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Sigmodon arizonae (Rodentia: Cricetidae)

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Abstract: *Sigmodon arizonae* Mearns, 1890, is a cricetid commonly called the Arizona cotton rat. *S. arizonae* is a large species of cotton rat with brownish black dorsal pelage and silvery or whitish underparts. Ranging from central Arizona in the United States south to Nayarit in Mexico with a disjunct population along the lower Colorado River in southwestern Arizona and California, it is primarily associated with riparian corridors, but also is found in more arid habitats such as semidesert grassland. Two subspecies of *S. arizonae* appear to be extinct and a 3rd subspecies is imperiled. However, in the majority of its range, *S. arizonae* is considered common and is not of conservation concern.

Key words: Arizona, Arizona cotton rat, California, cricetid, desert grassland, Mexico, Nevada, New Mexico, riparian woodlands, Sonoran Desert, subtropics

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Sigmodon arizonae Mearns, 1890
Arizona Cotton Rat

Sigmodon hispidus arizonae Mearns, 1890:287. Type locality "Fort Verde, Arizona."
Sigmodon hispidus major Bailey, 1902:109. Type locality "Sierra de Choix, 50 miles northeast of Choix, Sinaloa, Mexico."
Sigmodon hispidus jacksoni Goldman, 1918:22. Type locality "3 miles north of Fort Whipple (near Prescott), Arizona (altitude 5,000 feet)."
Sigmodon hispidus cienegae Howell, 1919:161. Type locality "Bullock's Ranch, 4 miles east of Fort Lowell, Pima County, Arizona."
Sigmodon hispidus plenus Goldman, 1928:205. Type locality "Parker, Arizona (altitude 350 feet)."
Sigmodon arizonae: Zimmerman, 1970:446. First use of current name combination.

CONTEXT AND CONTENT. Order Rodentia, suborder Myomorpha, superfamily Muroidea, family Cricetidae, subfamily Sigmodontinae, tribe Sigmodontini. A generic account and key to the species of *Sigmodon* was presented by Baker and Shump (1978a). Because of its significantly larger size *S. arizonae arizonae* may represent a separate species; however, analysis at the genetic level is impossible because no specimens of *S. a. arizonae* have been collected since 1932 (Hoffmeister 1986). All subspecies of *S. arizonae* were once considered subspecies of *S. hispidus* before the elevation by Zimmerman (1970) of *S. arizonae* to specific status. The following 5 subspecies are currently recognized (Hoffmeister 1986; Musser and Carleton 2005; Zimmerman 1970):

S. a. arizonae (Mearns, 1890:287). See above; (extinct).
S. a. cienegae (Howell, 1919:161). See above.
S. a. jacksoni (Goldman, 1918:22). See above; (extinct).
S. a. major (Bailey, 1902:109). See above.
S. a. plenus (Goldman, 1928:205). See above.

Fig. 1.—An adult male *Sigmodon arizonae* from Sweetwater Wetlands, Pima County, Arizona. Photograph by Geoffrey Palmer, used with permission.

DIAGNOSIS

The work done by Zimmerman (1970) on the systematics of *Sigmodon* showed the differences in chromosomal morphology that led to the elevation of *S. arizonae* (Fig. 1) to specific status distinct from *S. hispidus* (hispid cotton rat). *S. arizonae* also differs from *S. hispidus* morphologically in that it is larger (total length ≥ 365 mm with a hind foot measurement of ≥ 32 mm), but the 2 species are generally similar and are typically distinguished by cranial morphology. *S. arizonae* has a presphenoid that is broader; a wider distance between parietal and squamosal crests (≥ 3.2 mm), squamosal crest larger (≥ 7 mm); a dorsal border of supraoccipital that is curved; narrow and elongated anterior spine of the infraorbital plate; palatine slits tapered posteriorly; and angular anteroventral border of the foramen magnum (Fig. 2; Carleton et al. 1999; Hoffmeister 1986; Severinghaus and Hoffmeister 1978). In addition to being larger in overall size, *S. arizonae* differs from *S. mascotensis* (west Mexican cotton rat) in various aspects of cranial morphology (Carleton et al. 1999; Hall 1981); *S. fulviventer* (tawny-bellied cotton rat) in both cranial morphology and the absence of the tawny-colored dorsal pelage present in *S. fulviventer* (Baker and Shump 1978a; Hoffmeister 1986); *S. ochrognathus* (yellow-nosed cotton rat) by differing cranial morphology and the lack of yellowish fur around its nose (Baker and Shump 1978b; Hoffmeister 1986); and *S. alleni* (Allen's cotton rat) by cranial morphology, and also by possessing a more sparsely haired tail with larger scales (Shump and Baker 1978).

