

Survival and mortality of the Arizona gray squirrel (*Sciurus arizonensis*)

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SURVIVAL AND MORTALITY OF THE ARIZONA GRAY SQUIRREL (*SCIURUS ARIZONENSIS*)

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ABSTRACT—Arizona gray squirrels (*Sciurus arizonensis*) are endemic to the southwestern United States and northwestern Mexico. Despite classification as a species of concern in portions of its range, little is known about Arizona gray squirrels. We investigated survival and causes of mortality for a population of squirrels in the Huachuca Mountains in 2007 and 2008. Adult survival was high and did not differ between sexes, with probability of survival >0.70 one year postcapture. Predation was the most common known cause of mortality; consequently, management plans should account for habitat characteristics that provide protection from predators when managing for Arizona gray squirrels.

RESUMEN—La ardilla gris de Arizona (*Sciurus arizonensis*) es endémica del suroeste de los Estados Unidos y noroeste de México. A pesar de su clasificación como especie de interés en algunas porciones de su distribución geográfica, se sabe muy poco sobre las ardillas grises de Arizona. Investigamos la supervivencia y las causas de mortalidad en una población de ardillas en las montañas Huachuca en el 2007 y 2008. La supervivencia de adultos fue alta y no hubo diferencia entre los sexos, con una probabilidad de supervivencia de >0.70 después de un año de la captura. La depredación fue la causa conocida más común de mortalidad; consecuentemente, los planes de manejo para ardillas grises de Arizona deben considerar características del hábitat que provean protección contra depredadores.

Arizona gray squirrels (*Sciurus arizonensis*) are endemic to mountainous sky islands of the southwestern United States and northwestern Mexico (Thorington et al., 2012).

Populations are found at elevations >1,120 m within riparian, deciduous, and mixed forests in several mountain ranges within the Madrean Archipelago, including the

Huachuca Mountains, which are believed to have among the highest densities (Brown, 1984; Hoffmeister, 1986; Best and Riedel, 1995; Cudworth and Koprowski, 2011). Despite classification as a species of conservation concern in Mexico and portions of the United States (*S. a. catalinae*; Best and Riedel, 1995; Álvarez-Castañeda and Patton, 1999), data on Arizona gray squirrels are sparse, which resulted in classification as Data Deficient by the International Union for the Conservation of Nature (A. V. Linzey et al., www.iucnredlist.org). Recent publications have provided much-needed information on space use and ecology (Frey et al., 2008; Cudworth and Koprowski, 2010, 2011, 2013), yet no literature is available on survival and causes of mortality, although anecdotal reports suggest individuals may be killed by both mammalian and avian predators as well as through collisions with vehicles (Brown, 1984). A better understanding of survival and mortality is critical for conservation and management of this sensitive species.

We investigated survival of Arizona gray squirrels from April 2007 to December 2008 on Fort Huachuca Military Reservation on the northwestern portion of the Huachuca Mountains in southwestern Cochise County, Arizona. We restricted data collection to a population of squirrels in the oak–juniper (*Quercus–Juniperus*) and riparian forests of lower Huachuca Canyon between 1,555 and 1,860 m. We placed live traps baited with peanut butter and peanuts at the base of large-diameter trees to capture squirrels and transferred all individuals to a cloth handling cone (Koprowski, 2002). Upon capture, we recorded sex, age class, and reproductive status as well as marked individuals with unique combinations of metal ear tags and colored washers. We radiocollared adults (≥ 540 g) and homed to collared individuals multiple times throughout the day. Based on observations ($n = 1,626$) of marked and unmarked individuals, we estimated $>90\%$ of our population was marked. We collected trapping and telemetry data throughout the duration of the study to document mortality events and evaluate survival. The Arizona Game and Fish Department and The University of Arizona Institutional Animal Care and Use Committee approved all trapping and handling procedures.

We captured 48 squirrels; however, we restricted analysis to individuals equipped with a functioning collar for ≥ 1 month. Consequently, we conducted analyses on 26 adults (males: $n = 13$; females: $n = 13$) and 3 subadults (males: $n = 1$; females $n = 2$). We used a Kaplan–Meier survival analysis to estimate survival time and probability of survival from first capture and a Gehan–Breslow test to compare adult survival between sexes. For known mortalities, we used the median date between last observation and documented mortality as the date of mortality. Because our study ended or squirrel transmitters ceased functioning before we were able to document mortality for each individual, we censored individuals for which we were unsure of status at the last observation ($n = 19$ adults). We report all summary statistics ($\pm SE$).

