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CONSERVATION OF ENDEMIC MAMMALS OF MEXICO: THE PEROTE GROUND SQUIRREL (*SPERMOPHILUS PEROTENSIS*)

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About 25% of all land mammals from Mexico face conservation problems. Endemic species, particularly those with restricted distributions, contribute a disproportionately large number of species to the total number of endangered species. The Perote ground squirrel (*Spermophilus perotensis*), a species endemic to Mexico, has a distribution limited to the states of Puebla and Veracruz. Its geographic range is restricted to a 100-km strip covering 2,457 km^2 in the El Oriental Basin, where they occur in only 16 localities on arid plains and valleys at elevations of 2,200–2,700 m above sea level. Habitat destruction and fragmentation have been severe in the El Oriental Basin, leading to small isolated populations with high probabilities of extinction, and threatening the long-term survival of the species. Mean distance between localities was 15.8 km, which clearly indicates the severity of fragmentation. The Perote ground squirrel is a good example of the conservation problems faced by many Mexican endemics. Conservation of these species should be a priority for Mexico.

Key words: *Spermophilus perotensis*, Perote ground squirrel, endangered species, endemic species, geographic range, Mexico

Mexico maintains one of the most diverse mammalian faunas in the world (Ceballos and Brown, 1995; Mittermeier, 1988), which includes 146 endemic species (Ceballos and Navarro, 1991; Ramírez-Pulido and Mudespacher, 1987). Unfortunately, at least 129 species are facing conservation problems, including 55% of endemics (Ceballos, 1993; Ceballos and Rodríguez, 1993; Secretaria de Desarrollo Social, 1994).

Endangered species are disappearing mainly through destruction, fragmentation, or modification of their habitat (Ceballos, 1993), although other factors such as hunting, overgrazing, and introduced species are causing the demise of some species (Ceballos and Navarro, 1991; Mellink, 1992; Smith et al., 1993). In general, the geographic range of species at risk has been highly modified by activities of humans. Several trends are evident: 1) species with patchy populations surviving throughout their historic geographic ranges (*Glaucomys volans*—P. Manzaño, in litt.); 2) species such as *Ovis canadensis* (Ceballos and Navarro, 1991) with populations surviving only in a portion of the historic geographic range; 3) species such as *Ursus americanus* with one or two remnant populations in the periphery of their historic range, following the pattern described by Lomolino and Channel (1995).

Endemic species, particularly those with restricted distributions, contribute a disproportionately large number of species to the total number of endangered species (Ceballos and Rodríguez, 1993). To design appropriate conservation strategies for maintaining the mammalian diversity of Mexico, it is necessary to understand the patterns of geographic range collapse and document the causes of extinction of endemic species, such as the Perote ground squirrel (*Spermophilus perotensis*).

The Perote ground squirrel has a restricted distribution in the Trans-volcanic belt of Central Mexico (Davis, 1944; Hall, 1981).

It is found on the arid Perote grasslands in El Oriental Basin between Puebla and Veracruz (Davis, 1944; Hall, 1981; Ramírez-Pulido et al., 1983). In this paper we evaluate its present distribution and conservation status; information on natural history also is presented.

Materials and Methods

This study was conducted January 1990–December 1991 in El Oriental Basin, located between the states of Puebla and Veracruz. To determine the present distribution of Perote ground squirrels, all localities with historic records (Davis, 1944; Hall, 1981; Hall and Dalquest, 1963; Howell, 1938; Merriam, 1893) were evaluated by diurnal searches. We also sampled most grasslands in the El Oriental Basin, where the species has not been recorded previously. New areas were located through interviews with local residents and ground reconnaissance, and mapped on 1:50,000-scale topographic maps.

Searches were carried out in suitable grasslands from 0900 to 1600 h, following the wider section of the habitat. A specimen was collected, when possible, in each locality, using Sherman live traps baited with oats. Trapping effort was not the same in all localities, because of weather or logistic problems; so, information on abundance among localities is not comparable. Qualitative information about aspects of the vegetation and environmental impacts of humans also were gathered, including vegetation type, amount of suitable habitat, and major activities of humans (e.g., agriculture) negatively affecting the natural vegetation.

