

**Forest structure and squirrel populations in relation to fire history:
habitat use of endemic tree squirrels in the Sierra de San Pedro
Mártir National Park and Saguaro National Park**

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Picacho del Diablo seen from the National Astronomical Observatory in the Sierra de San Pedro

Mártir National Park, in Baja California, Mexico. Photo: David J. Wood.

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ABSTRACT

Management of forests in national parks is a challenge that highlights the potential conflict between passive preservation and active management strategies. Fire suppression in many forests of the United States lasted for >50 years during the 20th century. A recent shift in strategy has occurred in many of these forests in an effort to restore natural fire regimes. Tree squirrels have often served as indicators of forest health. The Mearns's squirrel (*Tamiasciurus mearnsi*) is an endemic species located in the Sierra de San Pedro Mártir (SSPM) Mountains in Baja California, Mexico. Although the species is listed as threatened in Mexico and as endangered by the IUCN, nothing is known about the biology and ecology of this southernmost *Tamiasciurus*. From November 2004 to August 2008, we studied the ecology of Mearns's squirrels and their habitat in the Sierra de San Pedro Mártir National Park using live trapping, observation, and radiotelemetric monitoring. These forests have experienced little fire suppression relative to forests such as those in the Rincon Mountains of Arizona in the Saguaro National Park (SAGU), the sister park of SSPM. We radiocollared 38 adult Mearns's squirrels and marked 41 juveniles. The home ranges of adult males were larger than those of adult females. Similarly, juvenile males traveled longer distances than juvenile females before settling in a new area of their habitat. Unlike other *Tamiasciurus*, Mearns's squirrels do not defend territories, nor do they build middens, but do feed heavily on pine (*Pinus*) and fir (*Abies*) seeds among other food items like fungi, pollen, bones, and branch tips. Mating season begins in March with litters emerging from May through October. Adult survival was greater for males than for females during both years of study. Mearns's squirrels do not construct leaf nests, relying only on tree cavities for nesting. We detected 115 tree cavities, of which 21 were used for reproduction (maternity nests). Most tree cavities were located in Jeffrey pines (*Pinus jeffreyi*); however, Mearns's squirrels used more white firs (*Abies concolor*) than available. Mearns's squirrels, like tree squirrels in the fire-

suppressed forests of Saguaro National Park, use specific characteristics of their habitat for nesting. Tree size and canopy cover influence nesting behavior: however, scarcity of dead trees and tree cavities may be an important factor in the reproduction and survival of Mearns's squirrels. We did not detect the presence of eastern gray squirrels (*Sciurus carolinensis*) previously introduced within the SSPM National Park. The high elevation conifer forests of Baja California that have received frequent low intensity ground fires due to lack of fire suppression are significantly more open than the fire-suppressed forests of Arizona. Tree squirrels show promise in serving as potential indicators of forest condition and forest change in the national parks of the Mexico-United States borderlands.

INTRODUCTION

Conservation of endemic organisms presents one of the greatest challenges for ecologists (Koprowski et al. 2006). Due to the current species extinction crisis, an urgent need exists to identify the most threatened areas of exceptionally high biodiversity and rates of endemism (Médail and Quézel 1999). Mexico, considered a megadiverse country, is estimated to contain 8-12% of the world's total plant and animal species, which ranks Mexico as the third-most-important country in biodiversity with an exceptional number of endemic species (Valdez et al. 2006). This biological richness is due to great habitat variation and diverse ecological regions, complex topography, heterogeneity of soils and climate, geological history, and geographic isolation (López-Wilchis et al. 1998).

Mexico's mammalian fauna ranks second in species richness at a global level, and ~32% of all mammals are endemics (Ceballos et al. 1998). Thirty five species of squirrels occur in Mexico of which 13 are endemic, representing 41.2% of the 86 species reported for North and Central America (Valdés-Alarcón 2003). Unfortunately, more than 50% of the species of tree squirrels in the world are of uncertain conservation status (Steele and Koprowski 2001). One hundred and twenty-nine (104 tree and 25 flying) of 176 squirrels are listed in the lowest risk category of the International Union for Conservation of Nature (IUCN), whereas the remaining 47 (30 tree and 17 flying) species are of elevated extinction risk (Koprowski and Nandini 2008). Mexico harbors 14 species of tree squirrels, divided into 3 genera (*Sciurus*, *Tamiasciurus*, and *Glaucomys*), of which 4 are endemic and 7 are listed in a category of risk by the Mexican government (SEMARNAT 2002; Villa and Cervantes 2003); all 14 species are currently included in the IUCN red list of threatened species under some category of risk. Endangered species are disappearing mainly through destruction, fragmentation, or modification of their habitat, although other factors such as hunting, overgrazing, and introduced species are causing the demise of some

species (Valdéz and Ceballos 1997). Unfortunately, like many species, a dearth of information still exists on the ecology of tree squirrels of Mexico and the United States borderlands. This is the case for the Mearns's squirrel (*Tamiasciurus mearnsi*), an endemic species that occurs only in the coniferous forests of the Sierra de San Pedro Mártir (SSPM) in Baja California with related species in the United States (Lindsay 1981; Fig. 1).



Fig. 1.—An adult male Mearns's squirrel (*Tamiasciurus mearnsi*) in the Sierra de San Pedro Mártir, in Baja California, on 16 June 2005. Photo: Nicolas Ramos-Lara.

The genus *Tamiasciurus* contains 3 recognized species (*T. mearnsi*, *T. douglasii*, and *T. hudsonicus*) distributed throughout montane and boreal forest regions of North America (Arbogast et al. 2001; Wilson and Reeder 1993). *T. mearnsi* is separated from the nearest populations of *T. douglasii* and *T. hudsonicus* by about 600 km of mostly non-forested lowlands in each case (Yensen and Valdés-Alarcón 1999; Fig. 2). However, the exact distribution of *T. mearnsi* within the Sierra de San Pedro Mártir Mountains is unknown, except for three sites <10

km apart reported in the literature during the past 100 years, which include the Vallecitos and La Grulla Meadows (Lindsay 1981; Yensen and Valdés-Alarcón 1999; Fig. 3). The species is known from about 2,100 m to 2,750 m elevation in the coniferous forests of the Sierra de San Pedro Mártir (Yensen and Valdés-Alarcón 1999).

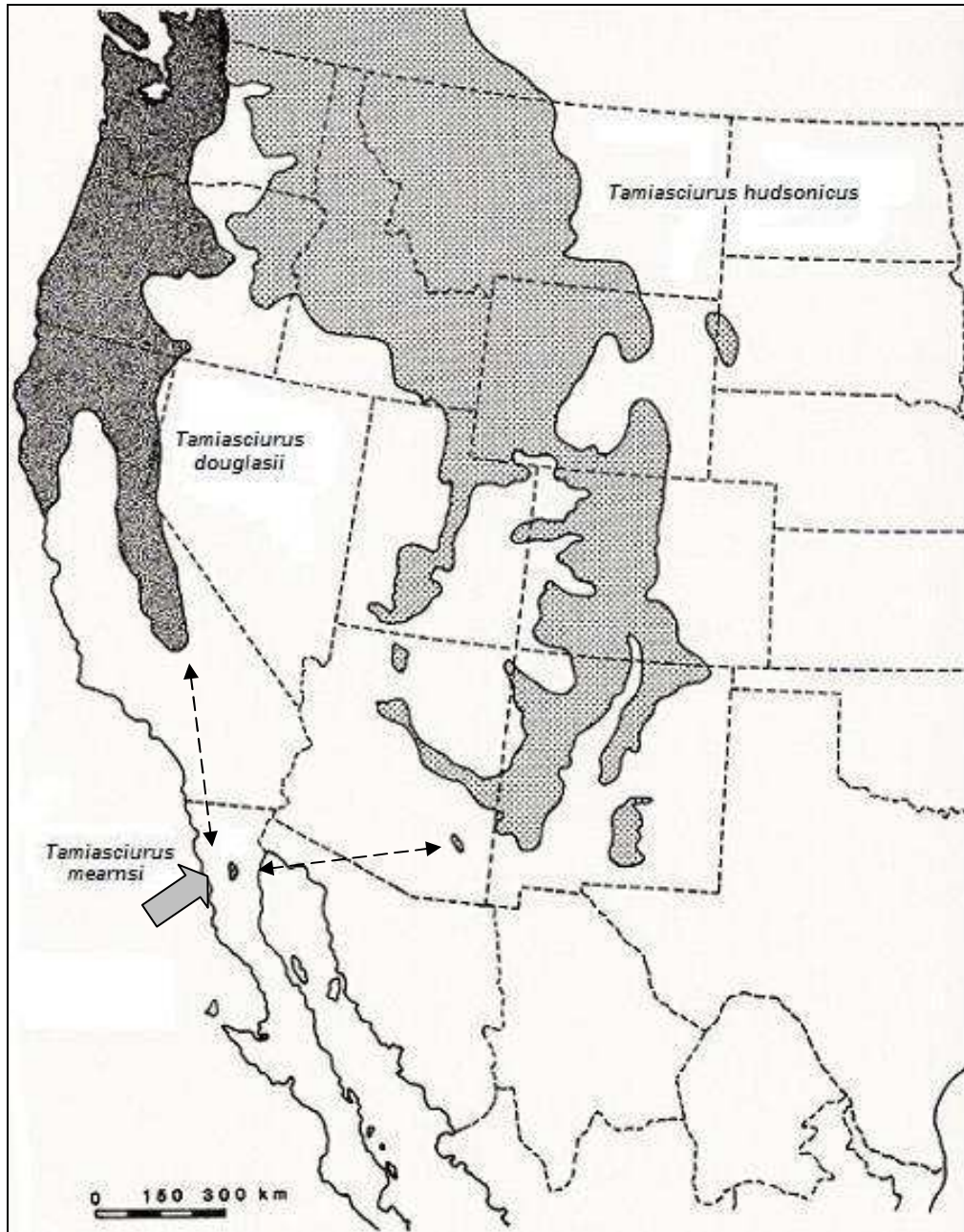


Fig. 2.—Distribution of *Tamiasciurus* in western North America (modified from Brown 1984).

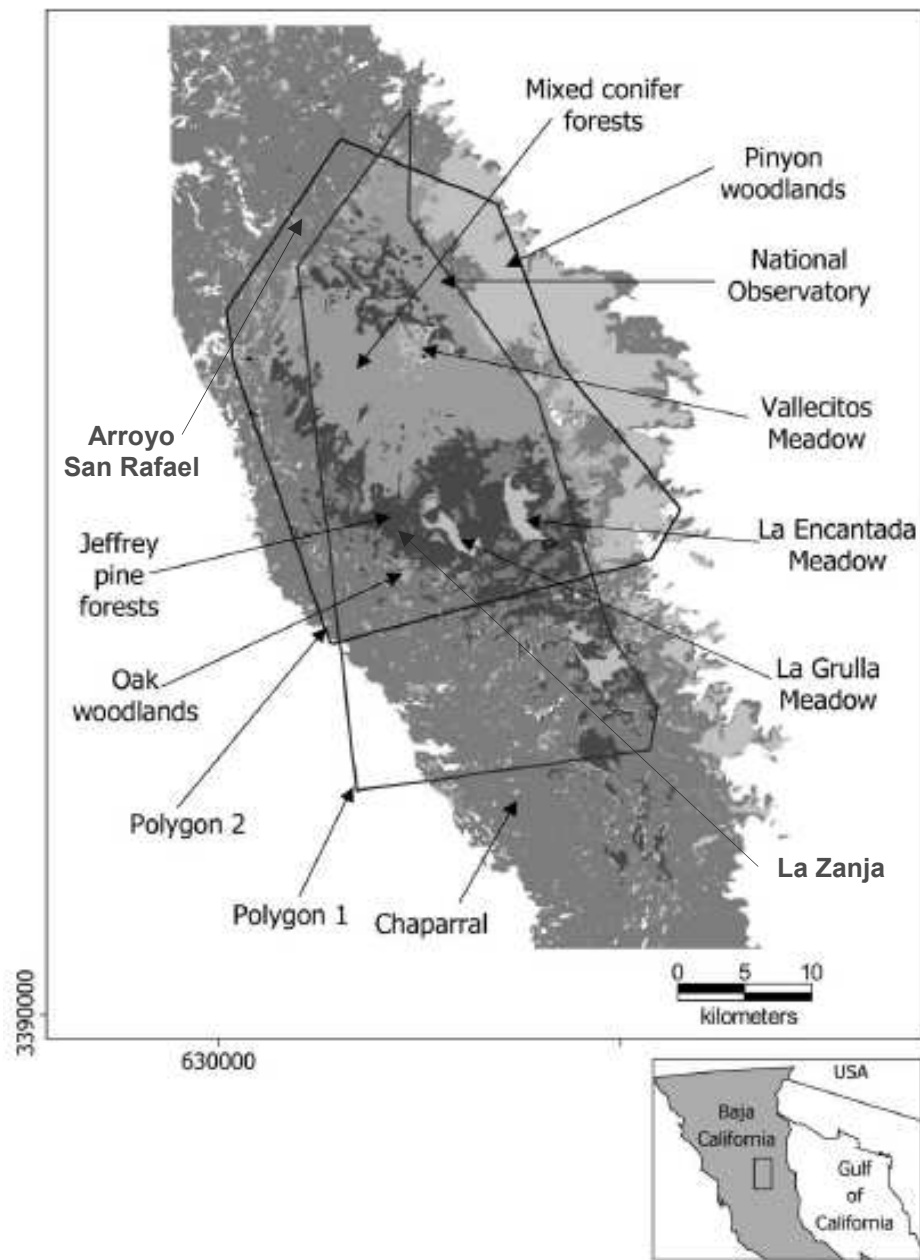


Fig. 3.—Vegetation types in the Sierra de San Pedro Mártir, Baja California, Mexico. The Sierra de San Pedro Mártir was first established as a Forest Reserve in 1932 (Polygon 2) and as a National Park in 1947 (Polygon 1) (modified from Bojórquez-Tapia et al. 2004).

Considered a rare species (Huey 1964), *T. mearnsi* is currently listed as threatened in Mexico (SEMARNAT 2002) due to its restricted distribution, low population density, and isolation in the Sierra de San Pedro Mártir Mountains. The species is also included in the IUCN Red List of Threatened Species as endangered (de Grammont and Cuarón 2008). Ancestors of *T. mearnsi* possibly invaded the Baja California Peninsula during one or more of the mesic cycles that began about 700,000 years ago (Haffner and Riddle 1997). *T. mearnsi* likely became isolated from *T. douglasii* most recently about 12,000 years ago (Arbogast et al. 2001; Lindsay 1981; Yensen and Valdés-Alarcón 1999). Unfortunately, although the Mearns's squirrel was first described more than 100 years ago (Allen 1893; Townsend 1897), only one paper on the ecology of this endemic species has been published to date (Koprowski et al. 2006). As a result, important aspects of its ecology like home range dynamics, reproduction, nesting requirements, social behavior, and diet are poorly known (Yensen and Valdés-Alarcón 1999).

Isolated from other native tree squirrels, a potential threat to Mearns's squirrels may be the presence of the eastern gray squirrel (*Sciurus carolinensis*) introduced at La Zanja and Arroyo San Rafael, on the western slopes of the Sierra de San Pedro Mártir in 1946 (Huey 1964; Yensen and Valdés-Alarcón 1999; Fig. 3). Although eastern gray squirrels still existed at La Zanja in 1956 and at Arroyo San Rafael in 1958 (Huey 1964), no more recent information exists on the status of these introductions. No individual or sign of eastern gray squirrels were reported in our earlier survey within the Sierra de San Pedro Mártir National Park (Koprowski et al. 2006). Eastern gray squirrels have displaced native tree squirrels in other localities where introduced (Bryce et al. 2002; Reynolds 1985; Rushton et al. 2002; Rushton et al. 1997; Usher et al. 1992; Wauters et al. 2001). Mearns's squirrels are smaller than eastern gray squirrels and could be displaced as in other localities (Yensen and Valdés-Alarcón 1999).

Fire plays a vital role affecting species composition, structure and function in many vegetation types of the world (Minnich et al. 2000). In the western United States and Mexico, fire is often considered to be *the* major disturbance under heavy anthropogenic influence (Pyne 1997, Flannigan et al. 2000, Kapler-Smith 2000). Policies of fire suppression for nearly a century in the United States and portions of Mexico have resulted in significant changes in cool fire frequency, catastrophic fire frequency, and forest structure (Pyne 1997). Saguaro National Park (SAGU) practiced fire suppression for more than 50 years before initiating controlled burns in 1985. The implications of these changes have only recently been realized (Pyne 1997) and very few forests with natural fire regimes remain where an appropriate comparison can be made.

The Sierra de San Pedro Mártir (SSPM) National Park is an isolate of forest that has never received substantial timber harvest or fire suppression in part due to its rugged terrain and isolation in Baja California (Minnich et al. 2000, Stephens et al. 2003). In addition, SSPM presents a landscape that consists of a mosaic of past natural fires and this history has been well-mapped (Bojórquez-Tapia et al. 2004, Minnich et al. 2000, Stephens et al. 2003) thus providing an excellent natural ‘experiment’ for the study of fire impacts on forest wildlife.

Tree squirrels have been suggested as excellent indicators of forest health and forest structure (Carey 2000, Koprowski and Steele 1998, Steele and Koprowski 2001) due to their dependence on mature forests for tree seed foods, nest sites, cover from predators, and maintenance of appropriate microclimates for food storage (Gurnell 1987, Steele and Koprowski 2001). As a result, the presence, demographics, and habitat use of tree squirrels can provide an indication of the status of the forested ecosystem. Two native endemic tree squirrels of special conservation concern are found in these two parks: Mearns’s squirrels (*Tamiasciurus mearnsi*) in SSPM, and Santa Catalina gray squirrels (*Sciurus arizonensis catalinae*) in SAGU. In addition, a non-native species may persist in each park: eastern gray squirrels (*S. carolinensis*) in SSPM, and

Abert's squirrels (*S. aberti*) in SAGU. Our report on the ecology of Santa Catalina gray squirrels and habitat use was provided elsewhere (Koprowski 2008); however, this companion project compares forest structure between fire-suppressed SAGU and the natural regimes of SSPM. As a result, the inability of these tree squirrels to persist is a significant shared resource issue between the parks on each side of the border. Ecological information is necessary to maximize the efficacy of management and interpretive efforts within these two national parks for the tree squirrels are uncommon and unstudied members of the forest ecosystems of these sky islands and likely excellent indicators of mature forest conditions for resource managers.

OBJECTIVES

The specific objectives of the study are:

1. To provide data on the population status, and habitat preferences of two uncommon and unstudied native tree squirrels: Mearns's squirrels and Santa Catalina gray squirrels.
2. To provide data on the demographic characteristics of these two endemic tree squirrels.
3. To examine the relationship between forest structure, nest-site selection, and fire suppression in SSPM and SAGU.
4. To assist in the development of interpretive materials for SAGU and SSPM.
5. To facilitate collaborative efforts between these two new sister parks.

STUDY AREAS

The Sierra de San Pedro Mártir (SSPM) is located approximately 100 km southeast of Ensenada, in Baja California, Mexico (Stephens et al. 2003). The Sierra de San Pedro Mártir was established as a Forest Reserve in 1932, as a National Park in 1947, and presently a proposal exists to transform the park into a Biosphere Reserve (Bojórquez-Tapia et al. 2004; Fig. 3).

