# NATURAL HISTORY OF THE TWIN-SPOTTED RATTLESNAKE (Crotalus pricei) in the Southernmost Range of its Distribution

## JUAN JOSÉ AYALA-RODRÍGUEZ<sup>1</sup>, JOSÉ JESÚS SIGALA-RODRÍGUEZ<sup>1,3</sup>, GILBERTO ALEJANDRO OCAMPO-ACOSTA<sup>2</sup>, JAIME ANTONIO ESCOTO-MORENO<sup>1</sup>, AND RUBÉN ALONSO CARBAJAL-MÁRQUEZ<sup>1</sup>

<sup>1</sup>Colección Zoológica, Universidad Autónoma de Aguascalientes, Avenida Universidad 940, CP 20100, Aguascalientes, Aguascalientes, México <sup>2</sup>Herbario, Universidad Autónoma de Aguascalientes, Avenida Universidad 940, CP 20100, Aguascalientes, Aguascalientes, México <sup>3</sup>Corresponding author, email: jesus.sigala@edu.uaa.mx

Abstract.—The Twin-Spotted Rattlesnake (Crotalus pricei) is a small-bodied rattlesnake that inhabits mountain systems from the southwestern tip of the USA to central México. Despite its wide distributional range, there is scarce information about its natural history in many localities where it is found, including the population occurring in Aguascalientes, México, where fewer than 10 individuals have been reported since 1953. The goal of this study was to describe ecological and morphological aspects of *C. pricei* in the southernmost portion of its distributional range and compare them with what we currently know for this species. We conducted field surveys in 2019 and 2020 searching for individuals of *C. pricei* and we found 19 individuals. General characteristics of this population did not vary from what we know for *C. pricei*, although we found some morphological differences at the subspecies level. *Crotalus pricei* was more easily found in July, August, and September, and it was commonly associated with Pine and Oak Forest leaf litter. Its main activity periods during the day were from 1100 to 1600. Two females gave birth while they were held captive; one gave birth to four neonates, and the other just six unfertilized ova. The information presented here increases the ecological knowledge of the population of this species occurring in Aguascalientes, México.

Key Words.-Aguascalientes; detection rate; ecology; México; morphology; reproduction; sexual dimorphism; Viperidae

#### INTRODUCTION

Despite México being the center of rattlesnake diversity (Crotalus and Sistrurus), there is a lack of biological information about many species, particularly those whose populations have been elusive (Armstrong and Murphy 1979; Campbell and Lamar 2004; Meik et al. 2007). Such is the case of the Twin-spotted Rattlesnake (Crotalus pricei); the species was described more than a century ago (Van Denburgh 1895; McCranie 1980), but there is almost no information for several populations in México, mostly because of habitat inaccessibility (Armstrong and Murphy 1979). Crotalus pricei is a small-bodied rattlesnake with sizes ranging from 130 to 650 mm in total length; the dorsal pattern is comprised of two rows of dark spots (sometimes fused), and the background varies from blue-gray to gray or pale brown (McCranie 1980). It inhabits places covered predominantly by Pine-oak Woodlands usually associated with rocky ridges and occasionally canyon bottoms, but it can also be found in grassy mountain valleys, basking in the open, moving across rocks,

or coiled under rocks or vegetation (Armstrong and Murphy 1979; Prival et al. 2002; Bryson et al. 2011b; Grabowsky and Mackessy 2019). It can be found at elevations between 1860–3350 m and maximum population densities have been recorded at the higher elevations (Contreras-Lozano et al. 2012; Prival and Schroff 2012).