GENERAL CHARACTERS

Sigmodon arizonae has a hispid, light brownish black dorsal pelage and light silver or whitish underparts with hairs having a blackish base. The feet are covered in grayish to dull brown-colored hair dorsally and tend to blend with the dorsal pelage. The tail is dark dorsally and grades into lighter brown or silvery on the underside. The tail has large, coarse caudal "scales" and is sparsely covered with long caudal hairs (Carleton et al. 1999; Hoffmeister 1986).

Means (ranges in parentheses) of external measurements (mm) of adult *S. arizonae* were: total length, 305.5 (247.0–363.0; $n = 154$); length of tail, 124.4 (101.0–145.0; $n = 154$); length of hind foot, 38.5 (34.0–43.0; $n = 158$); length of ear, 20.4 (18–24; $n = 127$—Carleton et al. 1999; Hoffmeister 1986). Mean (range) mass (g) of 19 adult *S. arizonae* was 150.3 (83.0–300.0—Carleton et al. 1999). Means (range) of cranial measurements (mm) for adult *S. arizonae* were: occipitonasal length, 35.2 (27.4–40.4; $n = 160$); zygomatic breadth, 20.9 (17.4–23.8; $n = 164$); interorbital breadth, 5.1 (4.5–5.6; $n = 164$); breadth of braincase, 14.9 (13.9–16.3; $n = 160$); breadth of occipital condyles, 8.1 (6.9–8.8; $n = 20$); depth of braincase, 11.7 (9.9–12.9; $n = 19$); distance between

Fig. 2.—Dorsal, ventral, and lateral views of skull and lateral view of mandible of an adult male *Sigmodon arizonae* (University of Arizona School of Ecology and Evolutionary Biology mammal collection [UAEEB]) from Arizona, Cochise County, 1.8 km east, 2.3 km north of Hereford–Paluminas Road, elevation 1,261 m. Occipitonasal length is 1.5 cm.

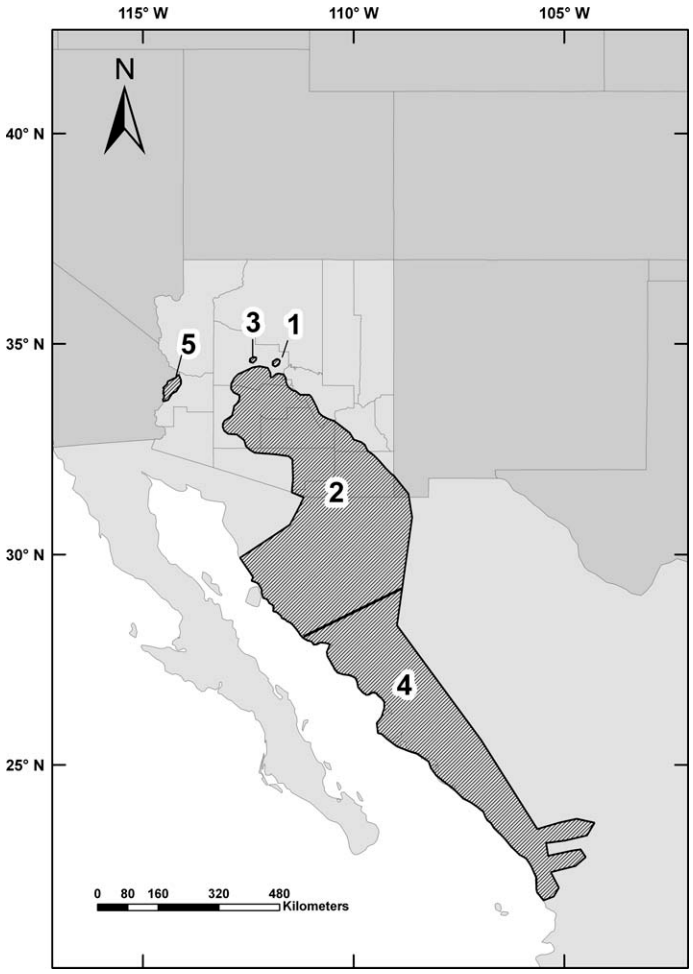

Fig. 3.—Geographic distribution of *Sigmodon arizonae*. Subspecies are: 1, *S. a. arizonae*; 2, *S. a. cienegae*; 3, *S. a. jacksoni*; 4, *S. a. major*; and 5, *S. a. plenus*. Map redrawn from Hall (1981) and Hoffmeister (1986) with modifications.

