

TAXONOMIC STATUS OF THE MADREAN ALLIGATOR LIZARD  
(LACERTILIA: ANGUIDAE) OF THE SIERRA DEL NIDO,  
CHIHUAHUA, MÉXICO

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ABSTRACT—New evidence is presented that suggests that the single specimen of *Elgaria usafa* from the Sierra del Nido in Chihuahua is an aberrantly patterned *E. kingii*. We suggest that *E. usafa* be considered a junior synonym of *E. kingii*.

RESUMEN—Presentamos evidencia nueva que sugiere que el único espécimen de *Elgaria usafa* de la Sierra del Nido en Chihuahua es un patrón aberrante de *E. kingii*. Sugerimos que *E. usafa* sea considerado un sinónimo menor de *E. kingii*.

Smith et al. (2003) described a new species of alligator lizard, *Elgaria usafa*, from the Sierra del Nido of north-central Chihuahua. This description was based on one specimen that exhibited unusual color and pattern differences not previously noted elsewhere for the closely related species *E. kingii*, and not found in 10 additional specimens of *E. kingii* from adjacent areas in Chihuahua examined by Smith et al. (2003). This evidence suggested that the Sierra del Nido specimen was indeed unique in its color and pattern, and that these differences were categorical. Upon the further examination of additional material from the Sierra del Nido and other areas in Chihuahua, however, it was discovered that the single specimen of *E. usafa* probably represents an aberrantly patterned *E. kingii*, and as such, is not worthy of formal recognition.

The single specimen of *E. usafa*, as described by Smith et al. (2003), is diagnosed from *E. kingii* based on its overall dark coloration caused by dark interspaces, mostly one scale long, between uniformly dark crossbars, black markings on the sides of the body, a mostly dark lateral fold, and a dark head and neck. Shortly after the discovery of *E. usafa* and subsequent to its publication, however, another *Elgaria* exhibiting the same aberrant pattern was

found by JLE near San Juanito in south-central Chihuahua. This specimen (UBIPRO-10573), illustrated in color in Lemos-Espinal et al. (2004:57), exhibits the same dark coloration and patterning as the Sierra del Nido specimen. Furthermore, additional preserved specimens of *Elgaria* from the Sierra del Nido in the Sul Ross State University (SRSU 4656, 4740) and Universidad Autónoma de Nuevo León (UANL 5700, 5701) collections are in agreement in color and pattern with *E. kingii*, not *E. usafa*. In the 3 adult specimens (SRSU 4656, 4740, and UANL 5700), the crossbands are brownish colored with distinct black edging, the interspaces between the crossbands are distinct and usually 2 or more scales wide, the lateral fold is light colored, and the sides of the body are sparsely mottled.

The findings presented herein suggest that the aberrant color and pattern found in the original specimen of *E. usafa* is not unique (as evidenced by UBIPRO-10573) and that other *Elgaria* from the Sierra del Nido do not exhibit this dark, aberrant coloration. In light of this, we suggest that *E. usafa* be considered a junior synonym of *E. kingii*.

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## UNUSUAL TAIL MEASUREMENTS OF *BUBO VIRGINIANUS* FROM TEXAS

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**ABSTRACT**—We performed Exploratory Data Analysis on data sets assembled to determine subspecies limits of great horned owls (*Bubo virginianus*) in Texas; the results revealed unusual patterns of tail measurements. In the subspecies *B. v. pallascens*, tail lengths of males (206.0 mm) were longer than those of females (202.5 mm). Additionally, tail length was longer in intergrades (males = 209.4, females = 213.5) than for either subspecies (*B. v. virginianus* males = 206.2, females = 209.0; *B. v. pallascens* males = 206.0, females = 202.5).

**RESUMEN**—Realizamos un Análisis Exploratorio de Datos para determinar límites de subespecies del búho cornudo (*Bubo virginianus*) en Texas; los resultados revelaron un patrón inusual en las medidas de la cola. En machos de la subespecie *B. v. pallascens* la longitud de la cola (206.0 mm) fue más larga que en las hembras (202.5 mm). Adicionalmente, la longitud de la cola fue más larga en estados intermedios (machos = 209.4, hembras = 213.5) que en las otras subespecies (*B. v. virginianus* machos = 206.2, hembras = 209.0; *B. v. pallascens* machos = 206.0, hembras = 202.5).

In most avian species where sexual size differences occur, the male is larger than the female. However, most birds of prey (raptors and owls) and some seabirds (jaegers and frigatebirds) show reversed sexual size dimorphism (RSD), with the female larger than the male (Amadon, 1959). RSD does not seem to be phylogenetically constrained, but rather is a species-specific characteristic (McGillivray, 1989). McGillivray (1989) measured a suite of 18 skeletal characteristics of great horned owls (*Bubo virginianus*) that grouped into 4 skeletal complexes (body, leg, wing, and head) and found the typical RSD pattern. Sunde et al. (2003) measured body length and mass, 3 wing measurements, and hallux diameter in tawny

owls (*Strix aluco*); they also reported the typical RSD pattern.

Several hypotheses have been proposed to explain the function of RSD. One of these suggests that dimorphic size classes between the sexes of a mated pair permits differential habitat use and prey consumption between males and females, leading to decreased competition and, consequently, higher reproductive fitness (Storer, 1966; Earhart and Johnson, 1970; Temeles, 1985). This is especially important in cases where a pair has a limited area due to territoriality (Sunde et al., 2003) or a spatially limited patch of habitat. Larger size of the female also can enable her to better defend more optimal foraging grounds to feed her off-

TABLE 1—Descriptive statistics of measurements (mm) of *Bubo virginianus* from Texas.

Subspecies	Culmen					
	Males			Females		
	Range	Mean	<i>n</i>	Range	Mean	<i>n</i>
<i>virginianus</i>	23.1 to 26.2	24.5	6	24.8 to 28.1	26.4	8
<i>pallascens</i>	21.2 to 26.3	23.6	10	22.8 to 27.3	25.0	4
Intergrades	21.6 to 26.0	24.0	10	23.2 to 27.4	25.2	6
Subspecies	Unflattened wing chord					
	Males			Females		
	Range	Mean	<i>n</i>	Range	Mean	<i>n</i>
<i>virginianus</i>	336 to 366	349.6	6	353 to 378	365.8	8
<i>pallascens</i>	320 to 365	339.2	10	347 to 378	363.2	4
Intergrades	320 to 365	339.6	12	347 to 383	365.3	6
Subspecies	Tail					
	Males			Females		
	Range	Mean	<i>n</i>	Range	Mean	<i>n</i>
<i>virginianus</i>	178 to 230	206.2	6	193 to 225	209.0	8
<i>pallascens</i>	182 to 237	206.0	10	182 to 214	202.5	4
Intergrades	187 to 241	209.4	12	197 to 232	213.5	7

spring (Temeles, 1986). However, Sunde et al. (2003) found that smaller size in males enhanced maneuverability in denser cover, driven by the role of the male as the primary provider of food for the offspring.

Another hypothesis for RSD suggests that larger females can better defend themselves from males that want to mate despite poor resources. Additionally, larger females can defend the young or themselves from predators (Wallin, 1987; Sunde et al., 2003) or cannibalism by the male (Amadon, 1959). Earhart and Johnson (1970) noted a higher rate of cannibalism in the burrowing owl (*Athene cunicularia*), the only species among the 32 they analyzed in which males exceeded females in both measurements (body mass and wing chord) of sexual dimorphism; this lends support to the hypothesis that larger females can better defend themselves and their offspring from cannibalistic males (Amadon, 1959).

Exploratory Data Analysis involves searching for patterns of structure in existing data sets. We performed Exploratory Data Analysis on data sets we assembled to determine subspecies limits of great horned owls in Texas. The

Exploratory Data Analysis revealed unusual patterns of tail measurements.

We examined 80 specimens housed either at the Texas Cooperative Wildlife Collections (TCWC) at Texas A&M University or in the Ornithology Section of the Vertebrate Zoology Collections of the Houston Museum of Natural Science (HMNS). We used only adult specimens of known sex taken in the state of Texas; specimens of unknown age or sex could bias the results by over-representing or under-representing mean measurements of either sex. As a result, we included 47 specimens (28 males and 19 females) from Texas (Appendix 1). We separated the subspecies *B. v. virginianus*, *B. v. pallascens*, and intergrades between the 2 taxa primarily on venter coloration (Dickerman, 2004). We took culmen measurements with Vernier calipers, and used a metal ruler to measure wing chord and tail length (all measurements in mm). Using Exploratory Data Analysis, we compared the different taxonomic and sex categories. Table 1 gives a summary of the descriptive statistics.