To assess the degree of habitat fragmentation, we calculated the mean distance and connectivity among localities. Mean distance among localities was calculated by measuring the distance from each locality to the nearest locality, following the shortest route through suitable or formerly suitable habitat. We assumed that greater distances between localities correspond to greater habitat fragmentation. Connectivity was calculated as the number of localities accessible from a particular locality through suitable or formerly suitable habitat. We assumed that fragmentation is inversely correlated with connectivity (i.e., localities have greater connectivity in less-fragmented habitat).

Information about natural history, such as reproductive condition, was gathered mainly in the field. Individuals were captured with Sherman live traps. For each individual captured we recorded total length, body mass, sex, age (i.e., juvenile or adult), and reproductive condition, before either releasing or collecting the animal. To determine the patterns of monthly activity, we counted the number of active individuals every 30 min in two 1-h observation sessions (1200 and 1600 h) 2 days/month, throughout the year at the same locality (2 km W Perote, 19°34′25″N, 97°14′47″W). This locality was chosen for its accessibility and because it was typical of grasslands where this species is found. The pattern of reproduction was determined by analyzing the reproductive tracts of collected specimens. Patterns of seasonal activity and reproduction were complemented with observations on four individuals maintained in captivity. Rectal temperature was recorded using a thermocouple and body mass was recorded by weighing the animals with a Pesola scale. Lethargic individuals apparently were not disturbed by the manipulation to obtain body mass and temperature; they did not change their position or activity during or after the manipulation.

Results and Discussion

Present distribution.—The Perote ground squirrel is endemic to Mexico (Fig. 1) and restricted to the states of Puebla and Veracruz. We found a larger geographic range than had been reported previously; new records extend the northern, southern, and western limits of the documented historic distribution.

The present range closely matches the boundaries of the arid El Oriental Basin in the eastern section of the Trans-volcanic belt, located between the Cofre de Perote and Pico de Orizaba volcanoes (Fig. 1). El Oriental Basin occupies an area of ca. 5,250 km^2, and is dotted with lava flows, isolated mountains, and volcanoes. The basin is almost completely surrounded by a belt of temperate mountains, including the Sierra de Tlaxco and the La Malinche Volcano to the north and west, the Sierra de Soltepec to the south, and the Sierra del Citlaltépetl, the Pico de Orizaba (Citlaltépetl), and Cofre