temporal ridges, 4.4 (3.3–5.0; $n = 24$); length of rostrum, 11.6 (8.3–13.7; $n = 25$); breadth of rostrum, 7.0 (5.4–8.9; $n = 163$); postpalatal length, 12.8 (9.6–15.5; $n = 20$); length of bony palate, 6.6 (5.3–8.0; $n = 25$); breadth of bony palate, 8.1 (6.7–9.2; $n = 25$); length of incisive foramen, 8.0 (6.2–9.7; $n = 25$); length of diastema, 9.8 (7.3–12.1; $n = 164$); breadth of zygomatic plate, 4.1 (3.1–5.1; $n = 164$); length of zygomatic spine, 5.0 (3.6–5.9; $n = 25$); length of auditory bulla, 6.1 (5.3–6.8; $n = 24$); length of maxillary toothrow, 6.82 (6.30–7.39; $n = 164$); length of mandibular toothrow, 7.2 (6.3–8.1; $n = 139$); width of M1, 2.29 (2.12–2.47; $n = 25$); depth of upper incisor, 2.01 (1.53–2.37; $n = 25$); and depth of mandible, 6.6 (5.2–7.6; $n = 25$—Carleton et al. 1999; Hoffmeister 1986). Males are slightly larger than females (total length in males = 289.4 mm versus 269.9 mm in females), and other than this modest size difference and some cranial characters there is no sexual dimorphism (Carleton et al. 1999; Hoffmeister 1986).

DISTRIBUTION

In the United States, *Sigmodon arizonae* is found from southern Yavapai County in central Arizona, southeast through Cochise County in southeastern Arizona and Hidalgo County in extreme southwestern New Mexico (Fig. 3; Frey et al. 2002; Hall 1981; Hoffmeister 1986). An isolated population of *S. a. arizonae* once occurred in the Verde Valley of Yavapai County, Arizona, where the species was 1st described (Mearns 1890). However, this subspecies is considered extinct because no specimen has been documented since 1932 (Hoffmeister 1986). *S. a. jacksoni*, which occurred in the area around the town of Prescott in Yavapai County, Arizona (Goldman 1918), is also considered extinct due largely to habitat destruction and alteration in the form of water impoundments and diversions (Arizona Game and Fish Department 2006). An isolated population of *S. a. plenus* occurs in La Paz County, Arizona, and extreme southeastern California in San Bernardino and Riverside counties along the Colorado River (Frey et al. 2002; Hoffmeister 1986). *S. a. plenus* once occurred in southern Nevada along the Colorado River (Hall 1946) but this population is apparently extinct (Bradley 1966). In Mexico, *S. arizonae* occurs from northern Sonora southwest to the coast of the Sea of Cortez through Sinaloa to southern Nayarit (Hall 1981; Musser and Carleton 2005).

FOSSIL RECORD

No fossils of *Sigmodon arizonae* are known (Martin 1979); however, speciation of *S. hispidus* species group may have occurred during the mid-Pleistocene (Zimmerman 1970). *S. arizonae* and *S. hispidus* could have been separated at this time by the formation of the pre-Wisconsin habitat and the Sierra Madre Occidental in Mexico (Zimmerman 1970).

FORM AND FUNCTION

Mammae counts vary from 10 to 12 in females (Burt 1933). Dental formula for *Sigmodon arizonae* is i 1/1, c 0/0, p 0/0, m 3/3, total 16. It is thought to have year-round reproduction (Hoffmeister 1986). In Arizona young individuals have been captured during all months except May, November, and December when trapping has not been performed (Hoffmeister 1986), and juveniles were present in all sampling periods in a population along the Colorado River (Anderson 1994). Other characteristics of this species may be similar to those of *S. hispidus* (Cameron and Spencer 1981).