Vegetation is composed of conifer forests and shrublands of the California floristic province that occur in no other areas of Mexico (Stephens et al. 2003). The Sierra de San Pedro Mártir National Park comprises 65,000 ha of which coniferous forests cover approximately 40,655 ha (Minnich et al. 2000; Appendix 1). Forests are composed of Jeffrey pine (*Pinus jeffreyi*), sugar pine (*P. lambertiana*), lodgepole pine (*P. contorta*), white fir (*Abies concolor*), and limited amounts of incense-cedar (*Calocedrus decurrens*). The most common forest types are Jeffrey pine, Jeffrey pine–mixed conifer, and mixed white fir forests, respectively (Stephens et al. 2003). Chaparral on the lower western slope is replaced by mixed conifer forest on the summit plateau. This is replaced by pinyon forest at higher elevations on the eastern escarpment, and by Sonoran Desert scrub at lower elevations. The most striking feature of the mixed conifer forests is an open park-like aspect that consists of mature trees reaching 30–45 m, with few pole-sized trees and saplings, and an open shrub cover (Bojórquez-Tapia et al. 2004). Elevation averages 2,600 m in the north and decreases to 1,800 m in the southern portion of the range (Stephens et al. 2003), creating a distinctive range of ecogeographic formations (Welsh 1994; Fig. 4), with the highest peaks over 3,000 m in height. The Sierra de San Pedro Mártir lies at the southern margin of the North American Mediterranean climate zone. Mean annual precipitation from winter frontal storms from the Pacific Ocean increases from 25 cm on the lower western escarpment to 55–70 cm on the plateau, then decreases to 15 cm at the Sonoran Desert. Summers are dry except for afternoon thunderstorms of the North American monsoon (Minnich et al. 2000).

The companion study area was located in the Rincon District of Saguaro National Park (SAGU) approximately 21 km east of Tucson, Arizona. The park encompasses the 23,443-ha Saguaro Wilderness Area. Our study area was within the higher park elevations, from 1372 to 2641 m (Mica Mountain Peak) and included oak woodland, pine-oak woodland, pine forest, and mixed conifer forest. During 2003 and 2004, our study was focused at Grass Shack Spring (1615

m), Happy Valley Saddle (1890 m), Spud Rock Spring (2256 m) and Manning Camp (2438 m). During 2005, we surveyed for squirrel dreys (leaf nests) and activity in Happy Valley Saddle and at varying elevations within Chiminea Canyon, Miller Canyon, and the gallery forest along Paige Creek adjacent to Forest Service Road 35. Fieldwork in 2006 was concentrated in Happy Valley Saddle and upper portions of Miller Canyon.

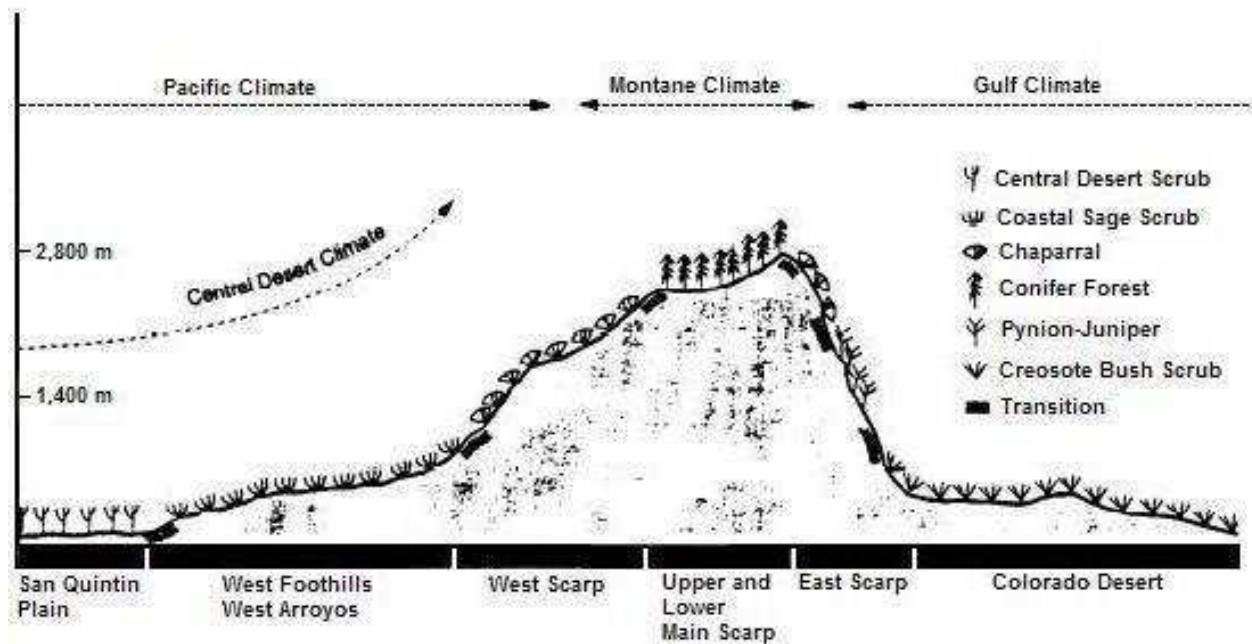


Fig. 4.—Ecogeographic formations of the Sierra de San Pedro Mártir, in Baja California, Mexico (Welsh 1994), where Mearns's squirrels (*Tamiasciurus mearnsi*) have lived in isolation for more than 10,000 years. The species is known from about 2,100 m to 2,750 m elevation in the Sierra de San Pedro Mártir Mountains (Yensen and Valdés-Alarcón 1999).

MATERIALS AND METHODS

Tree squirrel distribution and habitat associations: SSPM.—During 2005, we explored approximately 2,500 ha of forest around the Vallecitos Meadow (Fig. 5) in order to detect direct

(presence) and indirect (remnants of food) occurrence of both Mearns's and eastern gray squirrels within the SSPM National Park. The 2,500 ha of forest around the Vallecitos Meadow were searched systematically using a 5x5 km grid overlaid on a topographic map (Centra Publications 1988). Each square on the map (~25 ha) was scoured carefully and removed from the survey afterwards. Sites were recognized with the map and the distances measured using the odometer function of a GPS unit (Garmin Ltd., Kansas, USA). Each day we walked through the forested areas around the Vallecitos Meadow from 0800 h to 1900 h and with the aid of binoculars (Bushnell 10 x 50; Forestry Suppliers, Inc., Mississippi, USA) detected the presence of squirrels or their feeding signs. Locations where squirrels were detected directly or indirectly were recorded with a GPS unit (Garmin Ltd., Kansas, USA), with the locations of major squirrel activity around the Vallecitos Meadow serving as focal points for the rest of the study. In addition, remote areas within the SSPM National Park like La Tasajera, La Grulla, La Zanja, and Arroyo San Rafael (Fig. 3) were explored periodically. Data were employed to generate a digital map using the computer software ArcView GIS Version 3.2a (Environmental Systems Research Institute, Inc., Redlands, California) to examine the spatial distribution of Mearns's squirrels within the SSPM National Park.

We captured squirrels during the summer months (May-August) of 2006 and 2007. We placed live-traps (Model 201; Tomahawk Live Trap Co., Wisconsin, USA) close to large-diameter trees around the Vallecitos Meadow where high activity of Mearns's squirrels was verified during 2005. Traps were baited with peanuts and peanut butter and checked at 1-hr intervals to prevent stress on the animals. Captured squirrels were transferred into a cloth-handling cone (Koprowski 2002) where data on sex, age class, reproductive condition, and body mass of each animal were collected. Adult squirrels were fitted with uniquely-numbered Monel ear tags (Style #1005-1; National Band and Tag Co., Newport, Kentucky, USA) with colored

plastic washers (Style #1842, 3/8"; National Band and Tag Co., Newport, Kentucky, USA) on both ears for individual field identification, whereas juveniles were fitted only with ear tags on both ears without colored plastic washers.



Fig. 5.—View of the Vallecitos Meadow in the Sierra de San Pedro Mártir, in Baja California, Mexico. The forests at the perimeter of the Meadow provide habitat for the endemic Mearns's squirrel (*Tamiasciurus mearnsi*). Photo: Nicolas Ramos-Lara.

Distinction between adult and juvenile squirrels was made based on the reproductive condition and body mass (≥ 240 g) of captured animals. Adult Mearns's squirrels were fitted with radiocollars (Model SOM-2190; Wildlife Materials International, Inc., Carbondale, Illinois, USA) that weigh $< 5\%$ of body mass. Squirrels were released at the capture site after a maximum of 8 min of handling time. Trapping and handling of animals was conducted with approval from

The University of Arizona Institutional Animal Care and Use Committee, and permits from the following Mexican authorities: Parque Nacional Sierra de San Pedro Mártir, and Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT).

Telemetry was completed using a 3-element yagi directional antenna (Wildlife Materials International, Inc., Carbondale, Illinois, USA) and receiver (Model R-1000, Communications Specialists, Inc., Orange, California, USA). We tracked radiocollared squirrels monthly in spring (March and April) and fall (September through November) and weekly during the summer (May through August). The homing technique was used to determine home range and space use by Mearns's squirrels (White and Garrott 1990). Each location was mapped using a GPS unit (format: UTM; map datum: WGS 84). Location error was reduced by tracking squirrels until sighted; when hidden or resting in a tree, squirrels were located by following the transmitter signal and walking quietly in circles within a radius of <10 m (Farías et al. 2006; White and Garrott 1990). We located each radiocollared squirrel ≥ 2 -hr intervals from 0700 to 2000 h to minimize autocorrelation (White and Garrott 1990). Computer software ArcView GIS Version 3.2a (ESRI, Inc., Redlands, California) with the Home Range Analysis extension (Rodgers and Carr 1998) was used to estimate home-range size, home-range overlap, and distance traveled annually and during mating and non-mating seasons for males and females. Mating season was defined as the period during which females can possibly enter estrus (Edelman and Koprowski 2006), based upon observed and captured animals during the study as reproductive information on Mearns's squirrels is poorly known (Koprowski et al. 2006; Yensen and Valdés-Alarcón 1999). Maximum distance traveled was determined as the distance from a squirrel's nest to the farthest location obtained since the squirrel was fitted with a radiocollar. A plot of home-range size versus number of locations was used to determine the minimum number of fixes to be used in the analysis (Edelman and Koprowski 2006). Ranges were estimated as 95% fixed-kernels

using the automatic smoothing parameter, which is based on the smallest least-squares cross-validation. Fixed kernel estimators with band width chosen via least-squares cross-validation are at present the best estimators (Powell 2000). In addition, range sizes for 100% minimum convex polygons (MCP) also were estimated to facilitate comparisons with other studies (Edelman and Koprowski 2006; Hanski et al. 2000; Taulman and Smith 2004). Recaptured juvenile squirrels provided valuable data on how far they traveled from either the mother's nest or the location of first capture. Likewise, juveniles recaptured as adults permitted assessment of natal dispersal (Kemp and Keith 1970; Koprowski 1996; Larsen and Boutin 1994; Sun 1997). Radio-telemetry also provided data on number and types of nests used by individual Mearns's squirrels, as well as how far individuals moved in search of food or mates.

We generated digital maps using the computer software ArcView GIS Version 3.2a (Environmental Systems Research Institute, Inc., Redlands, California) to estimate population densities of Mearns's squirrels. To accomplish this, we plotted the locations all the animals captured in the surroundings of the Vallecitos Meadow in each trapping station during 2006 and 2007 (Appendix 2). The size of each trapping station was calculated by creating a polygon leaving a distance of 150 m between the outer points in each station and the margins of the polygon (Appendix 2). To quantify trap effort, we counted the total number of days and hours employed for trapping during 2006 and 2007, as well as the total number of Mearns's squirrels captured during the same period of time (Appendix 3).

Social behavior, diet, and activity patterns of Mearns's squirrels were observed opportunistically either while tracking radiocollared individuals or when exploring remote areas within the SSPM National Park. Observations were both direct (animals) and indirect (food items). Direct observations were conducted quietly from a distance ≥ 10 m and for a time period < 30 min to avoid interfering with the natural behavior of squirrels. When possible, food items

were identified recording tree species. In addition, we recorded date, time, and outdoor ambient temperature for each observation in order to examine seasonal differences.

Tree squirrel distribution and habitat associations: SAGU.—Search and trap efforts for Catalina gray and Abert's squirrels at SAGU have been described elsewhere (Koprowski 2008). Peanuts and peanut butter were scattered at 15 baiting stations in an attempt to habituate squirrels to trap locations and Tomahawk live-traps were set during daylight hours to check every 2-3 hours. Trapping success was extremely poor and we quickly realized that Arizona gray squirrels were extremely uncommon relative to non-native Abert's squirrels; therefore, we shifted our focus to radiocollar any animal that was captured and to use these animals to locate definitive nest sites that would provide insight to the status and ecology of these squirrels rather than provide limited data on home ranges of a small number of individuals that were isolated from each other. Five stations north of the campground in Happy Valley Saddle were the most successful and much of the trapping effort was concentrated at these sites after initial surveys of the Rincons were concluded (Fig. 6 and 7). Captured squirrels were transferred from traps to a cloth-handling cone (Koprowski 2002), physical data collected (sex, age, reproductive condition, body mass), and fitted with a radiocollar. Animals were released immediately at the site of original capture. Radiocollared squirrels were followed to nests <2 hours before sundown to find additional nests for analysis. During these periods, lost collars (collars found with no signs of predation) and squirrel mortalities were identified and recorded.

Demographic characteristics of endemic tree squirrels.—Data on survival and reproductive success through litter counts were provided by radiocollared squirrels. We collected data on litter size opportunistically either while tracking radiocollared individuals or when exploring other areas with the aid of binoculars (Bushnell 10 x 50; Forestry Suppliers, Inc., Mississippi, USA). We used the staggered entry design (Pollock et al. 1989) of the Kaplan-Meier method (Kaplan

and Meier 1958) to estimate survival rates of radiocollared Mearns's squirrels; too few of the rare Santa Catalina gray squirrels were radiocollared to conduct a parallel analysis. The Kaplan-Meier method allows newly-tagged animals to be added to the sample at any time and animals may be lost to the study inadvertently without affecting the estimated survival rate (Krebs 1999). Squirrels entered the analysis the day following capture and were censored upon loss of the radio signal or when a transmitter was found with no sign of mortality (Conner 2001; Krebs 1999). Survival rates were calculated separately for males and females to facilitate comparisons with other studies. The information was important to determine if Mearns's squirrels have survival rates similar or different to other species of tree squirrels.

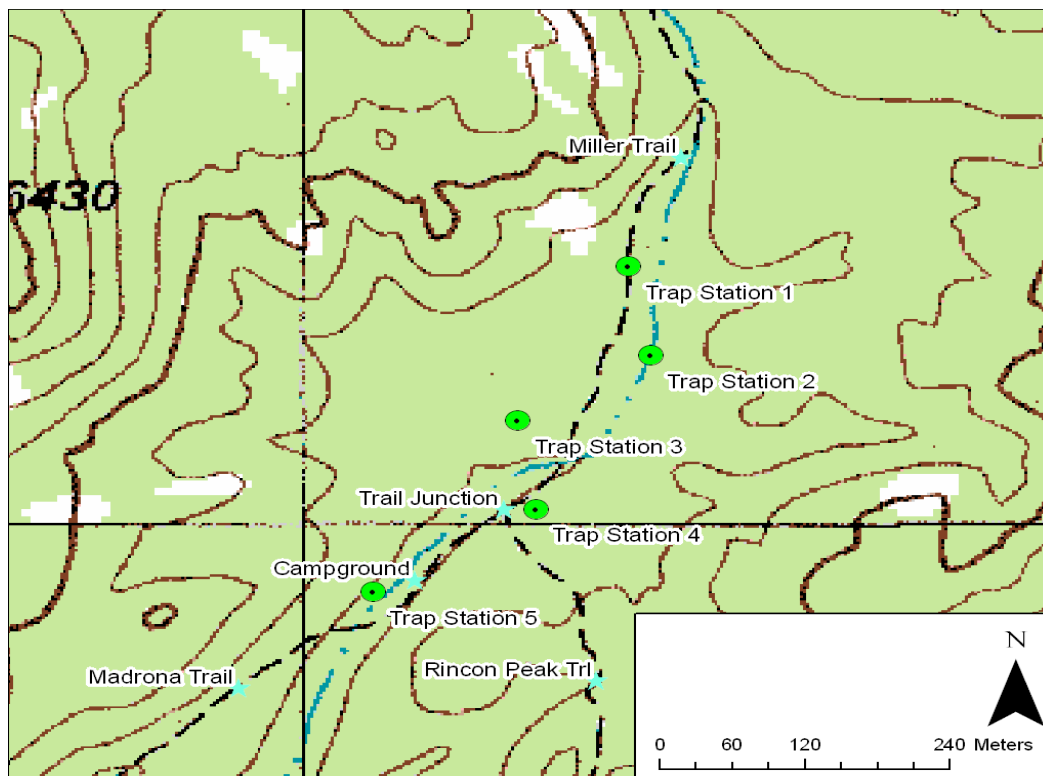


Fig. 6.—Trapping stations for Arizona gray squirrels (*Sciurus arizonensis*) and introduced Abert's squirrels (*Sciurus aberti*) in Happy Valley Saddle of the Rincon District of SAGU.



Fig. 7.—View looking south towards Happy Valley Saddle and Rincon Peak. The small stand of Ponderosa Pine and large oaks is center frame. The vegetation quickly changes from a Ponderosa pine forest to scrub oak and Pinyon-Juniper as distance is increased from the more mesic areas near the creek (low points in the saddle).

Habitat use and nest-site selection by squirrels.—We used nest trees to quantify the habitat to determine if Mearns’s squirrels and Arizona gray squirrels, like other species of tree squirrels (Cotton and Parker 2000; Edelman and Koprowski 2005; Edwards and Guynn 1995; Ramos-Lara and Cervantes 2007; Rothwell 1979; Setoguchi 1991), also rely on specific characteristics of its habitat for nesting. Nests were located either when tracking radiocollared squirrels or opportunistically by following squirrels when retreating to their nests. For each nest, we recorded height and aspect (degrees). For each nest tree, we recorded species, height, diameter at

breast height (DBH), condition (live/dead), tree crown size (4 cardinal directions averaged), and number of trees (≥ 5 cm DBH) with crowns interlocked. For each nest site, we recorded distance to nearest tree (≥ 5 cm DBH), total number of trees (≥ 5 cm DBH), logs (≥ 15 cm diameter and ≥ 1.5 m length), slope (degrees), slope aspect (degrees), and % canopy cover at 0, 5, and 10 m from the nest tree in the 4 cardinal directions (north, south, west, and east); measurements were averaged for each distance (% canopy cover at 0, 5, and 10 m) and for the nest site (% canopy cover). Species, condition, and DBH of each tree ≥ 5 cm DBH also was recorded. Tree condition was classified by using the following 3 classes: (1) live; (2) dead with intact branches; and (3) snag with trunk broken. Based on the measurements taken at nest sites, we calculated the following variables: small trees (≥ 5 cm DBH and < 40 cm DBH), medium trees (≥ 40 cm DBH and < 85 cm DBH), large trees (≥ 85 cm DBH), Jeffrey pines (SSPM), lodgepole pines (SSPM), white firs (SSPM), ponderosa pines (SAGU), Douglas-firs (SAGU), live trees, dead trees, snags, basal area, and species richness. In addition, the relative dominance, relative density, and relative frequency of each tree species were determined for all nest sites (Muller-Dombois and Ellenberg 1974). Finally, the Shannon diversity index (H') and evenness (E) also were calculated for all nest sites (Magurran 1988).