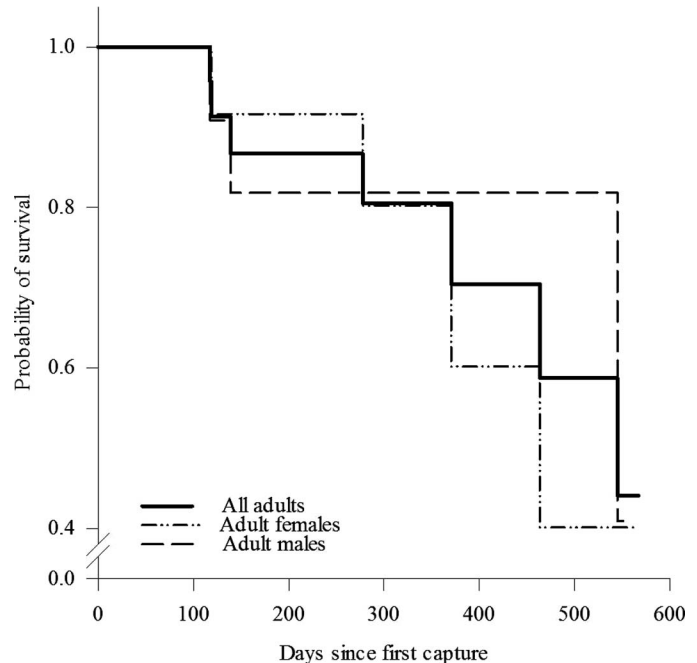


FIG. 1—Survival probability of adult Arizona gray squirrels (*Sciurus arizonensis*) following first capture in the Huachuca Mountains, Arizona, from April 2007–December 2008.

On average, adult minimum survival time was $455.3 (\pm 39.6)$ days following first capture (Fig. 1). Survival time did not differ between adult females (436.3 ± 56.2 days) and adult males (471.7 ± 59.8 days; $\chi^2_1 = 0.002$, $P = 0.961$; Fig. 1); therefore, we combined data from both sexes. Probability of survival 1 year postcapture was high, between 0.71 and 0.81, but dropped to 0.44 by the completion of the nearly 2-year study (Fig. 1). All subadults were alive at the completion of our study, and minimum survival time was $>322.3 (\pm 12.4)$ days postcapture. Eight adults were known to be alive at the completion of our study, and five individuals were known to survive >500 days postcapture. The longest documented life span was an adult female that survived ≥ 567 days postcapture, nearly the entire length of field observations; she was still alive at the completion of the study. Because this individual was an adult with a minimum age of 1 year upon first capture, this equates to a minimum ecological longevity of 2.6 years for our longest-lived individual.

We documented seven natural mortalities and received a report of an additional mortality nearly 1 year after the conclusion of field observations (Table 1). All mortalities occurred between late June and mid-October; we recorded no mortalities during the winter despite our year-round field efforts. Predation was the most common known cause of mortality, followed by vehicle collisions and hunting (Table 1). We also observed a predation attempt by a Cooper's hawk (*Accipiter cooperi*) on juvenile squirrels approximately 8 weeks old; the female successfully defended the young. The cause of death for the remaining individuals is unknown; all were found intact and did not

TABLE 1—Estimated date of mortality, age, sex, number of days alive following first capture, and suspected cause and documentation of known mortalities of Arizona gray squirrels (*Sciurus arizonensis*) in the Huachuca Mountains, Arizona, from April 2007–December 2008.

Date	Age	Sex	Days alive	Cause—documentation of mortality
29 September 2007	Adult	Male	117.5	Unknown—partially decomposed under Arizona white oak (<i>Quercus arizonica</i>)
29 September 2007	Adult	Female	119	Vehicle collision—road near maternity nest
28 June 2008	Adult	Female	370.5	Mammalian predator—collar and pelvic bone cached in log, hair at entrance
13 July 2008	Adult	Female	277.5	Unknown—fresh mortality in manzanita (<i>Arctostaphylos pungens</i>)
23 July 2008	Juvenile	Not recorded	N/A ^a	Unknown—4-week-old on ground under maternity nest
12 August 2008	Adult	Female	463.5	Mammalian predator—collar, remains, droppings
21 August 2008	Adult	Male	139	Avian predator—collar and clipped tail up mountainside
1 October 2009 ^b	Adult	Male	545	Hunting—reported by hunter

^a Not applicable.