Although our sample size was small, results of the Exploratory Data Analysis suggested an

atypical pattern of sexual dimorphism for these owls. In *B. v. pallascens*, mean tail lengths of males (206.0 mm) were longer than those of females (202.5 mm), even though mean culmen and mean wing chord measurements were longer in females (Table 1). This contradicts the general RSD rule of larger females. In addition, although intergrade measurements were between the 2 subspecies for mean culmen and mean wing chord measurements, this was not the case for mean tail length (Table 1). Mean tail length was longer in intergrades (males = 209.4, females = 213.5) than either *B. v. virginianus* (males = 206.2, females = 209.0) or *B. v. pallascens* (males = 206.0, females = 202.5).

Earhart and Johnson (1970) examined body mass and wing chord for 32 species of owls, including 5 subspecies of *B. virginianus*, and generally found the typical RSD pattern. Although Earhart and Johnson (1970) did not find larger males in *B. virginianus*, tail length was not examined. However, they reported larger males for both measurements in burrowing owls, and larger males for wing chord measurements in the flammulated owl (*Otus flammeolus*).

Exogenous events (environment-dependent selection) are the likely mechanism driving the increased tail lengths of intergrades (Arnold, 1997). In heterosis, or hybrid vigor, hybrids become more fit in certain environments than their parents (Endler, 1977; Arnold and Hodges, 1995). For example, Grant and Grant (1996) documented hybrid Galapagos finches that were more fit than their parents following an El Niño climatic perturbation event; the hybrids could better specialize on the seeds of the dominant plants present after the El Niño perturbation.

Examination of additional specimens would be useful in assessments of sexual dimorphism among subspecies of *B. virginianus*. We do not fully understand what selective pressures would result in the differences we observed in tail lengths in *B. virginianus*, but we present the apparent pattern herein. Perhaps some environmental factors are involved. The tail serves primarily as a steering or braking device during flight (Gill, 1994), which might benefit maneuverability in males more than females. Alternatively, increased wear on the tails of nesting females might result in shorter tails, al-

though such wear should be noticeable in the specimens. Stronger theories await ecological studies to test these hypotheses.

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APPENDIX 1—*Specimens Examined*—All specimens

from TCWC unless otherwise identified as HMNS. MALES: Archer: 12126–12127; Brazos: 7718; Comal: 9384; Culberson: 2601, 11079, 12128; Dallas: 7299; Dimmit: 8158; Duvall: 7082; Freestone: 9515; Galveston: HMNS 1593; Grayson: 9152, 11742; Harris: 1664; Lamar: 11741; Matagorda: HMNS 1225; Maveric: 1987; McLennan: 13161; Presidio: 2687; Red River: 11743; Sterling: 13072; Taylor: 5374; Tom Greene: 10196; Val Verde: 1811; Wichita: 12138, 12141. FEMALES: Anderson: 7717; Bell: 9481; Brooks: 8545; Crane: 11554; Culberson: 9844; Dimmit: 7994; Galveston: HMNS 1135; Jim Wells: 7189; Kerr: 311; Montague: 12137; Reagan: 10298; San Jacinto: 13111; Schleicher: 7420; Throckmorton: 2529; Trinity: 760; Van Zandt: 8107; Webb: 2230; Wichita: 12140, 12142; Williamson: 11008.

## SLATE-THROATED REDSTARTS (*MYIOBORUS MINIATUS*) BREEDING IN MADERAS DEL CARMEN, COAHUILA, MEXICO

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**ABSTRACT**—The breeding range of the slate-throated redstart (*Myioborus miniatus*) stretches from South America to Mexico, where it extends northward along the Sierra Madre Oriental to southeastern Coahuila and along the Sierra Madre Occidental to southern Chihuahua and Sonora. We report the discovery of slate-throated redstarts breeding in the Maderas del Carmen mountains in Coahuila. This represents a range extension of approximately 400 km and is, to our knowledge, the northernmost breeding record for this species.

**RESUMEN**—La distribución de cría del chipe de montaña (*Myioborus miniatus*) se extiende desde Sudamérica hasta México, donde comprende la Sierra Madre Oriental al sureste de Coahuila y la Sierra Madre Occidental al sur de Chihuahua y Sonora. Documentamos el descubrimiento de chipes de montaña criando en las montañas de Maderas del Carmen, Coahuila. Este hallazgo constituye una extensión de la distribución de cría de unos 400 km y posiblemente representa el registro de cría más norteño para esta especie.

The slate-throated redstart (*Myioborus miniatus*) is a broadly distributed species that inhabits montane and submontane forests from South America to northern Mexico (Curson et al., 1994). The range of the northernmost subspecies (*M. m. miniatus*) extends from Guatemala north to southern Chihuahua and Sonora in the Sierra Madre Occidental, and to southeastern Coahuila in the Sierra Madre Oriental, where it inhabits montane evergreen, pine-oak (*Pinus-Quercus*), and secondary forest from 600 to 2,500 m elevation (Howell and Webb, 1995; American Ornithologists' Union, 1998). Individuals have been seen in south-

eastern Arizona, southwestern New Mexico, and western Texas, but to our knowledge, there are no breeding records outside of the documented range.

The Maderas del Carmen, the major forested part of the Sierra del Carmen in the Big Bend region of northern Coahuila, shelters one of the largest expanses of moist coniferous forest for several hundred kilometers in any direction. Its avifauna has been the subject of several investigations in the last 50 years. Neither Miller (1955) nor Wauer and Ligon (1977) listed the slate-throated redstart among their observations. In 1999, biologists with the

El Carmen Project began a thorough inventory of the flora and fauna of the range. In July 2002, a single singing slate-throated redstart was observed by BM in Cañón Moreno in the area around Campo Dos, in riparian habitat surrounded by mesic montane forest.

Between 31 May and 10 June 2003, at least 4 males were seen and heard singing along a 1-km portion of Cañón Moreno. This habitat, at 2,300 m elevation, has a perennially running stream and is composed predominantly of southwestern white pine (*Pinus strobiformis*), ponderosa pine (*P. ponderosa* var. *scopulorum*), Arizona cypress (*Cupressus arizonica*), Douglas-fir (*Pseudotsuga menziesii*), Coahuila fir (*Abies coahuilensis*), netleaf oak (*Quercus rugosa*), and a Mexican oak species (*Q. sideroxila*).

A pair of slate-throated redstarts was observed on 9 June 2003 along Cañón Moreno near Campo Dos (28°59'36.6"N, 102°36'40.8"W). The male displayed territorial behavior, singing from various tree branches, mainly at heights of 5 to 10 m, and in the dense undergrowth along the stream. The female, tentatively identified at that time by duller plumage, interspersed periods of foraging with periods of inactivity perched on dead tree branches at heights less than 5 m. We used playback of the song of the male to lure the female into a mist-net. In-hand examination revealed a wrinkled brood patch, suggesting that she was tending a nest. After taking photographs, the bird was released.

We later observed the female carrying insects to a location near the ground, where she disappeared several times on a moderately sloping hillside covered with pine needles not more than 10 m from the stream. The area was approximately 5 m from one of the more densely vegetated portions of the canyon and was dominated by a thicket of mountain ninebark (*Physocarpus monogynus*). Territorial singing demonstrated by at least 3 nearby males suggests that a small breeding population existed there at that time.

This discovery extends the breeding range of the slate-throated redstart north by approximately 400 km in the Sierra Madre Oriental and it is, to our knowledge, the northernmost breeding record of this species (records of presumed breeding in Sonora are slightly more southern; Russell and Monson, 1998). Where it occurs, the slate-throated redstart is considered a resident, although there is seasonal al-

titudinal migration (Curson et al., 1994) and the northernmost breeding populations probably migrate south for the winter (Howell and Webb, 1995). Casual observation over several days around the site of the nest in October 2003 failed to locate any individuals. The following spring in 2004, only a single individual was seen in the canyon. From 5 May to 25 May, one male was consistently observed singing once every 10 seconds near the stream approximately 1 km north of Campo Dos. On 25 May from 0740 to 1240, the entire 5-km length of Cañón Moreno was traversed with only one individual recorded.

Whether long-lasting or ephemeral, this new breeding population merits further study to determine its size and seasonal movements. Investigations of recent colonization attempts such as this could shed light on the sometimes puzzling avian biogeography of isolated mountain ranges, which Gehlbach (1981) called "the hop, skip, and jump of breeding bird distributions." Considering the proximity of this population to the border, it is likely that more individuals will be sighted in the USA, particularly in the Chisos Mountains of Big Bend National Park, which lie 70 km to the northwest.

We thank the landowners, the Mexican cement company CEMEX, for the opportunity to make these observations. Special thanks go to S. Gibert Isern for field observations. We also thank the Museo del las Aves de México for their help with field work and permits. B. McKinney and 2 reviewers provided comments on the manuscript.

