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Sexual Dimorphism in the Ringtail (*Bassariscus astutus*) from Texas

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Abstract

Sexual dimorphism in the ringtail has been alluded to in the literature, but the phenomenon has not been documented. We present a morphometric assessment of cranial and dental features for 152 specimens of *Bassariscus astutus flavus* from Texas and contiguous regions of northern Mexico. Sample composition relative to age and sex is biased heavily towards young adult males, with juveniles and senile adults of both sexes poorly represented. Adult males averaged larger than females, and were significantly so for 12 of 17 characters examined. No discernible geographic variation was noted for the species in our study area.

Key words: *Bassariscus astutus*, cranial variation, ringtail, sexual dimorphism, Texas

Introduction

Cranial variation has been documented for some species of the Procyonidae, such as the raccoon, *Procyon lotor* (Kennedy and Lindsay 1984; Ritke 1990; Ritke and Kennedy 1993); mountain coatis, *Nasuella* spp., (Helgen et al. 2009); and the kinkajou, *Potos flavus* (Kortlucke 1973). Yet, little comparable information is available for the ringtail (*Bassariscus astutus*), a widespread and often common carnivore that ranges across much of the southwestern United States and into southern Mexico (Hall 1981; Baker 1999).

Males of the order Carnivora typically are larger than their female conspecifics—a trend especially pronounced in Mustelidae, Felidae, and Procyonidae (Gittleman and Van Valkenburgh 1997). Nowak (1999) stated that male procyonids generally are a fifth larger and heavier than females, an observation supported by each of the above cited studies except that of Helgen et al. (2009) for a limited sample of *Nasuella*. Poglayen-Neuwall and Toweill (1988) noted that the skulls of male ringtails generally are larger than comparably aged females, yet Baker (1999) remarked that little significant sexual dimorphism exists for *B. astutus*.

Population studies of the ringtail are available for Texas (Ackerson and Harveson 2006) and New Mexico (Harrison 2012), and synopses of the natural history of the species are provided by Poglayen-Neuwall and Toweill (1988) and Gehrt (2003). However, the most detailed morphometric assessment for *B. astutus* of which we are aware is Hoffmeister's (1986) presentation of selected cranial measurements for 15 skulls from Arizona, leading to his observation that males averaged larger for all skull measurements except for least interorbital breadth and M1 breadth. He suggested that further studies likely would demonstrate that males are significantly larger than females.

This study presents the first comprehensive morphometric assessment of the ringtail. We attempt to detail variation by age and sex for the species in Texas, and to the extent that our sample size permits, we address microgeographic variation within this northeastern most subspecies of the taxon, *B. astutus flavus*.

Materials and Methods

A total of 152 specimens (Appendix) of *Bassariscus astutus flavus* from the collections of the Department of Biology at Midwestern State University (MWSU; n = 88) and the Museum of Texas Tech University (TTU; n = 64) comprise the basis for this study. A total of 17 cranial and mandibular measurements (nine of which are illustrated in Fig. 1) were attempted from each specimen: rostral breadth (across base of upper canines), least interorbital breadth, postorbital breadth, greatest zygomatic breadth, mastoid breadth, length and width of auditory bullae, condylobasal length, maxillary toothrow (C–M2) length, width and height of foramen magnum, greatest breadth of M1, greatest breadth of m1, basal length and width of upper canine, and basal length and width of lower canine. All measurements were recorded with digital calipers to the nearest 0.01 mm. Paired elements were taken from the right side, unless missing or too damaged to assess.

Each specimen was classified by sex as recorded on the collector's tag. The few juveniles available, judged on the basis of their diminutive and sometimes fragmentary skulls and lack of complete adult dentition, were not included in this study. All older specimens were assigned to one of four relative age categories, based on relative degrees of cranial ossification and dental wear, as modified from Kortlucke's (1973) work on kinkajous, although our terminology varies somewhat. For our purposes, juveniles lack their complete adult dentition. Age class 1 (subadults) is characterized by complete but unworn dentition and basisphenoid unfused anteriorly and posteriorly; age class 2 (young adults) have slightly worn dentition and basisphenoid fused posteriorly; age class 3 (old adults) possess moderately worn dentition and basisphenoid fused anteriorly and posteriorly; and age class 4 (senile adults) are marked by heavily worn dentition and basisphenoid sutures tightly fused to obliterated.

