PROCEEDINGS OF THE BIOLOGICAL SOCIETY OF WASHINGTON
113(1):302–318. 2000.

Revision of the extant taxa of the genus *Notiosorex* (Mammalia: Insectivora: Soricidae)

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Abstract.—We evaluated the taxonomic status of three specimens of gray shrews, *Notiosorex* (Insectivora: Soricidae), collected in isolated mountain valleys in Tamaulipas, Mexico, with specimens referable to the Recent taxa *N. crawfordi crawfordi* (n = 229) and *N. c. evotis* (n = 34). Statistical analyses of cranial morphometric data revealed that the specimens from Tamaulipas represented a heretofore unknown taxon which is described herein as a new species of *Notiosorex* (*N. villai*). Also, *N. c. evotis* was found to be equally distinct from *N. c. crawfordi,* thus was elevated to specific status.

Resúmen.—Se evaluó el estado taxonómico de tres especímenes de la musaraña gris *Notiosorex* (Insectivora: Soricidae), colectados en valles dentro de las motañas en Tamaulipas, México y referidos a los taxa recientes *N. crawfordi crawfordi* (n = 229) y *N. c. evotis* (n = 34). Análisis estadísticos morfométricos del cráneo indicaron que los especímenes de Tamaulipas representan un taxón desconocido, el cual se describe como una especie nueva de *Notiosorex* (*N. villai*). Asimismo, *N. c. evotis* se encontró distinto a *N. c. crawfordi,* por lo que se elevó al nivel específico.

Gray shrews of the genus *Notiosorex* (Insectivora: Soricidae) are widely distributed in the southwestern United States and northern and western Mexico (Fig. 1). They range from southern California, Nevada, Utah, Colorado, Oklahoma, and western Arkansas, southward to southern Baja California Sur, Michoacan, and southern Tamaulipas (Sealander 1952, Baker 1966, Armstrong & Jones 1972, Woloszyn & Woloszyn 1982, Carie et al. 1989). Insular records are known from Isla San Martín, Baja California Norte (Schulz et al. 1970), and Isla Palmito del Verde, Sinaloa, Mexico (Armstrong & Jones 1971). Gray shrews occur in a variety of habitats including desert shrub (characterized by mesquites, *Prosopis*; palo verde, *Cercidium*; *Acacia*; *Yucca*; *Agave*; and scattered *Juniperus*; Lange 1959), pine-oak forest (characterized by *Abies religiosa, Populus tremuloides, Juniperus flaccida,* four species of *Pinus,* and three of *Quercus*; Alvarez 1963), in grassland with oak chaparral (characterized by chamise, *Adenostomna fasciculatum*; scrub oak, *Quercus dumosa*; California live oak, *Q. agrifolia*; and mountain lilac, *Ceanothus*) and oak woodland habitats nearby (Cunningham 1956), coastal sage scrub (characterized by coastal sagebrush, *Artemesia californica*; black sage, *Salvia mellifera*; laurel sumac, *Rhus laurina*; and grasses), yellow pine forest (*Pinus australis*; Lange 1959), alkaline marsh (Stephens 1906), arid grasslands (containing scattered catclaw, juniper, and mesquite; Baker 1966), and sandy flats (characterized by *Artemisia tridentata, Ephedra viridis, Peucephyllum schottii,* and *Chrysothamnus viscidiflorus*; Fisher 1941). Elevations of occupied habitats range from 3 to 2618 m (Fisher 1941, Lange 1959, Baker 1966, Da-

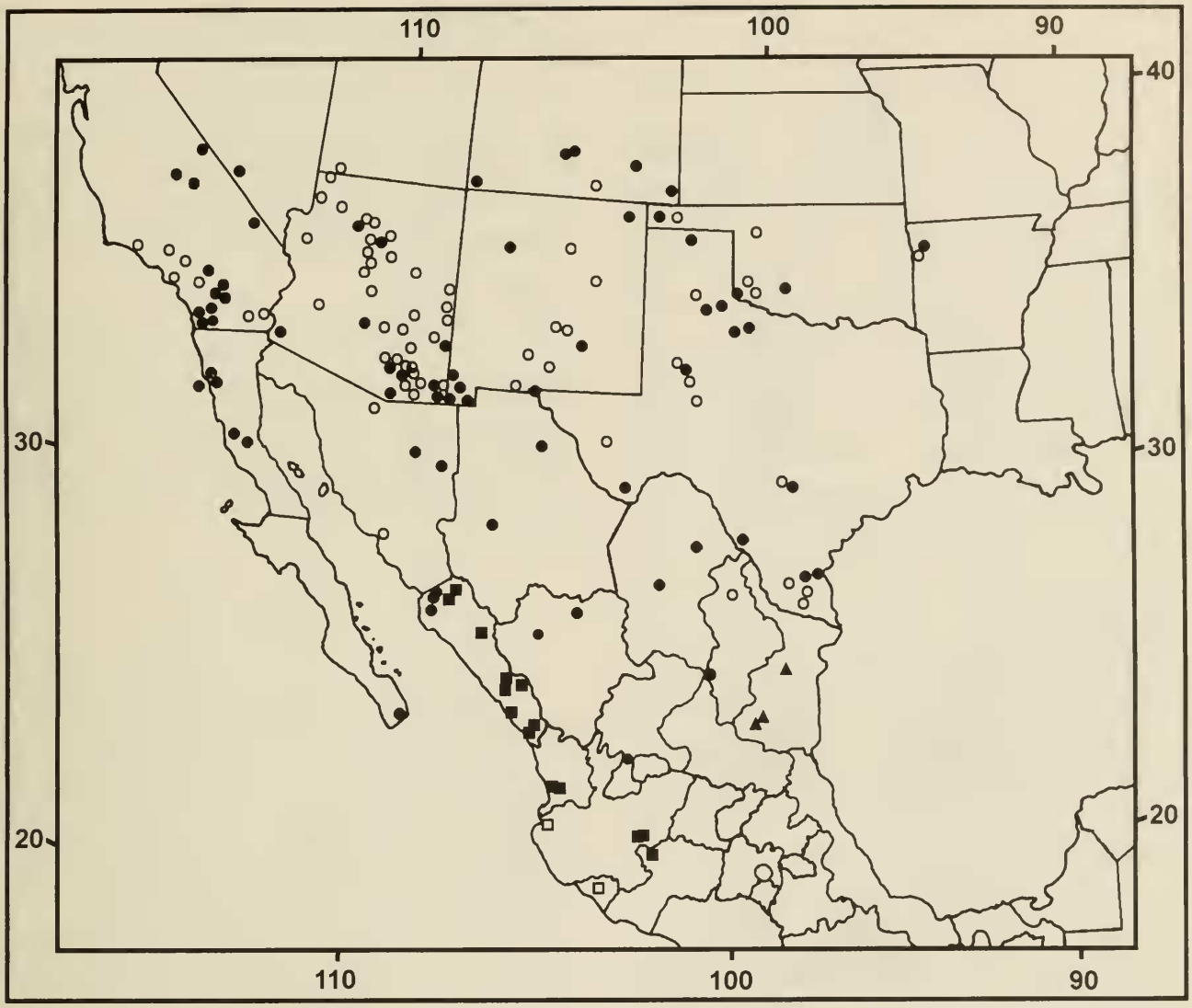

Fig. 1. Distribution of gray shrews (*Notiosorex*) based upon specimens examined herein: 1, *N. crawfordi crawfordi* (closed circles); 2, *N. c. evotis* (closed squares); and 3, *Notiosorex* unknowns from Tamaulipas (triangles). Open circles, *N. c. crawfordi,* and open squares, *N. c. evotis,* represent collection localities for which specimens were not examined (Bailey 1905; von Bloeker 1944; Cunningham 1956; Davis 1960; Baker 1966; Dalby & Baker 1967; Armstrong 1972; Armstrong & Jones 1972; Findley et al. 1975; Sealander 1979; Hoffmeister 1986; Caire et al. 1989; Rodríguez Vela 1999; Angeles Mendoza Duran, pers. comm.; Philip Myers, pers. comm.).

vis & Sidner 1989). Because of the wide range of habitats in which *Notiosorex* is know to occur, the commonly used vernacular name "desert shrew" (Hall 1981) is a misnomer. Herein, we recommend the use of gray shrew.