*Crotalus pricei* is protected by Mexican law in the Official Mexican Norm NOM-059-Semarnat-2010, under the category of Special Protection (Secretaría de Medio Ambiente y Recursos Naturales [SEMARNAT] 2010). The International Union for the Conservation of Nature (IUCN) has the species in the Least Concern category (Hammerson et al. 2007), and its estimated Environmental Vulnerability Score (EVS) is 14, placing it on the highest level of risk given by this scoring system (Wilson et al. 2013). Studies of *C. pricei* have dealt with its ecology (Prival et al. 2002; Prival and Schroff 2012), reproduction (Goldberg 2000), venom composition and effects (Minton and Weinstein 1984; Cruz et al. 1987; Grabowsky and Mackessy 2019), general biology (Axtell and Sabath 1963), and evolution (Bryson et al. 2011b),

focused mostly on northern populations. Females reach sexual maturity at 330 mm snout-vent length (SVL) and males at 322 mm SVL (Goldberg 2000; Prival et al. 2002), although Klauber (1972) reported a gravid female measuring 301 mm total length. The species exhibits a biennial reproductive cycle with litter sizes ranging from three to nine individuals born between July and August (Armstrong and Murphy 1979; Goldberg 2000). The diet of *C. pricei* is comprised mainly of lizards of the genus *Sceloporus* (usually Yarrow's Spiny Lizard, *S. jarrovii*), but there are reports of mammalian and bird prey items and one case of cannibalism (Cruz et al. 1987; Prival et al. 2002; Prival and Schroff 2012; Grabowsky and Mackessy 2019).

The Mexican highlands are known for being one of the biodiversity hotspots of Earth and are recognized for their rattlesnake species richness, and they also are hypothesized as the center of origin for this group of snakes (Alvarado-Díaz and Campbell 2004; Place and Abramson 2004; Bryson et al. 2011a). This region is home to a large number of small-bodied montane rattlesnake species, including the C. intermedius group containing C. pricei (Armstrong and Murphy 1979; Alvarado-Díaz and Campbell 2004). There are two recognized subspecies of C. pricei: C. p. miquihuanus, which occurs in the Sierra Madre Oriental (SMOr; Fig. 1) in the confluence of the Mexican states of Coahuila, Nuevo León, Tamaulipas, and San Luis Potosí (Armstrong and Murphy 1979; Contreras-Lozano et al. 2012), and C. p. pricei, which inhabits the Sierra Madre Occidental (SMOc; Fig. 1) and adjacent sky islands in southeastern Arizona (USA) and the Mexican states of Sonora, Chihuahua, Durango, Zacatecas,

Jalisco, and Aguascalientes (McCranie 1980; Bryson et al. 2011b; Prival and Schroff 2012). In México, *C. pricei* is probably the most common rattlesnake at higher elevations within its range, where it is sympatric with Ridge-Nosed Rattlesnakes (*C. willardi*), Rock Rattlesnakes (*C. lepidus*), and Black Tailed Rattlesnakes (*C. molossus*; Armstrong and Murphy 1979). Nonetheless, little is known about the conservation status, habitat use, behavior, ecology, natural history, and range limits of the subspecies of *C. pricei* in México (Prival and Schroff 2012; Grabowsky and Mackessy 2019).

The status of C. pricei in the Mexican state of Aguascalientes is especially uncertain, as it represents the southernmost population in the range of this species (Reyes-Velasco et al. 2012), inhabiting only the highest elevations in the Sierra Fría (a southern outlier of the SMOc) in the northwestern corner of the state (McCranie 1980; Carbajal-Márquez and Quintero-Díaz 2016). Despite intensive, long-term efforts to locate specimens of this species in Aguascalientes, few occurrences have been reported, it is considered a rare species in the state, and, as a consequence, there is little information about this population (Sigala-Rodríguez 2008; Carbajal-Márquez and Quintero-Díaz 2016). The first specimen of C. pricei for Aguascalientes was reported in 1953 and it was identified as C. p. miquihuanus (Klauber 1972). Some years later, Wilson and McCranie (1979) reported an additional specimen from Aguascalientes with characteristics of Mexican Smallhead Rattlesnake (C. intermedius) and proposed that it was an undescribed species of Crotalus. Based on data from this specimen and another subsequently collected in 1989, Campbell and Lamar (2004) determined that the population