All computations were performed with NCSS, Version 5.3 statistical package (Hintze 1990). Two-way analyses of variation (age, sex) were employed to inspect for an interaction effect between age and sex, and to assess secondary sexual dimorphism across age classes. Age was found to be unimportant, permitting the pooling of specimens regardless of age. However, we judged the middle two age classes to be sufficiently large (n = 80; 54 males, 26 females) to discard the smaller samples comprised of the youngest (n = 9; averaged smallest for most characters) and the oldest age classes (n = 4; averaged largest for several characters). We then used ANOVAs to characterize sexual dimorphism for each character of the pooled middle two age classes.

One-way ANOVAs and Duncan's multiple means tests were applied to test each sex independently for any microgeographic variation of individuals from the middle two age classes within the study area. Our sample originated entirely from within the geographic range of *B. astutus flavus* (sensu Hall 1981), but encompassed such a large and geographically variable region that we sorted specimens by biotic province (as figured by Blair 1950). These provinces are defined by distinctive physiographic and climatic regimes, and sufficient samples were available for four: Balconian (broken limestone terrain of central Texas); Chihuahuan (desert mountains and basins of mostly Trans-Pecos); Texan (rugged Cross Timbers of north-central Texas); and Kansan (mostly grassland and savanna, bisected by Caprock Escarpment). The Tamaulipan sample (subtropics of extreme southern Texas and contiguous Tamaulipas, Mexico) was of insufficient size to include in the geographic analysis. Because nearly a third of our specimens lacked data regarding sex, we applied discriminant function analysis to test the utility of sexually dimorphic features in accurately predicting the sex for those individuals not accompanied by such data.