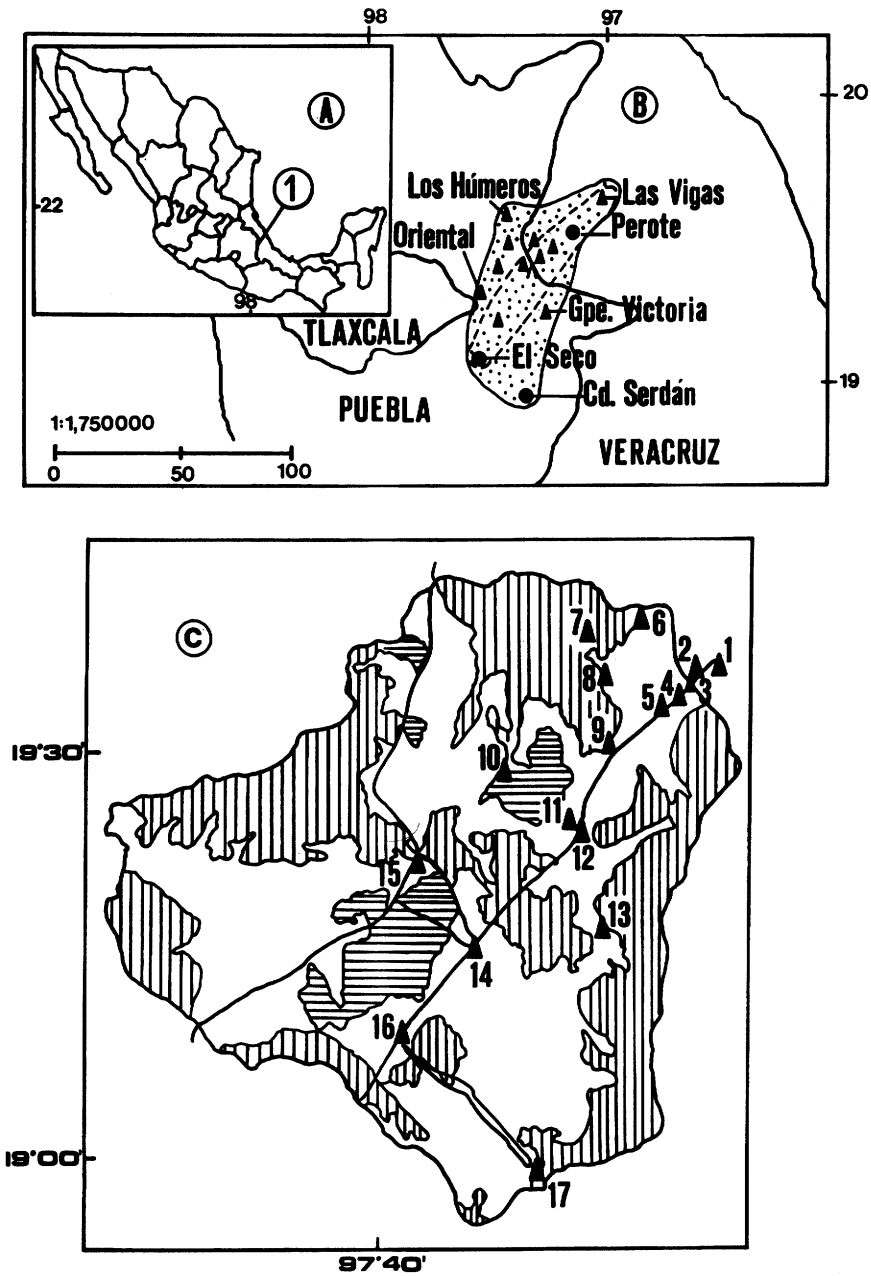

FIG. 1.—Geographic range of the Perote ground squirrel. A) Location of the El Oriental Basin in Mexico is indicated by 1; B) states of Veracruz and Puebla (the smaller area, marked by a dotted line, was the known distribution and the area limited by a solid line is the present distribution, marginal localities are identified by name); C) El Oriental Basin (localities where the species was observed are marked by a number). Locality names and geographic coordinates are in Appendix I. Hatched lines indicate areas >2,700 m above sea level.

de Perote volcanoes to the east (Reyes Cortés, 1979). Thus, suitable habitat for this squirrel is restricted to an area ca. 100 km long and 35–50 km wide, between 18°55′–19°38′N and 97°08′–97°40′W (Fig. 1) and encompassing ca. 2,427 km^2. Within this area, Perote ground squirrels occur in the arid plains and valleys at elevations of 2,200–2,700 m above sea level.

The Perote ground squirrel was recorded at 16 localities, including all but one (Las Vigas) where it had been recorded previously (Appendix I). Most localities (66%) were in Puebla, and the rest in Veracruz. The northern populations were found near Los Humeros, the southern near Ciudad Serdán, the western near El Seco and Oriental, and the eastern near Cruz Blanca. Cruz Blanca is ca. 10 km SW of Las Vigas, and represents the eastern limit of its distribution; it is probably the locality documented by Howell (1938) as "Las Vigas," because the coniferous forest in the vicinity of Las Vigas is unsuitable for this species.

Habitat characterization.—Climate in the Perote region is the most humid of the semiarid types (García, 1987). Average annual rainfall is 369.7 mm and is characterized by strong seasonality, with rains concentrated between June and September. Average temperature is 11.9°C, with monthly averages ranging from 14.7°C in June to 8.8°C in January (García, 1987).