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## DIMINUTIVE WOODRAT (*NELSONIA NEOTOMODON*) IN CHIHUAHUA, MEXICO

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**ABSTRACT**—*Nelsonia neotomodon* is recorded for the first time for the state of Chihuahua, Mexico. This record extends the distribution of this species 250 km to the north. Morphometric and reproductive information for a sample of *N. neotomodon*, as well as additional unpublished records, are provided. The data suggest that this species has a continuous distribution in the Sierra Madre Occidental and that there is no significant geographic variation or sexual dimorphism.

**RESUMEN**—Se registra por primera vez la presencia de *Nelsonia neotomodon* en el estado de Chihuahua, México. Este registro extiende la distribución de la especie 250 km al norte. Se proporcionan datos morfométricos y reproductivos de una muestra de *N. neotomodon*, así como de material que no había sido previamente documentada. Los datos disponibles sugieren que esta especie tiene una distribución continua en la Sierra Madre Occidental y que no existen ni dimorfismo sexual ni variación geográfica significativos.

The genus *Nelsonia* includes 2 species of rare, endemic rodents from the Mexican highlands. The distributions of these species do not overlap; *Nelsonia goldmani* is distributed in the central-west portion of the Transvolcanic Mexican belt, the northernmost record available being from Cerro Patambán, Michoacán. *Nelsonia neotomodon* is known from the Sierra Madre Occidental, from northwestern Durango to Aguascalientes, Zacatecas, and Jalisco (Fig. 1). These species are readily separated by a combination of external and cranial characters (Merriam, 1903; Engstrom et al., 1992).

Little is known on the biology of *N. neotomodon*. Although collection efforts have been intensive and frequent within its distribution area (Hooper, 1954; Álvarez and Polaco, 1984), specimens deposited in collections in the United States and Mexico scarcely add to 45 (Engstrom et al., 1992; Muñoz-Martínez and Arroyo-

Cabrales, 1996; López-Wilchis and López-Jardine, 1999). The diminutive woodrat occurs in high montane habitats (above 2,000 m), in coniferous or pine-oak (*Pinus-Quercus*) forests (Hooper, 1954; Álvarez and Polaco, 1984; Engstrom et al., 1992). It is restricted to rocky cliffs or hillsides, usually along streams with abundant, large-sized rocks and boulders. This species is under special protection by the Mexican government according to NOM-059-ECOL-2001 (SEMARNAT, 2002). As part of the efforts to inventory the fauna of small mammals of the Sierra Tarahumara in the southern portion of the Mexican state of Chihuahua, a specimen of *N. neotomodon* was captured in 2002; this record constitutes the first for the state. Thus, the objectives of this note are to document the range extension of *N. neotomodon* and to summarize additional records not published previously by other authors.

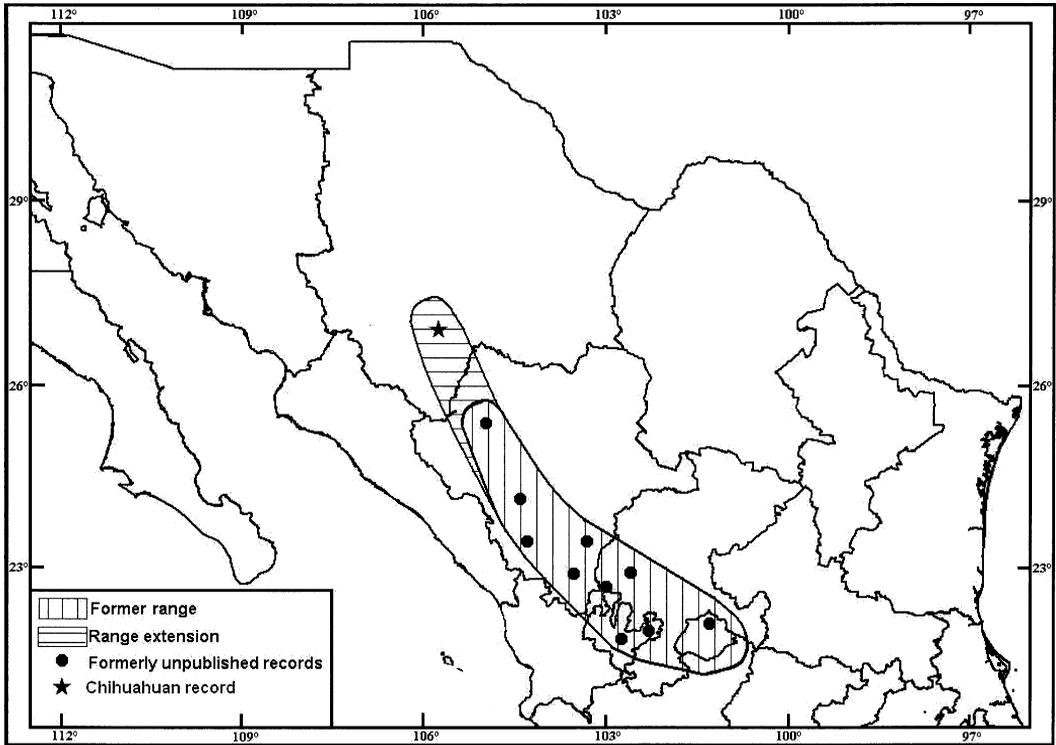


FIG. 1.—Distribution of *Nelsonia neotomodon* in Mexico. Circles show previously unpublished records; star indicates Chihuahuan record.

Fifteen individuals of *N. neotomodon*, including 4 topotypes, were examined. Specimens are deposited at the mammal collection, Escuela Nacional de Ciencias Biológicas (ENCB), Mexico City or at the Collection of Vertebrates at Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional (CIIDIR) Unidad Durango (CRD). Four external (from specimen labels) and 15 cranial measurements were taken to the nearest 0.1 mm using a digital caliper and following Engstrom et al. (1992) and Muñoz-Martínez and Arroyo-Cabralles (1996): total length (TL), length of tail (LT), length of hind foot (LHF), length of ear (LE), greatest length of skull (GLS), zygomatic breadth (ZB), interorbital constriction (IC), length of rostrum (LR), breadth of rostrum (BR), mastoid breadth (MB), length of interparietal bone (LIP), width of interparietal bone (WIP), breadth of zygomatic plate (BZP), length of palate (LP), length of maxillary toothrow (LMT), breadth across molars (BAM), length of auditory bulla (LAB), depth of skull (DS), and length of mandibular tooth-

row (MAN). For each variable, we tested for differences due to sex using Student's *t*-tests.

The *N. neotomodon* from Chihuahua (CRD3737), a male, was collected on 12 November 2002 in a Sherman trap at the Municipality of Guachochi, 2 km S Norogachi, elevation 2,133 m (27°15.6'N, 107°8'W) by D. F. García-Mendoza (field number DFGM 663). External and cranial measurements are given in Table 1. Weight was 46 g. Testes were 6 mm long, and no external signs of reproductive activity were evident. Degree of tooth-wear places this individual in age class 5 (Engstrom et al., 1992).

The specimen was taken from the rocky walls of the Urique River canyon. This portion of the canyon opens into a relatively wide valley, on which the village of Norogachi is settled. The town sits on a mixture of large boulders and rocky outcrops surrounded by open pine-oak forest and agricultural fields, in which corn is planted each year. The collection site was no farther than 100 m from human dwellings and less than 500 m from a disturbed

TABLE 1.—Mean, range, and standard error of selected external and cranial measurements for a sample of *Nelsonia neotomodon* by sex. Measurements for the specimen from Chihuahua, Mexico (CRD 3737) are given separately. Acronyms of variables as in text.

	TL	LT	LHF	LE	GLS	ZB	IC	LR	BR	MB	LIP	WIP	BZP	LP	LMT	BAM	LAB	DS	MAN
<b>Male</b>																			
<i>n</i>	6	6	8	8	6	7	7	8	8	5	7	7	7	7	8	8	6	5	8
Mean	226.3	107.0	25.6	21.1	31.6	16.5	4.6	12.4	4.5	13.3	4.3	9.6	2.9	5.9	6.2	6.1	5.6	10.1	6.0
SE	3.45	2.46	0.42	0.35	0.39	0.17	0.05	0.16	0.06	0.04	0.09	0.13	0.08	0.1	0.12	0.09	0.09	0.24	0.07
Minimum	215	96	24	20	30.2	16.1	4.5	11.7	4.3	13.2	3.8	9.1	2.7	5.4	5.8	5.9	5.4	9.2	5.7
Maximum	237	113	28	23	32.4	17.3	4.8	13.0	4.7	13.4	4.6	10.1	3.3	6.1	6.9	6.7	5.9	10.5	6.4
<b>Female</b>																			
<i>n</i>	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Mean	229.4	108.8	26.3	21.5	32.2	16.5	4.6	12.9	4.6	13.2	4.3	9.3	3.0	6.0	6.2	6.2	5.5	10.6	6.0
SE	1.47	3.45	0.42	0.67	0.14	0.18	0.08	0.10	0.05	0.05	0.03	0.31	0.04	0.06	0.14	0.07	0.08	0.09	0.07
Minimum	224	99	25	20	31.8	15.6	4.4	12.5	4.4	13.0	4.2	8.1	2.9	5.8	5.8	5.9	5.2	10.4	5.8
Maximum	232	116	28	24	32.8	17.0	5.0	13.2	4.8	13.4	4.4	10.3	3.2	6.2	6.6	6.3	5.8	11.0	6.3
CRD3737 (male)	235	115	28	23	32.4	16.8	4.6	13.1	4.6	13.1	4.6	9.7	3.3	6.7	6.2	6.1	5.3	10.2	6.0

pine-oak forest. This habitat corresponds to that described as typical for the species. Other rodents collected in the same locality were *Tamias dorsalis*, *Neotoma mexicana*, *Peromyscus boylii rowleyi*, *P. difficilis*, *P. gratus*, and *Mus musculus*.