In 1953, Gerd H. Heinrich collected two specimens of *Notiosorex* and in 1976 George D. Baumgardner collected a third from western Tamaulipas. Findley (1955: 616) unequivocally categorized the former two specimens as *Notiosorex crawfordi crawfordi* "on geographic grounds," whereas Alvarez (1963:397) later referred them to *N. crawfordi* noting that "When more abundant material is available the *Notiosorex crawfordi* of northeastern México probably will be found to represent a new subspecies." Schmidly & Hendricks (1984: 23) examined all three specimens and referred them to *N. c. crawfordi* because it was "the name currently applied to desert shrews in Texas and northern México." As these Tamaulipian shrews are isolated geographically from the widespread *N. c. crawfordi* and are much larger and quantitatively different from that taxon, we evaluated their taxonomic status.

Materials and Methods

Specimens from throughout the distribution of *Notiosorex* (n = 266) were examined. Seven cranial and five mandibular characters were recorded for each of the 139 specimens measured (Fig. 2). Relative age of specimens was indexed by the lateral length of the right I1 (first upper incisor; Carraway et al. 1996). Quantitative characters were analyzed by age to determine if age caused a bias. Greatest length of skull, rostral breadth, least interorbital breadth, and cranial breadth were measured to 0.01 mm with Mitutoyo Digimatic electronic calipers. All other quantitative characters were measured by use of an ocular micrometer mounted in a Bausch and Lomb binocular microscope. Values were converted from number of ocular lines to millimeters for multivariate analyses and tabulation of reported values. The states of a qualitative character, roof of glenoid fossa extending laterally from side of cranium, also were recorded for each specimen.

Three a priori groups were formed of individuals of *Notiosorex crawfordi crawfordi, N. c. evotis,* and the three specimens from Tamaulipas; assignment of individuals to their a priori group was based on the geographic location of their collection site. Multivariate analyses of the three a priori groups were performed on the 12 quantitative cranial and mandibular characters by use of multigroup discriminant-function analysis in BIOΣTAT II (Pimentel 1995). A large sample of *N. c. crawfordi* (n = 54) from Huachuca Mts., Arizona, was examined for intraspecific geographic variation and a comparison with the remaining *N. c. crawfordi* was performed with multigroup discriminant-function analysis. Univariate and regression analyses were calculated by use of STATGRAPHICS Plus (Statistical Graphics Corporation 1995). For all analyses, $P < 0.05$ was accepted as statistically significant.

Standardized canonical vectors for the 12 quantitative variables were plotted on the same graph as the three a priori groups with the same canonical variate axes. The plot of the variable vectors, when placed at the origin of the canonical variates plot, provided an indication of the direction and magnitude of effect that each variable had in discriminating the three a priori groups (Jolicoeur, 1959).

Summary statistics ($\bar{X} \pm SE$, range, and CV) were calculated for all 12 quantitative variables for the three taxa of *Notiosorex* under consideration (Table 1). Color of hair in the pelage was determined by comparison with Munsell soil color charts (Munsell Color 1975).

Results

Multigroup discriminant function analysis of *Notiosorex crawfordi crawfordi, N. c. evotis,* and *Notiosorex* unknowns from Tamaulipas, resulted in 99% correct classification of individuals into their a priori groups (Fig. 3). The two significant canonical-variate axes (χ^2 = 153.61, d.f. = 24 and χ^2 = 37.73, d.f. = 11, respectively) acounted for 81.10 and 18.90% of the variation, respectively. Variance in the first axis (canonical variate I) was accounted for by greatest length of skull, 98.19%; cranial breadth, 99.03%; length of unicuspid toothrow, 98.35%; width across M2–M2, 92.69%; length of mandible, 99.39%; length of mandibular toothrow, 89.70%; height of coronoid process, 96.08%; and length of the coronoid process-ventral point of upper condylar facet, 97.64%. The second axis (canonical variate II) was affected by length of the coronoid process-ventral point of lower condylar facet (89.98%). Only one individual (KU 105409), from 5 mi WNW El Carrizo, Sinaloa, Mexico, was not placed into its a priori group, *N. c. evotis*; it was classified as a *N. c. crawfordi.* This individual also was classified as a *N. c. crawfordi* based on morphological comparisons by Jones et al. (1962). Herein, this individual is considered *N. c. crawfordi* for purposes of further analyses.

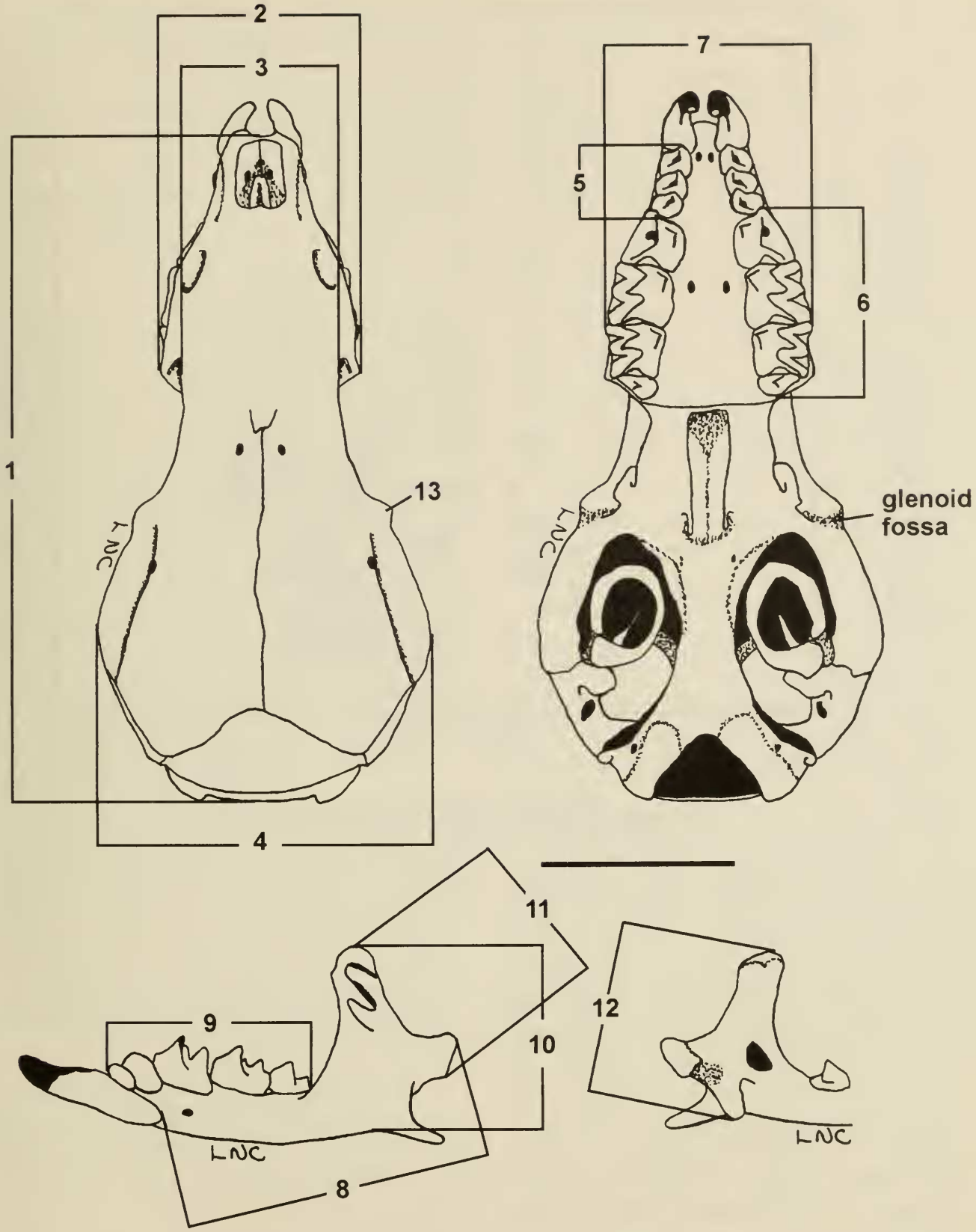

Fig. 2. Camera-lucida tracing of skull of a *Notiosorex* (KU 145262) illustrating skull dimensions measured: 1, greatest length of skull; 2, rostral breadth; 3, least interorbital breadth; 4, cranial breadth; 5, length of maxillary unicuspid toothrow; 6, length of maxillary complex toothrow; 7, width across M2–M2; 8, length of mandible; 9, length of mandibular toothrow; 10, height of coronoid process; 11, length of coronoid process-ventral point of upper condylar facet; and 12, length of coronoid process-ventral point of lower condylar facet. Qualitative character recorded is: 13, roof of glenoid fossa extending laterally from the side of the skull. Scale bar equals 5 mm.