**FIGURE 1**. Distribution of the Twin-spotted Rattlesnake (*Crotalus pricei*) in southern USA and northern Mexico. (A) Map showing the distribution of the two recognized *Crotalus pricei* subspecies: *C. p. pricei* (gray), *C. p. miquihuanus* (red; modified from Campbell and Lamar 2004). (B) Localization of the study site (green) in the northwestern corner of Aguascalientes, México.

present in Aguascalientes represented *C. pricei*, but they could not determine whether it was *C. p. pricei* or *C. p. miquihuanus* because the characteristics of the few available specimens were a mix of both subspecies. Since then, data have been collected on several individuals (from this study and opportunistic encounters), and two vouchered specimens have been deposited in the Zoological Collection of the Universidad Autónoma de Aguascalientes (CZUAA).

Historically, much has been learned about rattlesnake biology through basic studies focused on questions related to natural history, diet, population size, ecology, or new records of rare species (Alvarado-Díaz and Campbell 2004; Lillywhite 2010; Mata-Silva et al. 2018). The aim of this study was to provide new information about the natural history of the population of *C. pricei* in Aguascalientes from recent field surveys. This information may serve as baseline for future research and may help to evaluate its local conservation status.

### MATERIALS AND METHODS

Study site.—Our survey area was inside Comunidad Indígena Monte Grande (Fig. 1), with about 3,600 ha in Sierra Fría (the southern extreme of the SMOc) in the municipality of San José de Gracia, Aguascalientes, México (22.26092°N, 102.6016°W; WGS84; 2,200-3,050 m elevation). Mean annual rainfall oscillates between 200-1,800 mm and mean temperature between 12°-18° C (Arriaga et al. 2000). The vegetation types present in Monte Grande are Oak Forest, Pine-oak Forest, Oak-juniper Forest, and Template Scrub, and the most common tree species in the area are Santa Rosa Oak (Ouercus sideroxyla), Netleaf Oak (O. rugosa), Potosi Oak (Q. potosina), Durango Pine (Pinus duranguensis), Chihuahuan Pine (P. leiophylla), Drooping Juniper (Juniperus martinezii), Alligator Juniper (J. deppeana), and Pointleaf Manzanita (Arctostaphylos pungens; Siqueiros-Delgado et al. 2016, 2017).

*Survey design and data collection*.—We focused our surveys in Pine-oak Forests, following previous studies on the ecology and distribution of the species (Prival et al. 2002; Bryson et al. 2011b), and used two decades of survey information and aerial photographs to identify potential sites to survey. Specifically, we sought out elevated areas (> 2,700 m elevation) with presence of Pine-oak Forest and rocky slopes. Once a potentially viable site was located, we conducted direct searches for rattlesnakes, trying to cover as much area as we could during the periods of time set each day depending on weather conditions. The searches took place weekly from June 2019 to December 2020 during 2–4 d per week, usually with a team of three people each week. Most of the searches were carried out during the mornings and evenings (0700–1900). The surveys included looking for snakes beneath trees and rocks, between the shrubs and bunchgrasses, among the leaf litter, and opportunistic sightings along transects. Night surveys also took place (2000–2300), but these where less frequent, and the time intervals varied each day depending on the weather conditions. With this information, we calculated survey effort, accounting for the total of search hours per person. To determine relative abundance, we divided the number of individuals encountered by the total of search hours to obtain the number of hours required to find one individual of *C. pricei* in the study site. We also recorded other rattlesnake species encountered.

When a rattlesnake was encountered, we captured and placed it in a herpetological bag. Later in the laboratory, we contained the snake using acrylic tubes to collect the following data: mass (M; in g), snout-vent length (SVL;  $\pm 1$  mm), tail length (TL;  $\pm 1$  mm), total length (T;  $\pm 1$  mm), head width (HW;  $\pm 1$  mm), head length (HL;  $\pm 1$  mm), number of dorsal spots (DS), and squamation, consisting of counting ventral scales (VE), subcaudal scales (SU), and intercanthal scales (ICS). We determined sex by cloacal probing or by everting hemipenes. We collected venom, fecal samples, and biological samples (blood and scale clips) for future studies. For measurements < 50 mm, we used a vernier caliper.