Nest-site characteristics were measured employing a 10-m radius circular plot (0.03 ha) with the nest tree at the center (Muller-Dombois and Ellenberg 1974). Nest height, nest tree height, and slope were measured using an electronic clinometer (Haglöf Sweden; Forestry Suppliers, Inc., Mississippi, USA). Crown size, diameter at breast height (DBH), and distances were measured using a metric fabric diameter tape (Model: 283D; Forestry Suppliers, Inc., Mississippi, USA). Percent canopy cover was measured using a GRS Densitometer (Forestry Suppliers, Inc., Mississippi, USA). For comparison with nest trees and sites, we used randomly-selected trees to measure availability in the habitat. Randomly-generated numbers were used to

denote distance and direction, and the nearest tree with ≥ 40 cm DBH was used as the center of a 10-m radius circular plot from which the same data were collected. Focal trees with ≥ 40 cm DBH were large enough to contain cavities that could be used by Mearns's squirrels for nesting. However, we also evaluated the forest structure recording focal tree species, focal tree height, focal tree DBH, and focal tree condition for random trees ≥ 5 cm DBH. In other words, when we located a random tree ≥ 5 cm DBH we considered it as part of the habitat structure; we recorded species, height, DBH, and condition, but instead used the nearest tree ≥ 40 cm DBH to measure habitat availability for nesting.

Collaboration with and between Park Staff.—We worked with the resource management and interpretive staffs of both parks to develop management practices and educational displays that incorporated the findings of the study. Spatial imagery has been shared with both parks. Research updates were provided to staffs at each park. Staffs at each park collaborated in field efforts at either national park to learn the radio-telemetric and habitat analysis techniques employed. Furthermore, park personnel learned to distinguish sign of the rare endemic species and increased awareness of the presence of each species.

RESULTS

Tree squirrel distribution and habitat associations: SSPM.—We detected directly the presence of Mearns's squirrels in the surroundings of the Vallecitos Meadow and La Corona de Abajo (Fig. 8). However, in other remote areas of the park like Arroyo San Rafael, La Tasajera, and La Grulla Meadows, we only detected their presence indirectly by finding fresh eaten pine cones (Fig. 8). Mearns's squirrels have been reported in Vallecitos, La Grulla and La Corona de Abajo before (Yensen and Valdés-Alarcón 1999), but not in Arroyo San Rafael and La Tasajera. In March 2005, we explored La Zanja (Fig. 8) but did not detect either direct or indirect presence

of Mearns's squirrels. However, we only explored the forest for 1 hour which could account for our failure to detect their presence in that remote area. La Zanja is a forested area with presence of water (Fig. 9), and it is possible that we failed to detect the presence of Mearns's squirrels due to their secretive behavior and the month of the year when food is scarce in the forest. We did not have the opportunity to explore La Encantada Meadow (Fig. 8).

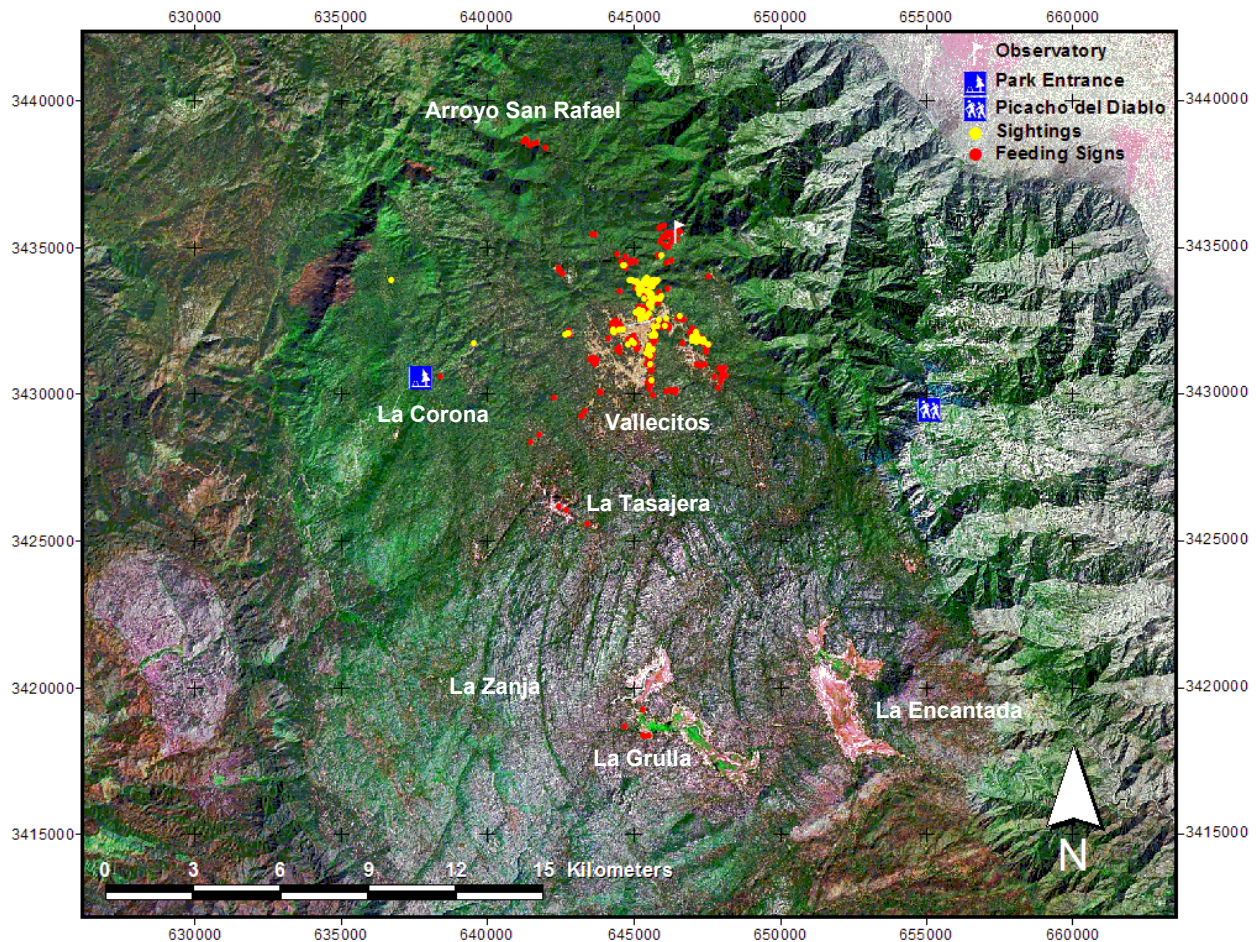


Fig. 8.—Detected presence of Mearns's squirrels (*Tamiasciurus mearnsi*) in the Sierra de San Pedro Mártir National Park, in Baja California, Mexico.

We did not detect directly or indirectly the presence of eastern gray squirrels (*Sciurus carolinensis*) in the surroundings of the Vallecitos meadow, and in the remote areas of the Sierra de San Pedro Mártir explored like La Corona de Abajo, La Tasajera, La Grulla, La Zanja, and Arroyo San Rafael (see Koprowski et al. 2006; Fig. 8). However, we were informed by Juan Vargas (California condor reintroduction project in the Sierra de San Pedro Mártir and who has explored the Sierra as part of his project), that in the summer of 2004 he saw what looked like ‘two big black squirrels’; one at La Zanja and another at Arroyo San Rafael (Fig. 3 and 8).



Fig. 9.—View of La Zanja in the central part of the SSPM National Park (Fig. 3 and 8), in Baja California, Mexico, where we failed to detect the presence of Mearns’s squirrels (*Tamiasciurus mearnsi*) and eastern gray squirrels (*Sciurus carolinensis*). Photo: Bret S. Pasch.

Eastern gray squirrels are larger than Mearns's squirrels and show melanistic variation (Koprowski 1994). Juan Vargas mentioned these locations without knowledge that these were actually the areas of introduction in the Sierra. If confirmed, eastern gray squirrels would be still persisting in the Sierra, but only in the two areas of introduction. We strongly believe that these sightings need to be confirmed. The last report of eastern gray squirrels in the Sierra de San Pedro Mártir is from 1956 at La Zanja and from 1958 at Arroyo San Rafael (Yensen and Valdés-Alarcón 1999).

During 2006 and 2007, we captured and recaptured a total of 79 Mearns's squirrels (adult males = 20; adult females = 18; juvenile males = 23; and juvenile females = 18; Appendix 4). There was no significant difference in the number of times adult males (mean = 3.1 times $\pm$ 2.77 *SD*, *n* = 20) and adult females (mean = 3.71 times $\pm$ 3.97 *SD*, *n* = 17) were recaptured during the study ($t = 0.5451$, *d.f.* = 35, $P = 0.5891$). However, whereas we recorded high presence of juveniles in 2006, we only captured one juvenile female in 2007 (Appendix 2).

Mean population densities for Mearns's squirrels during both years were 0.40 squirrels/ha ($\pm$ 0.04 *SD*) for all age classes, 0.24 squirrels/ha ($\pm$ 0.17 *SD*) for adults only, and 0.16 squirrels/ha ($\pm$ 0.21 *SD*) for juveniles only. However, it is important to note that trapping stations (Appendix 2) were located in areas previously reported in literature (Yensen and Valdés-Alarcón 1999), with probably higher densities compared to other areas within the SSPM forests. We also trapped squirrels during the mating seasons when males moved into these areas in search of females, and that possibly increased our density estimates. Sex ratios (males:females) were 1.24:1 for all age classes, 1.25:1 for adults only, and 1.23:1 for juveniles only. Trap effort for both years was 6.2 trap-hours for each squirrel captured (Appendix 3).

Home ranges of adult males were larger than those of adult females, using both 100% Minimum Convex Polygons (MCP: $t = 3.322$, *d.f.* = 35, $P = 0.0021$) and 95% fixed kernels with

cross validation ($t = 2.644$, $d.f. = 35$, $P = 0.0122$; Fig. 10). Eight Mearns's squirrels (males = 4; females = 4) were previously marked as juveniles in 2006 and provided important information on natal dispersal.

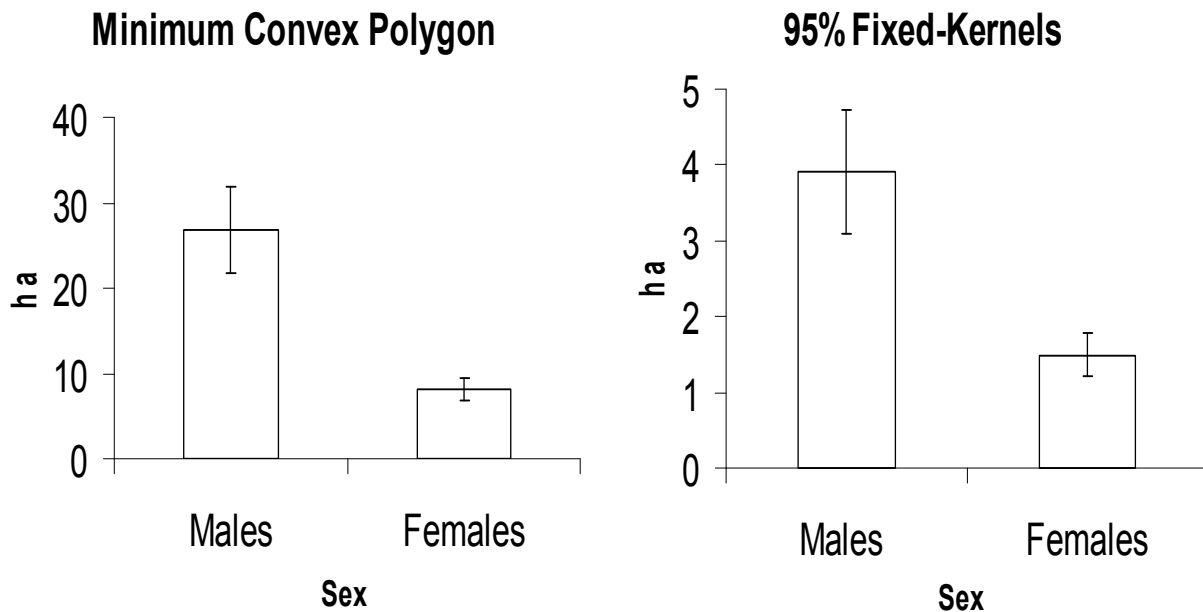


Fig. 10.—Mean home ranges ($\pm SE$) for both adult male ($n = 20$) and adult female ($n = 17$) Mearns's squirrels (*Tamiasciurus mearnsi*) in SSPM National Park using 100% Minimum Convex Polygons (MCP) and 95% fixed kernels with cross validation.

Male number 09 for instance, nested in a tree cavity 1.8 km from natal capture site (Fig. 11). Juvenile males (mean = 0.74 km $\pm$ 0.76 SD; $n = 4$) on average traveled longer distances than juvenile females (mean = 0.095 km $\pm$ 0.070 SD; $n = 4$) before settling in a new area of their habitat as adults. Like adults, there was no significant difference in the number of times juvenile males (mean = 1.83 times $\pm$ 0.98 SD, $n = 23$) and juvenile females (mean = 1.78 times $\pm$ 1.63 SD, $n = 18$) were captured during the study (Mann-Whitney, $U = 174.0$, $P = 0.3859$).

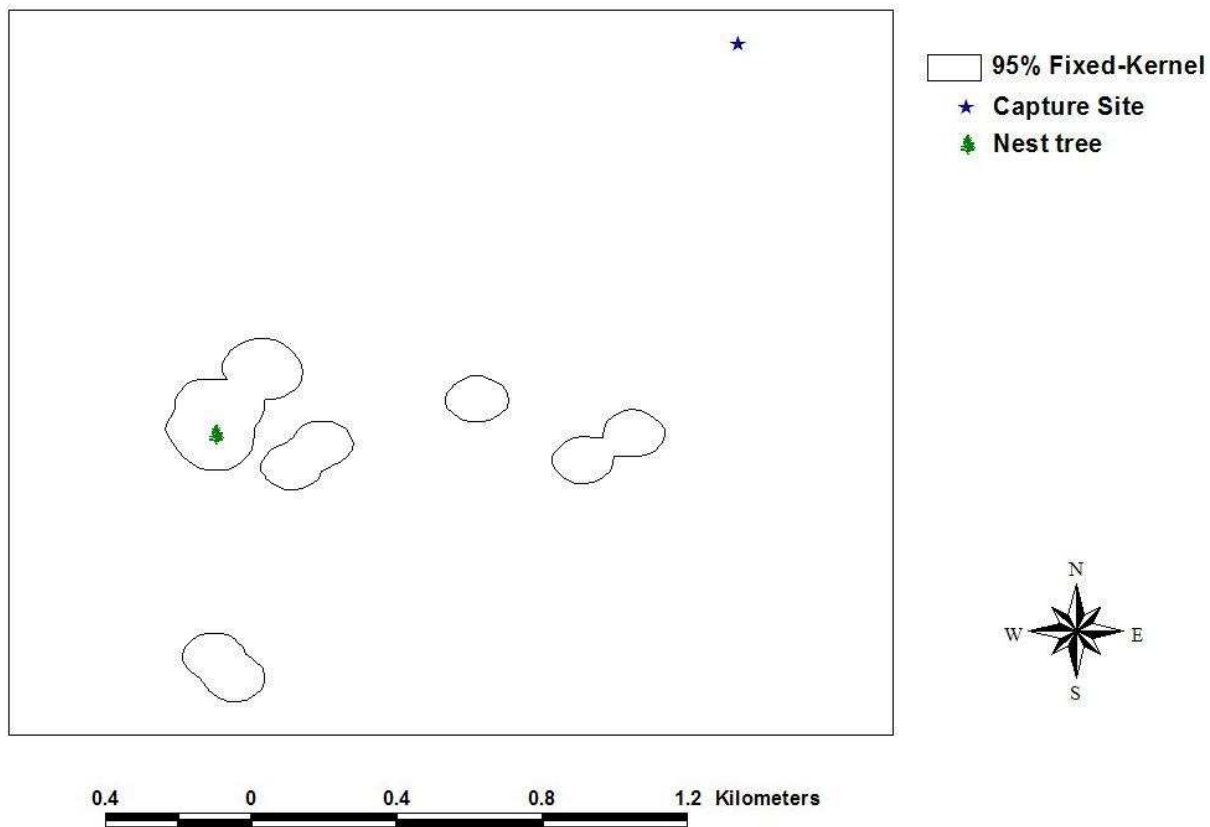


Fig. 11.—The 95% fixed kernel home range for male Mearns's squirrel (*Tamiasciurus mearnsi*) ID 09, the site where captured as a juvenile, and the location of the nest tree used a year later as an adult in the margins of the Vallecitos Meadow.

Our results suggest that Mearns's squirrels do not defend territories like other *Tamiasciurus* do, but instead defend specific trees either where they cache food or their tree cavities are located (Fig. 12). However, we constantly observed adult male and female squirrels exploring tree cavities for potential use.