This record extends the known distribution of *N. neotomodon* approximately 250 km to the north of the nearest known record, which was based on a mandibular branch recovered from owl pellets 15 km S, 21.4 km W of Los Herreras, Durango (Muñiz-Martínez and Arroyo-Cabrales, 1996). The closest records of complete specimens are from San Luis and Cerro Huehuento, Durango, about 350 km S of the Chihuahuan locality (Hooper, 1954; Engstrom et al., 1992).

Measurements of the specimen are within the range of variation observed previously (Engstrom et al., 1992; Muñiz-Martínez and Arroyo-Cabrales, 1996) for both cranial and external measurements (Table 1). No significant differences between sexes were found in the sample in any of the measurements examined. These results agree with those reported by Engstrom et al. (1992). The data so far available on *N. neotomodon* (Engstrom et al., 1992; this paper) suggest that the distribution of the species is continuous in the Sierra Madre Occidental (Fig. 1) and that there is little geographic variation in morphometric characters across its range.

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APPENDIX—*Specimens examined* (15)—Chihuahua: 2 km S Norogachi, 2,133 m, 1 (CRD3737). Durango: 3 km S, 5.8 km W Charcos, 2,720 m, 2 (CRD235–236); 1.5 km N, 3.8 km W Charcos, 2,900 m, 1 (CRD262); 6.2 km N, 4.8 km W Charcos, 2,890 m, 1 (CRD717); 16.9 km S, 0.2 km W Canoas, 2,430 m, 1 (CRD614); 5.5 km NW La Peña, 2,640 m, 1 (ENCB10606); 2 km N La Peña, 2,450 m, 3 (ENCB10605, 12774–12775); 1.5 km N, 2.5 km W La Peña, 2,450 m, 1 (ENCB10628). Zacatecas: 6.5 km N, 16 km W Valparaíso, 2,800 m, 4 (ENCB-32061–32064).

## WILDFIRE AND DESERT BIGHORN SHEEP HABITAT, SANTA CATALINA MOUNTAINS, ARIZONA

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ABSTRACT—The desert bighorn sheep (*Ovis canadensis mexicana*) population in the Santa Catalina Mountains, Arizona, has declined since the 1920s and was virtually extirpated in the late 1990s. Urban development, human recreation, and changes in habitat conditions due to wildfire suppression have contributed to the decline. Wildfires in 2002 and 2003 burned approximately 46,701 ha in the Santa Catalina Mountains, including areas previously inhabited by desert bighorn sheep. Our objectives were to estimate the amount of potential and historical bighorn sheep habitat in the Santa Catalina Mountains and to determine if the fires improved habitat quality for bighorn sheep. We created a spatial habitat suitability model to estimate the amount of potential and historical habitat available for bighorn sheep in the Santa Catalina Mountains. We then used Burn Severity maps and the Normalized Difference Vegetation Index to examine the impact of recent wildfires on bighorn sheep habitat. We calculated 39,201 and 9,017 ha of potential and historical habitat of desert bighorn sheep, respectively. Historical bighorn sheep habitat in the western Santa Catalina Mountains declined 64% since 1989. Approximately 21% of potential habitat and 24% of historical bighorn sheep habitat were burned during the fires, most of which experienced low burn severity that was not high enough to remove vegetation that decreases habitat quality for desert bighorn sheep. Any consideration of translocation of desert bighorn sheep to the Santa Catalina Mountains should further assess the suitability of the areas identified as potential habitat.

RESUMEN—La población del borrego cimarrón del desierto (*Ovis canadensis mexicana*) en las montañas de Santa Catalina, Arizona, ha disminuido desde que la década del 1920 y virtualmente se eliminó a finales de la década del 1990. El desarrollo urbano, la recreación humana, y los cambios en las condiciones de hábitat debidos a la supresión de incendios han contribuido al descenso. Los incendios forestales en 2002 y 2003 quemaron aproximadamente 46,701 ha en las Montañas de Santa Catalina, incluyendo áreas previamente habitadas por el borrego cimarrón. Nuestros objetivos fueron estimar la cantidad de hábitat potencial e histórico del borrego cimarrón en las Montañas de Santa Catalina y determinar si los fuegos mejoraron la calidad del hábitat para el borrego cimarrón. Creamos un modelo de hábitat espacial favorable para estimar la cantidad del hábitat potencial e histórico disponibles para el borrego cimarrón en las Montañas de Santa Catalina. Después, utilizamos mapas de Severidad de Incendio y un Índice de Diferencia de Vegetación Normalizado para evaluar el impacto de incendios recientes en el hábitat del borrego cimarrón. Calculamos 39,201 y 9,017 ha de hábitat potencial e histórico del borrego cimarrón, respectivamente. El hábitat histórico del borrego cimarrón en las Montañas de Santa Catalina occidentales disminuyó un 64% desde 1989. Aproximadamente 21% del hábitat potencial y 24% del hábitat histórico de borrego cimarrón se quemaron durante los incendios, la mayoría de los cuales tuvieron baja severidad y no debe haber sido suficientemente alta para eliminar el tipo de vegetación que disminuye la calidad del hábitat para el borrego cimarrón. Cualquier consideración de reintroducciones de borrego cimarrón a las Montañas de Santa Catalina debe evaluar aún más la posibilidad de uso de las áreas identificadas como hábitat potencial.

Desert bighorn sheep (*Ovis canadensis mexicana*) historically occupied approximately 25,000 ha in the western end of the Santa Catalina Mountains, Arizona, including the Pusch Ridge Wilderness (Etchberger et al., 1989). This population of desert bighorn sheep has declined since the 1920s and was virtually extirpated in the late 1990s (Krausman et al., 1979; Krausman et al., 2001). Although there are still occasional reports of individual bighorn sheep in the Santa Catalina Mountains, including the Pusch Ridge Wilderness, the herd is not considered a viable population and likely will not persist without active management; translocation of bighorn sheep from other populations will likely be necessary if this population is to be reestablished (Krausman et al., 2000).

Multiple factors have been associated with the decline of desert bighorn sheep in the Santa Catalina Mountains and Pusch Ridge Wilderness. Urban development (e.g., housing development, road construction) has reduced the amount of available habitat, and human recreation (e.g., hikers, hikers with dogs, trail development) and changes in habitat conditions due to fire suppression have decreased the quality of remaining habitat (Etchberger et al., 1989; Krausman et al., 1996; Czech and Krausman, 1997; Krausman et al., 2001; Papouchis et al., 2001). Because desert bighorn sheep prefer areas with high visibility, increases in shrubby vegetation due to fire suppression

have decreased visibility and lowered habitat quality for desert bighorn sheep (Wakelyn, 1987; Etchberger et al., 1989; Krausman et al., 2001).

In 2002, the Bullock fire burned approximately 12,378 ha from 21 May until 5 June in the Santa Catalina Mountains, and in 2003, the Aspen fire burned >34,323 ha from 17 June until 12 July; there was little to no overlap in the extent of these fires. Both fires burned areas previously inhabited by desert bighorn sheep; however, the effect of these fires on bighorn sheep habitat is unknown. We predicted that the fires improved habitat quality in burned areas by reducing vegetation, thus improving visibility. Our objectives were to estimate the amount of potential and remaining historical bighorn sheep habitat in the Santa Catalina Mountains and to determine how the Bullock and Aspen wildfires influenced these areas.