We used diagnostic characters described in the literature (Axtell and Sabath 1963; McCranie 1980; Campbell and Lamar 2004; Prival and Schroff 2012) such as number of VE, number of ICS, tail length-total length ratio (TL:T), and arrangement of dorsal spots to compare our individuals with geographic groups of C. pricei. For this, we divided C. pricei in four groups: our individuals, C. p. pricei SMOc North (approximate distribution), C. p. pricei SMOc South (approximate distribution), and C. p. miquihuanus, following the delineation presented in Bryson et al. (2011b). For the C. p. pricei SMOc South data, we used data in unpublished personal notes from L.M. Klauber from 1935 to 1954 provided by Harry W. Greene. For C. p. pricei SMOc North and C. p. miquihuanus, we used previously published information (Axtell and Sabath 1963; McCranie 1980; Campbell and Lamar 2004: Prival and Schroff 2012). For our data, besides the individuals we found in the field, we measured two individuals deposited in the Colección Zoológica de la Universidad Autónoma de Aguascalientes (UAAREP-290, UAAREP-377), one from the Universidad Autónoma de Nuevo León herpetological collection (UANL-4277), one from the University of Michigan Museum of Zoology (UMMZ-110878), and one measured in the field by us in 2009, for a total of 24 records. To determine activity patterns and habitat use, we recorded environmental data such as plant species, GPS coordinates, elevation, date, time, temperature, and humidity (approximately 1 m above ground level), canopy cover (using the cellphone application Canopeo from the Oklahoma State University), and behavior for every encounter. We marked all the snakes by painting the basal segment of the rattle with a unique combination of two colors. We kept the snakes for several days to allow them to defecate and for data acquisition, and subsequently released them in the same place where we found them.

Statistical analyses.—To determine if there is sexual dimorphism in *C. pricei*, we compared M, HW, HL, DS, SVL, TL, T, VE and SU between males and females. We also calculated the degree of sexual size dimorphism (SSD) in SVL following Gibbons and Lovich (1990) and Shine (1994). First, we used the Shapiro-Wilk test to evaluate if our data was normally distributed. For normally distributed data, we compared the characters using a Student *t*-test. For non-normal data, we used a Mann-Whitney U-test. For the statistical analyses, we only used adult individuals; males were considered adults at SVL  $\geq$  322 mm and females at SVL  $\geq$  330 mm (see Goldberg 2000; Prival et al. 2002). We conducted all statistical analyses using R version 3.6.3 (R Core Team 2020) with an alpha level of 0.05.

#### RESULTS

*Survey effort and detection rate.*—From June 2019 to December 2020, we accumulated 1,111.5 searchhours, during which we were able to locate 19 *C. pricei* (Fig. 2), resulting in a detection rate of 0.017 snakes per search-hour, or one individual per 58.8 search-hours. If we consider only the months in which we found the species, effort decreases only slightly to 0.018 snakes per search-hour or 55.5 search-hours to find a snake. We



**FIGURE 2.** One of the 19 individuals of the Twin-spotted Rattlesnake (*Crotalus pricei*) that we found at the study site in Aguascalientes, México, 2020. (Photographed by Juan José Ayala Rodríguez).

also did this for every month (Table 1), revealing that the month with the highest detection rate was August, where 38.8 search-hours were required to find a snake. July, September, and November also had higher values than the overall detection rate (Table 1).

We found 45 rattlesnakes across all species during the survey period, with *C. pricei* representing 42.2% (19 records) of the total as the second most detected rattlesnake species in the area. *Crotalus lepidus* represented 53.3% (24 records) of the total, making it the most frequently detected species in the area. We only found two specimens of *C. molossus*, representing 4.5% of the total of records.