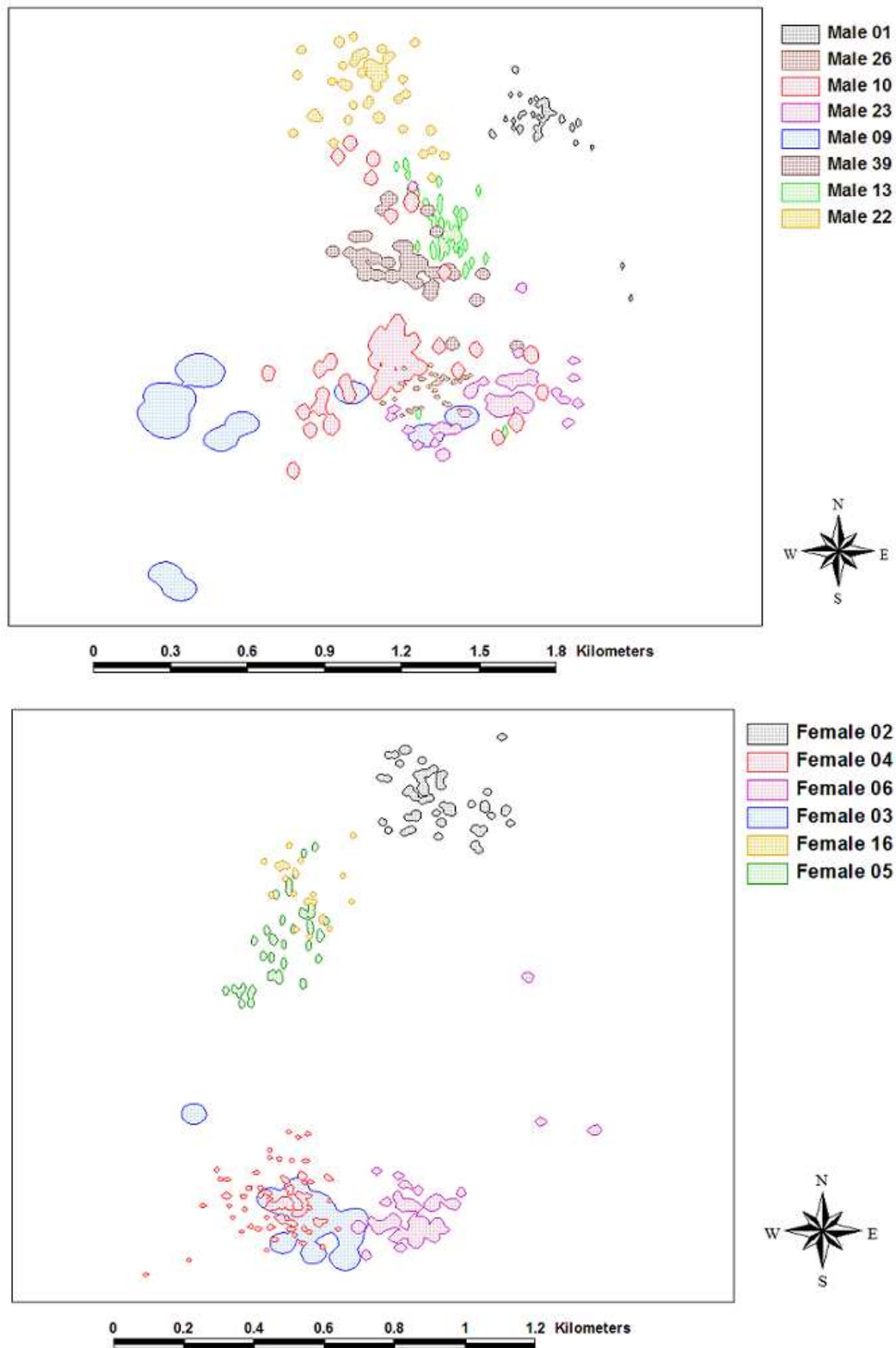


Fig. 12.—Home range overlap for eight adult male and six adult female Mearns's squirrels in the SSPM during 2006 and 2007, using 95% fixed kernels with cross validation.

Compared to other *Tamiasciurus*, Mearns's squirrels do not build larderhoards known as middens, feeding heavily on pine (*Pinus*) and fir (*Abies*) seeds, among other food items such as fungi, pollen, bones, deer antlers, branch tips, and twigs. We believe that the open forest characteristics of the Sierra de San Pedro Mártir, with high temperatures especially during the summer (25⁰ C in July; Michel et al. 2003) make impossible the cool and moist storage of cones in middens by Mearns's squirrels. This seems to be an important adaptation of this species compared to the other two species of the same genus: *T. hudsonicus* and *T. douglasii*.

Tree squirrel distribution and habitat associations: SAGU.—We found no evidence of Arizona gray squirrel presence in Chiminea Canyon or along Paige Creek. Four dreys were located at Grass Shack but all appeared to be old and in decay; Arizona gray squirrels were sighted at this location in 2004 and photographed by Don Swann, National Park Service. However, Arizona gray squirrels were observed on numerous occasions throughout the study period in Miller Canyon and Happy Valley Saddle. In particular, both Arizona gray squirrels and Abert's squirrels made daily visits to ephemeral pools at Happy Valley Saddle as other water sources diminished in the fall. Abert's squirrels were recorded from all high elevation sites including Manning Camp, Spud Rock Campground, Happy Valley Saddle, Mica Mountain, and upper Miller Canyon but appeared absent from lower elevation sites including Grass Shack Campground. We amassed > 430 trap-days (Grass Shack: 40 d; Happy Valley Saddle: 283 d; Miller Canyon; 135 d). We captured 17 squirrels (14 Abert's, 3 Arizona gray) at Happy Valley Saddle. Further information on habitat associations for Catalina gray and Abert's squirrels at SAGU have been described in detail elsewhere (Koprowski 2008).

Demographic characteristics of endemic tree squirrel.—Mating season for Mearns's squirrels seems to begin in March and last until July with litters emerging from May through October and 3-5 young/litter (Fig. 13). Juveniles began to explore the forest floor at ≥ 140 g, and were able to become sexually mature by 1 year of age when ≥ 240 g.



Fig. 13.—Five young Mearns's squirrels (*Tamiasciurus mearnsi*) being moved by their mother to a new tree cavity in SSPM National Park on 25 May 2006. Photo: Nicolas Ramos-Lara.

Whereas the weight of adults did not differ ($t = 0.0178$, $d.f. = 76$, $P = 0.9859$), the weight of juveniles was weakly significant ($t = 2.089$, $d.f. = 65$, $P = 0.0406$; Fig. 14). Home range size of both adult males (MCP: Pearson, $r = 0.1107$, $P = 0.6422$, $n = 20$) and adult females (MCP: Pearson, $r = -0.0538$, $P = 0.8375$, $n = 17$) was not correlated with body size.

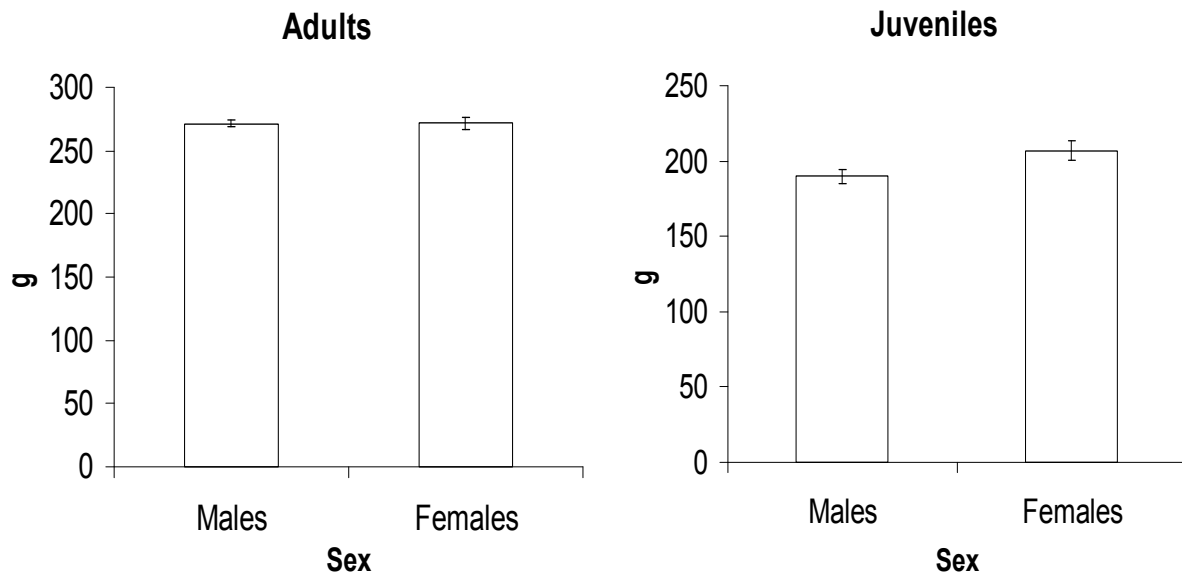


Fig. 14.—Mean body weight ($\pm SE$) for both adult (males, $n = 20$; females, $n = 18$) and juvenile (males, $n = 23$; females, $n = 18$) Mearns's squirrels (*Tamiasciurus mearnsi*).

Both adult male and female Mearns's squirrels survived on average 252.5 days ($\pm 183.5 SD$; $n = 38$). However, although adult males (mean = $284.35 \pm 194.56 SD$) survived more days than adult females (mean = $217.11 \pm 168.7 SD$), the difference was not significant ($t = 1.132$, $d.f. = 36$, $P = 0.2651$; Fig. 15). The Kaplan-Meier survival estimate was lower for adult females than for adult males during both years (Table 1). However, survival of females decreased drastically during the second year compared to that of males (Table 1). Maximum number of days survived by a male Mearns's squirrel was 704 days (ID: 026), and 464 days by a female (ID: 063); when captured in 2006, male 026 was an adult and female 063 a juvenile.

It is important to note that 2005 and 2006 were years with good precipitation and mast production by pine trees. However, 2007 was a dry year with low precipitation and scarcity of food. As a result, squirrels had to travel longer distances in search of food making them vulnerable to predation (Table 1).

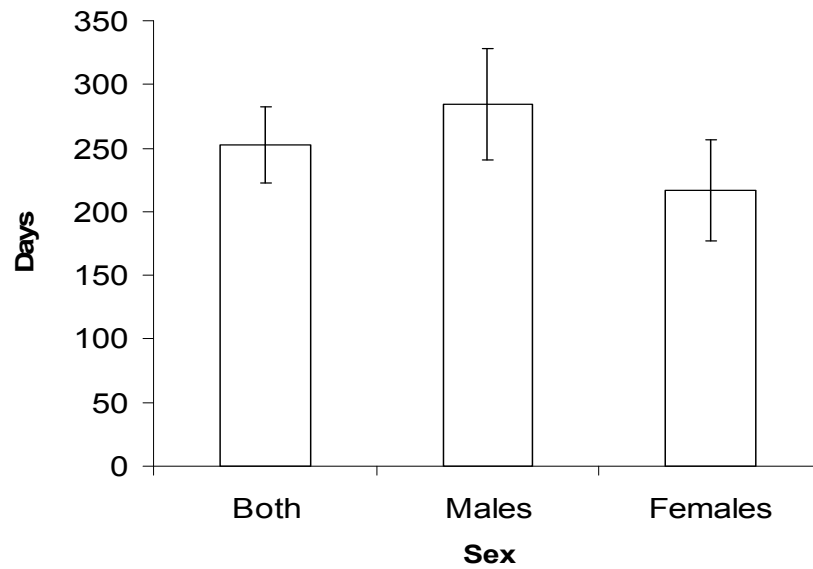


Fig. 15.—Mean survivorship ($\pm SE$) for adult male ($n = 20$) and adult female ($n = 18$) Mearns's squirrels (*Tamiasciurus mearnsi*) in SSPM National Park during 2006 and 2007.

Table 1.—Kaplan-Meier survival estimate for both adult male ($n = 20$) and adult female ($n = 18$) Mearns's squirrels (*Tamiasciurus mearnsi*) radio-tracked during 2006 and 2007 in SSPM National Park, Baja California.

Time period	At risk	Died	Survival
<i>Males</i>			
Year 1	14	1	0.93
Year 2	12	3	0.70
<i>Females</i>			
Year 1	12	2	0.83
Year 2	8	5	0.31
<i>Both sexes</i>			
Year 1	26	3	0.88
Year 2	20	8	0.53

Lower survival rates of adult females may be due to behavior associated with reproduction such as more time searching for food, especially during 2007, making them more susceptible to predation, and the stresses of raising a litter (Halvorson and Engeman 1983). Nonetheless, adult males traveled longer distances from their nests compared to adult females ($t = 2.462$, $d.f. = 35$, $P = 0.0189$; Fig. 16), possibly because besides food, adult males also had to find mates during the reproductive seasons.

As for squirrels at SAGU, we only analyzed changes in body mass in Abert's squirrels due to small sample sizes for Arizona gray squirrels. Mass varied by season (mean winter mass = 698 ± 32.0 g SE , spring = 711 ± 6.7 g, summer = 602 ± 9.7 g, fall = 695 ± 16.2 g; $F = 8.83$, $d.f. = 3, 32$, $P = 0.0002$). However, further details on changes in body mass by Abert's squirrels at SAGU have been described elsewhere (Koprowski 2008).

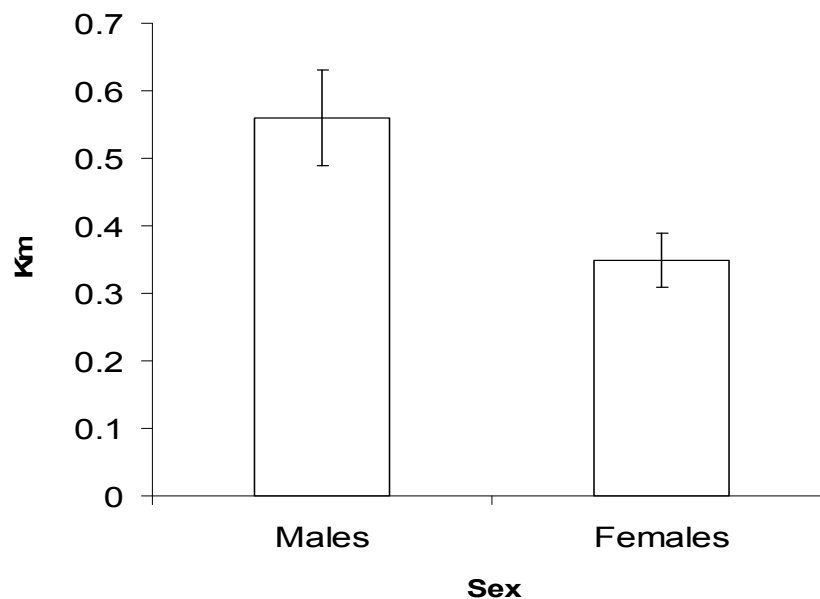


Fig. 16.—Mean longest distance ($\pm SE$) traveled by adult male ($n = 20$) and adult female ($n = 17$) Mearns's squirrels (*Tamiasciurus mearnsi*) from their nest tree in the SSPM National Park.

Nest-site selection.—We located a total of 115 nest trees of Mearns’s squirrels, of which 21 were used for reproduction, known as maternity nests (Appendix 5). Likewise, we also measured 155 random trees to evaluate habitat selection (Fig. 17).

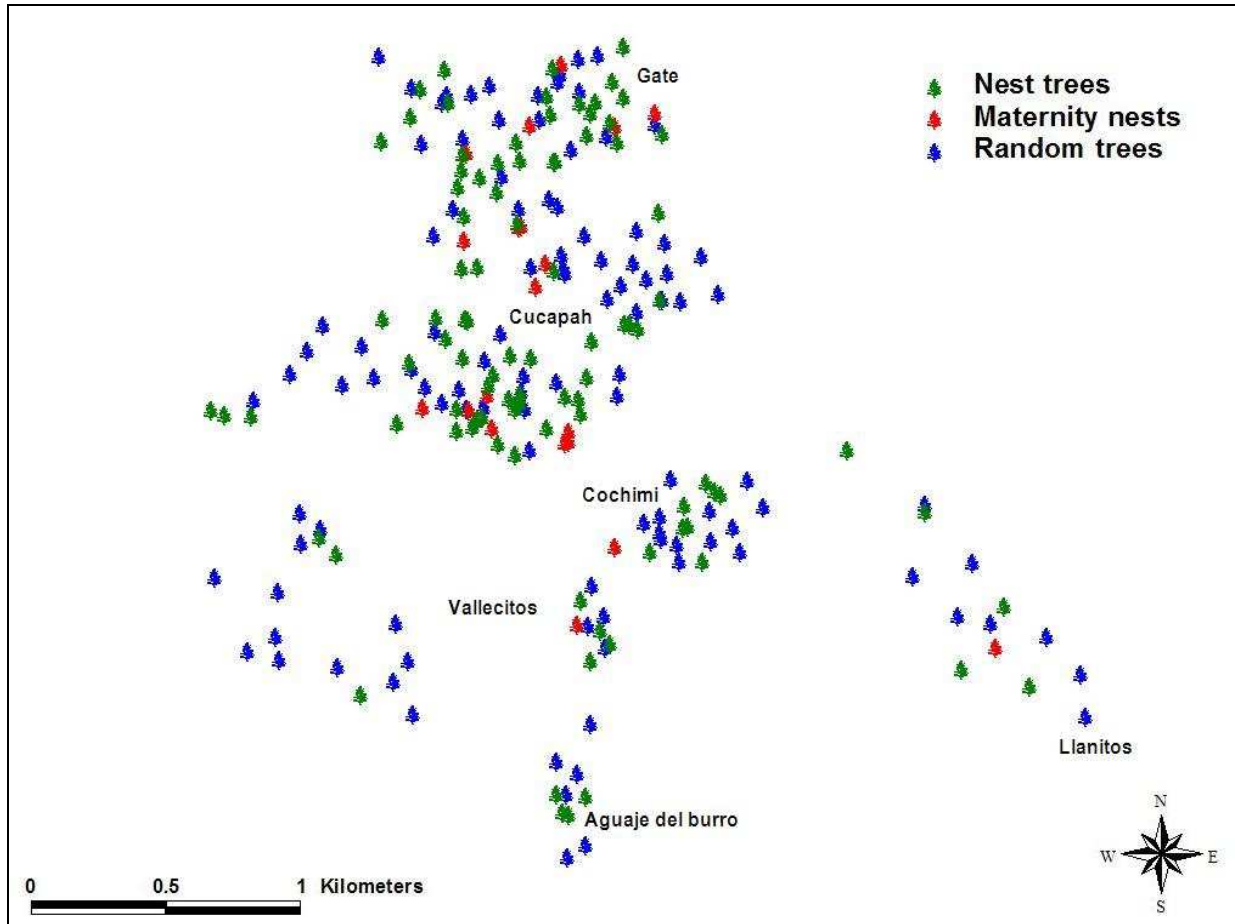


Fig. 17.—Spatial distribution of nest trees ($n = 94$), maternity nests ($n = 21$), and random trees ($n = 115$) used as focal trees to evaluate nest-site selection by Mearns’s squirrels (*Tamiasciurus mearnsi*) in the Sierra de San Pedro Mártir, Baja California, Mexico.

Unlike other *Tamiasciurus*, Mearns’s squirrels completely rely on tree cavities for nesting (Fig. 18). We also observed one instance of an adult male nesting underground for ≤ 3 days; however, the animal continued to use its usual tree cavity days later.



Fig. 18.—Two juvenile Mearns's squirrels (*Tamiasciurus mearnsi*) standing outside their nest in a live Jeffrey pine on 15 October 2005. Photo: Nicolas Ramos-Lara.

Tree cavities were located on average at 14.77 m (± 6.08 *SD*, $n = 79$). Entrances to both nest trees (Raleigh test, $Z = 0.483$, $P = 0.617$, $n = 76$) and random trees (Raleigh test, $Z = 0.134$, $P = 0.901$, $n = 2$) were randomly distributed around 360° (Fig. 19).

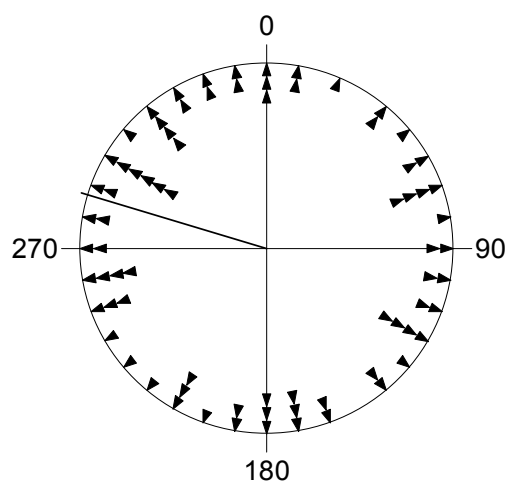


Fig. 19.—Entrances to Mearns's squirrels (*Tamiasciurus mearnsi*) nest cavities ($n = 76$) were randomly distributed around 360° .