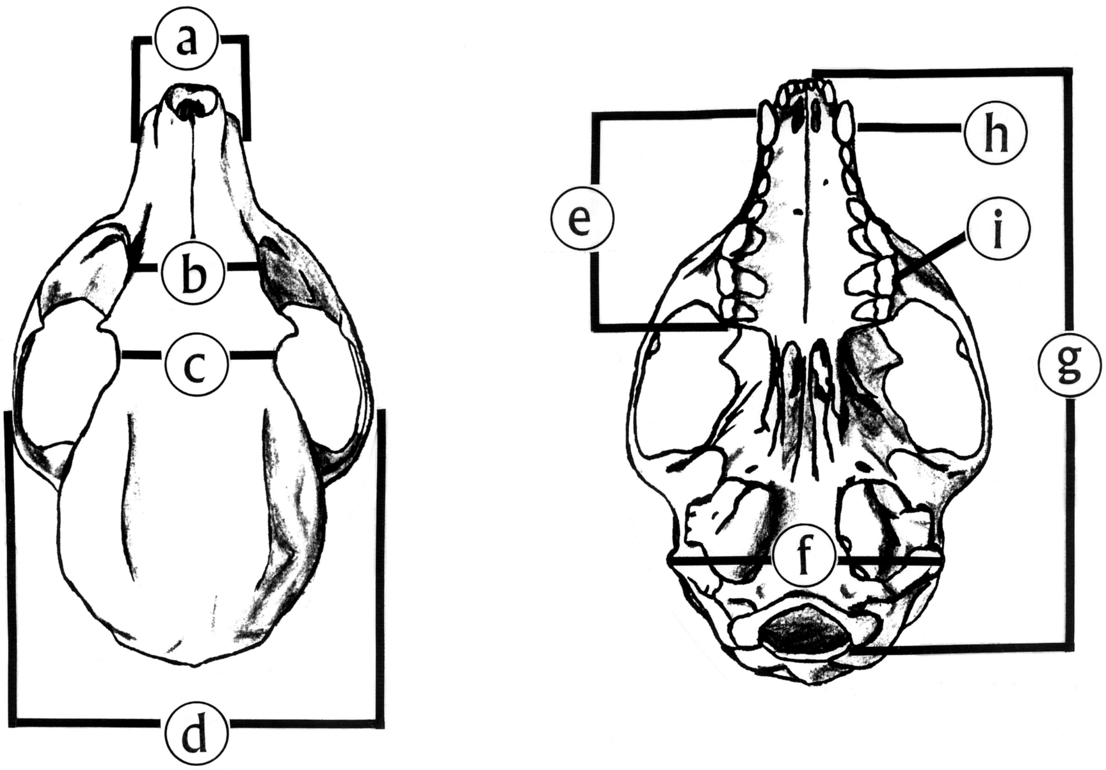

Figure 1. Dorsal and ventral views of skull of an adult male specimen of *Bassariscus astutus* (MWSU 8802). Representative measurements are: a) rostral breadth; b) interorbital breadth; c) postorbital breadth; d) zygomatic breadth; e) maxillary toothrow; f) mastoid breadth; g) condylobasal length; and upper canine (h) and M1 (i), for which dimensions were recorded. Other measurements not figured were dimensions of foramen magnum, auditory bullae, lower canine, and m1. (Drawing by Nicholas Lamar.)

RESULTS

Sexual dimorphism for *Bassariscus astutus* was pronounced (Table 1). Only for postorbital breadth did females average marginally larger than males, albeit insignificantly so. For the remaining characters, males averaged larger. These differences were highly significant, with the exceptions of bullar width, dimensions of foramen magnum, and breadth of M1. Discriminant function analysis of age classes 2 and 3 served to accurately predict the sex for 95% (74 of 78) of the individuals. Misclassified specimens included two animals listed as males (MWSU 7500, TTU 17409) and two listed as females (TTU 1671, TTU 6663).

Males comprised the majority of known-sex individuals (60 of 93), and outnumbered females for each of the first three age categories. Age categories and breakdown by sex were as follows: age class 1 (n = 13): 5 males, 4 females, 4 of unknown sex; age class 2 (n = 96): 42 males, 21 females, 33 of unknown sex; age class 3 (n = 34): 12 males, 5 females, 17 of unknown sex; and age class 4 (n = 9): 1 male, 3 females, 5 of unknown sex. As noted above, there were no significant differences among each of the four age classes for either sex, although subadults generally were smaller than older aged specimens, and senile adults generally larger than younger animals.

More than half of the specimens of *B. astutus* initially analyzed in this study originated from the Balconian (n = 88) Province. Remaining animals were taken from the Chihuahuan (n = 40), Texan (n = 15), Kansan (n = 7), and Tamaulipan (n = 1) provinces. Samples were small for some provinces, but there was no significant geographic variation noted of either sex for any character.

Table 1. Comparison of cranial and dental measurements (in mm) between sexes of adult (age classes 2, 3) ringtails (*Bassariscus astutus flavus*) from Texas. Descriptive statistics are: sample size (n), mean, standard deviation (SD), minimum and maximum measures, confidence intervals (C.I.), and coefficient of variation (CV). Probability values (P) derived from one-way ANOVAs; non-significant results indicated by n.s.

