

# Correlates of Vulnerability in Chiricahua Fox Squirrels

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**Abstract**—Chiricahua fox squirrels (*Sciurus nayaritensis chiricahuae*) are endemic to the Chiricahua Mountains of southeastern Arizona. A paucity of natural history information and uncertain conservation status served as impetus for us to initiate a descriptive ecological study of the species. We examined reproductive and population ecology of Chiricahua fox squirrels intermittently from 1994 to 2003. Chiricahua fox squirrels appear to possess 10 of 13 attributes associated with vulnerability to extinction, including low population densities and reduced reproductive capacity. We underscore potential negative impacts of fire suppression on the species and provide direction for future research and management.

## Introduction

Identifying patterns unique to endangered and threatened species are among the first questions asked in conservation biology. Ecological, behavioral, and distributional characteristics of a species help inform predictions about extinction risk (Purvis et al. 2000a). Numerous empirical studies have demonstrated that particular life-history attributes are associated with species most vulnerable to extinction (Russell et al. 1997). Characteristics of vulnerability include species with restricted ranges (Mace 1994), low population densities (Foufopoulos and Ives 1999), specialized habitat requirements (Purvis et al. 2000), and low rates of population increase (Bennett and Owens 1997). Accordingly, species that possess many traits associated with vulnerability should be primary targets for conservation action.

Chiricahua fox squirrels (*Sciurus nayaritensis chiricahuae*), a subspecies of the Mexican fox squirrel, are endemic to the Chiricahua Mountains of southeastern Arizona (Brown 1984). Chiricahua fox squirrels are large-bodied squirrels (~700 g) that lack sexual dimorphism and occur at low densities (Best 1995). Basic information on the ecology of *S. n. chiricahuae* is restricted to scant field notes of early naturalists (Cahalane 1939) and later compilers (Brown 1984; Hoffmeister 1986). A complete lack of ecological data resulted in Category 2 designation of the species (Drewry 1991), a listing category subsequently abandoned by the United States Fish and Wildlife Service.

Biogeographical isolation, a paucity of natural history information, and uncertain conservation status served as impetus for initiating our ecological study on Chiricahua fox squirrels. Our objectives were to (1) survey the population and (2) describe fecundity of reproductive females to determine if Chiricahua fox squirrels exhibited further characteristics associated with species vulnerable to extinction.

## Methods

### Study Area

Chiricahua National Monument (elevation 1,573-2,228 m) is located along the northwestern terminus of the Chiricahua

Mountains, 55 km southeast of Willcox, Cochise County, Arizona. Towering rhyolite pillars and rocky outcroppings covered with chaparral (*Arctostaphylos pungens*, *Quercus toumeyi*, *Pinus cembroides*) dominate the 5,000 ha preserve. Squirrels are relegated to canyon bottoms composed of pines (*P. engelmanni*, *P. leiophylla*, *P. ponderosa*), oaks (principally *Q. arizonica*, *Q. emoryi*, *Q. hypoleucoides*, *Q. rugosa*), alligator junipers (*Juniperus deppeana*), and Arizona cypress (*Cupressus arizonica*: Brown 1984; Cahalane 1939; Hoffmeister 1986).

### Trapping and Nest Use

We captured squirrels in live-traps (Tomahawk Live Trap Co., Tomahawk, WI, Model 104) baited with peanut butter. Squirrels were transferred to a cloth handling-cone (Koprowski 2002) and uniquely marked with numbered metal ear tags (National Band and Tag Co., Newport, KY, Model 1005-3) and colored washers (National Band and Tag Co., Newport, KY, 1-cm Model 1842). We radiocollared (Wildlife Materials, Inc., Carbondale, IL, Model SOM 2380) a subset of animals and homed-in on (White and Garrott 1990) squirrels at night to determine patterns of nest use.

### Reproductive Capacity

We traversed the study area in search of unmarked squirrels and identified lactating females with the aid of binoculars. Enlarged, blackened nipples surrounded by a ring of hairless skin characterized lactating females (Steele and Koprowski 2001). We homed in and/or followed all lactating females to their nests and determined litter size by revisiting nests until young emerged.

### Population Survey

A survey of drey (leaf nest) abundance yields a reliable index of population change in tree squirrels (Don 1985). Drey counts are a reasonable indicator of squirrel abundance because > 95% of Chiricahua fox squirrels use dreys as nest sites (unpublished data). We conducted walking surveys throughout

**Table 1**—Density and litter size of North American *Sciurus*.

Species	Density (animal/ha)	Average litter size	Source
<i>S. aberti</i>	0.3–1.1	3.3	Nash and Seaman 1977
<i>S. arizonensis</i>	NA	3.1	Best and Reidel 1995
<i>S. carolinensis</i>	3.0–21.0	2.5	Koprowski 1994a
<i>S. griseus</i>	0.3–4.3	2.7	Carraway and Verts 1994
<i>S. nayaritensis</i>	0.07–0.1	1.6	Herein
<i>S. niger</i>	1.0–12.0	2.7	Koprowski 1994b

the study area to locate dreys in the forest and scrub canopy in May–August of 1994, 1999, and 2003. We scored dreys based on their physical condition: (1) actively maintained and likely in use; (2) in mild disrepair but potentially in use; (3) in extreme disrepair and not in use. Drey categories 1 and 2 were considered actively in use.