The Santa Catalina Mountains are located in southeastern Arizona in the Coronado National Forest, bordered on the south and west by the metropolitan Tucson area (Gionfriddo and Krausman, 1986; Etchberger et al., 1989). The Santa Catalina Mountains are roughly triangular in shape, encompassing approximately 512 km<sup>2</sup>; elevations range from 850 to >2,745 m (Krausman et al., 1979). The Santa Catalina Mountains have a gradient of vegetation communities ranging from Sonoran desertscrub, semi-desert grassland, and Madrean evergreen

woodland at lower and mid elevations, to subalpine fir (*Abies lasiocarpa*) forests at upper elevations (Krausman et al., 1979; Brown, 1994; Pase and Brown, 1994; Turner and Brown, 1994). Mean annual precipitation in the Tucson area is approximately 28 cm, nearly half of which falls in the summer months; mean seasonal temperatures range from 16°C to 30°C (Gionfriddo and Krausman 1986; Etchberger et al. 1989). The historical distribution of desert bighorn sheep in the Santa Catalina Mountains was primarily restricted to elevations <1,840 m in the southwestern and northwestern portions of the mountains, which includes the Pusch Ridge Wilderness (Krausman et al., 1979; Etchberger et al., 1989).

We created a spatial model using ArcInfo and ArcView (Environmental System Research Institute, 2000) in a geographic information system (GIS) to investigate the amount of potential and historical bighorn sheep habitat remaining in the Santa Catalina Mountains and the impact of recent wildfires on this habitat. We obtained digital data from the United States Geological Survey, United States Census Bureau, and the United States Forest Service. We based our analysis on habitat characteristics common to viable populations of desert bighorn sheep, including proximity to escape terrain, slope, elevation, vegetation association, proximity to perennial water, roads, recreational areas, and urbanized areas (Cunningham, 1989; Wakeling and Miller, 1990; McCarty and Bailey, 1994). We used our spatial model to estimate the amount of potential and historical habitat available for bighorn sheep and used these areas as the basis for future calculations. We considered potential habitat to be the total area identified by our spatial model, and we considered historical habitat to be the areas identified by our model that are known to have been occupied since the 1920s by desert bighorn sheep, prior to the population decline beginning in the 1970s (Krausman et al., 1979; Etchberger et al., 1989). Therefore, the area considered to be potential habitat included the areas classified as historical habitat.

The model was based on a United States Geological Survey 1:24,000 digital elevation model that evaluated 30-m × 30-m cells. We defined habitat as areas within 500 m of escape terrain (>60% slope) that were within 4 km of a water source, <1,830 m elevation, and within

the Sonoran desertscrub, Madrean oak woodland, and semi-desert grassland vegetation associations. We used the digital elevation model to select all cells with an elevation ≤1,830 m because bighorn sheep in the Santa Catalina Mountains predominately used areas below this elevation (Gionfriddo, 1984). We converted the digital elevation model into a slope coverage, where the maximum rate of change in slope was calculated from each cell to its neighbors. We identified all cells with ≥60% slope and then buffered them by 500 m (Andrew et al., 1999; McKinney et al., 2003). We identified water sources using United States Geological Survey digital line graphs, updated with information from the United States Forest Service and the Arizona Game and Fish Department, and eliminated all cells >4 km from a water source from further analysis. We also identified all areas within the Sonoran desertscrub, Madrean oak woodland, and semi-desert grassland associations based on data obtained from the United States Forest Service. We delineated all areas that had been impacted by urban development. We defined urbanized areas as having residential development with a population density of ≥1,000 people/2.6 km<sup>2</sup>. We used urbanized area and road coverages provided by the United States Census Bureau to identify urban development. All urbanized areas and paved roads were buffered by 100 m, a minimum distance that bighorn sheep are displaced during human-bighorn sheep interactions (Light, 1971; Smith et al., 1991).

We identified all major trails, campgrounds, ski areas, and unpaved roads that were located within bighorn sheep habitat. Recreation areas were identified from digital line graphs and updated with maps provided by the land managers. Recreation areas also were buffered by 100 m. We then excluded all areas impacted by urban development and recreation from the areas classified as habitat based on proximity to escape terrain, slope, elevation, vegetation association, and proximity to perennial water sources.

We used an ArcInfo coverage of burn severity maps and the Normalized Difference Vegetation Index (NDVI) for the time periods immediately prior to and after the fire to evaluate the impact of the Bullock and Aspen fires on potential and historical bighorn sheep habitat. The United States Forest Service derived fire

TABLE 1—Area (ha) and burn severity of potential and historical habitat of bighorn sheep (*Ovis canadensis mexicana*) burned during the Bullock fire in 2002 and the Aspen fire in 2003, Santa Catalina Mountains, Arizona.

Wildfire	Potential habitat burn severity				Historical habitat burn severity			
	Low	Moderate	High	Total	Low	Moderate	High	Total
Aspen	520	4,581	347	5,448	1,905	158	3	2,066
Bullock	2,158	398	133	2,689	50	0	0	50

perimeters and burn severity index coverages by using LANDSAT images and on-the-ground assessments by the Burned Area Emergency Rehabilitation team. The perimeter of each fire was delineated using ArcView GIS; areas within the fire perimeter were then classified into burn severity classes: unburned, low burn, moderate burn, and high burn. Low burn severity was defined as ground vegetation burned with <10% needle scorch on trees; moderate burn severity was defined as ground vegetation burned with 10 to 70% needle scorch on trees; high burn severity was defined as needles and small branches consumed and some large branches consumed.

To determine the impact of the Bullock and Aspen fires on potential bighorn sheep habitat, we overlaid the fire perimeter and burn severity index coverages with the potential and historical bighorn sheep habitat coverages. We then calculated the area (ha) of bighorn sheep habitat that was affected by fire and the area (ha) of habitat by each burn severity class.

The NDVI, derived from remote sensing data, can be used to monitor spatial and temporal changes in vegetation (Huete and Jackson, 1987). Changes in the photosynthetic activity and biomass of vegetation result in changes in reflectance. These reflectance values can be used to generate the NDVI, which functions as an index of the greenness of vegetation and can be used to compare vegetation conditions (Huete and Jackson, 1987). We used NDVI images from 23 April to 8 May 2002 and 10 June to 25 June 2002, and from 25 May to 9 June 2003 and 12 July to 27 July 2003 to assess the greenness of vegetation immediately prior to and immediately after the Bullock and Aspen fires, respectively. First, we overlaid the bighorn sheep habitat coverages with the NDVI images. We then extracted the NDVI values for

all areas affected by the Bullock and Aspen fires. Because NDVI greenness values would be expected to decline during summer prior to the start of the summer rains, we also extracted all NDVI values for all (burned and unburned) areas within the potential and historical habitat coverages. We compared the pre-fire and post-fire NDVI values for both the historical and potential habitat using paired sample *t*-test.

Using our spatial model, we calculated 39,201 ha of potential habitat in the entire Santa Catalina Mountains, of which, 9,017 ha was considered historical desert bighorn sheep habitat (Fig. 1). Approximately 21% (8,137 ha; Table 1) of the potential bighorn sheep habitat was burned during the Bullock and Aspen fires. Seven percent of the area of the potential habitat experienced low burn severity, 13% experienced moderate burn severity, and <2% experienced high burn severity.

Approximately 24% (2,116 ha; Fig. 1; Table 1) of the historical bighorn sheep habitat was affected by the Bullock and Aspen fires. Approximately 22% experienced low burn severity, 2% experienced moderate burn severity, and <1% of the area experienced high burn severity.

The mean NDVI index for the burned areas of potential habitat was 37% lower after the Bullock fire than prior to the start of the fire ( $t_{491} = 34.28$ ,  $P \leq 0.001$ ; Table 2), whereas the NDVI index for unburned potential habitat declined 20% during the same period ( $t_{3,556} = 62.69$ ,  $P \leq 0.001$ ). Mean NDVI index for the burned areas of historical habitat declined by 37% during the Bullock fire ( $t_{147} = 27.71$ ,  $P \leq 0.001$ ; Table 2), whereas that of the unburned areas declined by 23% over the same period ( $t_{1,747} = 55.19$ ,  $P \leq 0.001$ ; Table 2).