Sex (n)	Mean ± SD	Minimum-maximum	95% C. I.	CV	P
		Rostral breadth			
Male (54)	14.9 ± 0.6	13.6–16.3	14.7–15.1	4.2	<0.0001
Female (26)	13.6 ± 0.8	12.6–15.5	13.2–13.9	5.8	
		Interorbital breadth			
Male (54)	16.6 ± 0.8	14.8–18.5	16.4–16.8	4.7	<0.0001
Female (26)	15.8 ± 0.8	14.7–17.6	15.5–16.2	5.4	
		Postorbital breadth			
Male (54)	17.7 ± 1.5	13.5–22.0	17.3–18.1	8.3	n.s.
Female (26)	18.0 ± 1.7	14.3–21.5	17.3–18.7	9.6	
		Zygomatic breadth			
Male (53)	50.6 ± 2.3	46.3–55.5	50.0–51.2	4.4	<0.0001
Female (26)	47.3 ± 2.4	43.0–54.6	46.4–48.3	5.2	
		Mastoid breadth			
Male (53)	36.0 ± 1.0	33.8–38.0	35.7–36.2	2.8	<0.0001
Female (26)	34.2 ± 1.0	32.3–36.7	33.8–34.6	2.9	
		Bullar length			
Male (54)	12.6 ± 0.5	11.6–13.7	12.4–12.7	3.8	<0.001
Female (25)	12.2 ± 0.5	11.4–12.9	12.0–12.4	3.8	
		Bullar width			
Male (54)	10.4 ± 0.5	9.4–11.4	10.3–10.6	4.2	n.s.
Female (26)	10.3 ± 0.3	9.7–10.8	10.1–10.4	2.7	
		Condylobasal length			
Male (52)	79.4 ± 2.2	74.1–83.4	78.8–80.0	2.7	<0.0001
Female (26)	76.2 ± 1.9	73.8–81.2	75.4–76.9	2.5	
		Foramen magnum width			
Male (50)	11.9 ± 0.6	10.6–13.3	11.7–12.0	5.2	n.s.
Female (26)	11.6 ± 0.5	10.7–12.5	11.4–11.8	4.3	

Table 1. (cont.)

Sex (n)	Mean ± SD	Minimum-maximum	95% C. I.	CV	P
		Foramen magnum height			
Male (50)	8.8 ± 0.6	7.7–10.4	8.6–8.9	6.7	n.s.
Female (26)	8.8 ± 0.6	7.7–10.6	8.6–9.0	6.5	
		Maxillary toothrow length (C-M2)			
Male (47)	31.7 ± 1.1	29.8–36.0	31.3–32.0	3.6	<0.0001
Female (25)	30.3 ± 0.7	28.8–31.6	30.0–30.6	2.5	
		Upper canine basal length			
Male (50)	3.6 ± 0.2	3.1–4.3	3.6–3.7	6.1	<0.0001
Female (25)	3.2 ± 0.2	2.9–3.7	3.2–3.3	6.1	
		Upper canine basal width			
Male (50)	2.7 ± 0.1	2.3–3.1	2.6–2.7	5.3	<0.0001
Female (25)	2.3 ± 0.1	2.1–2.6	2.3–2.4	5.2	
		M1 breadth			
Male (52)	8.2 ± 0.5	7.2–9.2	8.0–8.3	5.8	n.s.
Female (26)	8.0 ± 0.4	7.1–8.7	7.9–8.2	5.1	
		Lower canine basal length			
Male (51)	4.0 ± 0.3	3.4–4.8	3.9–4.1	7.0	<0.0001
Female (25)	3.5 ± 0.2	3.0–3.9	3.4–3.6	5.9	
		Lower canine basal width			
Male (51)	2.9 ± 0.3	2.2–3.7	2.8–2.9	8.9	<0.0001
Female (25)	2.5 ± 0.2	2.3–3.2	2.4–2.6	8.9	
		Breadth of m1			
Male (53)	3.8 ± 0.2	3.3–4.2	3.7–3.8	4.2	<0.0001
Female (25)	3.6 ± 0.1	3.4–3.9	3.6–3.7	3.8	