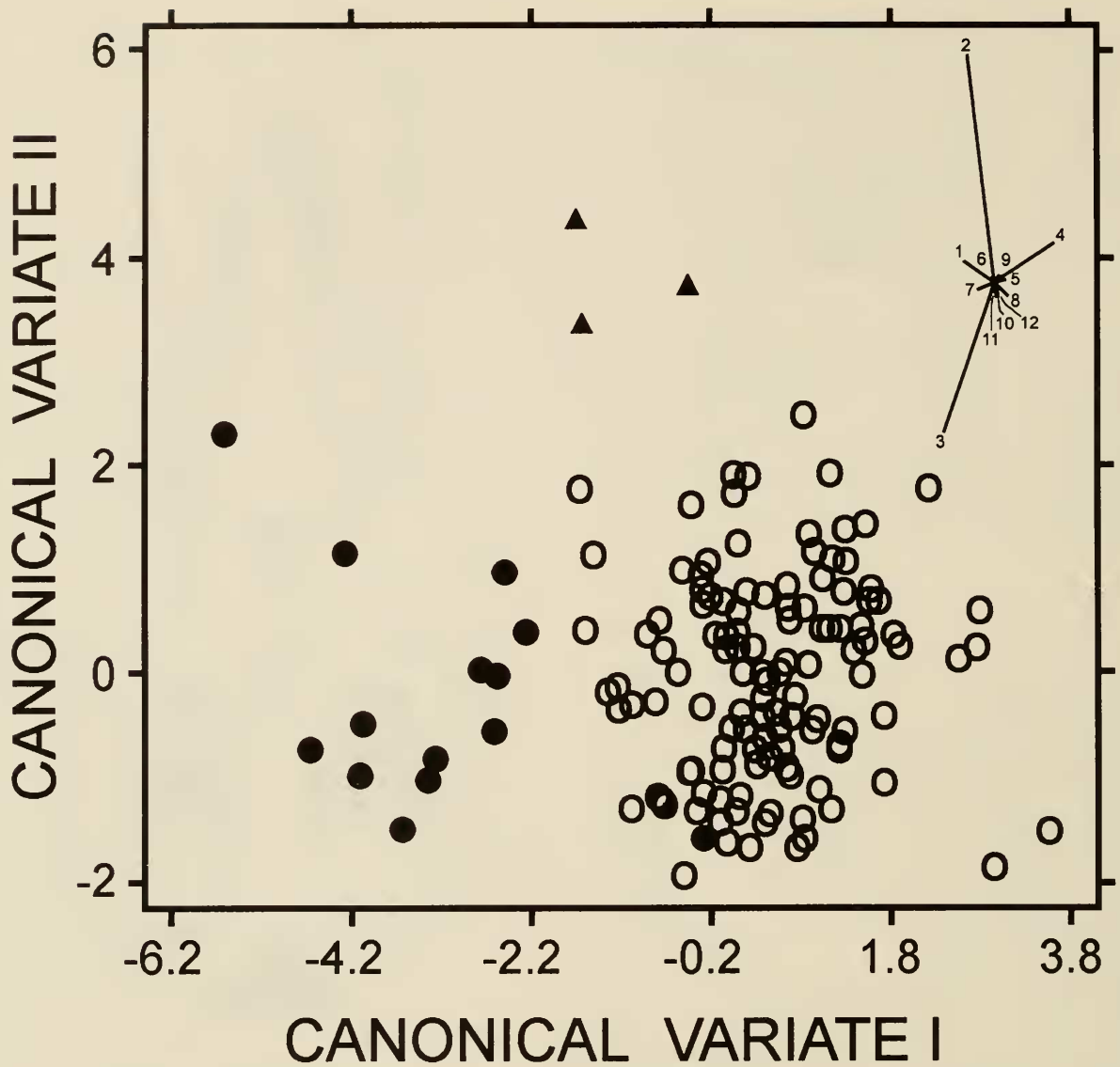

Fig. 3. Canonical-variates plot of *Notiosorex c. crawfordi* (open circles), *N. c. evotis* (closed circles), and *Notiosorex* new sp. (triangles) based on 12 measured variables. Canonical-variate axis I accounted for 81.10% and canonical-variate axis II 18.90% of the variation present among the three taxa. Differences in cranial morphology among the three taxa are characterized by the plot of the 12 variable vectors on the canonical-variates plot in the upper right corner. Numbers are as in Fig. 2. The relationship of the variables among the taxa are indicated by the length and orientation of the vector relative to the canonical-variate axes. From left to right, taxa have shorter skulls relative to cranial breadth and taller and narrower coronoid processes. From bottom to top, taxa have greater rostral breadth relative to length of maxillary complex toothrow.

Coefficients of variation for the *N. c. crawfordi* from Huachuca Mts., Arizona, ranged from 2.276% to 4.918% with one outlier at 6.46%. Whereas, the same values for the remaining *N. c. crawfordi* ranged from 3.028% to 8.098%. This indicates that among specimens of *Notiosorex* from the Huachuca Mts. the level of variation within and among the 12 quantitative characters examined is very low. The one discriminant function produced by a multigroup discriminant-function analysis of the two a priori groups of *N. c. crawfordi* was not significant at $P < 0.05$. Therefore, these two a priori groups are acting as a single unit.

Regression analyses indicated weak relationships between age and length of unicuspid toothrow for *crawfordi* ($r^2 = 0.24$) and *evotis* ($r^2 = 0.53$) and between age and least interorbital breadth ($r^2 = 0.04$) and length of mandible ($r^2 = 0.04$) for *crawfordi*. When the discriminant analysis was repeated without these three variables, 93.5%

of individuals still were classified correctly into their a priori groups.

For all *N. c. crawfordi* and *N. c. evotis* the roof of the glenoid fossa extends laterally from the cranium. However, among the *Notiosorex* from Tamaulipas the roof of the glenoid fossa does not extend laterally from the cranium.

Discussion

Morphometrically, the three specimens of *Notiosorex* from Tamaulipas are most similar to each other and are distinct from all specimens of *crawfordi* and *evotis* (Fig. 3) in terms of size and shape of their skulls. We had expected this outcome after making careful visual comparisons (with aid of a binocular microscope) of the three groups. The discovery that *evotis* was equally distinct from the two other groups (Fig. 3) necessitated a reevaluation of its taxonomic status. Previously, *N. c. evotis* was recognized as being larger than *N. c. crawfordi,* but we also found significant differences in the shape of skulls and mandibles between individuals of the two taxa.

Based on analyses reported herein we refer the three specimens from Tamaulipas to a new species and elevate *N. c. evotis* to species level.

Class Mammalia Linnaeus, 1758
Order Insectivora Bowdich, 1921
Family Soricidae Fischer von Waldheim, 1817
Subfamily Soricinae Fischer von Waldheim, 1817
Genus *Notiosorex* Coues, 1877

Notiosorex villai, new species
Villa's Gray Shrew
Fig. 4A

Notiosorex crawfordi.—Findley 1955:616, Ball & Kelson 1959:64 [part], Alvarez 1963:397, Hall 1981:65 [part], Schmidly & Hendricks 1984:22.