Dominant vegetation associations include alkaline grasslands and arid scrub in the bottom lands and several kinds of more mesic scrub and coniferous forests at higher elevations. The Perote ground squirrel was strongly associated with alkaline grasslands, and 76% (13) of the localities supported such vegetation (Fig. 2). In Perote and Los Humeros (12% of the localities), it was found in areas of bunch grasses. In the vicinity of Alchichica and Tepeyehualco (12% of the localities), it was found peripherally in hilly and rocky areas, covered by dense scrub. Perote ground squirrels were never recorded in agricultural fields, although they were present in the small belts of natural grasslands adjacent to crop lands.

Vegetation in the grasslands was variable, characterized in some areas by bunch grasses or prostrated herbs and short grasses. A dominant species of grass in the alkaline grasslands was *Distichlis spicata*. Other species of herbs and grasses included *Actinella chrysanthemoides*, *Atriplex pueblensis*, and *Bouteloua breviseta*. Most herbs in these grasslands are annual and complete their life cycle in late autumn.

Structure and composition of the arid scrub varies in the region mainly in relation to soil, slope, and humidity factors (Alvarez and González-Medrano, 1972; Gómez Pompa, 1978). Dominant species include cactus such as prickly pear and jumping cholla (*Opuntia*), *Mammillaria*, and *Agave obscura*.

Perote ground squirrels are sympatric with rock squirrels (*Spermophilus variegatus*) throughout their geographic range, although they use different habitat and microhabitats. In one locality (Oriental) they share their habitat with the Mexican ground squirrel (*Spermophilus mexicanus*).

Patterns of activity and reproduction.—Based on our captures and field observations, there is apparently a 9-month period of activity (March to November) and a 3-month period (December to February) of reduced activity or inactivity. Average and minimum temperatures in the months of inactivity were 8 and −3°C, respectively. Active individuals were observed or collected from the 3rd week of March to the last week of November (Fig. 3). Adult males, which had scrotal testes, became active in late March, before subadults and adult females. Activity was generalized in April and May, when copulation occurred. Pregnant and lactating females were collected June–August; mean number of embryos was six (n = 3; range, 5–7). Emerging juveniles were observed or collected from mid-July to late October. Average litter size, documented by the number of