Most tree cavities were located in Jeffrey pines (*Pinus jeffreyi*), followed by white firs (*Abies concolor*), and lodgepole pines (*P. contorta*) (Fig. 20). We did not detect squirrels nesting in sugar pines (*P. lambertiana*) nor in quaking aspens (*Populus tremuloides*). Number of trees per species used for nesting were significantly different from random trees ≥ 5 cm DBH (forest structure; $\chi^2 = 22.161$, $d.f. = 2$, $P < 0.0001$) and random trees ≥ 40 cm DBH (availability; $\chi^2 = 21.208$, $d.f. = 2$, $P < 0.0001$). Whereas white firs were more widely used for nesting, lodgepole pines were considerably less used (Fig. 20).

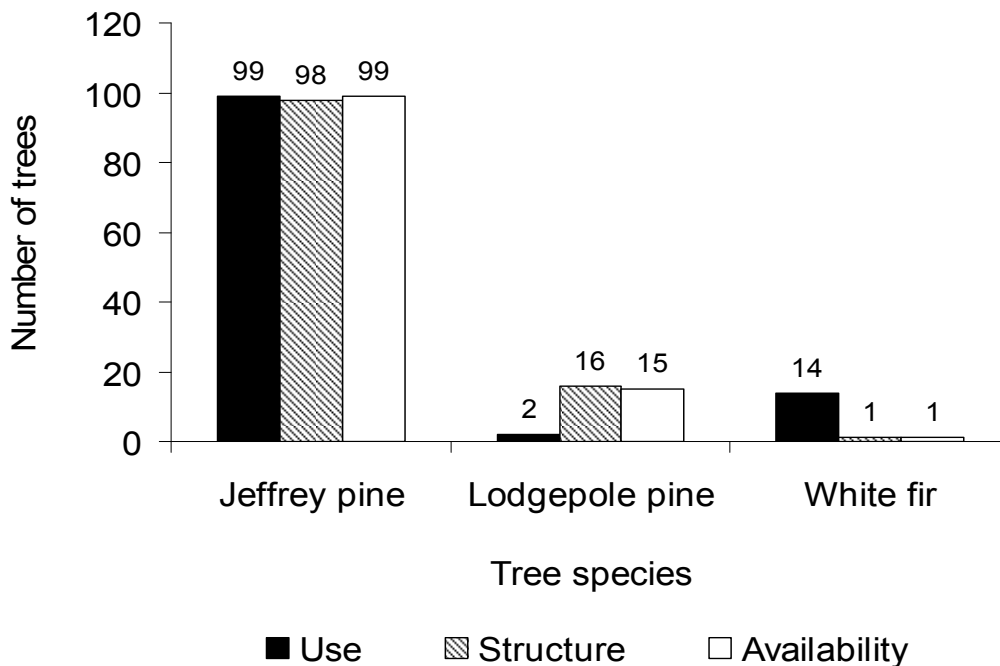


Fig. 20.—Number of trees per species used by Mearns's squirrels for nesting compared to random trees ≥ 5 cm DBH (forest structure) and random trees ≥ 40 cm DBH (availability).

Because dead trees ($P = 0.28$) and snags ($P = 0.71$) did not differ between nest trees and random trees ≥ 40 cm DBH (availability), we decided to pool these data into a single variable,

hereafter referred to as dead trees. Number of tree cavities located in live and dead trees was different from random trees ≥ 5 cm DBH (forest structure; Fisher, $P < 0.0001$) and random trees ≥ 40 cm DBH (availability; Fisher, $P < 0.0001$). Tree cavities were more evenly distributed between live and dead nest trees (Fig. 21).

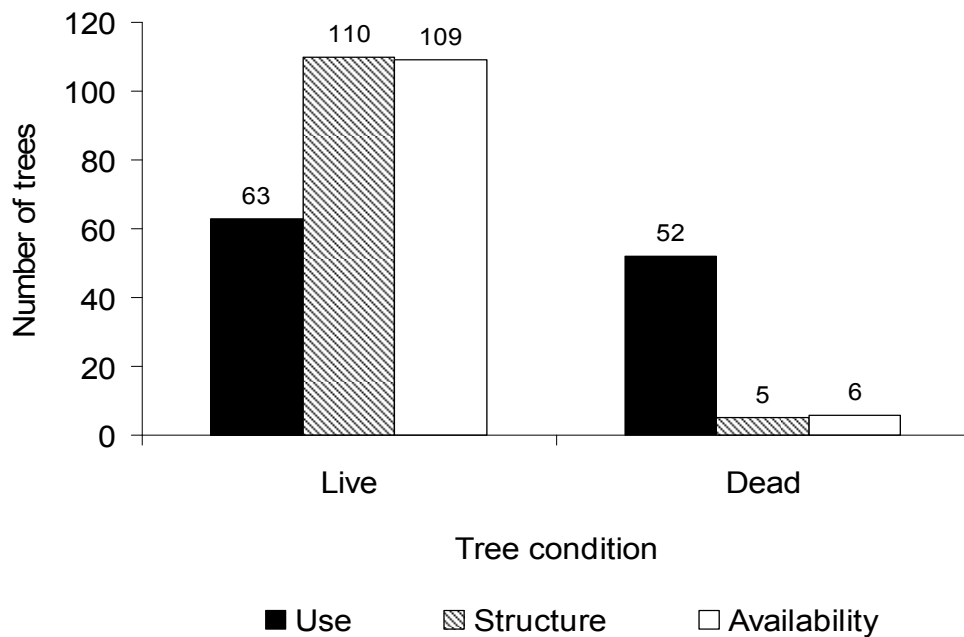


Fig. 21.—Number of live and dead trees used by Mearns's squirrels for nesting compared to random trees ≥ 5 cm DBH (forest structure) and random trees ≥ 40 cm DBH (availability).

Nest trees were taller and larger (DBH) than random trees ≥ 5 cm DBH (forest structure), and had crown sizes bigger than those found at random trees ≥ 40 cm DBH (availability; Table 2). Slope aspect at nest sites was randomly distributed around 360° (Raleigh test, $Z = 1.482$, $P = 0.227$, $n = 115$), and when compared to random trees ≥ 40 cm DBH (availability), we did not find differences between sites (Table 2 and Fig. 22).

Table 2.—Tree cavities, physical, and vegetational characteristics used in univariate analysis to compare nest sites of Mearns’s squirrels (*Tamiasciurus mearnsi*) to random sites with focal trees ≥ 40 cm DBH (availability), except focal tree height and focal tree DBH (≥ 5 cm DBH; structure). Sample size for all variables is $n = 115$, except for tree cavity height (nest sites, $n = 79$; random sites, $n = 2$), tree cavity aspect (nest sites, $n = 76$; random sites, $n = 2$), crown size (nest sites, $n = 63$; random sites, $n = 109$), and slope aspect (random sites, $n = 114$). Comparisons were made using t -tests, Mann-Whitney (U), and Mardia-Watson-Wheeler test (W). Data for tree cavity aspect and slope aspect is mean vector $\pm$ circular SD .

Characteristics	Nest sites $\bar{X} \pm SD$	Random sites $\bar{X} \pm SD$	Results
<i>a) Tree cavities</i>			
Height (m)	14.77 ± 6.08	10.0 ± 10.182	-
Aspect (degrees)	286.78 ± 128.86	305.0 ± 94.203	-
<i>b) Sites</i>			
Focal tree height (m) ^a	24.63 ± 8.96	18.92 ± 10.21	$t_{228} = 4.51, P < 0.0001$
Focal tree DBH ^a	95.63 ± 26.93	47.42 ± 26.78	$t_{228} = 13.61, P < 0.0001$
% canopy cover ^b	41.59 ± 15.91	43.75 ± 9.82	$t_{228} = 1.24, P = 0.2154$
Crown size (m)	4.45 ± 1.30	2.73 ± 1.01	$t_{228} = 9.67, P < 0.0001$
Trees/ha	176.52 ± 167.13	215.07 ± 268.28	$U = 6056.0, P = 0.2703$
Small trees/ha ^c	130.14 ± 161.50	166.09 ± 271.12	$U = 6005.0, P = 0.2285$
Live trees/ha	166.96 ± 163.09	210.43 ± 268.43	$t_{228} = 1.93, P = 0.0547$
Slope aspect (degrees)	246.81 ± 119.52	261.49 ± 101.69	$W = 2.581, P = 0.2750$

^a Random trees ≥ 5 cm diameter at breast height (DBH; forest structure)

^b All distances combined (0 m, 5 m, and 10 m)

^c Trees ≥ 5 cm DBH and < 40 cm DBH

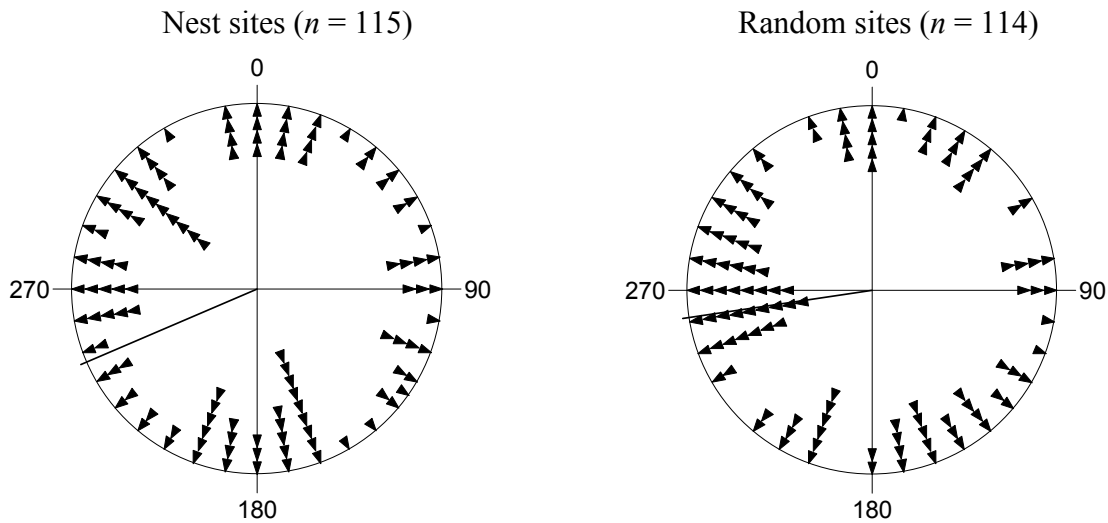


Fig. 22.—Slope aspect at nest sites of Mearns's squirrels (*Tamiasciurus mearnsi*), compared to random sites with focal trees ≥ 40 cm DBH (availability).

We used 21 variables in a principal component analysis (Table 3). The analysis generated 6 components with eigenvalues greater than 1.0, which explained 76.05% of the variance. The first component is largely represented by tree density, and characterized by a high occurrence of small and live trees (≥ 5 cm DBH and < 40 cm DBH), increased basal area and species richness, particularly Jeffrey pines and white firs. The second component is represented by canopy cover, and characterized by canopy cover at 0 m and 5 m, total % canopy cover, and crowns interlocked to other trees (Table 3). The third component describes a more open forest characterized by medium-sized trees (Trees ≥ 40 cm DBH and < 85 cm DBH), lodgepole pine trees, and a reduction in canopy cover at 10 m. The fourth component is represented by large trees and slope. The fifth and sixth components are represented by logs and dead trees respectively, which were not very abundant in the forest (Table 3).

Table 3.—Eigenvectors from principal component analysis of physical and vegetational characteristics of nest sites of Mearns's squirrels (*Tamiasciurus mearnsi*) in a coniferous forest of the Sierra de San Pedro Mártir in Baja California, Mexico. Only principal components with eigenvalues greater than 1.0 and loadings greater or less than ± 0.45 were used in the ecological interpretation of the information.

	Principal components					
	1	2	3	4	5	6
Nest tree height (m)		0.55				
Nest tree DBH	-0.51					
% canopy cover at 0 m		0.69				
% canopy cover at 5 m		0.83				
% canopy cover at 10 m			-0.45			
% canopy cover ^a		0.93				
Interlocked trees		0.60				
Distance to nearest tree (m)	-0.65					
Trees/ha	0.96					
Small trees/ha ^b	0.80					
Medium trees/ha ^c			-0.56			
Large trees/ha ^d				0.64		
Jeffrey pines/ha	0.90					
Lodgepole pines/ha			0.57			
White firs/ha	0.62					
Live trees/ha	0.93					
Dead trees/ha						0.75
Logs/ha ^e					0.49	
Slope (degrees)				-0.58		
Basal area (m ² /ha)	0.59					
Species richness of trees	0.75					
<i>Eigenvalue</i>	<i>6.47</i>	<i>3.30</i>	<i>2.44</i>	<i>1.51</i>	<i>1.22</i>	<i>1.03</i>
<i>% total variance</i>	<i>30.82</i>	<i>15.71</i>	<i>11.62</i>	<i>7.20</i>	<i>5.79</i>	<i>4.91</i>
<i>% accumulated variance</i>	<i>30.82</i>	<i>46.54</i>	<i>58.15</i>	<i>65.36</i>	<i>71.14</i>	<i>76.05</i>

^a All distances combined

^b Trees ≥ 5 cm diameter at breast height (DBH) and < 40 cm DBH

^c Trees ≥ 40 cm DBH and < 85 cm DBH

^d Trees ≥ 85 cm DBH

^e Logs ≥ 15 cm diameter and ≥ 1.5 m length

We also analyzed our data with a stepwise discriminant function analysis (DFA). In order to prevent multicollinearity, high pairwise correlations ($r > 0.70$) between variables were identified prior to stepwise DFA. As a result, the variables: % canopy cover, trees/ha, small trees/ha and live trees/ha were removed prior to stepwise DFA (Table 4).

Table 4.—Physical and vegetational characteristics used in stepwise discriminant function analysis to compare nest sites of Mearns's squirrels (*Tamiasciurus mearnsi*) to random sites with focal trees ≥ 40 cm DBH (availability) in a coniferous forest of the Sierra de San Pedro Mártir in Baja California, Mexico.

Site characteristics	Nest sites ($n = 115$) $\bar{X} \pm SD$	Random sites ($n = 115$) $\bar{X} \pm SD$
Focal tree height (m) ^a	24.63 $\pm$ 8.96	24.98 $\pm$ 6.41
Focal tree DBH ^a	95.63 $\pm$ 26.93	65.34 $\pm$ 17.51
% canopy cover at 0 m	75.07 $\pm$ 26.43	86.40 $\pm$ 16.95
% canopy cover at 5 m	30.91 $\pm$ 23.30	24.85 $\pm$ 17.77
% canopy cover at 10 m	18.78 $\pm$ 17.18	20.01 $\pm$ 14.54
Interlocked trees	1.34 $\pm$ 2.49	2.35 $\pm$ 3.63
Distance to nearest tree (m)	5.13 $\pm$ 3.27	4.15 $\pm$ 2.61
Medium trees/ha ^b	37.10 $\pm$ 46.26	44.06 $\pm$ 43.61
Large trees/ha ^c	9.28 $\pm$ 17.41	4.93 $\pm$ 12.68
Jeffrey pines/ha	134.78 $\pm$ 128.37	198.55 $\pm$ 271.21
Lodgepole pines/ha	18.26 $\pm$ 51.54	11.59 $\pm$ 33.05
White firs/ha	23.19 $\pm$ 53.20	4.64 $\pm$ 18.67
Dead trees/ha	9.57 $\pm$ 20.12	4.64 $\pm$ 12.40
Logs/ha ^d	62.32 $\pm$ 58.83	47.83 $\pm$ 40.26
Slope (degrees)	22.16 $\pm$ 13.03	19.86 $\pm$ 10.94
Basal area (m ² /ha)	21.84 $\pm$ 20.68	20.67 $\pm$ 16.48
Species richness of trees	1.37 $\pm$ 0.79	1.24 $\pm$ 0.57

^a Random trees >40 cm diameter at breast height (DBH; availability)

^b Trees ≥ 40 cm DBH and <85 cm DBH

^c Trees ≥ 85 cm DBH

^d Logs ≥ 15 cm diameter and ≥ 1.5 m length

Selection criterion for entry and removal of variables in stepwise DFA was: F , entry = 3.0 and removal = 2.5. Out of 17 variables (Table 4), 7 discriminated between nest sites and random sites (Wilks' $\lambda = 0.481$, $\chi^2 = 164.239$, $d.f. = 7$, $P < 0.001$; Table 5). Nest sites and random sites differed among all characteristics except focal tree height, as indicated by the correlation between the discriminant function (eigenvalue = 1.078, $\chi^2 = 164.239$, $d.f. = 7$, $P < 0.001$) and original variables (Table 5). Original grouped cases correctly classified were 84.8%.

Table 5.—Correlation between original variables selected in stepwise discriminant function analysis and discriminant function for nest sites of Mearns's squirrels (*Tamiasciurus mearnsi*) and random sites with focal trees ≥ 40 cm DBH (availability).

Site characteristics	Correlation with discriminant function	
	r	P
Focal tree DBH	0.659	<0.0001
% canopy cover at 0 m	-0.247	<0.0001
White firs/ha	0.241	<0.0001
Interlocked trees	-0.185	0.004
% canopy cover at 5 m	0.141	0.028
Large trees/ha ^a	0.138	0.031
Focal tree height	-0.022	0.734

^a Trees ≥ 85 cm diameter at breast height (DBH)

In addition to the univariate analysis (Table 2), nest sites also had larger focal trees, less canopy cover at 0 m but more at 5 m, more white firs, fewer interlocked trees, and more large trees than found at random sites with focal trees ≥ 40 cm DBH (availability) (Table 4 and 5). Sierra de San Pedro Mártir is composed by an open forest with more canopy cover close to focal trees (Fig. 23 and 24); with differences found at 0 m and 5 m (Table 5) and represented by the second and third principal components (Table 3).

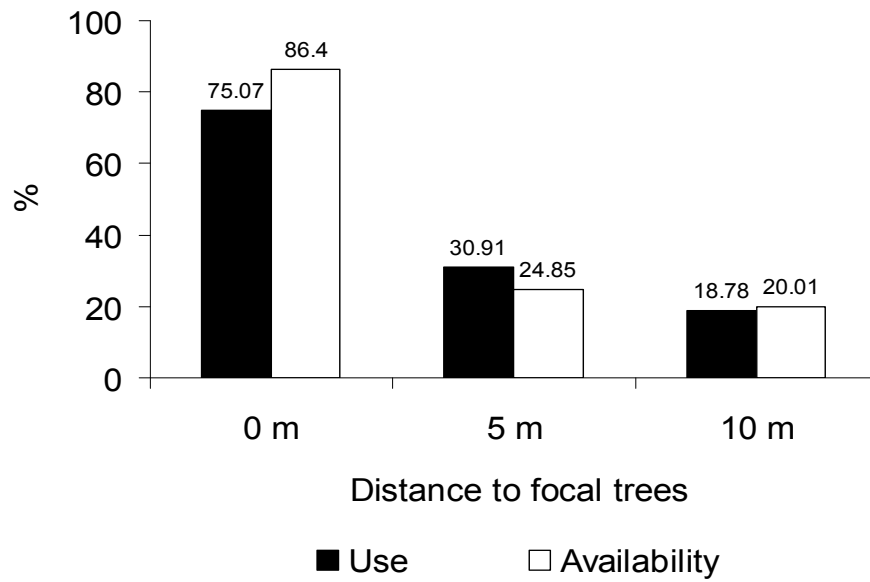


Fig. 23.—Canopy cover at nest sites of Mearns's squirrels (*Tamiasciurus mearnsi*) in SSPM National Park compared to random trees ≥ 40 cm DBH (availability).