The mean NDVI index of the burned areas of potential habitat was 32% lower after the

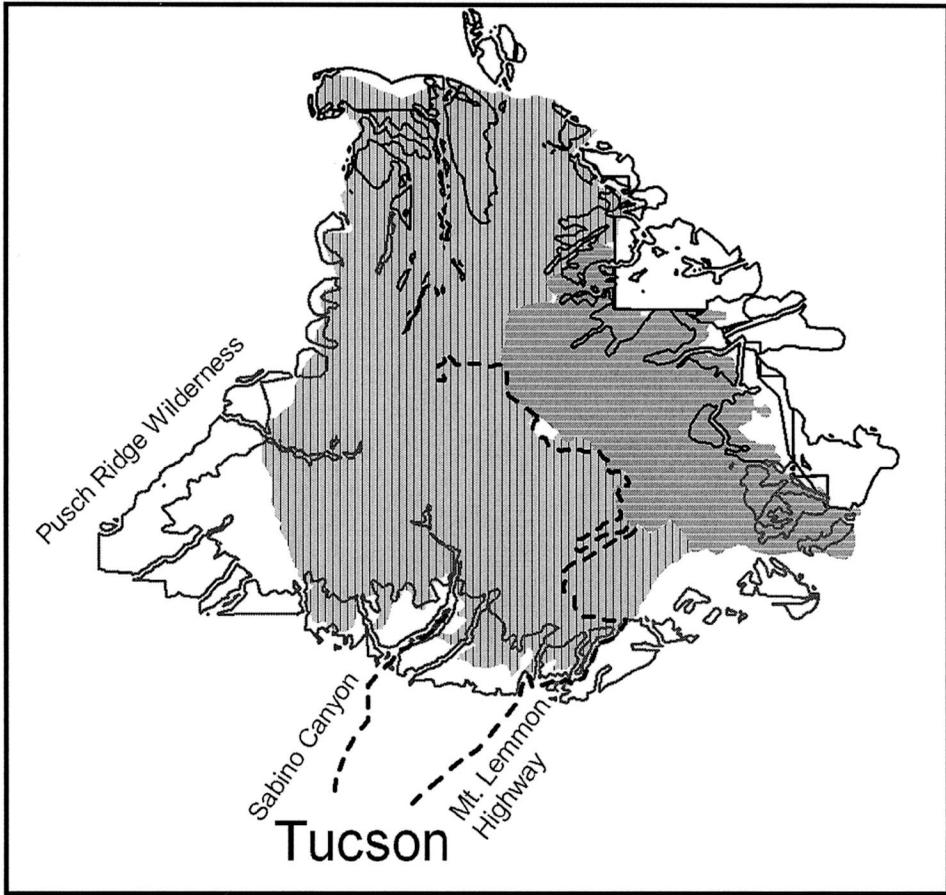


FIG. 1—Area of the Bullock fire in 2002 and Aspen fire in 2003 in relation to historical habitat (south and west) and potential habitat (north and east) of desert bighorn sheep (*Ovis canadensis mexicana*) in the Santa Catalina Mountains, Arizona.

TABLE 2—Mean Normalized Difference Vegetation Index (NDVI) for burned and unburned areas in historical and potential bighorn sheep habitat in the Santa Catalina Mountains, Arizona, observed prior to and after the 2002 Bullock fire.

	Unburned habitat					Burned habitat				
	Pre-fire NDVI		Post-fire NDVI		<i>P</i>	Pre-fire NDVI		Post-fire NDVI		<i>P</i>
	Mean ( <i>SD</i> )	<i>n</i>	Mean ( <i>SD</i> )	<i>n</i>		Mean ( <i>SD</i> )	<i>n</i>	Mean ( <i>SD</i> )	<i>n</i>	
Potential habitat	0.272 (0.089)	3,557	0.217 (0.064)	3,557	<0.001	0.284 (0.069)	492	0.178 (0.027)	492	<0.001
Historical habitat	0.258 (0.066)	1,748	0.199 (0.059)	1,748	<0.001	0.270 (0.045)	148	0.170 (0.020)	148	<0.001

Aspen fire than immediately prior to the start of the fire ( $t_{1,020} = 43.93$ ,  $P \leq 0.001$ ; Table 3). During this same time period, the area of potential habitat that was not burned only declined by 10% ( $t_{3,022} = 42.63$ ,  $P \leq 0.001$ ). The mean NDVI index for the burned areas of historical habitat declined by 30% during the Aspen fire ( $t_{387} = 33.1$ ,  $P \leq 0.001$ ; Table 3), whereas the mean NDVI index for the unburned areas of historical habitat only declined by 15% ( $t_{1,293} = 38.8$ ,  $P \leq 0.001$ ).

Bighorn sheep habitat in the western Santa Catalina Mountains has declined by approximately 64% from the 25,000 ha that was reported to have been used historically by bighorn sheep to 9,017 ha (Etchberger et al., 1989). The major factors involved in the decline of desert bighorn sheep in the Santa Catalina Mountains were habitat change due to fire suppression, urban development, and recreation (Etchberger et al., 1989; Krausman et al., 1996; Krausman et al., 2001). The lack of a natural fire regime has encouraged vegetation that reduces visibility, thereby reducing habitat quality, which might have caused bighorn sheep to abandon some areas (Wakelyn, 1987; Etchberger et al., 1989; Krausman et al., 1996). However, based on our habitat model, there might be more potential bighorn sheep habitat in the Santa Catalina Mountains if the area in the eastern Santa Catalina Mountains is considered. Any consideration of translocations of desert bighorn sheep in an attempt to reestablish bighorn sheep to the Santa Catalina Mountains should further assess the suitability of the areas identified as potential habitat by our model. Much of the potential habitat for bighorn sheep in the eastern Santa Cat-

alina Mountains is not known to have been occupied historically by bighorn sheep, and the reason this area was not used by bighorn sheep should be determined. If there are factors not incorporated in our model that contributed to this area not being occupied, thus making this area unsuitable for translocations, these factors need to be identified.

The Bullock and Aspen fires in bighorn sheep habitat were limited to <25% of potential and historical habitat areas. Furthermore, the majority of habitat that burned might not have burned severely enough to remove vegetation that decreases visibility and habitat quality for desert bighorn sheep. While, we recognize that changes in NDVI alone are not an adequate assessment of changes in the structure of vegetation that most influences visibility, they do support the results obtained from the burn severity maps. Both of these measures indicated that a large portion of the vegetation remains in much of the burned areas and that the Bullock and Aspen fires did not greatly improve visibility or habitat quality for desert bighorn sheep in the Santa Catalina Mountains.

The use of natural and prescribed fires to restore the habitat conditions preferred by bighorn sheep has been recommended (Etchberger et al., 1989; Krausman et al., 1996) and will likely be a necessary component of habitat restoration. Wildfires have to be of a high enough severity and in appropriate locations to improve habitat quality for desert bighorn sheep in the Santa Catalina Mountains. If bighorn sheep are to be translocated and are to persist in the Santa Catalina Mountains, the other factors (i.e., urban development and rec-



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## SAGUARO SPINE PENETRATED BIGHORN SHEEP SKULL

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ABSTRACT—Animals that inhabit vegetative communities where thorns and spines are common should be capable of moving while avoiding injury from thorns and spines. On 21 December 2003, we found that a saguaro cactus (*Carnegiea gigantea*) spine had penetrated the lacrimal bone into the orbit of a desert bighorn sheep (*Ovis canadensis*) in south-central Arizona. The animal was observed with clinical infectious keratoconjunctivitis and was blind for 3 weeks prior to death. It is likely that the animal collided with a saguaro cactus after she became blinded by disease.

RESUMEN—Los animales que habitan comunidades de vegetación donde las púas y espinas son comunes deben ser capaces de trasladarse y a la vez evitar lesiones producidas por púas y espinas. El 21 de diciembre del 2003 encontramos que una espina del cactus saguaro (*Carnegiea gigantea*) había penetrado el hueso lacrimal hasta la órbita de un borrego cimarrón (*Ovis canadensis*) en Arizona sur-central. El animal tuvo una infección keratoconjunctivitis y estuvo ciego durante tres

semanas antes de morir. Es posible que el animal chocara con un cactus saguaro después de haber sido cegada por una enfermedad.

On 21 December 2003, we recovered the remains of a 3-year-old female bighorn sheep (*Ovis canadensis*) that had died recently of malnutrition related to infectious keratoconjunctivitis in the Silver Bell Mountains, Pima County, Arizona (32°24.5'N, 111°29.5'W). This animal was radiocollared as part of ongoing research and was observed with clinical symptoms of the disease for approximately 3 weeks prior to death. Field necropsy suggested malnutrition as the proximate cause of death, and subsequent laboratory work did not refute malnutrition as the cause of death. Upon preparation of the skeletal anatomy for accession into the mammal collection at the University of Arizona (UA26967), we discovered that a spine from a saguaro cactus (*Carnegiea gigantea*) had penetrated the lacrimal bone into the left orbit (Fig. 1). The spine was 13.2 mm long

and 0.9 mm wide at its greatest diameter. The spine penetrated 5.2 mm of bone and was protruding 7.9 mm into the orbit.

Vegetation on the Silver Bell Mountains is common to the Arizona Upland subdivision of the Sonoran Desertscrub community (Turner and Brown, 1994). Cacti are an important group in the Sonoran Desertscrub, and many other woody plants have spines or thorns to discourage herbivory (Turner and Brown, 1994).

An epizootic of infectious keratoconjunctivitis occurred in bighorn sheep in the Silver Bell Mountains from 1 December 2003 to 31 March 2004. Bighorn sheep with clinical infectious keratoconjunctivitis are completely blind, at least temporarily, but can recover at least partial vision.