ECOLOGY

Sigmodon arizonae requires dense stands of herbaceous vegetation including grasses and forbs in semidesert

grasslands and riparian corridors (Anderson and Nelson 1999; Hoffmeister 1986; Williams 1986; Zimmerman 1970). The isolated populations of *S. a. plenus* are found in marshy and dense grassy cover along the Colorado River floodplain in California near the town of Bard (Williams 1986) and prior to extirpation in Nevada the species was found in a cattail marsh along the Colorado River (Bradley 1966; Hall 1946); this subspecies is found in Lower Colorado Sonoran desertscrub in Arizona (Arizona Game and Fish Department 2006). *S. a. jacksoni* occurred in isolated pockets of moist plains and Great Basin grasslands, whereas *S. a. cienegae* is found in semidesert grassland and associated riparian areas in Arizona and New Mexico (Arizona Game and Fish Department 2006; Frey et al. 2002; Hoffmeister 1986). In Mexico, *S. a. major* is found in savanna–woodland, deciduous tropical forest, palm forest, and mangrove swamp (Carleton et al. 1999). Microhabitats in this part of the range were described as open, grassy, and herbaceous, and usually in the presence of water (Carleton et al. 1999). Microhabitat characteristics of collection sites for *S. arizonae* in the United States and Mexico consist of stands of thick grass or herbaceous vegetation (Allen 1895; Burt 1933; Carleton et al. 1999; Frey et al. 2002; Hoffmeister 1986; Hoffmeister and Goodpaster 1954). Moreover, almost all collection sites were in the presence of some type of water source, be it natural (streams and rivers), or man-made (irrigation canals, ponds, and agricultural fields—Allen 1895; Burt 1933; Carleton et al. 1999; Frey et al. 2002; Hoffmeister 1986; Hoffmeister and Goodpaster 1954). The presence of grassy areas as microhabitats is very important to *S. arizonae* throughout its range. This is evidenced by populations of *S. arizonae* that were reduced in number by the experimental reduction of overall grass density and structure (Litt 2007; O'Dell 2008).

Sigmodon arizonae accounted for 8.5–16% of the total biomass of small mammals captured in a riparian zone revegetated with native trees along the Colorado River over the period of 1 year (Anderson 1994). In semidesert grasslands dominated by gramma grasses (*Bouteloua*), Arizona cottontop (*Digitaria californica*), and three-awn (*Artistida*) on Fort Huachuca in southeastern Arizona, *S. arizonae* represented 7.22% and 20.31% of the total individuals captured in 2 separate studies (Litt 2007; O'Dell 2008). *S. arizonae* has a negative response to fire treatments in semidesert grassland (Litt 2007).

Presence and abundance of *S. arizonae* increased 92% (51–148%) and 35% (23–48%), respectively, with each 100-g/m^2 increase in the biomass of a nonnative grass in grasslands in southeastern Arizona (Litt 2007). The proportion of adult *S. arizonae* decreased 13% (2–23%) in relation to juveniles with the same increase in nonnative grass biomass (Litt 2007). Both the proportion of reproductively active females and pregnant female *S. arizonae* decreased 17% (1–32%) and 32% (0–53%), respectively, in response to each 100-g/m^2 increase in nonnative grass biomass (Litt 2007).

Abundance of *S. arizonae* ranged from an average of 7.9 (± 3.08 *SE*) to 4.4 (± 2.07 *SE*) individuals per 9.8-ha plot (O'Dell 2008). Abundance of *S. arizonae* was decreased in experimental plots where vegetative cover was reduced by trail construction (O'Dell 2008). Apparent survival for individuals remaining on experimental plots increased after treatment (O'Dell 2008); however, the majority of resident individuals likely emigrated from those areas that received the trail construction treatments. Overall, estimates for apparent survival ranged from 0.98 (± 0.007 *SE*) to 0.82 (± 0.068 *SE*) for trapping sessions during autumn 2003, spring 2004, and autumn 2004 (O'Dell 2008). The sex ratio of *S. arizonae* changed on experimental plots after treatment; however, this change differed between the severity of treatments, with the ratio of males to females decreasing with the construction of 5 trails per plot, but increasing with the construction of 10 trails (O'Dell 2008).

Adult survival increased between 2 trapping periods, with individuals having higher survival between June and September than from February to June of 1992 (Anderson 1994); however, apparent survival of *S. arizonae* was lower in the autumn of both 2003 and 2004 than in the spring of 2004 (O'Dell 2008). Juvenile rats were most abundant during a September trapping session and composed 40% of the total population of *S. arizonae* at that time (Anderson 1994).

Sigmodon arizonae is active both day and night based on livetrapping captures (Zimmerman 1970). Other habits are likely similar to those of *S. hispidus* (Cameron and Spencer 1981). *S. arizonae* in southeastern Arizona grasslands moved an average distance ranging from 30.9 m (± 3.42 *SE*) to 43.4 m within trapping grids, and 10 individuals were documented to move ≥ 50 m away from treatment plots onto adjacent trapping grids (O'Dell 2008).