Holotype.—Adult, female, skin and skull; KU 54932, University of Kansas, Natural History Museum, Mammal Collection; from "Jaumave, Tamaulipas, Mexico, 2400 ft."; obtained 26 July 1953 by Gerd H. Heinrich, original number 7612. Alvarez (1963:386) recorded the latitude and longitude of Jaumave as 23°34′N, 99°23′W.

Distribution.—Known only from the Potosian Biotic Province (=Sierra Madre Oriental Biotic Province) of the central mountains of Tamaulipas, Mexico (Fig. 1).

Diagnosis.—As in all *Notiosorex,* specimens of *N. villai* (Fig. 4A) have a combination of a deeply emarginated area between the condylar processes, e.g., interarticular breadth about half the width of the superior condylar process; the alveolus of i1 extending posteriorly beneath at least part of paraconid of m1 (Carraway 1995); pigment present of some teeth; and three unicuspids.

Notiosorex villai can be distinguished from other *Notiosorex* by the roof of the glenoid fossa not extending laterally from the cranium when the skull is viewed from the dorsal aspect (Fig. 4A); and usually from *N. c. crawfordi* by greatest length of skull ≥16.97 mm and from *N. c. evotis* by length of maxillary unicuspid toothrow ≥2.0 mm, height of coronoid process ≤4.1 mm, length of coronoid process-ventral point of upper condylar facet ≤3.8 mm, and length of coronoid process-ventral point of lower condylar facet ≤3.4 mm. All specimens of *N. villai* can be separated from specimens of *N. c. crawfordi* and *N. c. evotis* by application of the following discriminant-function equation: discriminant score = 1.30722 (cranial breadth) − 0.34104 (height of coronoid process) − 0.01685 (length of maxillary complex toothrow) − 4.87675 (least interorbital breadth) − 0.10742 (length of coronoid process-central point of lower condylar facet) − 0.16575 (length of mandible) + 0.22460 (length of mandibular toothrow) + 0.88996 (greatest length of skull) + 0.22980 (length of maxillary unicuspid toothrow) − 0.03089 (length of coronoid process-ventral point of upper condylar facet) + 6.66117 (rostral

breadth) − 0.23311 (width across M2–M2) − 11.0491. Those specimens with scores ≥3.359 are referrable to *villai* and those with scores ≤2.454 are referrable to *crawfordi* or *evotis*.

Description.—As in all soricids, *Notiosorex villai* has a double-faceted condylar process and a fissident I1 with a large hook-shaped anterior cusp and a posterior ventrally directed cusp. The skull is moderately large, smooth, and without prominent ridges and processes. The paroccipital processes are small and lie against the exoccipitals (Fig. 4A). The upper condylar facets are inflected; the corresponding areas in the superior portion of the glenoid fossas are depressed.

The pelage is composed of multibanded hairs. In summer, hairs of the dorsal pelage have a narrow band of silver gray (10YR 6/1) distally and a wide band of dark gray (7.5YR N4/0) proximally. Hairs of the venter are the same colors, except that the distal band of silver gray is wide and the proximal band of dark gray is narrow producing a silver wash. In winter, hairs of the dorsal pelage have a narrow band of very dark grayish-brown (10YR 3/2) distally, a narrow band of pinkish white (7.5YR 8/2) medially, and a wide band of very dark-gray (7.5YR N3/0) proximally. Hairs of the ventral pelage have a distal wide band of pinkish white (7.5YR 8/2) and a proximal narrow band of very dark-gray. The tail is very dark grayish-brown.

Measurements.—Individuals of *Notiosorex villai* are smaller than those of *N. c. evotis,* but larger than those of *N. c. crawfordi* (Table 1).

Ecology.—The three known specimens of *Notiosorex villai* were collected in different habitats within the Potasian Biotic Province (Alvarez 1963). The area of Jaumave is pine-oak forest, that of Palmillas is tropical forest, and the habitat of the collection site near Rancho Carricitos is riparian. The subprovince, within the Potosian Biotic Province, from which the three specimens were collected contains "low meseta-like folded mountains" characterized by "closely spaced ridges" (Ferrusquía-Villafranca 1993:33).

Mammal associates of the holotype were *Baiomys taylori, Onychomys arenicola, Oryzomys couesi, Peromyscus leucopus, Reithrodontomys fulvescens, Sigmodon hispidus, Liomys irroratus, Mephitis macroura,* and *Mustela frenata*; only *Peromyscus pectoralis* was collected in the vicinity of the specimen from Palmillas (G. H. Heindrich, in litt.). *Cryptotis parva, Mormoops megalophylla, Desmodus rotundus, Myotis californicus, Lasiurus borealis, L. cinereus, Antrozous pallidus, Tadarida brasiliensis, Sylvilagus floridanus, Sciurus aureogaster, S. alleni, Liomys irroratus, Peromyscus leucopus, P. pectoralis, P. boylii, Baiomys taylori, Mus musculus, Bassariscus astutus,* and *Mephitis mephitis* were collected in the vicinity of the specimen from SW of Rancho Carricitos (Schmidly & Hendricks 1984). One of the *C. parva* was collected in the same pitfall as the *Notiosorex.* The greater species richness noted for the latter locality is almost certainly the result of greater trapping effort and not necessarily an indication that the other mammal associations were depauperate.

Etymology.—The species epithet is a patronymic to honor Bernardo Villa-R., the "father" of Mexican mammalogy.

Remarks.—All three specimens of *Notiosorex villai* were collected in isolated mountain valleys. The extent of the distri-

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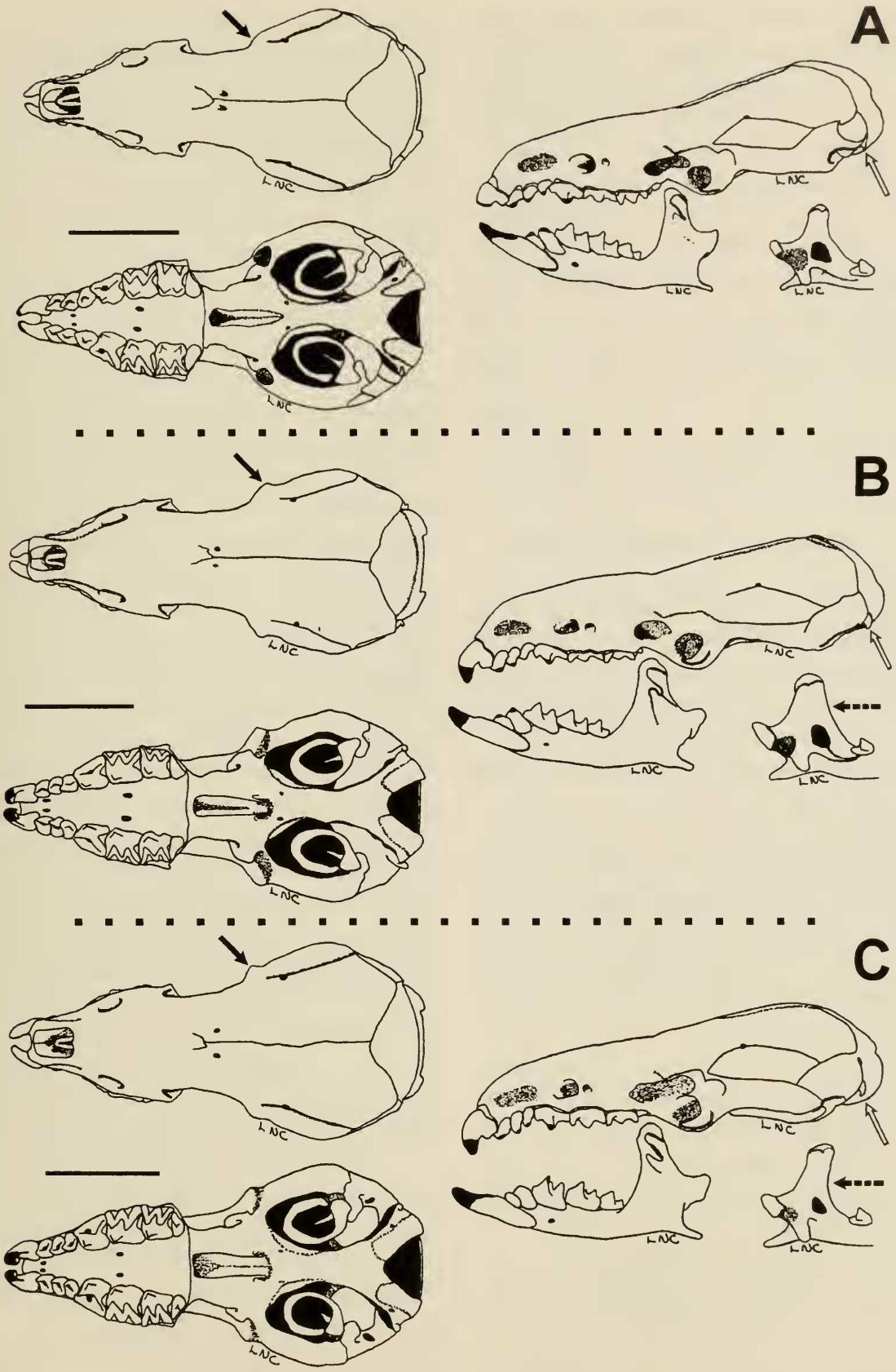
Fig. 4. Camera-lucida tracings of dorsal, lateral, and ventral views of the cranium, and lateral view of labial side of mandible and oblique view of posterior portion of lingual side of left mandible of taxa of *Notiosorex.* A, Holotype of *Notiosorex villai* (KU 54932, adult female). Note smooth lateral edge of cranium when viewed from dorsal aspect (solid arrow), absence of extension of roof of glenoid fossa, small paroccipital processes