^b Taken during hunting season sometime before 24 October 2009; exact date unknown.

appear to have suffered predation, although we were unable to rule out other potential causes of mortality.

Food availability is often a major factor influencing survival of tree squirrels, especially juveniles (Gurnell, 1983; Steele and Koprowski, 2001). Although food availability was not likely limiting during our study (Cudworth and Koprowski, 2013), this may play a larger role during drought and nonmasting years (Koprowski, 1991). Instead, predation was the most common known cause of mortality. Squirrels are consumed by a variety of mammalian and avian predators, and predation may constitute a substantial portion of mortalities, although most predators consume squirrels opportunistically and may have little impact on populations (Gurnell, 1987; Conner, 2001; Steele and Koprowski, 2001; McCleery et al., 2008). Human-caused mortalities due to vehicle collisions and hunting did occur during our study but are likely limited because of the relative protection provided by the active military reservation, where hunting is restricted and vehicular disturbance is minimal. However, we were unable to document the fate of nearly half of the individuals in our population. We lost 11 individuals prior to the completion of the study, either because the radiocollar was no longer functioning, predators carried individuals out of radio range, or individuals emigrated from the study area. The importance of emigration is difficult to quantify, but this may represent a major loss of individuals from a population, especially in food-poor years when emigration by both juveniles and adults may be high (Gurnell, 1983).

Tree squirrels in general experience high levels of mortality as juveniles, but survival increases once individuals reach adulthood at 1 year of age (Gurnell, 1983; Koprowski, 1991; Steele and Koprowski, 2001). Fox squirrels (*S. niger*), for example, are known to reach >7.5 years of age in protected woodlots (Koprowski et al., 1988). Overall, survival of Arizona gray squirrels appears to mimic that of other large-bodied tree squirrels. Although we were unable to estimate survival for

juveniles, all subadults initially captured in the winter of 2007 were still alive at the completion of the study the following winter. Adult survival was high, and, given that adults were ≥ 1 year old at initial capture, survival of Arizona gray squirrels ≥ 2.5 years is likely common. However, we detected no difference in survival time between adult males and females, despite the differing energetic demands and movement patterns between sexes (Havera, 1979; Cudworth and Koprowski, 2010). Because predation is likely an important factor contributing to mortality of adults, land management plans that maintain important habitat characteristics that provide protection from predators (Cudworth and Koprowski, 2011) should be considered when attempting to conserve and manage this sensitive species.

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NEW RECORDS OF SPIDERS (ARACHNIDA: ARANEAE) FROM THE BALSAS BASIN IN CENTRAL MEXICO

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ABSTRACT—The Balsas Basin is one of the largest and most varied formations in Mexico with a high degree of endemism and variety of flora and fauna. To date, there has been no in-depth study of spider diversity in this region. This paper details a survey of spiders found in the Balsas Basin, collected at 20 localities in the states of Guerrero, Puebla, and Morelos between 1997 and 2011. During our survey, we identified 437 mature spiders and grouped them into 24 families, 53 genera, and 56 species and sorted as follows: we found 15 species in Guerrero, 29 in Morelos, and 20 in Puebla. We found five new country records for Mexico and 28 new state records (nine for Guerrero, 10 for Morelos, and nine for Puebla), with a total of 13 possible new species. We estimated beta diversity (change in species composition), and indicated that most localities shared only a few species (fewer than 40%), which suggests that each locality has a unique suite of species with specific habitat characteristics. This first report on spiders from this extensive region shows the necessity for further study in the areas of biodiversity, ecology, and conservation biology.

RESUMEN—La cuenca del río Balsas es una de las formaciones más variada y extensa de México, destaca por la riqueza y grado de endemismo en su flora y fauna. Hasta el momento no existe ningún estudio que involucre a la diversidad de arañas. Aquí presentamos los resultados de un muestreo de arañas que se ha recolectado en la cuenca del Balsas en 20 localidades en los estados de Guerrero, Puebla y Morelos, entre los años 1997 y 2011. Durante nuestro estudio identificamos 437 arañas adultas, que fueron agrupadas en 24