## Results

### Female Reproductive Performance

Females had (mean  $\pm$  SD)  $1.62 \pm 0.51$  (range 1–2,  $n = 13$ ) offspring per litter, representing the smallest litter size of all North American tree squirrels (table 1). All young emerged from nests during May–August, indicating that a second reproductive bout did not occur during the late summer or early winter season.

### Drey Use and Population Index

On average, squirrels used (mean  $\pm$  SD)  $4.32 \pm 3.33$  dreys ( $n = 20$ ) and shared at least 22 dreys. Lactating females used tree cavities to raise young but promptly returned ( $4.5 \pm 2.1$  days,  $n = 2$ ) to their drey(s) following juvenile dispersal. Female Chiricahua fox squirrels appear to have a similar birthing length (8–12 weeks) as other tree squirrels (Steele and Koprowski 2001). Therefore, drey counts do not overlook lactating females because abandoned nests do not begin to decay until after four months of neglect (Bret S. Pasch, personal observation).

The number of active dreys was 166 in 1994, 126 in 1999, and 108 in 2003, indicating a 35% decrease in active dreys over 9 years. If we assume that squirrels use at least two dreys per year, we estimate the population size to be at 54 individuals in 2003. Approximately 821 ha (~16%) of the Chiricahua National Monument are forested and available to squirrels. Consequently, the population density of Chiricahua fox squirrels (0.07/ha) is lower than all North American tree squirrels (table 1).

## Discussion

Examination of current population trends is an essential research priority when studying species at risk. The apparent decline in Chiricahua fox squirrel numbers from 1994 to 2003 therefore warrants attention. Understanding the dynamics of potentially threatening processes is imperative to conserving the species. Tree squirrel populations can vary annually in size, but densities tend to remain constant over the long term.

Survivorship and reproduction of tree squirrels is often correlated with tree-seed productivity (Gurnell 1987). Population size decreases significantly following food crop failures and increases following abundant mast years (Koprowski 1991). Because tree seeds constitute the majority of Chiricahua fox squirrels' diet (Koprowski and Corse 2001), we recommend annual surveys of both drey abundance and tree seed productivity. Synthesizing intrinsic risk factors (e.g., low rate of population increase) with extrinsic factors (e.g., food availability) will enable managers to decipher typical population fluctuations against other threatening processes (Beissenger and Westphal 1998).

Measures of female productivity indicate that Chiricahua fox squirrels have small litter sizes and a low frequency of reproduction relative to other congeners. Eastern gray squirrels (*S. carolinensis*) and fox squirrels (*S. niger*) average 2.5–3.0 offspring per litter and potentially produce a second litter in good mast years (Koprowski 1994a,b; Nixon and McClain 1975). The low reproductive potential of Chiricahua fox squirrels translates into a limited ability to recover quickly from disturbance events that decrease population size (Gaston and Blackburn 1995). Therefore, particular care must be taken to maintain mature trees in canyon bottoms to ensure already low squirrel densities do not decrease further.

Island ecosystems are known for endemic species' susceptibility to extinction in the presence of anthropogenic disturbances (Olson 1989). Indeed, the primary threats facing Chiricahua fox squirrels appear to be anthropogenic in nature. Their status as a U.S. Forest Service sensitive species does not prohibit hunting of squirrels for meat and pelt (USDA 1999). Though not popular as a game species, local individuals continue to hunt squirrels on an annual basis (Donna Laing, personal communication). Hunting of Chiricahua fox squirrels could potentially exacerbate population decline by removing females that possess already low reproductive rates.

Decades of fire suppression in a system that experienced a mean fire interval of 15 years prior to European settlement may negatively impact Chiricahua fox squirrels (Swetnam et al. 1989). Squirrels may suffer higher predation within suppressed areas than in prescribed-burned areas, perhaps due to the increased visual obscurity associated with the dense understory where squirrels forage. Unnaturally intense fires characteristic of suppressed forests negatively impact tree squirrels by destroying leaf nests and killing nestlings (Kirkpatrick and Mosby 1981). Conversely, low-intensity fires characteristic of prescribed burns do not damage nests and may stimulate increased cone and mast production (Weigl et al. 1989). Future

studies should survey seed production in prescribed-burned areas and determine the mechanism causing increased mortality of squirrels in suppressed areas.

The mountains of the Madrean Archipelago stand as mesic "islands" in a sea of xeric deserts and grasslands that serve as hostile barriers to dispersal. Tree squirrels epitomize island endemism because of their dependence on mature forests and difficulty in colonizing isolated "sky islands" (Brown 1984). Because tree squirrels serve as reliable indicators of forest health due to their dependence on mature trees (Gurnell 1987; Steele and Koprowski 2001), our study has ancillary application to forest management of the Madrean Archipelago. Understanding the ecology of relict populations in Arizona (e.g., Chiricahua fox squirrels, Arizona gray squirrels, Mt. Graham red squirrels) is of value to managers throughout the sky island region. The potential decline of *S. nayaritensis chiricahuae* is one of many ecological studies that should continue on Arizona's tree squirrels if we are to conserve our unique island endemics.

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