lying against the exoccipitals (open arrow), and coronoid process slender relative to height. B, *N. evotis* (KU 89214, adult male). Specimen from 17 km SW Choix, Sinaloa. Note prominent ridge on lateral edge of cranium caused by extension of roof of glenoid fossa (solid arrow), low-set paroccipital processes extending at an oblique angle from skull (open arrow), and coronoid process broad relative to height (dashed arrow). C, *N. crawfordi* (KU 145262, adult male). Specimen from Peloncillo Mts., Guadalupe Canyon, Hidalgo Co., New Mexico. Note prominent ridge on lateral edge of cranium caused by extension of roof of glenoid fossa (solid arrow), small paroccipital processes lying against the exoccipitals (open arrow), and coronoid process slender relative to height (dashed arrow). Scale bar equals 5 mm.

bution of the species has yet to be determined. However, considering the three different habitat types represented, *N. villai* likely has a reasonably wide distribution in Tamaulipas.

Heinrich, both in his field catalog and on the specimen tag of one of the specimens included herein, clearly recorded the locality as Palmilla. However, on a map of Heinrich's collecting localities drawn on 1 September 1953 by Hildegarde Heinrich, his wife who accompanied him both in 1952 and 1953, the name is spelled Palmillas. The hand-drawn map used by Heinrich in 1953 is believed to be based on the copy of "Mapa de la Republica Mexicana—Estado de los Caminos Federales Estatales y Vecinales" (1944) on deposit in the Natural History Museum at the University of Kansas. Notations made by E. R. Hall on the latter map identify it as a gift to the museum. The name of the town on this map is spelled Palmillas; all subsequent authors who have published upon this specimen used the spelling Palmillas.

Specimens examined.—3, as follows.

Mexico: Tamaulipas: Jaumave, 2400 ft (KU 54932, ♀); Palmilla [sic], 4400 ft [23°18′N, 99°33′W; Alvarez 1963:386] (KU 54933, ♀); 0.3 mi SW Rancho Carricitos, San Carlos Mts., 1900 ft (TCWC 30492, ♂).

Notiosorex evotis (Coues)
Large-eared Gray Shrew
Fig. 4B

Sorex (Notiosorex) evotis Coues, 1877:652.
N[otiosorex]. evotis Coues, 1877:652.
Notiosorex crawfordi evotis Merriam, 1895: 34; Hall & Kelson 1959:64 [part], Jones et al. 1962:151, Hall 1981:65 [part].

Holotype.—Adult, no sex given, skin only; USNM 9066, National Museum of Natural History; from "area of Mazatlan, Sinaloa, Mexico"; obtained February 1868 by Ferinand Bischoff. The skull is mentioned by Coues (1877), but apparently was never cataloged into the National Museum collection. A sketch of the lateral view of the right-side rostral area of the cranium was included in Dobson (1890). However, by the time Merriam (1895) published his revision of the genus, the skull was missing.

Distribution.—Notiosorex evotis is known from the states of Colima, Jalisco, Michoacan, Nayarit, and Sinaloa, Mexico (Fig. 1).

Diagnosis.—Notiosorex evotis can be distinguished from *N. villai* by the roof of the glenoid fossa extending laterally beyond the curve of the cranium (Fig. 4B) and usually by length of maxillary unicuspid toothrow ≤2.1 mm, height of coronoid process ≥4.3 mm, length of coronoid process-ventral point of upper condylar facet ≥3.8 mm, and length of coronoid process-ventral point of lower condylar facet ≥4.0 mm; and usually from *N. crawfordi* by rostral breadth ≥5.2 mm, width across M2–M2 ≥5.1 mm, length of mandible ≥7.4 mm, height of coronoid process ≥4.3 mm, length of coronoid process-ventral point of upper condylar facet ≥4.0 mm, and length of coronoid process-ventral point of lower condylar facet ≥3.8 mm. *N. evotis* usually can be distinguished from *N. crawfordi* by use of a combination of height of coronoid process and cranial breadth (Fig. 5). Based on the results of the discriminant analysis, all specimens of *N. evotis* can be separated from specimens of *N. crawfordi* by application of the following discriminant-function equation: discriminant score = 1.73654 (cranial breadth) + 0.22159 (height of coronoid process) + 0.06177 (length of maxillary complex toothrow) − 0.65656 (least interorbital breadth) − 0.00471 (length of coronoid process-central point of lower condylar facet) + 0.27652 (length of mandible) + 0.08699 (length of mandibular toothrow) − 0.86213 (greatest length of skull) + 0.23251 (length of maxillary unicuspid toothrow) − 0.02611 (length of coronoid process-ventral point of upper condylar facet) − 0.92248 (rostral breadth) + 0.10899 (width across M2–M2) − 37.2423. Individuals with a score ≤−2.26 are refer-

rable to *evotis* and those with a score ≥ -1.65 are referrable to *crawfordi.*

Description.—Within extant members of the genus *Notiosorex, evotis* has the largest skull with prominent ridges (the roof of the glenoid fossa) on the lateral sides of the cranium and the paroccipital processes are set low on the mastoid and extend at an oblique angle from the skull (Fig. 4B). The coronoid processes are broad relative to their height (Fig. 4B; Choate 1969:473, fig. 3b) resulting in different placement of the condyloid processes relative to each other (Choate 1969:473, figs. 3b–c) for *N. evotis* and *N. crawfordi.*

The pelage is composed of multibanded hairs. In summer, hairs of the dorsal pelage have a narrow band of very dark grayish-brown (10YR 3/2) distally, a narrow band of pinkish white (7.5YR 8/2) medially, and a wide band of dark gray (7.5YR N4/0) proximally. The hairs of the venter have a wide distal band of pinkish white and a narrow proximal band of very dark-gray (7.5YR N3/0). The winter pelage consists of hairs of the dorsum with a wide distal band of very dark grayish-brown (10YR 3/2) and a proximal band of very dark-gray (7.5YR N3/0). The hairs on the venter have a wide distal band of light yellowish-brown (10YR 6/4) and a narrow proximal band of dark gray (7.5YR N4/0). The hairs on the tail are very dark grayish-brown.

Measurements.—Individuals of *Notiosorex evotis* are the largest members of extant *Notiosorex* (Table 1).

