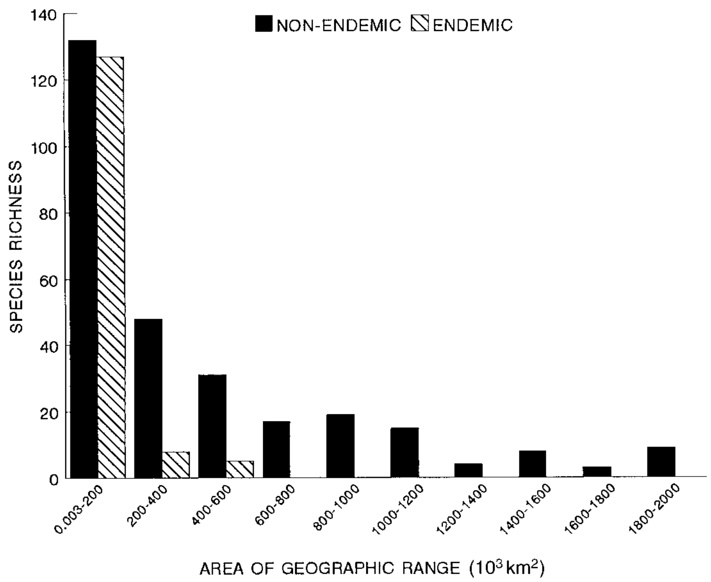

FIG. 3. Frequency distribution of areas of geographic range for endemic and non-endemic mammals of Mexico.