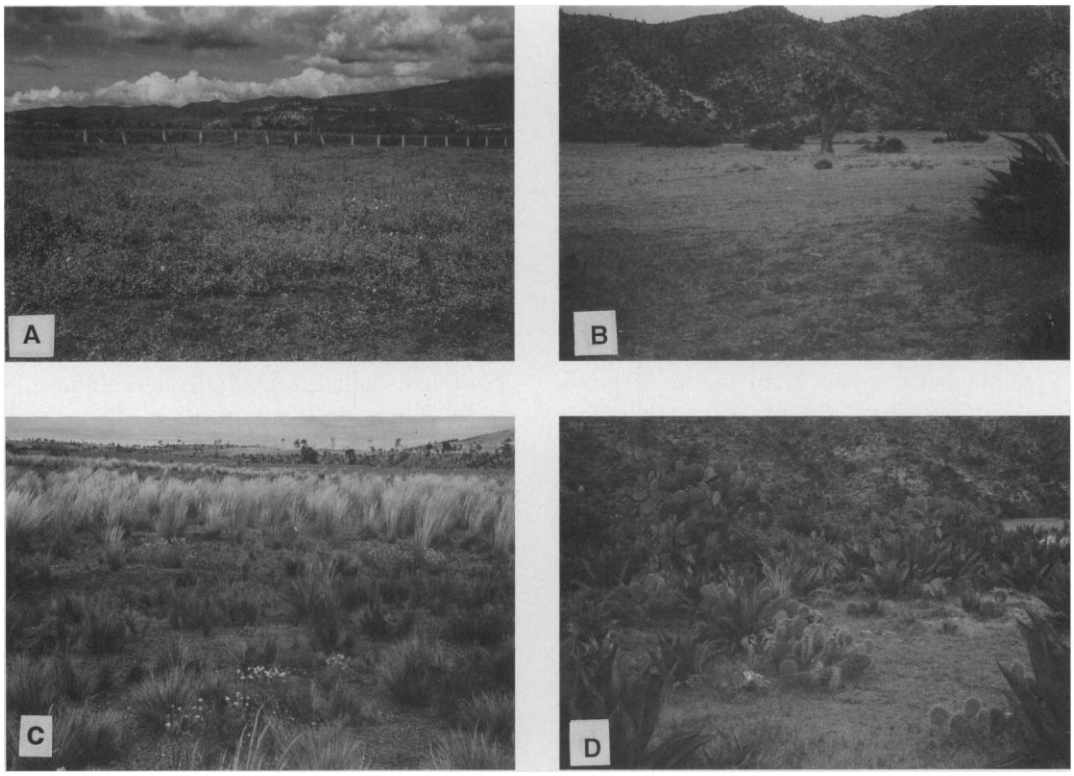

FIG. 2.—Vegetation types where Perote ground squirrels are found. A) and B) alkaline grasslands near Perote; C) grassland with bunch grasses near Los Humeros; and D) dense scrub in rocky areas near Alchichica (photographs by M. Valdéz).

emerging juveniles, was four (n = 4, range 3–5). Adult squirrels remained active until late October, and juveniles were observed from July to late November.

Information on four individuals kept in captivity supported field observations on activity patterns, because they showed periods of inactivity ranging from 1 to 40 days, from late November to early March. In such lethargic periods the squirrels lost body mass (0.7–1.0 g/day), and body temperature fell from 35 to 19–23°C.

Predators in the region are diverse, but only long-tailed weasels (*Mustela frenata*) and domestic dogs were seen preying upon squirrels. All collected specimens harbored fleas (*Opisodasys*) and an endoparasitic nematode (*Ctenghthalmus*).

Conservation status.—Although the species is still found throughout its historic geographic range, its distribution has been extremely fragmented and reduced. Most localities (i.e., populations) are separated from other localities by >10 km (Fig. 4), and mean distance among localities was 15.8 km (n = 28; SD = 10.16; range, 2.4–55.2 km), which clearly indicates the severity of fragmentation. Mean connectivity among localities was 3.5 (n = 16; SD = 1.6; range, 1–7); isolated localities such as Ciudad Serdán, San Salvador El Seco, and Los Humeros had the lowest connectivity.

Interestingly, localities from San Antonio Limón to the northeast are less fragmented and have a higher connectivity, reflecting that historically more suitable habitat was found in this region. Localities to the southwest of the El Oriental Basin are isolated (e.g., Ciudad Serdán is located 55 km from San Salvador El Seco, the nearest popula-