Ecology.—*Notiosorex evotis* is known to occur from 3-m elevation along the Pacific Coast to 550 m in the Sierra Madre Occidental, Sinaloa, and to 2317 m in the Sierra Moroni, Zacatecas. It is know to occur in habitats characterized by scattered cacti and dense thornbush, and abandoned agricultural fields bordered by an area of scattered cacti, thornbush, and mesquite (scientific names not given—Armstrong & Jones 1971); communities that "consisted mostly of dry, dense weeds and short, thorny shrub with a few trees" and "in low weeds near thorn bush" (Jones et al. 1962:148–149); "in damp spots under rocky ledges" (Fisher & Bogan 1977:826); and in "semi-desert habitat" (Schlitter 1973:423).

Reported small-mammal associates are *Liomys pictus, Chaetodipus pernix, Sigmodon hispidus,* and *Mus musculus* (Baker 1962, Jones et al. 1962).

Etymology.—The species epithet is derived from the Greek *ev,* meaning good, and *otus,* meaning ear, possibly in reference to its "extremely large" ears (Coues 1877: 652).

Remarks.—A discussion of the taxonomic history of *Notiosorex evotis* is presented in Jones et al. (1962).

Specimens examined.—34, as follows.

Mexico: Jalisco: 13 mi S, 15 mi W Guadalajara (KU 33318); 21 mi SW Guadalajara (KU 42583–42585). Michoacan: 2 mi E La Palma, SE side of Lago de Chapala (KU 42586–42588). Nayarit: El Refilion (USNM 508358); Tepic (USNM 314064). Sinaloa: 20 km N, 5 km E Badiraguato (KU 96419); 16 km NNE Choix, 1700 ft (KU 89210–89213); 1 mi S El Cajón, 1800 ft (KU 100319); 15 mi SE Escuinapa (MSUM 5691); Isla Palmito del Verde, 6 mi NNW Teacapan (KU 98880); Laguna, 17 km SW Choix, 500 ft (KU 89214–89216); Mazatlán (KU 85533–85536; USNM 9066); 1 mi N Mazatlan, 10 ft (MSUM 8149); 1 mi N Mazatlan, 25 ft (MSUM 5690); Rosario, 500 ft (KU 90581); 10 km S, 38 km E Sinaloa (KU 125476–125479); 44 km ENE Sinaloa, 600 ft (KU 89998); HWY 15, 0.25 mi S Sonora state line (UMMZ 109403).

Notiosorex crawfordi (Coues)
Crawford's Gray Shrew
Fig. 4C

Sorex (*Notiosorex*) *crawfordi* Coues, 1877: 651.

Notiosorex crawfordi Coues, 1877:652, True 1884:606, Merriam 1895:32, Hall & Kelson 1959:64 [part], Hall 1981:65 [part].

Holotype.—Adult, no sex recorded, skin

Table 1.—Means (±*SE*), ranges (in parentheses), and *CV*s of measurements (in mm) of skull characters of *Notiosorex crawfordi crawfordi* (*n* = 122), *N. evotis* (*n* = 14), and *N. villai* (*n* = 3).

Character	*Notiosorex*		
	crawfordi	*evotis*	*villai*
Greatest length of skull	16.08 ± 0.04[a]	17.26 ± 0.13[b]	17.17
	(14.95–17.25)	(16.49–18.41)	(16.97–17.27)[c]
	0.03	0.03	
Rostral breadth	4.83 ± 0.02	5.33 ± 0.04[c]	5.19
	(3.70–5.23)	(5.0–5.63)	(5.01–5.30)
	0.04	0.03	
Least interorbital breadth	3.76 ± 0.01	3.98 ± 0.04[c]	3.83
	(3.42–4.14)	(3.65–4.16)	(3.57–4.01)
	0.04	0.04	
Cranial breadth	7.96 ± 0.02[a]	8.56 ± 0.07[b]	8.30
	(7.05–8.52)	(8.02–8.99)	(8.07–8.53)[c]
	0.03	0.03	
Length of maxillary unicuspid toothrow	1.9 ± 0.01	2.0 ± 0.03	2.2
	(1.5–2.2)	(1.80–2.3)	(2.0–2.3)
	0.05	0.05	
Length of maxillary complex toothrow	4.3 ± 0.01	4.6 ± 0.03[c]	4.6
	(3.9–4.6)	(4.5–5.0)	(4.4–4.7)
	0.02	0.02	
Width across M2–M2	4.8 ± 0.01	5.3 ± 0.03[c]	5.0
	(3.7–5.3)	(4.9–5.4)	(4.9–5.1)
	0.02	0.02	
Length of mandible	7.0 ± 0.02[c]	7.7 ± 0.04	7.4
	(6.4–7.7)	(7.4–8.2)	(7.3–7.5)[c]
	0.03	0.03	
Length of mandibular toothrow	4.7 ± 0.01[d]	5.0 ± 0.03	5.1
	(4.4–5.1)	(4.9–5.3)	(5.0–5.1)[c]
	0.02	0.02	
Height of coronoid process	4.0 ± 0.02	4.7 ± 0.05	4.1
	(3.4–4.9)	(4.3–5.0)	(4.0–4.1)[c]
	0.02	0.04	
Length of coronoid process–ventral point of upper condylar facet	3.3 ± 0.02[c]	3.9 ± 0.04	3.8
	(2.7–3.9)	(3.8–4.2)	(3.7–3.8)[c]
	0.06	0.03	
Length of coronoid process–ventral point of lower condylar facet	3.7 ± 0.02	4.3 ± 0.05	3.4
	(3.2–4.3)	(4.0–4.7)	(3.3–3.4)[c]
	0.05	0.05	

[a] Sample size reduced by 6.
[b] Sample size reduced by 2.
[c] Sample size reduced by 1.
[d] Sample size reduced by 3.

and skull; USNM 2653/4437, National Museum of Natural History; from "near Fort Bliss, about 2 miles above El Paso, El Paso County, Tex."; obtained September 1861 by S. W. Crawford.

Distribution.—From southern California, Nevada, Utah, Colorado, Oklahoma, and western Arkansas, United States, southward to southern Baja California Sur, and eastward to northern Sinaloa, and southern Zacatecas and Nuevo León, Mexico (Fig. 1).

Diagnosis.—*Notiosorex crawfordi* can be distinguished from *N. villai* by the roof of the glenoid fossa extending laterally beyond the curve of the cranium (Fig. 4C) and by the greatest length of skull usually ≤16.98 mm. It usually can be distinguished from *N. evotis* by rostral breadth ≤5.14

mm, width across M2–M2 ≤5.1 mm, length of mandible ≤7.5 mm, height of coronoid process ≤4.4 mm, length of coronoid process-ventral point of upper condylar facet ≤3.9 mm, and length of coronoid process-ventral point of lower condylar facet ≤4.1 mm. *N. crawfordi* usually can be distinguished from *N. evotis* by use of a combination of height of coronoid process and cranial breadth (Fig. 5). Specimens of *N. crawfordi* can be separated from 100% of specimens of *N. villai* and *N. evotis* by application of the discriminant-function equations presented in the Diagnoses sections of those species accounts.

Description.—The skull of *Notiosorex crawfordi* is much like that of *N. evotis,* except that it is much smaller, the coronoid processes are slender compared to their height, and the paroccipital processes are small and lie against the exoccipitals (Fig. 4C). The latter two characters are similar in form to *N. villai.* Although significant genetic differences (M. B. O'Neill, C. Porter, and R. J. Baker, pers. comm.) occur between populations of *N. crawfordi* in Baja California and Texas, we found no identifiable morphological differences.

The pelage is composed of multibanded hairs. In summer, hairs of the dorsal pelage have a narrow band of very dark grayish-brown (10YR 3/2) distally and a wide band of dark gray (7.5YR N4/0) proximally. The hairs of the venter have equal-width bands of pinkish white (7.5YR 8/2) distally and very dark-gray (7.5YR N3/0) proximally. The winter pelage consists of hairs of the dorsum with a narrow band of very dark grayish-brown distally, a narrow band of pinkish white medially, and a wide band of dark gray (7.5YR N4/0) proximally. The hairs of the venter have a wide band of white (7.5YR N8/0) distally and a very narrow band of gray (7.5YR N5/0) proximally creating a silvery wash effect over the venter. The hairs of the tail are dark grayish-brown (10YR 4/2).

Measurements.—Individuals of *Notiosorex crawfordi* are the smallest extant members of the genus (Table 1).