Bighorn sheep in the Silver Bell Mountains

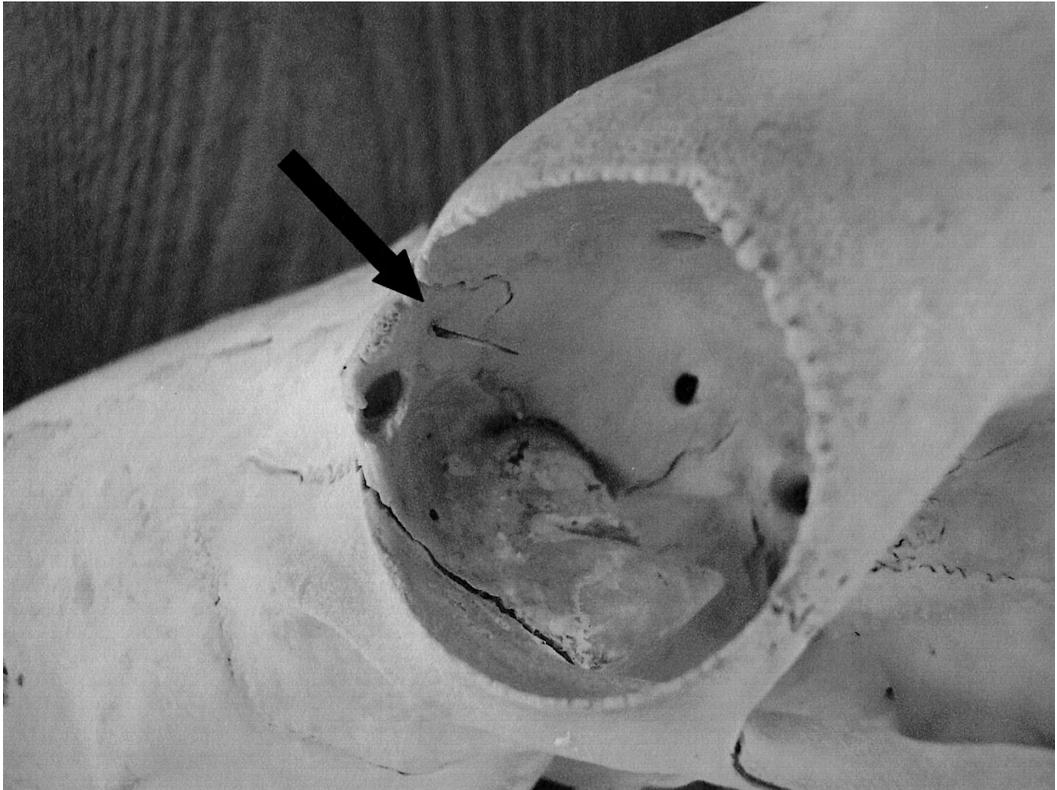


FIG. 1—Saguaro spine (*Carnegiea gigantea*) penetrating the lacrimal bone (at end of arrow) into the orbit of a female bighorn sheep (*Ovis canadensis*) from the Silver Bell Mountains, Pima County, Arizona.

are an indigenous population and are capable of moving among the spiny vegetation to avoid collisions that could result in injuries. Clinically affected bighorn sheep move erratically when alarmed and often collide with obstacles, whereas animals with normal vision do not. It is likely that this animal collided with a saguaro cactus driving the spine through the lacrimal bone into the orbit after it had become blinded by disease. We were unable to locate previously published literature documenting plant spines or thorns penetrating the bones of animals.

R. Felger identified the spine. This study was supported by the Arizona Game and Fish Department and the School of Natural Resources, University of Arizona, Tucson.

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## DIGESTIVE EFFICIENCY OF COLLARED PECCARIES AND WILD PIGS

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**ABSTRACT**—Collared peccary (*Tayassu tajacu*) and wild pig (*Sus scrofa*) exist in sympatry in southern Texas. These species vary in the structure of the digestive system and in adult body size, which might influence digestive performance. Our objective was to assess differences in digestive system efficiency between these species, controlling for body size. Four peccaries and 4 young pigs of similar size were fed a standardized amount of a commercial feed (38% neutral detergent fiber, 12% crude protein) based on metabolic body weight ( $\text{kg}^{0.75}$ ) for 8 days. Feed consumed and feces produced were measured during the last 5 days of the trial. No differences were found for digestive performance between the 2 species, although pigs excreted 95% of chromium-marked fiber sooner than peccaries. Although peccaries have a complex stomach in which fermentation occurs, they apparently do not gain a significant benefit in digestibility of dry matter, energy, or fiber relative to a hindgut fermenter of similar body size when eating similar amounts of food. Peccaries might, however, benefit from microbial products (e.g., vitamins and amino acids) that would not be readily available if fermentation occurred exclusively in the hindgut. Our results do not suggest that either species has a competitive advantage in dry matter digestion of plant material.

**RESUMEN**—El jabalí (*Tayassu tajacu*) y el cerdo (*Sus scrofa*) coexisten en el sur de Texas. Estas especies difieren en la estructura del sistema digestivo y en tamaño corporal adulto, lo cual puede influenciar su funcionamiento digestivo. Nuestro objetivo fue evaluar las diferencias en la eficacia del sistema digestivo entre estas especies, controlando por el tamaño corporal. Cuatro jabalíes y 4 cerdos jóvenes de tamaño similar fueron alimentados con una dieta estándar de alimento comercial (38% fibra detergente neutra, 12% proteína bruta) en base a su peso metabólico ( $\text{kg}^{0.75}$ ) durante 8 días. Se midieron la comida consumida y las heces producidas durante los últimos cinco días de la prueba. No se encontraron diferencias en el funcionamiento digestivo entre las 2 especies, aun cuando los cerdos excretaron 95% de la fibra marcada con cromo más rápido que los jabalíes. Aunque los jabalíes poseen un estómago complejo donde ocurre la fermentación, aparentemente no existe un beneficio significativo en la digestibilidad de la materia seca, energía, o fibra comparado con los fermentadores post-gástricos de tamaño similar cuando consumen cantidades iguales de alimento. Los jabalíes podrían tener algún beneficio de productos microbiales (i.e., vitaminas y aminoácidos), los cuales no estarían disponibles si la fermentación fuera

exclusivamente post-gástrica. Nuestros resultados no indican que cualquiera de las especies posea ventaja competitiva para la digestión de material seca vegetal.

Structure and physiology of the digestive system affect digestive performance (Hanley, 1982; Baker and Hobbs, 1987; Hume et al., 1993). Sites of microbial fermentation and nutrient absorption vary among foregut fermenters and hindgut fermenters (McBee, 1971; Reece, 1990), and hindgut fermenters generally are less efficient at digesting fiber than foregut fermenters. However, hindgut fermenters are able to pass a larger amount of highly fibrous food and, thus, might extract more nutrients per unit time than foregut fermenters (Hanley, 1982; Duncan et al., 1990).

The collared peccary (*Tayassu tajacu*) is native to North and South America, with a range extending into parts of the southwestern United States (Sowls, 1997). The wild pig (*Sus scrofa*) is an exotic species in North America, whose expanding range overlaps that of the collared peccary in Texas (Gipson et al., 1998). Digestive systems of collared peccaries and wild pigs differ in form and function. The peccary is a foregut fermenter, with a complex (sectioned) stomach containing large concentrations of protozoa (Langer, 1978; Stevens, 1988) capable of producing volatile fatty acids from structural carbohydrates of plants (Langer, 1978, 1979; Carl and Brown, 1983). The peccary forestomach has a large storage capacity and many folds that slow the passage of food (Langer, 1979), which can allow more time for microbial fermentation to occur. The wild pig, a hindgut fermenter, has a simple stomach, and microbial fermentation occurs primarily in the large intestine (Stevens, 1988; Cork et al., 1999). The cecum and colon support a large volume of digesta, increasing retention time and the duration of microbial digestion (Reece, 1990).

Collared peccaries and wild pigs are sympatric in rangelands in southern Texas and, because there is some dietary overlap, especially for forbs and mast (Ilse and Hellgren, 1995; Taylor and Hellgren, 1997), competition is possible between the 2 species. However, the extent of competition is unknown and presumably is influenced by many factors, including digestive efficiency. Studies on digestive performances of collared peccaries and wild pigs

are limited and offer conflicting results. Shively et al. (1985) suggested that fiber digestion by the peccary might be more similar to that of swine than of ruminants. However, Carl and Brown (1986) found that fiber digestion by the peccary was similar to that of white-tailed deer (*Odocoileus virginianus*), presumably because of the long retention of digesta in the forestomach. Comizzoli et al. (1997) suggested that collared peccaries were more similar to ruminants than monogastric animals because of the highly efficient digestion of fibrous foods.