Little information specific to the ontogeny and reproduction of *S. arizonae* is found in the primary literature. Embryo counts of pregnant females range from 6 to 17 (Burt 1933; Hoffmeister and Goodpaster 1954). A nest dug up by a domestic dog yielded 4 immature *S. arizonae* of 95 mm total length (Hoffmeister and Goodpaster 1954). More recently, a female trapped on 23 September 2007 likely gave birth to a litter of 3 in a Sherman live trap (H. B. Sherman Traps, Inc., Tallahassee, Florida) because the pups still had closed eyes. *S. arizonae* is likely similar to the closely related *S. hispidus* in other aspects of ontogeny and reproduction (Cameron and Spencer 1981; Meyer and Meyer 1944; Svihla 1929).

GENETICS

Phylogenetic divergence is believed to have occurred approximately 22 million years ago between the genera *Sigmodon* and *Peromyscus* based on albumin evolution as measured by the quantitative microcomplement fixation technique (Fuller et al. 1984). Phylogenetic relationships within *Sigmodon* have been analyzed recently using sequence

data from multiple gene regions, the result of which placed *Sigmodon arizonae* in a species group (clade) with *S. alleni*, *S. hirsutus* (southern cotton rat), *S. hispidus*, *S. mascotensis*, *S. ochrognathus*, and *S. toltecus* (Toltec cotton rat—Henson and Bradley 2009). Sequence data also recovered a subclade in this species group with *S. arizonae* and *S. mascotensis* as sister species (Henson and Bradley 2009). These data are consistent with other genetic analyses of the systematics and evolution of the genus *Sigmodon*; *S. arizonae* is in a species group with other species that are most similar to *S. hispidus* and has a close relationship with *S. mascotensis* (Carroll and Bradley 2005; Carroll et al. 2005; Peppers et al. 2002).

Sigmodon arizonae is differentiated from *S. hispidus* by typically having a diploid number (2n) of 22 chromosomes with a fundamental number (FN) of 38 instead of a diploid number of 52 with a fundamental number of 52 as is found in *S. hispidus*; this karyotype is found in specimens of *S. arizonae* from central Arizona in the United States, and southern Sinaloa and northern to central Nayarit, Mexico (Carleton et al. 1999; Zimmerman 1970; Zimmerman and Sihvonen 1973). The autosomes include 4 pairs of large metacentrics and submetacentrics, 2 pairs of large subtelocentrics, 2 pairs of medium metacentrics, 1 pair of small submetacentrics, and 1 small pair of acrocentrics (Carleton et al. 1999; Zimmerman 1970; Zimmerman and Sihvonen 1973). Comparisons of the albumin serums within the genus *Sigmodon* showed an immunological distance of 3 units from *S. hispidus* (Fuller et al. 1984). Electrophoretic analysis has shown that *S. arizonae* is distinct from both *S. hispidus* and *S. mascotensis* (Johnson et al. 1972).

Sex determination for this species is XX/XY, and the X chromosome is easily identified as being a medium-sized acrocentric chromosome comprising 5.42–5.46% of the haploid female complement, whereas the Y chromosome is the smallest acrocentric (Carleton et al. 1999; Zimmerman 1970; Zimmerman and Sihvonen 1973). Individuals from Parker, Yuma County, Arizona, have 24 chromosomes, which is likely due to a Robertsonian variant of the 22 chromosome karyotype, and this isolated population is most likely the remains of the founder population of this species (Zimmerman 1970).

CONSERVATION

Sigmodon arizonae arizonae and *S. a. jacksoni* are believed extinct (Arizona Game and Fish Department 2004a, 2004b). However, the status of these subspecies remains uncertain because no surveys for these taxa have been attempted in recent times. *Sigmodon a. jacksoni* is classified in Arizona as Tier 1b (Highly Vulnerable) if it is not already extinct due to alternations in the water table and flow, whereas the vulnerability of the isolated range of *S. a. cienegae* is unknown (Arizona Game and Fish Department 2006). *S. a. plenus* is of "Highest Priority" of concern in California (Williams 1986), in Arizona, this subspecies is classified as a Tier 1c species (Vulnerable—Arizona Game and Fish Department 2006). *S. a. plenus* is apparently extinct in Nevada (Bradley 1966). *S. a. cienegae* and *S. a. major* are classified as of "Least Concern" and are considered common throughout their range (Hoffmeister 1986; Linzey et al. 2008).

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