DISCUSSION

The documented sexual dimorphism for ringtails is sufficiently pronounced to suggest that the phenomenon is typical for the ringtail across its range. Elucidation of other aspects of cranial variation must await studies of larger sample sizes of greater spatial and temporal representation. Attempts to fully characterize age variation are confounded by the dearth of specimens representing the age extremes: juveniles and senile adults. Few wild individual ringtails seem to reach the 11–14 years-of-age reported for some captives (Crandall 1974), as evidenced in the few senile adults in our sample. Mortality rates for *Bassariscus astutus* in nature are high, as evidenced by one Texas study (Ackerson and Harveson 2006) where 6 of 17 tagged animals were lost to predation during the course of their 15-month study. The great horned owl (*Bubo virginianus*) is thought to be a major predator (Poglayen-Neuwall and Toweill 1988), and larger carnivores (e.g. coyote, *Canis latrans*; bobcat, *Lynx rufus*) are common across the state. Juveniles are scarce in collections, as the young animals remain close to the den and grow quickly—weaning occurs within 10 weeks of birth, adult dentition acquired 10 weeks later, and adult size is achieved by 30 weeks-of-age (Toweill and Toweill 1978; Poglayen-Neuwall and Toweill 1988). This rather narrow window of availability to collectors also coincides with late summer and early fall—a period in the academic calendar of historical collecting inactivity, as reflected in the paucity of such records for ringtails of any age from the collections of Midwestern State and Texas Tech universities (Stangl and Jones 1987).

Our own sample is comprised largely of specimens salvaged from fur trappers and as automobile traffic fatalities. Population studies of *B. astutus* in Texas (Ackerson and Harveson 2006) and contiguous New Mexico (Harrison 2012) indicated occurrence of the sexes in equal numbers, although our sample was skewed heavily towards males. This increased vulnerability likely emphasizes naive or inexperienced yearlings and young adults of both sexes during dispersal, but particularly males with their greater dispersal distances, larger home ranges, and perhaps less cautious behavior. Road-killed ringtails are not as frequently encountered as one might expect for so common an animal, but it is trapped easily and is often taken in traps intended for more valuable furbearers (Schmidly 1984).

Hoffmeister (1986) noted the need for a comprehensive systematic review of *B. astutus*. Lack of any discernible pattern of microgeographic variation from within the geographic range of the nominal subspecies *B. a. flavus* likely reflects continuous gene flow across suitable habitat of a moderate-sized and vagile carnivore. Adequate habitat exists from the Chihuahuan Desert mountains and foothills of the Trans-Pecos to the rocky terrain across central Texas and northward along the rugged, wooded hills of the Cross Timbers. These three areas represent our largest regional sample sizes, and coincide with those parts of the state referenced by Schmidly (2004) as supporting the largest populations.

Faunal treatments commonly offer a select series of cranial measurements for included taxa, although sample sizes generally are small, only a few measurements of unaged adults are usually provided, and selected measurements vary among authors. A literature survey of representative skull measurements from across the range of the species (Table 2) provides data too limited for any taxonomic inferences, although they are supportive of the suggestion that ringtails from our study area are larger than animals from the Sonoran Desert southwest, and smaller than those from southern Mexico (Poglayen-Neuwall and Toweill 1988).

Finally, we noted during the course of this investigation that there is some confusion in the literature regarding the dental formula of *B. astutus* that could adversely impact future studies. The P4 is a large tooth that was interpreted incorrectly as an M1 by Elbroch (2006) and perhaps others, perpetuating the original error seemingly first applied by Poglayen-Neuwall and Toweill (1988). Gehrt (2003) first reported this discrepancy, but left the issue unresolved. As typical for the family Procyonidae (Stains 1984), the correct formula for the ringtail is: i 3/3, c 1/1, p 4/4, m 2/2 = 40.

Table 2. Selected available cranial measurements (means, to nearest 0.1 mm) of the ringtail (*Bassariscus astutus*) from the literature. Abbreviations are as follows: IOB, interorbital breadth; ZYG, zygomatic breadth; MAST, mastoid breadth; CNB, condylobasal length; and MAXT, maxillary tooth row length.