Direct comparisons between the digestive systems of the peccary and wild pig are confounded by the large difference in body size between adults of the 2 species. Average adult weight of collared peccaries in Texas ranges from 19 to 23 kg (Sowls, 1997), but adult wild pigs can weigh from 62 to 75 kg (Ilse and Hellgren, 1995). Body size constraints were reduced in this study by using collared peccaries and wild pigs of varying age but similar body size. Such comparisons are meaningful not only to understand digestive strategies of these species, but also will have implications regarding competition between the 2 species; high reproduction rates of wild pigs (Taylor et al., 1998) typically result in a high proportion of young wild pigs in free-ranging populations.

The objective of this study was to determine whether differences in digestive efficiency and passage rate of digesta exist between collared peccaries and wild pigs. Based on the large stomach and foregut fermentation capabilities of collared peccaries, we tested the hypotheses that: 1) collared peccaries have a higher capability to digest fiber than wild pigs of similar body size, and 2) collared peccaries have a slower digesta passage rate than wild pigs of similar body size. If our hypotheses are supported, it would suggest that collared peccaries could have a competitive advantage when both species are consuming similar forages.

We conducted feeding trials with 4 collared peccaries (2 males, 2 females) and 4 wild pigs (1 male, 3 females) from April through July 2000 at the Caesar Kleberg Wildlife Research Institute wildlife research facility at Texas A&M University-Kingsville. Animals ranged in size

from 15.7 to 35.4 kg. Three of the collared peccaries were one year of age and one female was approximately 8 to 9 months of age. All wild pigs were <1 year of age.

Four plywood metabolism crates (ca. 1.2 × 1.5 × 1.2 m) with expanded metal flooring were used. Crates were equipped with pullout trays for fecal collection and were kept in the same open-sided barn.

We collected data from 3 trials: from 2 collared peccaries and 2 wild pigs during the first trial, 1 peccary and 2 wild pigs during the second trial, and 1 peccary during the third. Animals were weighed, placed singly into a crate, and fed a commercial feed (Table 1) for 8 days. During the trials, each individual received the same amount of food based on metabolic body weight ( $\text{kg}^{0.75}$ ), determined by measuring the amount of food that the smallest animal consumed in a day, and dividing that amount by its metabolic body weight ( $\text{g feed}/\text{kg}^{0.75}$ ). This value was multiplied by the metabolic body weight of each individual to calculate the daily ration. All animals were fed the diet ad libitum for approximately one month before feeding trials began. Water was provided ad libitum.

The first 3 days of the trial served as an acclimation period to the metabolism crate. Orts (uneaten food) and feces were collected during the last 5 days of the trial. Animals also were fed 5 g of a chromium (Cr)-mordanted fiber sample (Uden et al., 1980) on the first day of fecal collection to determine rate of passage. To facilitate consumption, the Cr-marked fiber sample was offered along with small amounts of banana or apple and whole corn. Feces were collected every 4 hours during the first 2 days after feeding the marked fiber, every 6 hours during the third day, every 8 hours during the fourth day, and twice on the fifth day. After the final collection period, animals were removed from crates, weighed, and returned to their home pens.

Samples of feed and feces were frozen until laboratory analyses began. We dried Orts at 100°C for 24 h and samples of feed and feces at 50°C for 48 h. Dried feed and fecal samples were ground through a centrifuge grinder with a 1-mm screen. A composite fecal sample for analysis was made for each animal by combining 25% of each fecal collection. The remaining fecal sample from each period was kept

separate for analysis of Cr concentrations. Feed and fecal samples were analyzed for neutral detergent fiber, acid detergent fiber, and acid detergent lignin (Goering and Van Soest, 1970) using an Ankom (Macedon, New York) fiber analyzer. Crude protein was determined via the Kjeldahl procedure using a Tecator Kjeltec (Eden Prairie, Minnesota) digester and distiller. We determined gross energy with bomb calorimetry (Parr Instrument Co., Moline, Illinois), and calculated dry-matter intake, digestible energy, and the digestibility of dry matter, fiber, and crude protein.

We extracted Cr from fecal samples (Williams et al., 1962) and sent it to the Texas A&M Agricultural Experiment Station in Uvalde, Texas, for atomic absorption determination. Total marker excretion (100%) was assumed to be the sum of all markers recovered over the collection period. Transit time was the number of hours for the marker to first appear in the feces. Passage rate was determined by the time after feeding the marked fiber that 50% (mean retention time) and 95% of the marker was recovered in the feces (Hewitt et al., 1997).

Digestion of feed components and rate of passage data were analyzed by a Student's *t*-test, with animal species as the factor. Differences in means were considered significant when  $P < 0.05$ . Means are given with standard errors.

We attempted to conduct this study with collared peccaries and wild pigs of the same weight, but wild pigs had a high growth rate. As a result, collared peccaries weighed less than wild pigs during the trials (collared peccary mean body weight = 21.1 kg; wild pig mean body weight = 31.9 kg). Collared peccaries and wild pigs both lost body mass during the trials (collared peccary mean loss =  $7.5 \pm 2.4\%$ ; wild pig mean loss =  $8.1 \pm 1.9\%$ ), though there was no difference between species ( $P = 0.847$ ). Dry-matter intake did not vary between collared peccaries ( $24.1 \pm 4.33 \text{ g}/\text{kg}^{0.75}/\text{day}$ ) and wild pigs ( $31.95 \pm 1.63 \text{ g}/\text{kg}^{0.75}/\text{day}$ ;  $P = 0.143$ ). No differences in digestibility of dry matter, fiber, crude protein, or energy between the 2 species were observed (Table 1). There was no difference in transit time or mean retention time (Table 2) between the 2 species. However, wild pigs excreted 95% of the marked fiber approximately 28 hours sooner than collared peccaries (Table 2).

Although the wild pigs grew quickly after we

TABLE 1—Composition (percent for all components, except gross energy, which was cal/g) of commercial diet fed to collared peccaries (*Tayassu tajacu*) and wild pigs (*Sus scrofa*) in Kingsville, Texas, April through July 2000, and apparent digestibility (%) of dietary components.

Composition	Collared peccary		Wild pig		P-value
	Mean	SE	Mean	SE	
Dry matter	89.9	49.9	50.3	2.98	0.906
Neutral detergent fiber	38.3	13.5	12.3	6.01	0.851
Acid detergent fiber	26.5	10.7	9.6	6.24	0.880
Acid detergent lignin	7.4	6.9	7.7	9.96	0.951
Crude protein	12.5	65.4	64.5	1.69	0.690
Gross energy	4,130	53.5	52.3	2.23	0.640

obtained them and, therefore, were heavier than collared peccaries during the trials, the wild pigs were <50% of the body mass of adults, so our results still provide evidence that there are no differences in digestive ability between collared peccaries and wild pigs of similar body size. We also offered each individual the same amount of food based on metabolic body weight, because differences in intake can affect digestion (Robbins, 1993). Therefore, differences in dry-matter intake in our study were not expected. Wild pigs could have consumed more food than was offered, whereas collared peccaries tended to leave food. These differences in desired intake by each species could be explained by the ages and sizes of the animals. Collared peccaries were close to or had achieved their adult body size. Wild pigs were less than half their expected adult size, were growing quickly, and would be expected to have greater metabolic demands.

The diet used in this study had moderate concentrations of fiber, and it is possible that differences in digestibility between the 2 species would have been observed with a diet higher in fiber. However, dry-matter digestibility of the diet was similar to that of foods commonly eaten by collared peccaries in southern

Texas (Strey and Brown, 1989). Thus, our results are applicable to free-ranging populations of collared peccaries and wild pigs.

Although collared peccaries have a complex stomach in which fermentation occurs, they apparently do not gain a significant benefit in digestibility of dry matter or fiber relative to a hindgut fermenter of similar body size when eating the same amount of feed. Collared peccaries might, however, benefit from microbial products that would not be readily available if fermentation occurred exclusively in the hindgut. For these reasons, we concluded that the outcome of competition between individuals <35 kg body mass of these 2 species will not be influenced significantly by differences in digestive function.

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TABLE 2—Passage rate of diet fed to collared peccaries (*Tayassu tajacu*) and wild pigs (*Sus scrofa*) in Kingsville, Texas, April through July 2000.

	Collared peccary		Wild pig		P-value
	Mean	SE	Mean	SE	
Transit time (h)	6.00	1.15	4.00	0.0	0.134
50% passage time (h)	40.53	1.14	39.77	4.93	0.889
95% passage time (h)	96.03	7.73	68.40	3.28	0.017

viewed and approved by the Texas A&M University-Kingsville Animal Care and Use Committee (#99-5-3). This is publication number 04-108 of the Caesar Kleberg Wildlife Research Institute.

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