Fig. 24.—Open forest that serves as habitat for Mearns's squirrels (*Tamiasciurus mearnsi*) in the Sierra de San Pedro Mártir, Baja California. Photo: Nicolas Ramos-Lara.

The number of small trees that are potentially not available to Mearns's squirrels for nesting are more abundant than medium and large trees (Fig. 25); with differences found in large trees (Table 5) and represented by the first principal component (Table 3). This, together with the fact that the number of dead trees available in the forest is scarce (Fig. 21 and Table 4), and that only 3 out of 115 random trees (≥ 40 cm DBH) had cavities, suggest that availability of tree cavities may be an important factor in the reproduction and survival of Mearns's squirrels (*Tamiasciurus mearnsi*) in the Sierra de San Pedro Mártir.

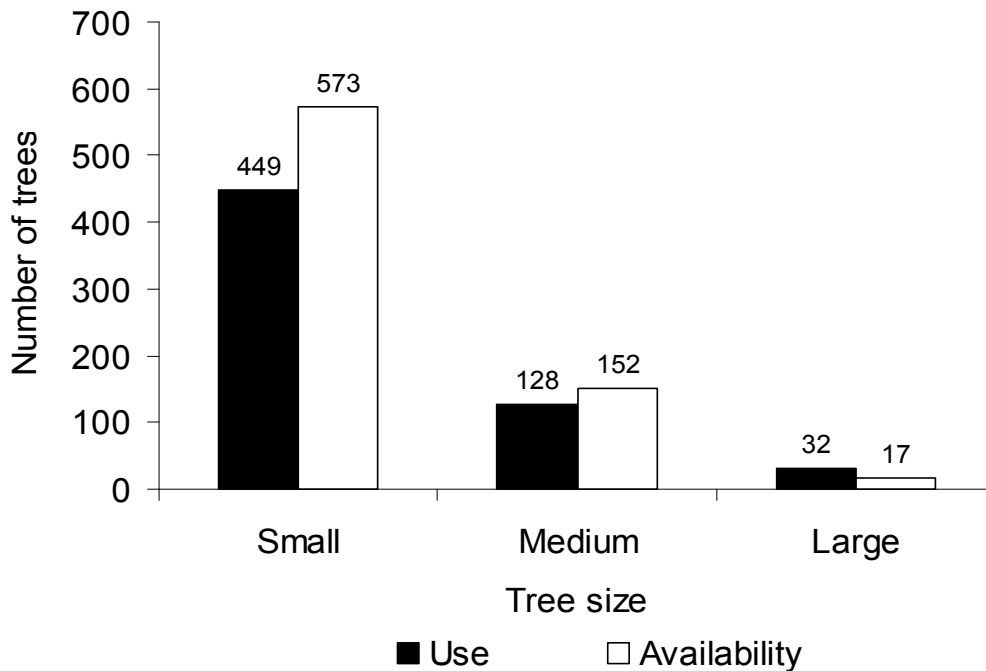


Fig. 25.—Total number of small (≥ 5 cm DBH and < 40 cm DBH), medium (≥ 40 cm DBH and < 85 cm DBH), and large (≥ 85 cm DBH) trees found at nest sites ($n = 115$) of Mearns's squirrels, compared to random sites ($n = 115$) with focal trees ≥ 40 cm DBH (availability).

Diversity (H') was different between nest sites and random sites with focal trees ≥ 40 cm DBH (availability; $t = 8.601$, $d.f. = 1318$, $P < 0.0001$). Tree diversity at nest sites ($H' = 0.718$, $S = 5$, $E = 0.446$, $n = 609$) was higher than that at random sites ($H' = 0.323$, $S = 5$, $E = 0.201$, $n = 742$; $H'_{max} = 1.609$). This difference is probably explained by the presence/absence of quaking aspen and sugar pines at both nest sites and random sites, and by the differences in abundance among species (Table 6). Jeffrey pine was the species with the highest relative density, relative dominance and relative frequency (Table 6). However, the density of white firs on nest sites was higher than at random sites (Table 5 and 6).

Table 6.—Relative dominance (Rdo), relative density (Rde) and relative frequency (Rfr) for each tree species at nest sites of Mearns's squirrels (*Tamiasciurus mearnsi*), compared to random sites with focal trees ≥ 40 cm DBH (availability), in a coniferous forest of the Sierra de San Pedro Mártir in Baja California, Mexico.

Tree species	Nest sites ($n = 115$)			Random sites ($n = 115$)		
	Rdo	Rde	Rfr	Rdo	Rde	Rfr
Jeffrey pine (<i>Pinus jeffreyi</i>)	84.81	76.36	64.05	89.55	92.32	77.30
Lodgepole pine (<i>P. contorta</i>)	2.88	10.34	16.34	7.16	5.39	15.60
Sugar pine (<i>P. lambertiana</i>)	0	0	0	0.55	0.13	0.71
White fir (<i>Abies concolor</i>)	12.27	13.14	18.95	2.74	2.16	6.39
Quaking aspen (<i>Populus tremuloides</i>)	0.04	0.16	0.66	0	0	0
<i>Total (%)</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>

The same variables and statistical analyses (except principal component analysis) used to compare nest sites and random sites were used to compare the sites where nests were used for reproduction, known as maternity nests (Fig. 17), and those only used for refuge. However, we did not find significant differences in any of the variables analyzed (all univariate, $P > 0.05$; stepwise DFA, Wilks' $\lambda = 0.966$, $\chi^2 = 3.841$, $d.f. = 1$, $P = 0.050$). In other words, the characteristics of nest trees and sites used for reproduction and rearing young by Mearns's squirrels were not different from those only used for refuge (Fig. 26).

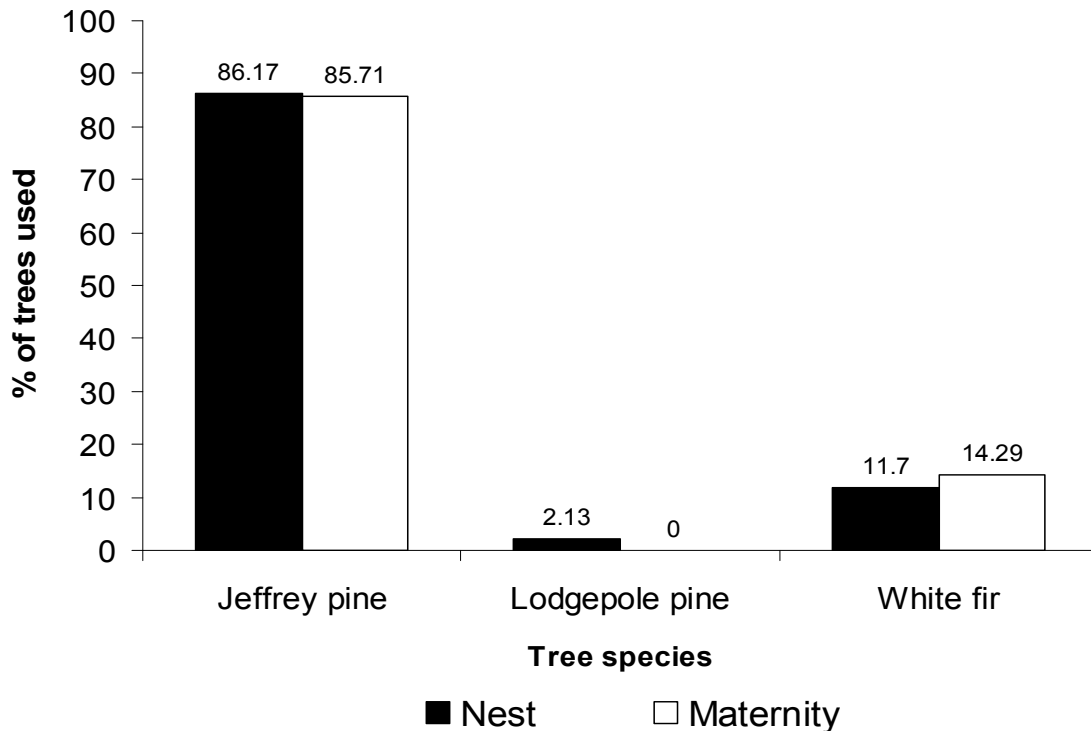


Fig. 26.—Percent of trees per species used by Mearns's squirrels (*Tamiasciurus mearnsi*) for nesting ($n = 94$) compared to maternity nests ($n = 21$).

The percent of live and dead trees was similar between sites where nests were used for refuge and sites where nests were used for reproduction (Fig. 27).

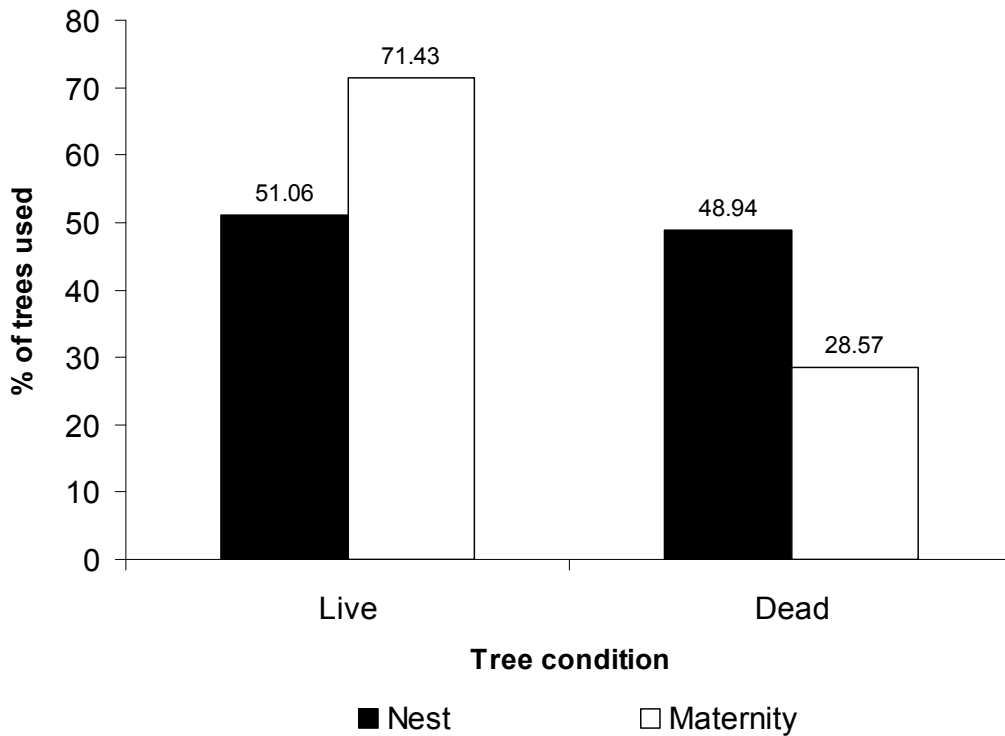


Fig. 27.—Percent of live and dead trees used by Mearns's squirrels (*Tamiasciurus mearnsi*) for nesting ($n = 94$) compared to maternity nests ($n = 21$) in SSPM National Park, Baja California.

Although the relative density of white firs was similar between sites where nests were used only for refuge and sites where nests were also used for reproduction, the basal area and frequency of this species was slightly higher at sites with maternity nests (Table 7). Diversity (H') was similar between sites ($t = 1.822$, $d.f. = 181.05$, $P = 0.0704$). Tree diversity at sites with nests used for refuge ($H' = 0.744$, $S = 5$, $E = 0.463$, $n = 489$) was also similar than that at sites with maternity nests ($H' = 0.591$, $S = 5$, $E = 0.367$, $n = 120$; $H'_{max} = 1.609$).

Table 7.—Relative dominance (Rdo), relative density (Rde) and relative frequency (Rfr) for each tree species at nest sites of Mearns’s squirrels (*Tamiasciurus mearnsi*) in the coniferous forest of the Sierra de San Pedro Mártir, where nests where used only for refuge, compared to sites where nests also were used for reproduction (maternity nests).

Tree species	Nests for refuge (<i>n</i> = 94)			Maternity nests (<i>n</i> = 21)		
	Rdo	Rde	Rfr	Rdo	Rde	Rfr
Jeffrey pine (<i>Pinus jeffreyi</i>)	87.75	75.05	64.75	73.26	81.67	61.29
Lodgepole pine (<i>P. contorta</i>)	3.41	11.45	17.21	0.80	5.83	12.90
Sugar pine (<i>P. lambertiana</i>)	0	0	0	0	0	0
White fir (<i>Abies concolor</i>)	8.80	13.29	17.21	25.94	12.50	25.81
Quaking aspen (<i>Populus tremuloides</i>)	0.04	0.21	0.83	0	0	0
<i>Total (%)</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>

As for squirrels at SAGU, we discovered 87 nest trees of *Sciurus* in the higher elevations of the Rincon Mountains, only 6 of which were leaf nests in oak trees. Squirrels used ponderosa pine trees more for nests than their availability on the landscape and also nested in Arizona white pines (*Pinus reflexa*), silver-leaf oaks (*Quercus hypoleucoides*), and Arizona white oaks (*Q. arizonica*; Fig. 28). Arizona gray squirrels were almost exclusively found nesting in oaks (*n* = 5), whereas Abert’s squirrels used ponderosa pine (*P. ponderosa*) more frequently than available in SAGU high elevation forests. We surveyed 9 random transects and measured habitat characteristics of 44 leaf nests and 45 random trees (Table 8). Arizona gray squirrels and Abert’s squirrels selected nest trees with greater DBH than random trees ($t = 6.62$, $d.f. = 87$, $P < 0.0001$). Tree height was almost twice as great in nest trees than random trees ($t = 7.25$, $d.f. = 87$, $P <$

0.0001). Nest trees had more interlocking branches than random trees ($t = 4.51$, $d.f. = 87$, $P < 0.0001$). Nest sites were found on less steep sites than random sites ($t = 3.89$, $d.f. = 84$, $P = 0.0002$) but did not differ by aspect. Nest trees provided a greater overall percentage of canopy cover than random sites ($t = 4.43$, $d.f. = 85$, $P < 0.0001$; Table 8).

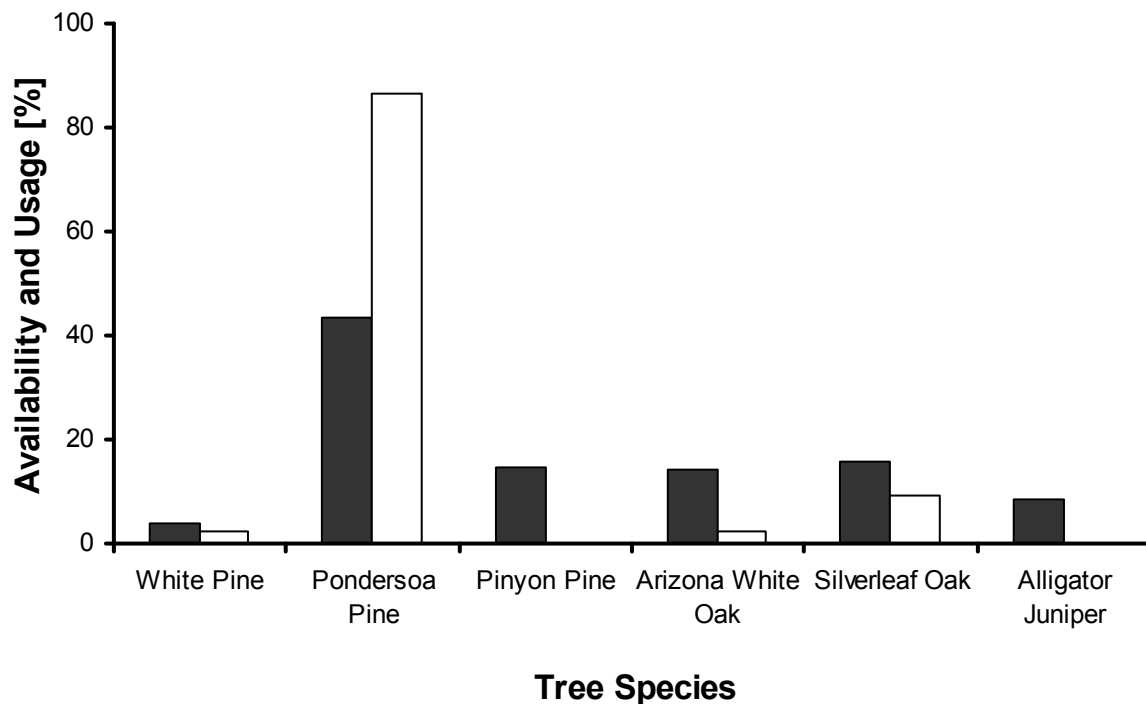


Fig. 28.—Availability of tree species (black bars) in the upper elevation forests of Saguaro National Park, Arizona, compared to the usage of tree species by Arizona gray squirrels and introduced Abert's squirrels (pooled totals in white bars) for nesting.

However, nest sites had on average about 2 fewer live trees per plot (80 trees/ha) than random sites ($t = 1.67$, $d.f. = 87$, $P = 0.09$), but nest sites did have higher overall basal area than random sites ($t = 3.85$, $d.f. = 87$, $P = 0.0002$), indicating squirrels used sites with overall fewer but larger trees. Nest sites also had more logs than random sites ($t = 2.37$, $d.f. = 87$, $P = 0.02$;

Table 8). Nest sites in the Rincon Mountains were characterized by large trees and open stands of trees but with closed and interlocking canopies with many downed logs. Further information on nest-site selection by Catalina gray and Abert's squirrels at SAGU has been described in detail elsewhere (Koprowski 2008).

When tree squirrel site selection (nest sites) and forest availability (random sites) between SSPM and SAGU were compared, we found that nest sites at SSPM had many of the same characteristics exhibited by nest sites at SAGU (Table 8). Trees large in both diameter and height were used by squirrels at both sites; however, tree height at nest sites of tree squirrels at SSPM were not different from random sites as they were at SAGU (Table 4 and 5).

Table 8.—Physical and vegetational characteristics (mean $\pm$ SE) for nest sites and random sites in a coniferous forest of the Sierra de San Pedro Mártir (SSPM: *Tamiasciurus mearnsi* only) in Baja California, Mexico, and the Rincon Mountains, Saguaro National Park (SAGU: *Sciurus arizonensis* and *S. aberti*) in Arizona, USA.