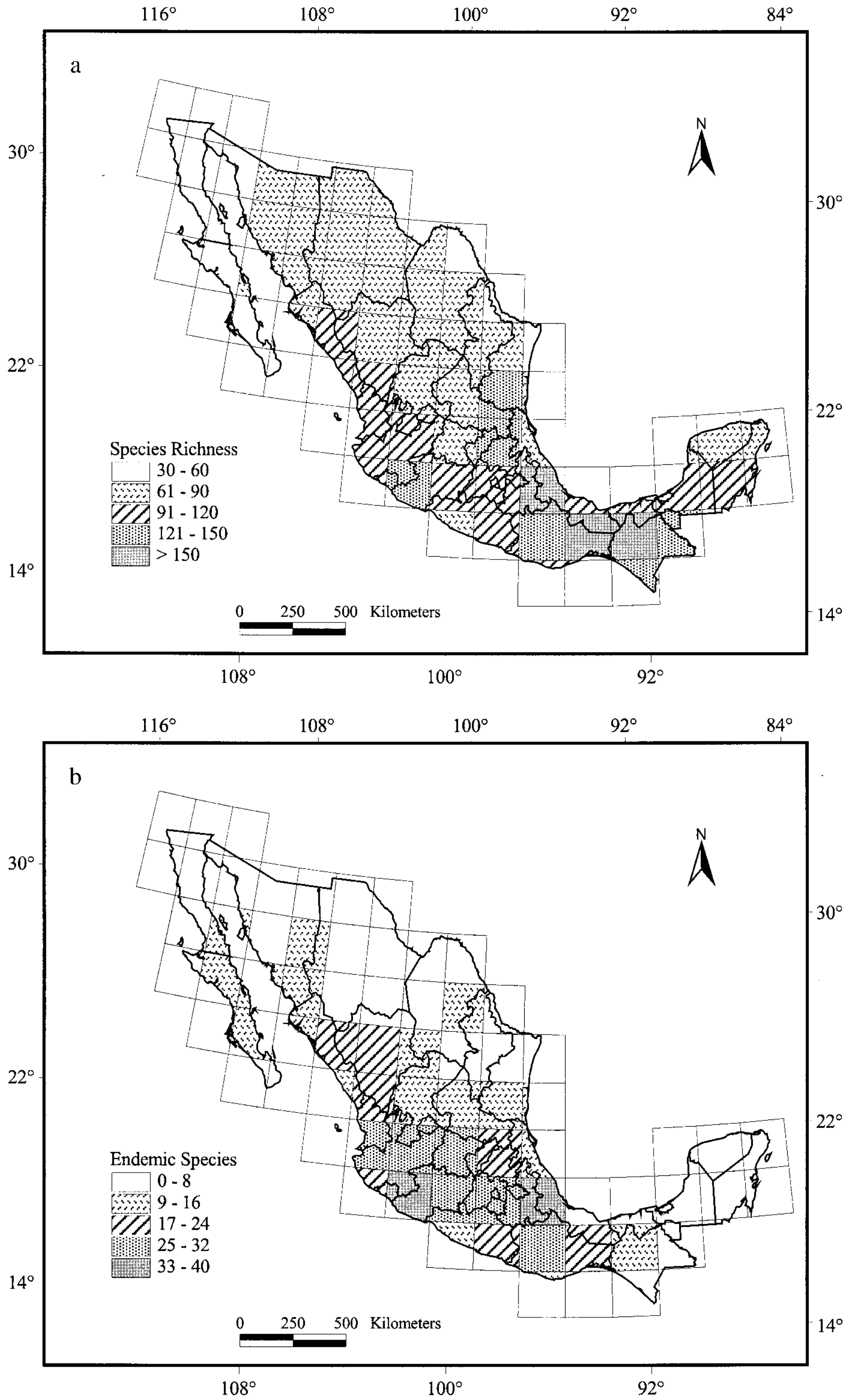

FIG. 4. Latitudinal trends of (a) species richness, (b) endemic species, and (c) endangered species in Mexico.

and *Tylomys tumbalensis*) and from some islands off Baja California Peninsula (e.g., *Peromyscus guardia*) had the most restricted distributions.

The average geographic range size of endangered species was much smaller than the one for non-endangered species (Table 2). The endangered taxa had smaller geographic ranges than species at low risk in both endemic and non-endemic groups, but the differences were stronger in endemic taxa. Endangered endemic species had, on average, geographic ranges 36

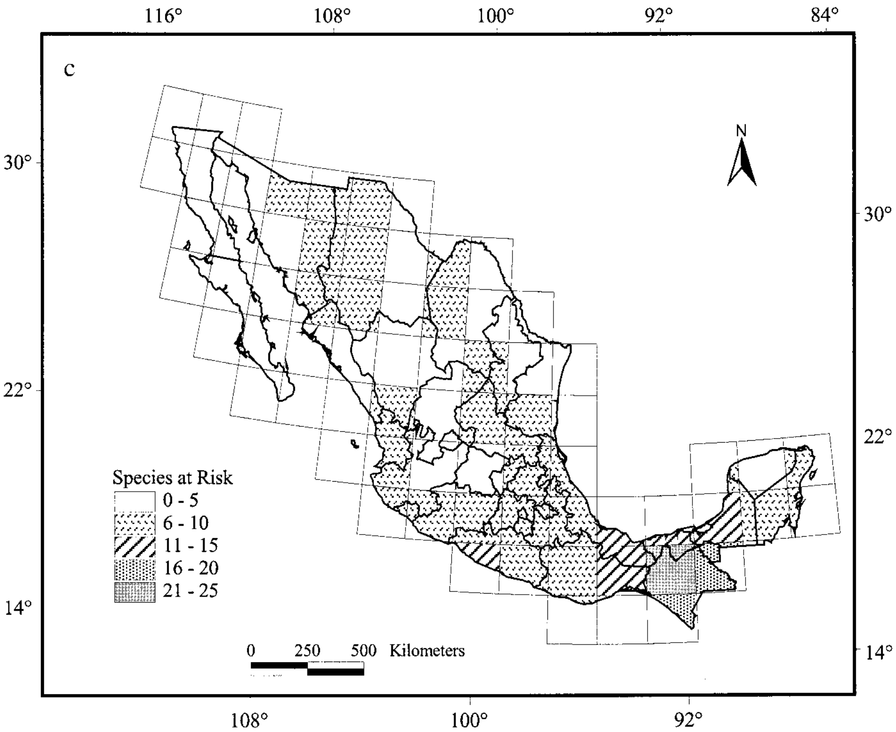

FIG. 4. Continued.

times smaller than endangered non-endemic species (Table 2).