Ecology.—*Notiosorex crawfordi* is known to occur in habitats as diverse as desert shrub and yellow pine forest (Lange 1959), pine-oak forest (Alvarez 1963), in grassland with oak chaparral and oak woodland habitats nearby (Cunningham 1956), alkaline marsh (Stephens 1906), sandy flats (Fisher 1941, Yensen & Clark 1986), "arid grasslands with scattered catclaw, juniper and mesquite" (Baker 1966:345), and near "a mesquite tree on a moist mud flat" (Armstrong & Jones 1971:751). It is known to occur at elevations at least as great as 2618 m (Davis & Sidner 1989).

From throughout the range of Crawford's gray shrew, known mammal associates are members of the genera *Cryptotis, Sorex, Scapanus, Sylvilagus, Lepus, Tamias, Sciurus, Spermophilus, Thomomys, Cratogeomys, Liomys, Dipodomys, Perognathus, Chaetodipus, Baiomys, Neotoma, Peromyscus, Onychomys, Reithrodontomys, Sigmodon, Microtus, Mus, Rattus,* and *Odocoileus,* plus 14 species of bats (Chiroptera; Cunningham 1956, Anderson & Long 1961, Coulombe & Banta 1964, Baker 1966, Dalby & Baker 1967, Davis & Sidner 1989). Also, Crawford's gray shrew is well known for its association with woodrat (*Neotoma*) nests throughout its distribution (Armstrong & Jones 1972).

Etymology.—The species epithet is a patronymic to honor the collector of the type specimen, S. W. Crawford.

Remarks.—Although trapping success for specimens of *Notiosorex crawfordi* is limited, remains thereof commonly occur in pellets regurgitated by barn owls (*Tyto alba*) and great horned owls (*Bubo virginianus*) throughout its distribution in the United States and Mexico (Twente & Baker 1951, Baker 1953, Baker & Alcorn 1953, Cunningham 1956, Anderson & Ogilvie 1957, Lange & Mikita 1959, Bradshaw & Hayward 1960, Anderson & Long 1961, Glass & Halloran 1961, Schaldach 1966, Anderson 1972).

Jones et al. (1962:150–151), in a review of *Notiosorex* from Sinaloa, treated *evotis* and *crawfordi* as full species, stating that "*evotis* has a longer body and hind foot than *crawfordi* but a relatively (sometimes actually) shorter tail and ear, and a distinctly larger, heavier skull . . . . *Notiosorex evotis* differs cranially from *Notiosorex crawfordi* as follows: larger . . . ; mesopterygoid fossa squared rather than broadly U-shaped anteriorly; rounded process on maxillary at posterior border of infraorbital canal well developed . . . ; occipital condyles smaller and, in lateral view, elevated above basal plane of skull; upper molars slightly more crowded in occlusal view." Armstrong & Jones (1971:750), in their update on Sinaloan mammals, treated the two forms as subspecies stating that "the population in northern Sinaloa is intermediate between *crawfordi* and *evotis*" and that some of the cranial differences noted earlier now appear to be inconsistent. After examination of the 263 specimens referrable to *N. crawfordi* and *N. evotis* included in this study, we found that most of the characters presented in Jones et al. (1962) are either inconsistent or strongly age-related, thus are of limited use in distinguishing *crawfordi* and *evotis.*

A discussion of the natural history, fossil record, and reproduction of *N. crawfordi* can be found in Armstrong & Jones (1972) and Coulombe & Banta (1964).

Specimens examined.—229, as follows.

Mexico: Baja California: 9 mi N Catavina on Mexico HWY 1 (MVZ 159725); 10 mi SE El Rosario (MVZ 159726); San Martín Island, 300 yds. inland from Hassler's Cave (MVZ 136207); San Quintin (CAS 52); San Quintin, San Simon River (USNM 139592–139593); San Tomas (USNM 137142); Santa Anita (USNM 74550, 79088–79092, 146693, 146933–146934, 146936, 147352, 147421). Chihuahua: 3.5 mi ESE Los Lamentos (KU 76488); 2 mi W Minaca (KU 109475). Coahuila: 3 mi NW Cuatrociénegas (KU 51571–51572); Sabinas (USNM 277621). Durango: 2 km SE Atotonilco, 6680 ft (MSUM 13887–13888); 4.8 km SE Atotonilco, 6680 ft (MSUM 13889–13890); 7 mi NNE Boquilla, 6400 ft (MSUM 10260). Nuevo Leon: 3 mi SW Galeana, 5100 ft (MSUM 11238). Sinaloa: On HWY 15, 0.25 mi S Sonora line (UMMZ 109403); 5 mi WNW El Carrizo (KU 105409); El Fuerte (KU 75184). Sonora: 14.6 mi E [by road] Mazocahui (MVZ 148830); 4.1 mi NW [by road] Nacori Chico (MVZ 148831). Zacatecas: Plateado (USNM 90845).

United States: Arkansas: Crawford Co.: Natural Dam (USNM 286549). Arizona: Apache Co.: 1 mi N Spigerville (UMMZ 80236); Cochise Co.: 9.1 mi S Chiricahua (USNM 552386); Huachuca Mts. (MSB 62141–62144, 62146–62148, 62150, 62154–62155, 62158–62159, 62161–62166, 62168, 62171–62173, 62175–62177, 62179, 62183–62184, 62188–62189, 62210–62215, 62218–62219; 62223–62238); 20 mi E Pearce, Pinery Canyon, 6500 ft (UMMZ 64102); Coconino Co.: 10 mi SW Black Falls (USNM 244129); Grand Canyon (USNM 250676); Greenlee Co.: Blue River (USNM 144533); Maricopa Co.: Phoenix South Mt. (CAS 13928); Pima Co.: 36 mi S Tucson (USNM 272515–272516); 40 mi S Tucson (USNM 272844); Santa Cruz Co.: locality unknown (USNM 289955); Yuma Co.: Yuma (USNM 120357). California: San Bernardino Co.: San Bernardino (USNM 187011); Inyo Co.: Panamint Range Cottonwood Canyon (CAS 23228–23230); Saline Valley (CAS 21270); Saline Valley, Grapevine Canyon, 4036–5750 ft (CAS 23231–23232, 21249–21269); Silver Canyon Rd., 4.3 mi E [by road] jct. with California HWY 6 (MVZ 158116); Riverside Co.: Millard Canyon (CAS 23240); San Bernardino Co.: Cottonwood (CAS 23242); Deep Canyon (CAS 23238); Kingston Range (CAS 21518); San Gorgonia, Cottonwood (CAS 23233–23237, 23241); San Diego Co.: locality unknown (USNM 62619); Lakeside, head of Wildcat Canyon, 2100 ft (KU 92627); Escondido (MVZ 33582); 9 mi S Escondido (MVZ 33388); Santer Mts.