Authority/subspecific taxon	n	IOB	ZYG	MAST	CNB	MAXT
Hoffmeister (1986) from Arizona						
B. a. arizonensis	5 males	14.7	47.4	34.6	77.4	30.7
	5 females	15.5	46.9	33.4	74.3	30.0
B. a. yumanensis	1 male	15.8	41.6	--	74.8	29.8
	3 females	16.5	45.1	36.0*	73.9	30.2
Hall (1946) from Nevada						
B. a. nevadensis	2 males	14.7	47.0	33.5	--	--
Verts and Carraway (1998) from Oregon						
B. a. raptor	3 males	15.3	47.8	--	78.0	31.1
	3 females	15.8	48.2	--	--	30.5
Durrant (1952) from Utah						
B. a. nevadensis	1 male	13.9	46.7	32.4	74.3	--
	1 female	14.4	44.4	32.9	75.6	--
Anderson (1972) from Chihuahua						
B. a. consitus	1 unknown	14.8	47.6	--	73.9	--
Baker (1956) from Coahuila						
B. a. flavus	3 males	16.5	44.2	--	--	31.0
Goodwin (1969) from Oaxaca						
B. a. astutus	1 male	16.6	57.7	--	89.7	33.5
	1 female	18.2	55.7	--	85.0	32.8
B. a. macdougalli	1 female	16.3	53.0	--	83.9	32.4
B. a. bolei	1 male	16.0	56.5	--	84.5	31.7

* n = 1

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Appendix

Following is a list of 152 specimens of *Bassariscus astutus* examined from the collections of Midwestern State University (MWSU; n = 88) and the Museum of Texas Tech University (TTU; n = 64).

TEXAS (n = 146).—Bandera Co.: 18 mi NW Medina, 1 (TTU 92544). Brewster Co.: Black Gap Wildlife Area, 1 (TTU 1381); BBNP, Harte Ranch Mt. Lodge, 1 (TTU 62985); 13 mi N, 3 mi W Marathon, 1 (TTU 29028); 13.4 mi N, 4 mi W Marathon, 1 (TTU 29026); 13.5 mi N, 2.5 mi W Marathon, 1 (TTU 29025); 13.75 mi N, .75 mi W Marathon, 1 (TTU 29024); 17.3 mi N, 0.6 mi E Marathon, 1 (TTU 22980); 17.9 mi N, 0.3 mi E Marathon, 1 (TTU 22981); 18 mi N, 3.0 mi E Marathon, 1 (TTU 22982). Burnet Co.: Burnet, 1 (MWSU 21871); 1.5 mi N, 3 mi W Naruna Community, 1 (TTU 59703). Clay Co.: 20 mi S Henrietta, 1 (MWSU 11040). Comanche Co.: 6 mi S Gorman, 1.5 mi E Hwy 6, 1 (TTU 43365). Crockett Co.: 9 mi S, 5 mi E Iraan, 1 (TTU 58509). Culberson Co.: Guadalupe Mts., Lower McKittrick Canyon, 1 (TTU 25167); Guadalupe Mts., Upper Dog Canyon, 1 (TTU 32452); Sierra Diablo WMA, 1 (TTU 75781). Edwards Co.: 18 mi N Barksdale Eagles Nest Ranch, 1 (TTU 107712). Garza Co.: 16 mi S, 5 mi E Post, 2 (TTU 56563-4). Hood Co.: 4.2 mi N Granbury, 1 (MWSU 21769). Howard Co.: Big Spring, 1 (MWSU 6049). Jack Co.: 9 mi N Graford, 1 (MWSU 10946). Jeff Davis Co.: Fort Davis, 1 (MWSU 10945); 9 km N, 9.5 km E Fort Davis, 2 (TTU 32453, 32455); 9 mi NE Fort Davis, 2 (TTU 14063, 17409); 9.2 mi NE Fort Davis, 1 (TTU 17408). Kendall Co.: 2 mi N, 2 mi W Sisterdale, 1 (TTU 57961). Kerr Co.: 14 mi W Hunt, 1 (MWSU 9808). Kimble Co.: 5 mi E Junction, 1 (MWSU 7507); 6 mi E Junction, 1 (MWSU 1378); 7 mi E Junction, 17 (MWSU 1767-9, 1777, 8785, 8788-9, 8791-2, 8794, 8797, 8800-1, 8803, 8806-7, 8811); 8 mi E Junction, 14 (MWSU 6473, 6484-6, 6488, 8779-80, 8784, 8786, 8795-6, 8798-9, 8809); 10 mi E Junction, 21 (MWSU 3388, 3704, 4077, 6469, 6474, 6476-83, 7499-506); 12 mi E Junction, 8 (MWSU 8778, 8781-2, 8787, 8790, 8793, 8805, 8808); Kimble Co., no specific locality, 3 (MWSU 1374, 3387, 6475); 1.6 mi S, 3 mi W Junction, 3 (TTU 23724-23726); 5 mi W Junction, 1 (TTU 39494); Texas Tech University Center at Junction, 1 (TTU 71102); Walter Buck WMA, 1 (TTU 76655). McCulloch Co.: Near Brady, 1 (MWSU 16527). Menard Co.: 20 mi E Menard, 1 (MWSU 6050); 4 mi N, 8 mi W Menard, 1 (TTU 59704); 14 mi W, 2 mi S Menard, 1 (TTU 6661). Nolan Co.: 14 mi SE Sweetwater, 1 (TTU 6664). Palo Pinto Co.: 1 mi S Brad, 1 (MWSU 11512); 4 mi NNE Palo Pinto, 1 (MWSU 750); 10 mi W Graford, 1 (MWSU 8932); 11 mi W Graford, 1 (MWSU 13326); 15 mi W Graford, 1 (MWSU 18723); 17 mi SW Graford, Brazos River, 1 (MWSU 11513); Possum Kingdom State Fish Hatchery, 1 (MWSU 13386); Santo, 1 (MWSU 747); Possum Kingdom Lake, 2 (TTU 38698, 38699). Pecos Co.: 5 mi S, 2 mi E Girvin, 1 (TTU 49075); 12.2 mi N, 19.7 mi E Marathon, 1 (TTU