Biogeographic patterns of species distribution

Species richness greatly increased with decreasing latitude in Mexico (Fig. 4a). However, the correlation between latitude and species richness, although significant, explained only 48% of the variation (Table 3). For example, the number of species increased from an average of 55 in northern arid lands (32° N latitude), to 79 in the conifer forests of the Transvolcanic belt (20° N), and to 134 in the southern tropical rain forests (16° N).

These results did support our hypothesis that predicted a low correspondence between areas of high endemicity and diversity: the number of endemic species was weakly correlated with both total species richness and latitude (Table 3). Areas with higher numbers of endemic genera and endemic species ($\overline{X}$ = 28) were located in central and western Mexico, in regions of intermediate species richness (Fig. 4b). The distribution of endemic genera was restricted to 15 (21%) quadrats, distributed from southern Sinaloa to Oaxaca in western Mexico and from Colima to Veracruz in central Mexico. Mexican islands maintained a significantly larger proportion of endemic species that the continental land area (χ^2 = 7.18, df = 3, P <0.01). Thirty endemic species from 11 genera were insular species, distributed on 22 islands off Baja California, 4 islands on the Tres Marías archipelago, and on Cozumel island.

TABLE 3. Correlations between latitude, mammalian species richness, number of endemic species, or number of endangered species. Analyses were performed using log-transformed data, and the slope is the *z* value.

Variables	*N*	r^2	Slope (*z*)	*P*†
Latitude				
Species richness	64	0.48	0.55	0.0001
Endemic species	64	0.29	0.55	0.02
Endangered species	64	0.33	0.05	NS
Species richness				
Endemic species	64	0.28	0.052	0.02
Endangered species	56	0.58	0.51	NS
Endemic species				
Endangered species	58		(None)	

† NS = not significant.

Our predictions about the correspondence between areas of high diversity, endemicity, and endangered species were partly supported. The average number of species at risk per quadrat was 7 (range: 3–22 species). The number of endangered taxa in most quadrats was, however, between 3 and 10. Only one quadrat in western Mexico and seven in southern Mexico had more than 11 endangered species, and only one quadrat in the tropical ecosystems of southern Mexico had >20 endangered taxa (Fig. 4c). The distribution of endangered species had a weak correlation with latitude, species richness, or endemic species (Table 3). However, the relationship was stronger between species richness and numbers of endangered species. The highest concentration of endangered species showed a close correspondence with the quadrats with highest species richness in southern Mexico; the correlation was not significant, however, because in a large portion of the country the number of endangered species is very variable, regardless of total species richness.

Discussion

Our results show evidence of basic ecological and biogeographic patterns of diversity: an increase in species richness with decreasing latitude, more species in tropical than temperate regions, and more endemic species on islands (Brown 1995, Rosenzweig 1996). Our data confirm the generality of the latitudinal trend in mammal species richness documented in North America (e.g., Simpson 1964, Wilson 1974), including Mexico (Ceballos and Navarro 1991).

The low correspondence among areas of high species richness, and high concentration of endemic and endangered species, has major ecological, biogeographical, and conservation implications. Our findings of a low correspondence between diversity and endemicity confirm those of other studies on a variety of taxa at different spatial scales (Prendergast et al. 1994, Ceballos and Brown 1995, Kershaw et al. 1995). In Mexico this pattern has qualitatively been documented in other vertebrate groups (Escalante et al. 1993, Flores Villela 1993), and underlines the influence of historical and biogeographic events that promoted the differentiation of endemic forms. Endemism is exceptionally high on some islands and long-isolated ''island'' habitats, indicating that isolation of land or habitat can increase biodiversity by promoting the differentiation of endemic forms (MacArthur and Wilson 1967, Heaney 1986, Lawlor 1983). On the continent, the highest concentrations of endemic mammals are found in tropical dry forests of western Mexico and in oak and conifer forests in the temperate mountains of the Transvolcanic belt. Interestingly, similar patterns of endemicity have been reported for birds, reptiles, and amphibians (Escalante et al. 1993, Flores-Villela 1993, Ceballos and García 1995). These tropical and temperate forests suffered expansions, contractions, fragmentation, displacement, and isolation throughout the Pleistocene, but maintained their function and structure in at least some habitat patches (Toledo 1982).