Site characteristics	SSPM	SSPM	SAGU	SAGU
	Nests	Random	Nests	Random
	(n = 115)	(n = 115)	(n = 44)	(n = 45)
Focal tree height (m) ^a	24.63 $\pm$ 0.84	24.98 $\pm$ 0.60	21.33 $\pm$ 0.99	11.29 $\pm$ 0.97
Focal tree DBH ^a	95.63 $\pm$ 2.51	65.34 $\pm$ 1.63	55.02 $\pm$ 2.57	31.12 $\pm$ 2.54
% Canopy cover	41.59 $\pm$ 1.48	43.75 $\pm$ 0.92	80.48 $\pm$ 2.34	66.09 $\pm$ 2.28
Interlocking trees	1.34 $\pm$ 0.23	2.35 $\pm$ 0.34	4.02 $\pm$ 0.25	2.44 $\pm$ 0.25
Live trees/ha	166.96 $\pm$ 15.21	210.43 $\pm$ 25.04	373 $\pm$ 34.5	455 $\pm$ 34.1
Logs/ha ^b	62.32 $\pm$ 5.49	47.83 $\pm$ 3.76	63.63 $\pm$ 3.04	25.19 $\pm$ 3.03
Slope (degrees)	22.16 $\pm$ 1.22	19.86 $\pm$ 1.02	12.02 $\pm$ 2.16	23.64 $\pm$ 2.07
Basal area (m ² /ha)	21.84 $\pm$ 1.93	20.67 $\pm$ 1.54	38.9 $\pm$ 2.42	25.8 $\pm$ 2.3

^a Random trees >40 cm DBH (availability; SSPM)

^b Logs $\geq$ 15 cm diameter and $\geq$ 1.5 m length

DISCUSSION

In contrast to the forests of the western United States, including SAGU, wildfires are allowed to burn in SSPM and as a result the forest displays the open structure associated with unmanaged fires (Savage 1997; Fig. 5 and 24). The gradual build up of subcontinuous shrub cover, conifer recruitment, and litter accumulation may be responsible for the trend in long fire rotation periods in SSPM. In the Sierra Nevada for instance, rapid litter accumulation rates combined with low mass losses from decomposition result in rapid build-up of surface dead fuel loads (Minnich et al. 2000). Fire frequency in the Sierra Nevada was reduced late in the 19th century due to the introduction of livestock grazing, elimination of Native American ignitions, and fire suppression policies (Stephens 2001). Many forest fires in California have exceeded 50,000 ha or an order of magnitude greater than any in SSPM. This large size of fires in California has been attributed to lengthening fire intervals and increased fuel build-up (Minnich et al. 2000). In 2003 for instance, whereas a fire in SSPM is estimated to have created 40 snags/ha in Jeffrey pine-mixed conifer forests, in comparable forests of southern California, the multi-year drought of 1999-2003 killed millions of trees without any impact of fire. Similarly, drought-induced stress has led to increased susceptibility of trees to native tree-killing insects similar to those found in the SSPM, with the addition of western pine beetle (*Dendroctonus brevicomis*) in southern California (Stephens et al. 2008).

In fire-suppressed forests, like those of the Sierra Nevada, insects and diseases in association with periodic drought events have largely replaced fire as the main stand thinning agents, whereas insects, diseases, and fire maintain tree diversity and evenness in the SSPM (Maloney and Rizzo 2002). Recent mortality in southern California forests is thought to be the result of recent droughts and subsequent beetle attacks. The more open structure of the forest in Baja California, Mexico, maintained by frequent surface fires, may have resulted in lower stress

to trees during recent droughts (Savage 1997), and also in lower stress to wildlife species occurring in SSPM like the Mearns's squirrel, which depend on mature and healthy forests for food and refuge (Koprowski and Nandini 2008).

The impacts of decades of fire suppression on the forests of the Rincon Mountains are evidenced in nearly all of the characteristics measured. When comparing the random locations at fire-suppressed SAGU and unsuppressed SSPM (Table 8), the differences in forest structure are evident. In Arizona, trees are smaller in height and diameter and forests are nearly twice as dense with about 20% greater basal area and a closed, interlocking canopy in comparison with the SSPM forests in Baja California; log densities are lower in the areas with fire suppression perhaps indicative of reduced tree mortality (Table 8). Natural fire regimes in the SSPM have maintained open and dry forests (Savage 1997) which we believe prevent Mearns's squirrels from building middens like other *Tamiasciurus* at higher latitudes. The unique characteristics of the SSPM forests, and the more than 10,000 of isolation, seem to have created unique adaptations on Mearns's squirrels like not defending territories like the other members of the same genus *Tamiasciurus*. These unique adaptations require to be studied in order to understand not only the ecology of the genus but also the adaptations of other sky-island organisms. Unlike Catalina gray and Abert's squirrels at SAGU which also rely on leaf nests for nesting, the reliance of Mearns's squirrels on tree cavities make them more vulnerable to the mistakes committed in the fire-suppressed forests in the USA which have resulted in wildfires (Minnich et al. 2000) and insect infestations (Maloney and Rizzo 2002). Forest management in the SSPM require to protect mature a dead trees that are more vulnerable to wildfires and insect infestations. As observed in Table 8, because of the dry and open characteristics of the SSPM as a result of natural fire regimes (Savage 1997), Mearns's squirrels seem to be less selective in the vegetation and physical characteristics of their habitat for nesting compared to Catalina gray and Abert's

squirrels at SAGU where fire-suppressed regimes have resulted in denser forests with higher presence of smaller trees in height and size. It is important to consider that perturbations caused by wildfires at SAGU might have a negative effect on native Arizona gray squirrels and a positive effect on Abert's squirrels for management plans for the non-native species always focus on opening forests to promote *Sciurus aberti* population growth (reviewed by Keith 2003). As a result, more studies are needed to understand the ecology and habitat requirements of native squirrels Arizona gray squirrels at SAGU and Mearns's squirrels at SSPM in order to retain these uncommon endemics within the forests in their current narrow distributions. Such studies will yield further insight into the management of forests within these two sister parks.

COMMUNICATION AND COLLABORATION WITH OTHER COLLEAGUES

As part of our study, we were in contact with people in both Mexico and the United States. In Mexico we met Juan Vargas and Catalina Porras who are in charge of the California condor reintroduction project in the Sierra de San Pedro Mártir. We also had direct contact with the people of the UNAM's National Astronomical Observatory (OAN) in San Pedro Mártir and Ensenada, Baja California, and were in communication with Joaquin Bohigas and David Hiriart-García, former and present heads of the observatory respectively. We also were in communication with SEMARNAT, who provided the permits to work with the endemic Mearns's squirrel in SSPM. Walter Zúñiga and Ángel López, former and present directors of the SSPM National Park respectively, gave us all their support to our project. We had the opportunity to interact with Ernesto Franco-Viscaino and Eric Mellink from *Centro de Investigación Científica y de Educación Superior de Ensenada* (CICESE), and Roberto Martinez-Gallardo from the Baja California State University, each in Ensenada, Baja California, who have done research in the Sierra de San Pedro Mártir and nearby mountains. In the USA, we worked

closely with SAGU resource staff Don Swann and Natasha Kline. We were in communication with Drs. Scott L. Stephens and Richard Minnich, who have been studying fires in SSPM for many years and have initiated a collaboration with the latter's research group at the University of California at Berkeley. We involved 14 researchers from the United States in our research and interactive efforts to include: Drs. William Shaw, William Mannan, Samuel Drake, and John L. Koprowski (all of the University of Arizona). Doctoral students: Melissa Merrick (University of Arizona), Bret Pasch (University of Florida) and Nicolas Ramos-Lara (University of Arizona). Master of Science students: Claire Zugmeyer and David Wood (University of Arizona), and undergraduate students: Chris Schvarcz and Nicole Tautfest (University of Arizona). We are confident that these connections have already facilitated communication and hope that this final report provides justification for further collaboration.

MANAGEMENT AND CONSERVATION IMPLICATIONS

1. Forests within the Sierra de San Pedro Mártir are more open in canopy cover and stem density than in Saguaro National Park where forest fires have been suppressed.
2. Mearns's squirrels seem to be widely distributed in the Sierra de San Pedro Mártir, although at low densities. This study provides the first information on the biology and ecology of the species, which can be used for its conservation and management.
3. Introduced eastern gray squirrels, if still present in the Sierra de San Pedro Mártir, do not seem to be a threat to native Mearns's squirrels, and presence of this species near the areas of introduction (Arroyo San Rafael and La Zanja) still needs to be confirmed. However, Introduced Abert's squirrels in the Rincon Mountains represent a much greater threat to native Arizona gray squirrels.
4. With more than 10,000 years of isolation from the other 2 members of the same Genus (*Tamiasciurus*), Mearns's squirrels seem to have developed unique adaptations to persist and survive in the arid open Sierra de San Pedro Mártir Mountains.
5. Mearns's squirrels may be an excellent model to study adaptation in endemic sky-island species.
6. The Sierra de San Pedro Mártir is an important place to study natural and undisturbed fire regimes. The information is needed to understand why forests in other areas of Mexico and the USA are currently challenged by problems related to wildfires and insect infestations. In this way, the sister park relationship between SSPM and SAGU likely will prove useful for each reserve in the future.
7. Mearns's squirrels, like other species of tree squirrels, may be used as indicators of forest health in the Sierra de San Pedro Mártir. A healthy forest can be monitored through a

healthy population of Mearns's squirrels, and vice versa. Because these squirrels only rely on tree cavities for nesting, artificial nest boxes can be used to estimate the response of the species to these structures, as a better approach to manage the forest to protect this endemic species. Studies using food supplement also can be used to understand how these squirrels depend on mature trees for food as another approach manage the SSPM forests and maintain a good quality of the habitat.

8. The study of the SSPM forests and the ecology of Mearns's squirrels require the collaboration not only of different disciplines in ecology, but also of institutions in both Mexico and the USA.
9. Further studies are needed to understand the natural dynamic of the Sierra de San Pedro Mártir, and the biology and ecology of the Mearns's squirrel. Similarly, the Rincon Mountains and the biology and ecology of the Santa Catalina subspecies of the Arizona gray squirrel serve to provide an important companion ecosystem and indicator species.

PROFESSIONAL PUBLICATIONS AND PRESENTATIONS

1. **February 2006**, we participated in the 39th Joint Annual Meeting of the Arizona-New Mexico Chapters of The Wildlife Society in Flagstaff, with the poster:

Ecology of the Mearns's squirrel (*Tamiasciurus mearnsi*) in the Sierra de San Pedro Mártir.

2. **September 2006**, we published the article:

Koprowski, J. L., N. Ramos, B. S. Pasch, and C. A. Zugmeyer. 2006. Observations on the ecology of the endemic Mearns's squirrel (*Tamiasciurus mearnsi*). The Southwestern Naturalist 51:426-430.

3. **February 2007**, we participated in the 40th Joint Annual Meeting of the Arizona-New Mexico Chapters of The Wildlife Society in Albuquerque, with the oral presentation:

Ecology of the Mearns's squirrel (*Tamiasciurus mearnsi*) in the Sierra de San Pedro Mártir.

4. **September 2007**, we participated in the 14th Annual Conference of The Wildlife Society in Tucson, with the poster:

Ecology of the Mearns's squirrel (*Tamiasciurus mearnsi*) in the Sierra de San Pedro Mártir, Mexico.

5. **August 2009**, we will participate in the 5th International Colloquium on Arboreal Squirrels, in Kamloops, Canada.

6. Additional manuscripts that report the details described here are currently nearing completion for submission.

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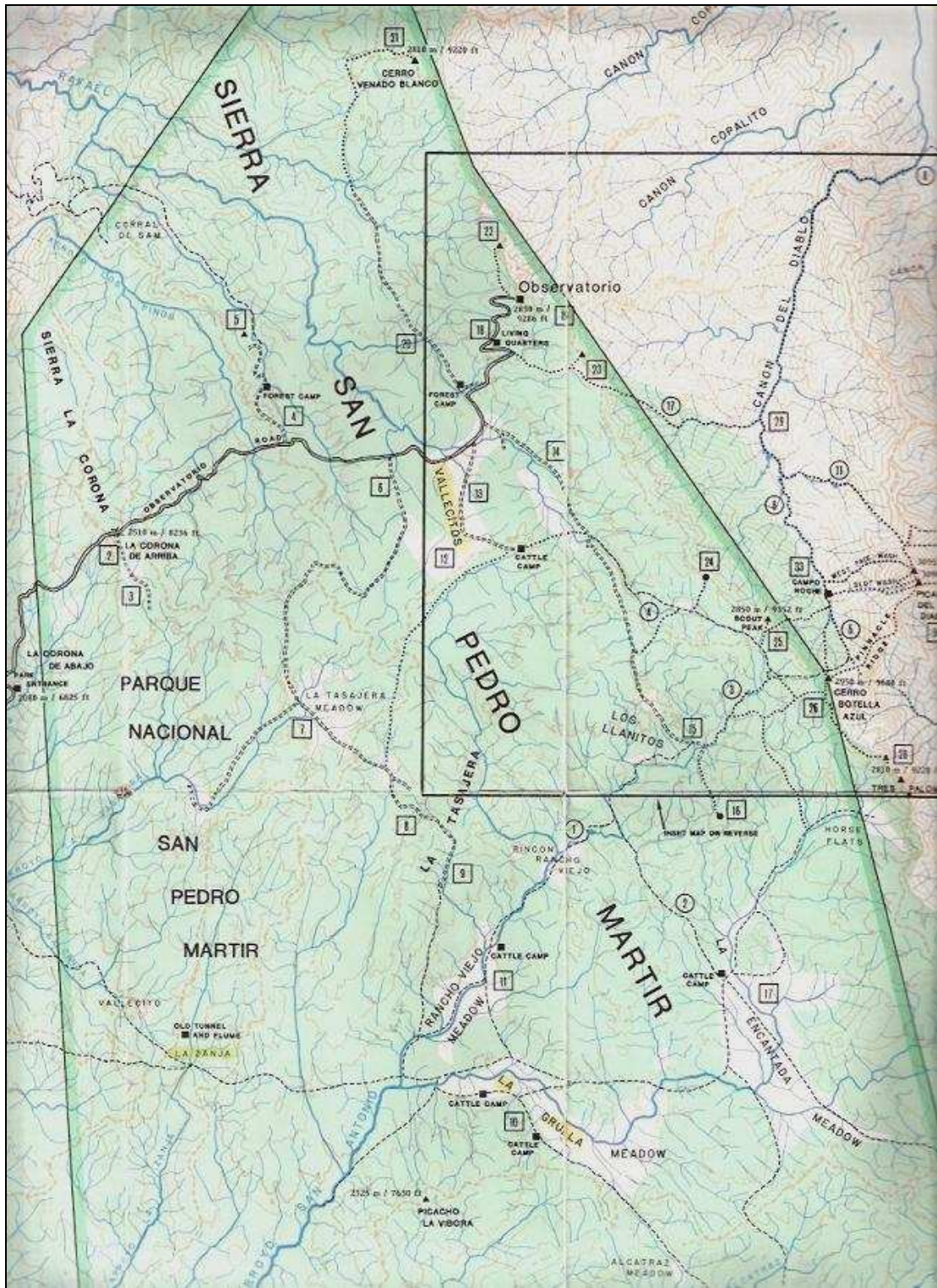
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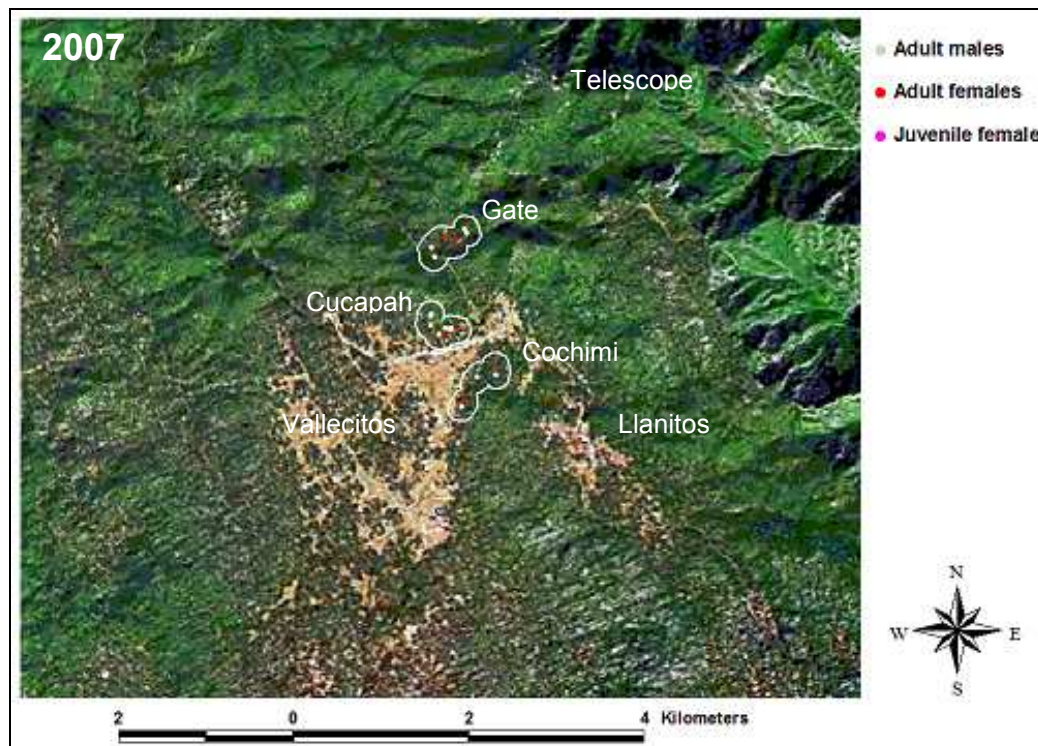
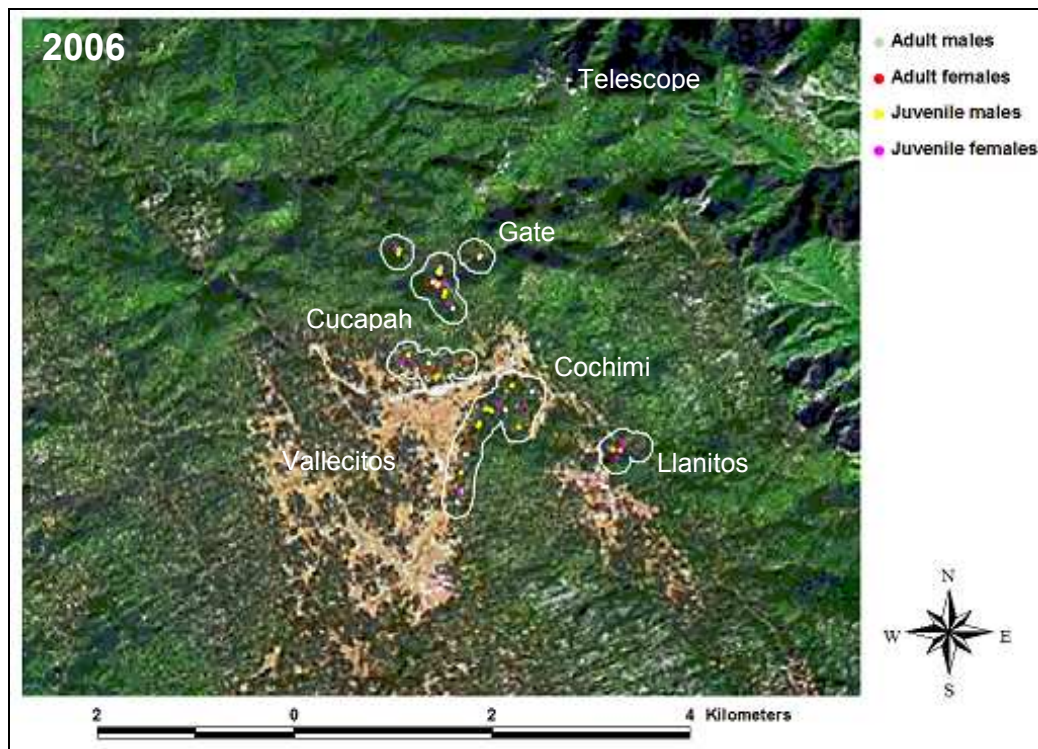
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APPENDIX 2.—Trapping stations and locations of Mearns’s squirrels (*Tamiasciurus mearnsi*) captured in the Sierra de San Pedro Mártir (SSPM) from May 2006 to August 2007.