APPENDIX (CONT.)

25161). Presidio Co.: 6.5 mi NW Plata, 1 (MWSU 8802); Big Bend Ranch State Natural Area, 2 (TTU 67579, 67580); Clay Miller Ranch, 2 (TTU 9755, 11770); 10 mi WSW Valentine, Clay Miller Ranch, 1 (TTU 78532); 11 mi W Valentine, 4 (TTU 92744-92746, 92764). San Saba Co.: 5 mi E Cherokee, 1 (TTU 92786); 7 mi SE Bend, 1 (TTU 92787). Stephens Co.: 4 mi E Breckenridge, 1 (MWSU 8810). Sutton Co.: 4 mi S Sonora, Hwy 1691, 1 (TTU 9756); 35 mi E Sonora, 1 (TTU 35908). Terrell Co.: 20 mi S Sheffield, 1 (TTU 92796); 23 mi S Sheffield, 1 (TTU 92801). Tom Green Co.: 2 mi S San Angelo, 1 (TTU 92810). Travis Co.: 5 mi W Austin, Gaines Ranch, 1 (TTU 92820); 6 mi SW Leander, 1 (TTU 1671B); Travis Co., no specific locality, 1 (TTU 1671A). Val Verde Co.: 3 mi W Comstock, 1 (MWSU 7839); 12 mi N Comstock, 1 (MWSU 15459); 44 mi N Del Rio, 1 (TTU 6663). Wichita Co.: 1 mi W Wichita Falls, 1 (MWSU 751). Young Co.: Young Co., no specific locality, 1 (MWSU 5986).

MEXICO (n = 6).—Coahuila: 15 mi E Monclova, Gloria Mts., 2 (TTU 92458, 92459); 27 mi NE Muzquiz, Mariposa Ranch, 3 (TTU 92462-92464). Nuevo Leon: 1 km N San Josecita, Zaragoza, 1 (TTU 57122).

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