The degree of correspondence between areas of high diversity and endemicity is also, apparently scale dependent. The correspondence seems to increase if a whole biogeographic region is included in the analysis. Because of biogeographic and historical reasons, as the study area increases, the likelihood of including the whole geographic range of most taxa also increases. So most species would be considered endemic. For example, there is a high degree of correspondence between diversity and endemicity in the mammals from Africa, because ∼95% of all species are endemic to the continent (I. Castro and G. Ceballos, *personal observations*). By contrast, there is low correspondence between diversity and endemicity in mammals worldwide when analyzing mammalian faunas at a country level (Ceballos and Brown 1995).

Assessing conservation priorities

Few studies have addressed the relationship among ecological characteristics and vulnerability to extinction in a complete group of a whole region (Gaston and Blackburn 1996). Our results clearly indicate that such analysis can provide useful insights for conservation. For example, although the relationships between ecological traits such as body size and geographic range size and extinction is rather complex (see Gaston and Blackburn [1996] for a review), our analyses grouped together species of mammals with similar ecological characteristics correlated with extinction. This provided insights about sets of species that were not previously considered in conservation strategies and helped to determine critical conservation areas for all species of concern.

We suggest that a basic conservation strategy should try to maximize the preservation of species considered endangered or having ecological characteristics correlated with extinction. A higher priority should be assigned to endangered species, followed by non-endangered taxa with restricted distributions (Table 4). Other species should be considered of lower priority, especially those such as raccoons (*Procyon lotor*) or deer mice (*Peromyscus maniculatus*) for which there is evidence that their populations are favored by human disturbances. Within endangered taxa, geographically restricted species should have priority over species with widespread distribution, and in both categories endemic taxa should be of higher priority than non-endemic ones. This is supported by a large amount of evidence showing that species with restricted geographic ranges are more extinction prone (Terborgh and Winter 1980, Rabinowitz 1981, Lawton 1993, Dobson et al. 1997), and by the fact that endemic taxa in Mexico have been significantly more affected by human disturbances than non-endemic species (Ceballos and Rodríguez 1993). Non-endangered species with restricted distributions should be also be given priority for conservation, because of the extinction threat associated with small geographic ranges. Some of these species may already be facing conservation problems, but they may have been omitted from conservation lists because of a lack of current data about their status.

A comprehensive conservation strategy should be based on a network of reserves that include areas with a high concentration of endangered species, high endemicity, high concentration of restricted species, and high species (alpha) diversity. Additionally, the network should include areas of high beta diversity; i.e., the similarity and complementarity of the areas should be a guiding principle (Margules et al. 1988, Pressey et al. 1993, Rodríguez 1997).

TABLE 4. Classification of terrestrial mammal species of Mexico for conservation priority according to their conservation status and geographic range. The number of species is given in parentheses; ''restricted'' means occupying an area <50 000 km². A few examples of the species in each category are provided.

- Endangered (96)
  - Endemic (49)
    - Restricted (44)
      - Flat-headed brown bat (*Myotis planiceps*)
      - Volcano rabbit (*Romerolagus diazi*)†
      - Omiltemi rabbit (*Sylvilagus insonus*)†
      - Tehuantepec jackrabbit (*Lepus flavigularis*)
      - Michoacan pocket gopher (*Zygogeomys trichopus*)†
      - Zinzer's pocket gopher (*Pappogeomys zinzeri*)
      - Perote ground squirrel (*Spermophilus perotensis*)
      - Tres Marias Island raccoon (*Procyon insularis*)
    - Widespread (5)
      - Mexican long-tongued bat (*Musonycteris harrisoni*)†
      - Pygmy skunk (*Spilogale pygmaea*)†
  - Non-endemic (47)
    - Restricted (17)
      - Arizona shrew (*Sorex arizonae*)
      - Broad-handed mole (*Scapanus latimanus*)
      - Meadow mole (*Microtus pennsylvanicus*)
      - Naked-tailed armadillo (*Cabassous centralis*)
    - Widespread (30)
      - Black-tailed prairie dog (*Cynomys ludovicianus*)
      - Black howler monkey (*Alouatta pigra*)†
      - Spider monkey (*Ateles geoffroyi*)†
      - Central American tapir (*Tapirus bairdii*)†
- Non-endangered
  - Endemic
    - Restricted
      - Carter's little brown bat (*Myotis carteri*)
      - Chihuahuan mouse (*Peromyscus polius*)
      - Brown deer mouse (*Peromyscus megalops*)
  - Non-endemic
    - Restricted
      - Western gray squirrel (*Sciurus griseus*)†
      - Texas kangaroo rat (*Dipodomys compactus*)
      - Texas pocket gopher (*Geomys personatus*)