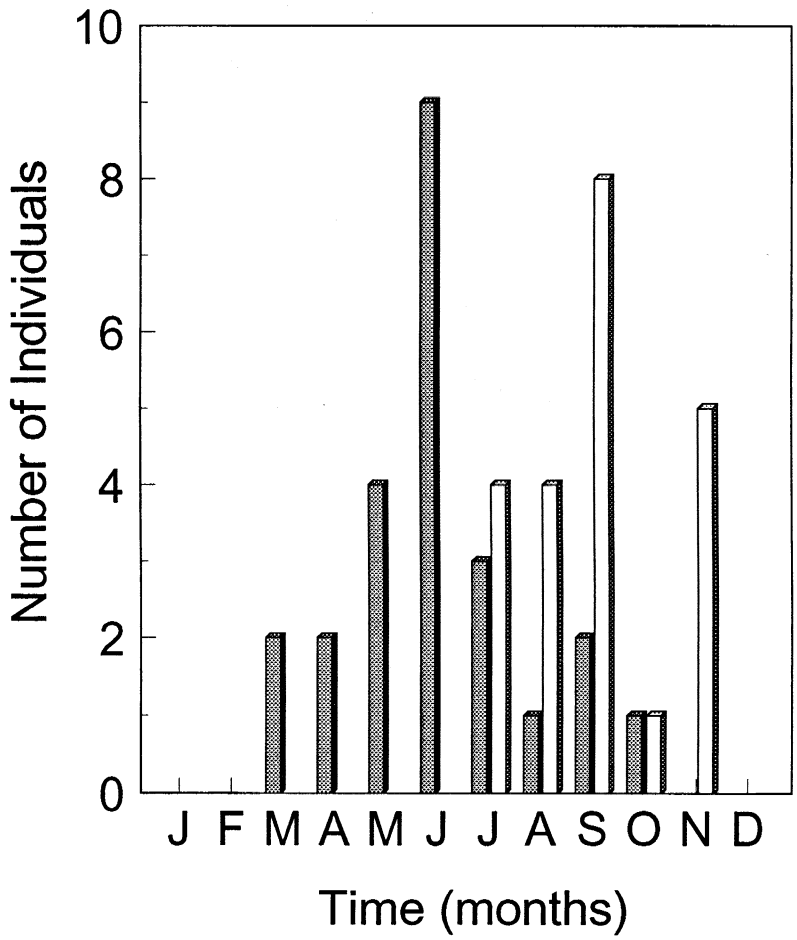

FIG. 3.—Number of adults (dark bars) and juveniles (lightbars) captured throughout the year. Note the seasonal activity of ground squirrels, from March to November, and the presence of juveniles from July to November.

tion). These populations are, presumably, more prone to extinction.

Most negatively impacted areas for the Perote ground squirrels are along Federal Highway 140, where natural vegetation has been highly modified mainly by agriculture; main crops are corn, beans, and barley. Overgrazing and urbanization also are important factors in some localities. Cattle and goats are the main domestic grazing animals. As an example of rates of habitat loss, the total available habitat in the vicinity of Perote, the type locality, has been reduced to <5% in the past 3 decades. Similar trends are visible around Ciudad Serdán, Oriental, El Seco, Zacatepec, and Guadalupe Victoria. In most localities (82%), such as Perote, this species was found only in a narrow strip (20–50 m) of grasslands along the railways, and well-preserved habitat was found only in small areas near Tepeyehualco, Los Humeros, and Totalco or San Antonio Limón.

The presence of the Perote ground squirrel in localities throughout its historic range masks the threat of continued habitat loss, because based solely on its geographic range, the species could be incorrectly classified as having no conservation problems. However, habitat deterioration creates

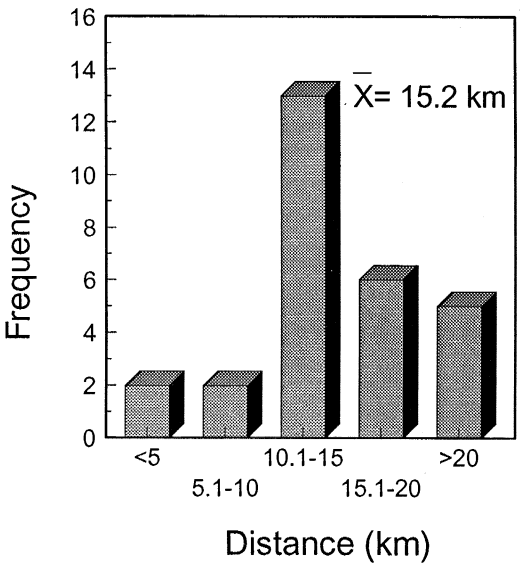

FIG. 4.—Frequency distribution of the distance among localities where Perote ground squirrels were observed. Note that most localities are separated by >10 km.

small, isolated populations with higher probabilities of extinction, and threatens the long-term survival of species. Indeed, the risk of extinction may increase faster than the amount of habitat lost, because of cumulative and synergic effects (Ceballos et al., 1992; Wilcove et al., 1986; Wilcox and Murphy, 1985).