APPENDIX 3.—Trap effort for Mearns's squirrels (*Tamiasciurus mearnsi*) captured during 2006 and 2007 in the Sierra de San Pedro Mártir, Baja California, Mexico.

Year/Month	No. Days	No. Hours	No. Traps	No. Squirrels
- 2006				
May	10	95	40	6
June	14	130	40	33
July	10	99	40	21
August	6	56	40	6
<i>Total</i>	<i>40</i>	<i>380</i>	<i>40</i>	<i>66</i>
- 2007*				
May	8	79	40	15
June	7	68	40	7
July	4	39	40	5
August	2	17	40	1
<i>Total</i>	<i>21</i>	<i>203</i>	<i>40</i>	<i>28</i>

*Includes recaptures of adults and juveniles from 2006.

APPENDIX 4.—Trapping data for Mearns’s squirrels (*Tamiasciurus mearnsi*) in the Sierra de San Pedro Mártir (SSPM) from May 2006 to August 2007.

Animal	Age	Sex	Left ear	Right ear	Radio freq.	Date capt.
001	Adult	♂	224 Red	222 Red	150.596	May/19/06
					Dropped	
				526 Red	150.205	May/14/07
						May/16/07
						June/09/07
						Aug/06/07
002	Adult	♀	248 White	246 Red	150.695	May/20/06
					150.626	June/05/06
003	Adult	♀	248 White	247 Blue	150.348	May/21/06
				258 Blue		May/24/06
004	Adult	♀	228 White	227 Green	150.486	May/21/06
						June/20/06
			473 White			June/21/06
			Ripped	227 No color	Dropped	July/08/06
				227 Green	150.596	July/09/06
						July/10/06
			495 White	227 -		July/11/06
					No signal	
				227 Green	150.476	May/21/07
						May/22/07
						May/23/07
						June/11/07
						June/12/07
						June/15/07
						June/21/07
				227 -		Aug/05/07
						Aug/05/07
						Aug/05/07
005	Adult	♀	210 White	250 white	150.545	May/22/06
006	Adult	♀	237 Orange	238 Blue	150.656	May/24/06
					Dropped	
					151.845	Aug/05/07
007	Adult	♀	267 Yellow	269 Blue	150.447	June/06/06
						June/07/06

008	Juvenile	♀	229	252	None	June/07/06
						June/11/06
009	Juvenile	♂	262	263	None	June/07/06
	Adult		549 Red	263 Pink	150.016	June/12/07
010/068	Adult	♂	230 Red	231 Green	150.517	June/07/06
			Ripped	Ripped		
			491 Red			July/10/06
					No signal	
	Adult	♂	Ripped	Ripped	Worn out	?
			530 Blue	531 Red	150.146	May/14/07
						May/15/07
						May/16/07
						May/22/07
						June/15/07
011	Juvenile	♂	244	245	None	June/07/06
						June/24/06
						July/11/06
012	Juvenile	♂	242	243	None	June/07/06
013	Adult	♂	240 Blue	241 Yellow	150.405	June/10/06
					No signal	
					150.086	May/13/07
						May/16/07
014	Juvenile	♂	237	236	None	June/10/06
015	Juvenile	♂	232	233	None	June/11/06
						June/12/06
						June/17/06
016	Adult	♀	424 Pink	425 Orange	150.036	June/11/06
					150.316	June/24/06
017	Juvenile	♂	316	317	None	June/11/06
018	Juvenile	♀	421	422	None	June/12/06
						June/17/06
019	Juvenile	♀	401	402	None	June/12/06
020	Juvenile	♂	403	404	None	June/13/06
						June/17/06
021	Juvenile	♂	300	301	None	June/13/06
						June/14/06

						June/17/06
022	Adult	♂	302 Green	303 Green	150.066	June/14/06
023	Juvenile	♂	304	305	None	June/17/06
				Ripped		June/24/06
						July/09/06
	Adult		304 Red	548 Yellow	150.286	June/12/07
						June/21/07
024	Juvenile	♂	306	307	None	June/17/06
025	Juvenile	♀	308	309	None	June/17/06
026/073	Adult	♂	310 Red	311 Orange	150.276	June/19/06
				Ripped		June/20/06
					No signal	
					150.106	July/08/06
					No signal	
	Adult	♂	541 Blue	542 Pink	150.185	May/21/07
						May/22/07
						May/23/07
						June/11/07
						June/12/07
						June/15/07
						June/21/07
027	Juvenile	♂	312	313	None	June/19/06
028	Juvenile	♂	411	412	None	June/19/06
						June/21/06
029	Juvenile	♀	413	414	None	June/20/06
030	Juvenile	♀	418	417	None	June/20/06
031	Juvenile	♀	474	475	None	June/20/06
032	Juvenile	♂	419	420	None	June/21/06
				494		July/11/06
033	Juvenile	♀	471	472	None	June/21/06
				500		July/11/06
034	Juvenile	♀	469	470	None	June/21/06
035	Juvenile	♀	467	468	None	June/24/06
036	Juvenile	♂	465	466	None	June/24/06

037	Juvenile	♂	463	464	None	June/24/06
038	Juvenile	♂	461	462	None	June/24/06
039	Adult	♂	459 Green	460 Yellow	150.155	June/24/06
040	Adult	♂	457 Blue	458 Blue	150.245	July/04/06
				Ripped		July/11/06
						July/12/06
						Aug/07/06
041	Juvenile	♀	455	456	None	July/04/06
						July/04/06
						July/05/06
						July/12/06
						July/12/06
						July/15/06
						July/22/06
042	Juvenile	♀	453	454	None	July/04/06
						July/22/06
	Adult		453 Yellow	556 White	151.235	July/15/07
			453			July/17/07
043	Juvenile	♂	451	452	None	July/04/06
			480			July/05/06
						July/11/06
044	Juvenile	♂	476	477	None	July/04/06
			Ripped			July/08/06
045	Juvenile	♂	478	479	None	July/05/06
046	Juvenile	♂	481	482	None	July/08/06
	Adult		481 Orange	560 White	151.547	July/16/07
047	Juvenile	♂	483	484	None	July/08/06
			519			Aug/06/06
						Aug/07/06
048	Juvenile	♂	485	486	None	July/08/06
						July/09/06
						July/10/06
						July/11/06
	Adult		485 Green	540 Blue	150.566	May/21/07
						May/21/07
						May/22/07
						June/15/07

						June/21/07
049	Juvenile	♀	487	488	None	July/08/06
	Adult		487 Yellow	488 Yellow	150.586	May/21/07
						May/22/07
						May/23/07
						May/23/07
						June/11/07
						June/12/07
						June/15/07
						June/21/07
050	Juvenile	♂		490		July/09/06
			489		None	July/09/06
						July/10/06
051	Juvenile	♀	492	493	None	July/10/06
						July/15/06
052	Juvenile	♀	496	497	None	July/11/06
053	Juvenile	♀	498	499	None	July/11/06
054	Adult	♂	501 Green	502 Orange	150.196	July/12/06
					Dropped	
					151.885	July/17/07
055	Juvenile	♂	503	504	None	July/12/06
056	Adult	♂	505 Blue	506 White	150.005	July/12/06
057	Juvenile	♂	507	508	None	July/12/06
						July/17/06
						July/17/06
						July/22/06
058	Juvenile	♂	509	510	None	July/15/06
059	Adult	♂	511 Green	512 Red	150.175	July/15/06
060	Juvenile	♂	513	514	None	July/17/06
061	Juvenile	♀	515	Ripped	None	Aug/04/06
062	Juvenile	♀	516	Ripped	None	Aug/05/06
	Adult	♀	516 Pink	529 Green	150.335	May/14/07
						Aug/06/07
063	Juvenile	♀	517	518	None	Aug/05/06

	Adult	♀	517 Orange	518 Red	150.315	May/14/07
						June/06/07
			517 -			Aug/06/07
						Aug/06/07
064	Adult	♀	521 Orange	522 Orange	150.395	Aug/07/06
065	Juvenile	♀	523	Ripped	None	Aug/08/06
066	Juvenile	♀	524	525	None	Aug/08/06
067	Adult	♀	527 Orange	528 Yellow	150.136	May/14/07
						May/16/07
					151.405	June/22/07
						Aug/06/07
069	Adult	♀	532 Orange	533 Green	150.215	May/14/07
					150.536	June/09/07
					151.385	July/22/07
					151.215	Aug/06/07
070	Adult	♀	534 White	535 Orange	150.375	May/14/07
					151.506	June/22/07
071	Adult	♂	536 Green	537 White	150.056	May/16/07
					No signal	
					150.825	June/06/07
						Aug/06/07
072	Adult	♀	538 Yellow	539 Green	150.355	May/16/07
074	Juvenile	♀	543	Not put on	None	May/23/07
						May/23/07
						June/12/07
						June/15/07
						June/21/07
075	Adult	♂	544 Red	545 White	150.806	June/11/07
076	Adult	♂	546 Blue	547 Orange	150.756	June/12/07
						June/21/07
077	Adult	♂	550 Blue	551 Green	150.436	June/15/07
078	Adult	♂	552 Green	553 Pink	150.785	June/15/07
079	Adult	♀	554 Pink	555 Red	150.456	June/15/07
				Ripped		Aug/05/07

						Aug/05/07
080	Adult	♂	Red 557	Blue 558	151.816	July/16/07
081	Adult	♀	561 Pink	562 Yellow	151.016	July/17/07

APPENDIX 5.—Coordinates of nest locations of Mearns's squirrels (*Tamiasciurus mearnsi*) in the Sierra de San Pedro Mártir (SSPM); cavities in yellow boxes are maternity nests.

CAVITY	LAT	LONG	Y_PROJ	X_PROJ	ALTITUDE
MAT CS 01	31.0285053	-115.473476	3433761.64	645695.96	2469
CAV MM10	31.0252886	-115.477272	3433400.12	645338.536	2419
SQU 012	31.0286097	-115.473642	3433773	645680.007	2469
SQU 034	31.0187072	-115.479002	3432668.36	645183.352	2452
SQU 038	31.0263406	-115.478095	3433515.65	645258.408	2437
SQU 053	31.0226863	-115.471824	3433118.81	645862.565	2441
SQU 060	31.0101526	-115.460357	3431744.63	646976.429	2464
SQU 065	31.0095847	-115.483623	3431651.15	644756.038	2425
SQU 075	31.0195833	-115.477298	3432767.69	645344.743	2431
MAT 076	31.0195476	-115.478564	3432762.08	645223.886	2450
SQU 079	31.0122429	-115.458649	3431978.59	647136.298	2450
SQU 082	31.0256019	-115.47183	3433441.98	645857.562	2552
SQU 086	31.0095788	-115.457698	3431684.55	647231.147	2511
SQU 092	31.0150314	-115.471054	3432271.32	645947.705	2439
SQU 104	31.0282038	-115.471634	3433730.64	645872.27	2480
MAT 115	31.0288958	-115.471901	3433806.99	645845.725	2449
SQU 132	31.0192968	-115.477285	3432735.95	645346.363	2431
SQU 136	31.017547	-115.477514	3432541.7	645327.159	2440
SQU 140	31.018822	-115.478753	3432681.4	645206.983	2439
SQU 144	31.0179177	-115.478178	3432581.91	645263.294	2429
MAT 147	31.0108634	-115.45903	3431825.17	647102.071	2435
SQU 154	31.0279671	-115.473391	3433702.1	645704.892	2478
MAT 155	31.0191872	-115.481042	3432718.89	644987.913	2423
MAT 159	31.0251455	-115.477249	3433384.29	645340.994	2488
SQU 162	31.0191084	-115.479755	3432711.84	645110.857	2447
MAT 163	31.0179808	-115.475421	3432592.52	645526.358	2440
MAT 169	31.0239239	-115.476228	3433250.22	645440.312	2469
MAT 170	31.0231733	-115.476596	3433166.54	645406.303	2475
SQU 171	31.0188993	-115.474918	3432694.99	645573.004	2411
SQU 173	31.0186494	-115.482054	3432657.96	644892.108	2429
MAT 175	31.0247568	-115.479372	3433338.43	645138.907	2488
SQU 176	31.0220861	-115.479279	3433042.53	645151.83	2462
SQU 178	31.0184041	-115.476263	3432638.33	645445.338	2455
SQU 181	31.0280159	-115.477306	3433702.39	645331.17	2440
SQU 184	31.0293835	-115.479921	3433850.56	645079.437	2445
SQU 185	31.0294618	-115.473107	3433868.15	645729.763	2437
SQU 186	31.0276426	-115.479385	3433658.29	645133.251	2416
SQU 187	31.0265338	-115.479561	3433535.16	645118.185	2448
SQU 188	31.0213295	-115.474471	3432964.95	645611.9	2462
MAT 189	31.0276594	-115.479237	3433660.34	645147.426	2484
SQU 192	31.0150883	-115.470839	3432277.91	645968.143	2462

MAT 193	31.0187203	-115.478956	3432669.87	645187.749	2541
MAT 194	31.0305682	-115.475526	3433987.62	645497.179	2441
SQU 195	31.0198858	-115.478522	3432799.62	645227.382	2408
SQU 196	31.0161249	-115.469572	3432394.48	646087.511	2452
SQU 197	31.0116234	-115.474308	3431889.29	645642.276	2444
SQU 198	31.00619	-115.476085	3431284.72	645480.859	2446
SQU 199	31.0183693	-115.479743	3432629.93	645113.178	2435
SQU 200	31.0238054	-115.479471	3433232.84	645130.892	2502
SQU 201	31.0175629	-115.464662	3432560.33	646554.075	2451
SQU 202	31.0055772	-115.475849	3431217.1	645504.325	2441
SQU 203	31.0060646	-115.474979	3431272.25	645586.645	2454
SQU 204	31.02984	-115.480963	3433899.8	644979.304	2419
SQU 205	31.0238348	-115.478846	3433236.92	645190.497	2499
MAT 206	31.0285726	-115.476753	3433764.81	645383.129	2420
SQU 207	31.030452	-115.475823	3433974.36	645469.001	2441
SQU 208	31.015455	-115.46167	3432330.63	646842.907	2416
MAT 209	31.0190709	-115.479276	3432708.31	645156.659	2463
SQU 210	31.0236919	-115.475895	3433224.94	645472.461	2471
MAT 212	31.0118204	-115.475206	3431909.96	645556.249	2450
SQU 215	31.0111862	-115.473955	3431841.3	645676.647	2467
SQU 216	31.0165179	-115.470109	3432437.33	646035.691	2442
SQU 217	31.0304537	-115.480039	3433969.03	645066.573	2441
SQU 218	31.0202116	-115.478318	3432836	645246.435	2437
SQU 219	31.0126642	-115.475023	3432003.73	645572.419	2459
SQU 220	31.0106346	-115.474684	3431779.21	645607.889	2444
MAT 226	31.0179243	-115.475583	3432586.04	645510.97	2421
SQU 229	31.0162495	-115.469789	3432408	646066.611	2438
SQU 230	31.0289382	-115.474421	3433808.39	645605.18	2441
SQU 237	31.0193808	-115.475032	3432748.21	645561.357	2434
SQU 240	31.0054916	-115.475606	3431207.92	645527.655	2458
SQU 246	31.0268308	-115.478743	3433569.14	645195.833	2425
SQU 248	31.0255665	-115.479333	3433428.23	645141.416	2475
SQU 249	31.0295227	-115.476082	3433871.01	645445.683	2406
SQU 251	31.0190919	-115.4775	3432712.96	645326.229	2427
MAT 252	31.0184585	-115.478362	3432641.63	645244.846	2437
SQU 253	31.0214599	-115.480114	3432972.02	645073.062	2463
SQU 254	31.0273311	-115.477998	3433625.57	645266.162	2446
SQU 259	31.0271071	-115.479437	3433598.86	645129.142	2451
SQU 260	31.020675	-115.481567	3432883.12	644935.539	2451
SQU 261	31.0208035	-115.479468	3432900.11	645135.74	2455
SQU 262	31.0143066	-115.484463	3432173.45	644668.752	2436
SQU 263	31.0190045	-115.488739	3432688.63	644253.403	2434
SQU 264	31.0194625	-115.475523	3432756.63	645514.369	2440
SQU 265	31.0289058	-115.475943	3433802.81	645459.959	2437
SQU 266	31.018976	-115.487713	3432686.8	644351.401	2422
SQU 267	31.0191713	-115.48926	3432706.45	644203.445	2421
SQU 268	31.0218523	-115.472995	3433024.83	645752.025	2451
SQU 269	31.0207771	-115.47685	3432900.6	645385.69	2450
SQU 270	31.0282044	-115.474575	3433726.86	645591.583	2455

SQU 271	31.0184834	-115.479135	3432643.38	645171.081	2432
SQU 273	31.0273391	-115.475823	3433629.3	645473.765	2473
SQU 274	31.0201239	-115.474706	3432831.01	645591.322	2454
SQU 275	31.0221535	-115.482563	3433045.7	644838.244	2443
SQU 276	31.0218649	-115.473206	3433025.95	645731.89	2448
SQU 277	31.0157634	-115.470988	3432352.55	645952.942	2450
SQU 278	31.0138883	-115.470311	3432145.59	646020.394	2456
SQU 279	31.0273568	-115.475818	3433631.27	645474.203	2454
MAT 000	31.0251989	-115.477165	3433390.32	645348.905	2479
SQU 280	31.0193918	-115.477693	3432745.94	645307.267	2424
SQU 281	31.0221136	-115.479386	3433045.43	645141.587	2467
NT 35	31.0142265	-115.47235	3432180.4	645825.22	2467
MAT 282	31.0182909	-115.475399	3432626.92	645527.959	2466
SQU 283	31.029309	-115.474208	3433849.77	645624.881	2449
SQU 284	31.0148714	-115.485131	3432235.19	644604.051	2446
SQU 285	31.0217127	-115.472705	3433009.73	645779.978	2448
SQU 286	31.028118	-115.482505	3433706.91	644834.761	2461
SQU 287	31.0274031	-115.47718	3433634.63	645344.133	2435
SQU 288	31.0311771	-115.47311	3434058.28	645726.886	2483
SQU 290	-	-	3432911.86	645311.397	2445.46
SQU 291	-	-	3433048.71	645035.457	2463.73
SQU 293	-	-	3433845.43	645567.725	2426.23
SQU 294	-	-	3433927.7	645686.525	2447.14
SQU 296	-	-	3433794.5	644943.389	2413.98
MAT 297	-	-	3432198.37	645696.181	2436.09