Notes: Populations of species marked with a dagger (†) are found in at least one protected nature reserve. Non-endangered species with restricted distributions could also be given priority for conservation.

Although there were not strong correlations among endangered species, endemic species, and species richness, several areas showed correspondence for concentrations of some of these groups of species, and therefore should be ranked with the highest priority for conservation (Fig. 5). Four quadrats in eastern and southern Mexico have high species richness, and either high numbers of endangered and non-endemic restricted taxa, or both. These quadrats maintain the last remnants of tropical rain forests in the country that a century ago covered more than 22×10^6 ha and now only cover 1.5×10^6 ha fragmented and isolated. Some of the most threatened regions in these quadrats, like Los Tuxtlas and Santa Martha in Veracruz (quadrat 19° N, 97° W) and Lacandona in Chiapas (quadrat 17° N, 93° W), have been decreed as reserves; other areas like Los Chimalapas (quadrat 17° N, 95° W) in Oaxaca, perhaps the most diverse region in the whole country, urgently need to be protected.

Areas considered of high priority for the conservation of endemic species are located in temperate mountains of the Transvolcanic belt, the dry forests of western Mexico, and the islands off Baja California (Fig. 5). All the islands off Baja California (quadrats 30°–22° N, 114°–110° W) are protected as biosphere reserves. Similarly, some important conifer forests in the Trasvolcanic belt are protected as national parks, like the Popo-Izta, Ajusco, Nevado de Toluca, and Nevado de Colima (quadrats 19° N, 102°–96° W; see also Fa and Morales [1993]). In contrast, the dry forests of western Mexico are not well represented in reserves (Ceballos and García 1995). They are protected only in the Chamela-Cuixmala biosphere reserve in the Jalisco coast (quadrat 19° N, 105° W), and part of the Manantlan (Jalisco, quadrat 19° N, 103° W) and La Sepultura (Chiapas, quadrat 17° N, 93° W) biosphere reserves. Additional dry-forest reserves are needed in Sinaloa, Nayarit, Michoacan, Guerrero and Oaxaca.

Two biogeographic realms integrate in Mexico, and many species of Nearctic or Neotropical affinities have their geographic distribution limits in that country. This is reflected in the areas with relatively high numbers of non-endemic, restricted species. At a global or continental level, these species are generally referred to as ''peripheral,'' and conservation strategies have not considered them a priority. Their conservation is, however, relevant because their populations play important ecological roles at local scales and in many instances are genetically very distinct (WMCM 1992). Additionally, they may comprise a relatively large percentage of the national biodiversity, as in the case of Mexico. Interestingly, the concentration of restricted Neotropical species has a high correspondence with areas of high species richness and high concentration of endangered species (Fig. 5). Most of these species, like the brown four-eyed opossum (*Metachirus nudicaudatus*) and Central American armadillo (*Cabassous centralis*), are protected in diverse rain forests reserves. On the other hand, restricted Nearctic species are found along the Mexico–USA border in areas considered until recently of low conservation priority. Fortunately, some of these regions have been protected; that is true in the case of the Maderas del Carmen wildlife refuge in Coauhuila (quadrat 29° N, 103° W; protects species like *Scalopus aquaticus*, *Erethizon dorsastum*, and *Castor canadensis*), the proposed Janos-Casas Grandes biosphere reserve in Chihuahua (quadrat 31° N, 109° W; *Cynomys ludovicianus*, *E. dorsatum*, and *Bison bison*), and the San Pedro Martir National Park in Baja California (quadrat 17° N, 93° W; *Sciurus griseus*, *Tamias merriami*, and *Scapanus latimanus*). An additional reserve is needed in Tamaulipas (quadrat 25° N, 97° W; *Dipodomys compactus*, *Geomys personatus*, and *Lutra canadensis*).