Habitat fragmentation is a common factor causing the extirpation or extinction of populations and species of mammals (e.g., Newark, 1995; Wilcove et al., 1986). In Mexico, habitat fragmentation is the leading cause of endangerment of mammal species. Interestingly, the patterns of geographic range collapse in both non-endemic and endemic species with restricted distributions are similar. Some endemic species such as the Perote ground squirrel and the Mexican prairie dog (*Cynomys mexicanus*; Ceballos et al., 1992) are still found scattered throughout their historic geographic range; others, such as *Geomys tropicalis* (R. Márquez, in litt.), have populations surviving only in a portion of their original range; finally a few species such as *Peromyscus guardia* (J. Ramírez, pers. comm.) have only one or two remnant populations. It is likely, that these patterns form a continuum, where species tend to progressively disappear from their geographic range until they are reduced to one or two remnant populations (Brown, 1995; Lomolino and Channel, 1995).

Finally, there is no doubt that the Perote ground squirrel faces long-term conservation problems, and this study strongly suggests that the species is at risk of extinction. Using the new classification of the International Union for the Conservation of Nature and Natural Resources (1994), the species should be classified as endangered. No protected areas have been set aside or are planned in El Oriental Basin, because the area has a low ranking in terms of concentration of biodiversity or endemic species (Arita et al., in press; Ceballos and Navarro, 1991; Ceballos and Rodríguez, 1993).

The Perote ground squirrel is a good example of the conservation problems faced by many Mexican endemics. It is clear that reserves will not be sufficient to maintain all the endemic and endangered mammals of Mexico (Ceballos, 1993; Ceballos and Rodríguez, 1993). This is an important lesson for conservation; if biodiversity of Mexico is going to be preserved, a high priority in any conservation strategy should be those endemic, endangered species with restricted distributions. However, because many of these species are distributed in areas with low priority for conservation, the only real chance to save them is the careful management of natural resources outside reserves. To be successful, such a strategy must be based on solid scientific knowledge and shaped into a regional socio-economic perspective.

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Appendix I

Localities searched or trapped for Perote ground squirrels (*Spermophilus perotensis*) in Puebla and Veracruz, Mexico. Locality numbers correspond to numbering in Fig. 1.

Veracruz: *Locality 1*—Las Vigas (19°37′30″N, 97°06′00″W), none observed; *Locality 2*—3 km SW Cruz Blanca (19°37′30″N, 97°12′25″W), 1 ♀; *Locality 3*—Los Molinos (19°35′25″N, 97°14′30″W), observed; *Locality 4*—2 km W Perote (19°34′25″N, 97°14′47″W), 6 (4 ♂♂, 2 ♀♀); *Locality 5*—Guadalupe Victoria (19°32′30″N, 97°16′30″W), observed; *Locality 9*—San Antonio Limón (19°30′00″N, 97°21′00″W), 14 (9 ♂♂, 5 ♀♀). Puebla: *Locality 6*—Orilla del Monte (19°40′00″N, 97°17′35″W), observed; *Locality 7*—Los Humeros (19°35′45″N, 97°20′49″W), observed; *Locality 8*—El Frijol Colorado (19°32′27″N, 97°18′00″W), observed; *Locality 10*—Tepeyehualco de Hidalgo (19°29′00″N, 97°30′00″W), 5 (3 ♂♂, 2 ♀♀); *Locality 11*—Laguna de Achichica (19°24′50″N, 97°24′00″W), observed; *Locality 12*—Zolayeta (19°23′00″N, 97°24′00″W) observed; *Locality 13*—Guadalupe Victoria (19°25′00″N, 97°17′00″W), observed; *Locality 14*—1 km SW Zacatepec (19°15′25″N, 97°31′00″W), 1 ♂; *Locality 15*—Oriental (19°19′00″N, 97°37′30″W), observed; *Locality 16*—4 km San N Salvador El Seco (19°15′00″N, 97°34′00″W), 1 ♂; *Locality 17*—2 km N Ciudad Serdán (18°52′35″N, 87°20′45″W), 6 (4 ♂♂, 1 ♀).