(USNM 62919). Colorado: Baca Co.: 14 mi N, 4 mi E Springfield (KU 116960); Fremont Co.: Phantom Canyon, Eightmile Creek (KU 125348–125367); Wet Mt. (KU 125368–125379); Montezuma Co.: Mesa Verde National Park (KU 105109); Otero Co.: 3 mi NW Higbee (KU 51673). New Mexico: Cibola Co.: Juan Tofoya (USNM 147966); Hidalgo Co.: locality unknown (KU 145266, MSB 46468); 7.5 mi W Animas, Antelope Pass (KU 145258–145259); Cienega Ranch ruins (KU 144031); 30 mi E Douglas, Guadalupe Canyon, Peloncillo Mts. (KU 145260–145265); San Luis Spring, Mexican Boundary (USNM 38250); Lincoln Co.: Capitan Mts. (USNM 127229); Shafer Ranch (UMMZ 114784); Otero Co.: 3 mi N Tularosa (UMMZ 81380); Union Co.: Tollgate Canyon, 10 mi N Folson (MWSU 15900). Nevada: Nye Co.: 1 mi N, 5 mi E Grapevine, Peak Mt., 5500 ft (MVZ 92391). Oklahoma: Cimarron Co.: 2 mi N Kenton (MWSU 15867–15868, 15895); 3 mi N Kenton (MWSU 15902); 4 mi N Kenton (MWSU 15779); Comanche Co.: Wichita Mts. National Wildlife Refuge (USNM 271959); Harmon Co.: 4 mi S Hollis (OSU 5823). Texas: Archer Co.: intersection US 82 and 277, 22 mi SW Holliday (UMMZ 167208–167209); 14 mi WNW Archer City (MWSU 8584, 8586); Lake Kickapoo (MWSU 5614), NW side Lake Kickapoo (MWSU 7016, 11106); Bexar Co.: San Antonio (USNM 125708); Brewster Co.: Burro Mesa, 3500 ft (MVZ 80281); Briscoe Co.: Tule Canyon (UMMZ 67277); Cottle Co.: 8 mi ESE Paducah (KU 64560); Dickens Co.: 1 mi E Dickens (MWSU 2543); El Paso Co.: near Fort Bliss, about 2 miles above El Paso (USNM 2653/4437); Garza Co.: locality unknown (MMNH 12502–12503); 1 mi SE Post (PSM 13878); Hansford Co.: 10 mi S, 3 mi W Gruver (KU 119395); Howard Co.: Big Spring (UMMZ 80248); Jim Wells Co.: near Alice (TCWC 53283); Knox Co.: 4 mi E Benjamin (MWSU 16023); Nueces Co.: Corpus Christi (USNM 120087). Locality unknown: (USNM 4437).

Conclusions

As presently understood, the geographic distributions of these three taxa do not overlap, although those of *Notiosorex crawfordi* and *N. evotis* are parapatric in northern Sinaloa. We believe the lack of overlap in geographic ranges is the result of these taxa being low in abundance wherever they occur, use of trapping techniques inappropriate for collecting shrews during surveys of small mammals, and lack of collecting effort for soricids over large segments of the distribution of *Notiosorex* in Mexico.

In multivariate space, not only can 100% of *N. villai, N. crawfordi,* and *N. evotis* be separated (Fig. 3), but *N. villai* can be distinguished from *N. crawfordi* and *N. evotis* by the qualitative character of the roof of the glenoid fossa not extending laterally from the cranium (Fig. 4). Also, *N. crawfordi* and *N. evotis* can be distinguished by the qualitative character of the relative shape of the coronoid processes (Figs. 4B–C; Choate 1969:473, figs. 3b–c) and the quantitative relationship of height of coronoid process and cranial breadth (Fig. 5).

With recognition herein of three species in the genus *Notiosorex,* the Mexican mammalian fauna now includes 28 species in the family Soricidae (Ramírez-Pulido et al. 1996, Woodman & Timm 1999). In Mexico, the greatest diversity of shrews is in the Trans-Mexican Volcanic Belt and the Sierra Madre del Sur provinces. Our discovery of the distinctive new species *Notiosorex villai* in Tamaulipas, part of the Sierra Madre Oriental Province, an area not especially known for endemism (Fa & Morales 1993), and that all three species of *Notiosorex* occur in Mexico, highlights the need for continued collection of specimens and study of available museum specimens to better understand the mammalian fauna of Mexico.

Acknowledgments

For the loan of specimens in their care, we thank the curators and collection managers of the California Academy of Scienc-

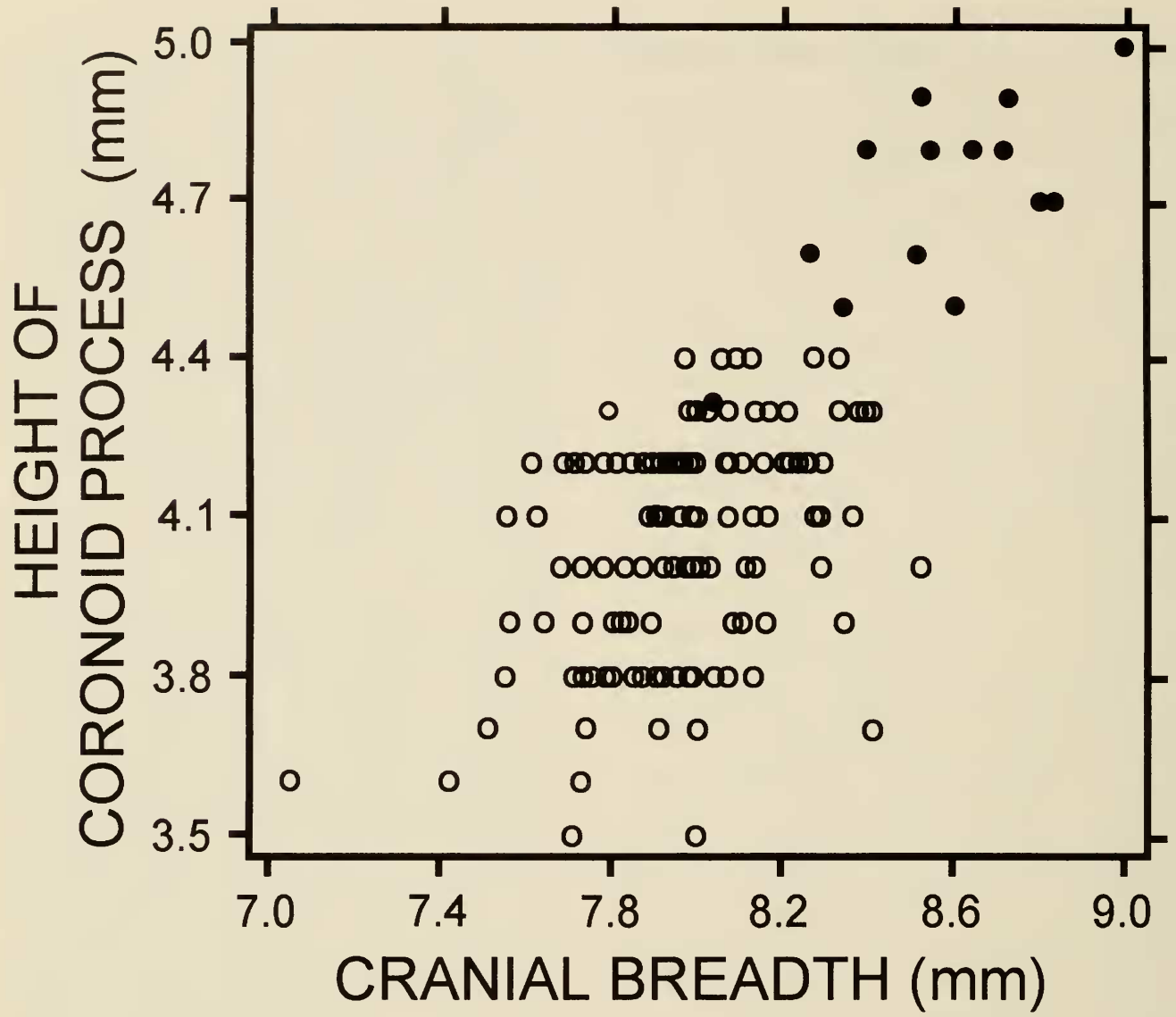


Fig. 5. Bivariate plot of height of coronoid process and cranial breadth illustrating almost complete separation of *Notiosorex evotis* (closed circles) and *N. crawfordi* (open circles).

es (CAS); Michigan State University Museum (MSUM); Midwestern University, Wichita Falls, Texas (MWSU); Mammal Division, National Museum of Natural History (USNM); Collection of Vertebrates, Oklahoma State University (OSU); Texas Cooperative Wildlife Collection, Texas A&M University (TCWC); Museum of Vertebrate Zoology, University of California at Berkeley (MVZ); Museum of Zoology, University of Michigan (UMMZ); James Ford Bell Museum of Natural History, University of Minnesota (MMNH); the Museum of Southwestern Biology, University of New Mexico (MSB); and James R. Slater Museum of Natural History, University of Puget Sound (PSM). We thank T. Holmes for preparation of problematic specimens, V. Sánchez-Cordero for translation of our Abstract into Spanish, and N. A. Slade for statistical advice. F. Cervantes, R. S. Hoffmann, V. Sánchez-Cordero, and B. J. Verts read earlier drafts of this manuscript.

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