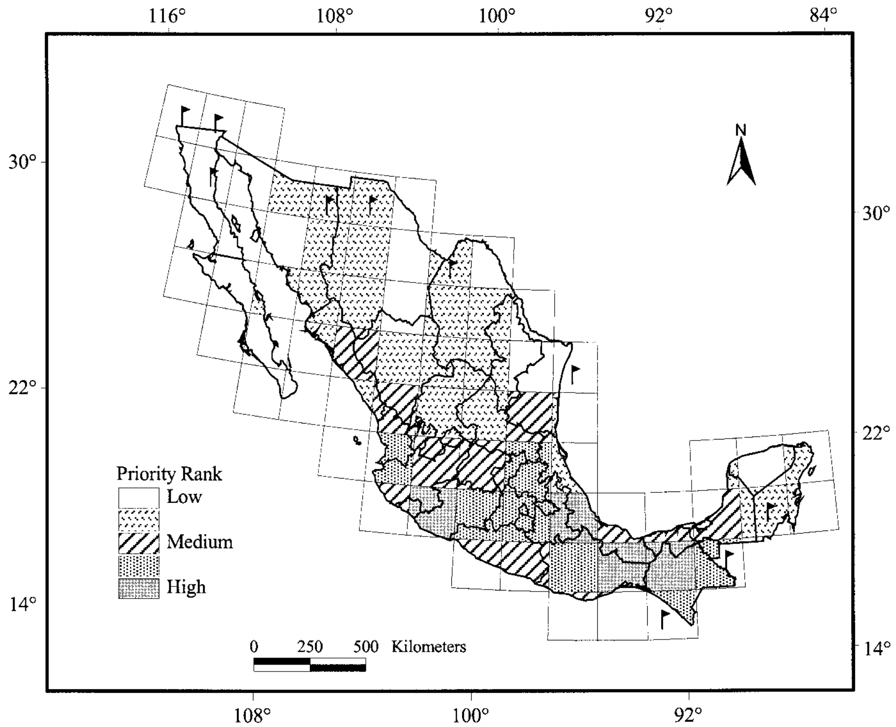

FIG. 5. Priority regions for the conservation of the mammals of Mexico. The quadrats are classified from low to high priority according to their number of endangered species, endemic species, and total species richness. The quadrats marked with a flag are the ones with the highest concentrations of non-endemic species with restricted geographic ranges. Additional analyses should provide information about the similarity and complementarity of these priority regions; we should then be able to rank them accordingly.

Finally, endangered endemic taxa with very restricted distributions, like the Perote ground squirrel (*Spermophilus perotensis*), Mexican prairie dog (*Cynomys mexicanus*), Tehuantepec jackrabbit (*Lepus insularis*), San Quintin kangaroo rat (*Dipodomys gravipes*), and several species of pocket gophers (e.g., *Pappogeomys zinzeri*, *Geomys tropicalis*, *Zygogeomys trichopus*), are dispersed throughout the country, and do not occur in reserves or areas with high species richness, high endemicity, or high concentration of endangered species (see also Ceballos and Rodríguez [1993], Arita et al. [1997]). Similar patterns have been documented for birds, reptiles, amphibians, and freshwater fishes. In order to protect these species, special wildlife refuges or sanctuaries will have to be established.

In summary, Mexico needs more reserves to protect additional ecosystems and species. However, even in the best scenario, the conservation of the country's biological diversity exclusively in reserves will be a very complex and difficult task. So, to avoid the isolation of the reserves and to increase the number of surviving species, the ecosystems and natural resources outside reserves must be carefully managed and restored.

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