Morphology and population structure.--From the 19 specimens assessed, 12 were adults (six males and six females) and seven were juveniles (two males and five females). Of the five individuals previously collected, four were adults (one male, three females) and one was a juvenile male. Morphological comparisons revealed two characters as sexually dimorphic (Table 2). We found significant difference in TL (t = -2.65, df = 11.224 P = 0.022), with males having longer tails, with measurements ranging between  $44.14 \pm 5.81$  (standard deviation) mm for males and  $36.56 \pm 3.68$  for females. We also found a significant difference in SU (t = -4.52, df = 10.839, P = 0.001) with males having more subcaudal scales  $(29.71 \pm 2.98)$  than females  $(24.78 \pm 1.64)$ . The SSD index of -0.005 indicated that males were slightly larger than females.

As previously mentioned, there has been uncertainty in the assignment of individuals of *C. pricei* from Aguascalientes to one of the two recognized subspecies (*C. p. pricei* and *C. p. miquihuanus*) using morphological characters. There were not remarkable differences between the characteristics of *C. p. pricei* SMOc North (n = 304) and *C. p. pricei* SMOc South (n = 16; Table 3). The number of VE of female individuals from Aguascalientes (n = 24) overlapped with the known data for *C. p. miquihuanus* (n = 3), and the number of VE

**TABLE 1.** Search effort, detection rate, and the required searchhours to find a Twin-spotted Rattlesnake (*Crotalus pricei*) by month in Aguascalientes, México, 2019–2020. Only the months when snakes were detected are included.

Month	Search- hours	Snakes found	Detection rate (snakes/ search-hour)	Search- hours per snake
June	150	1	0.007	150
July	240.5	5	0.021	48.1
August	194	5	0.026	38.8
September	207	5	0.024	41.4
October	129	1	0.008	129
November	109	2	0.018	54.5

**TABLE 2.** Morphological differences between adult females (n = 9) and adult males (n = 7) of the Twin-spotted Rattlesnake (*Crotalus pricei*) from Aguascalientes, México. Abbreviations are M = mass (g), HW = head width (mm), HL = head length (mm), SVL = snoutvent length (mm), TL = tail length (mm), T = total length (mm), DS = dorsal spots, VE = number of ventral scales, SU = number of subcaudal scales, and SD = standard deviation. Significant differences (P < 0.05) designated by an asterisk (\*).

Character	Sex	$Mean \pm SD$	Range	test	P-value
М	Male	$37.6 \pm 18.97$	19–73	10	1.00
	Female	$34.3\pm9.42$	26–48	U = 18	1.00
HW	Male	$12.1 \pm 1.54$	10.0-13.6	(- 0.520	0.600
	Female	$11.5 \pm 0.92$	10.6-13.5	10.339	
HL	Male	$19.8 \pm 3.61$	16.4–27.2	0.100	0.955
	Female	$19.2 \pm 1.01$	17.8-20.6	l = -0.189	0.855
SVL	Male	$368.4\pm37.03$	336-446	11 42	0.596
	Female	$366.3\pm24.92$	335-400	U = 42	
TL	Male	$44.1 \pm 5.81$	2-34	(-2)(5)	0.022*
	Female	$36.6 \pm 3.68$	3-31	<i>l</i> = -2.05	
Т	Male	$412.6\pm40.73$	382–498	11-275	0.923
	Female	$402.9\pm27.48$	366-439	U = 37.3	
DS	Male	$49.3 \pm 5.22$	41–56	4 - 1.96	0.084
	Female	$54.6\pm6.09$	47-67	l = 1.80	
VE	Male	$149.1\pm4.78$	140–154	11-45	0.400
	Female	$152.0 \pm 3.74$	143–157	0 - 45	0.409
SU	Male	$29.7\pm2.98$	24–33	t - 4.52	0.001*
	Female	$24.8 \pm 1.64$	22-27	l = -4.32	0.001

in male individuals overlapped with the known data for *C. p. pricei* (Table 3). The number of ICS overlapped with the two subspecies and the DS arrangement is more similar to *C. p. miquihuanus*. Finally, the TL:T ratio resulted in differences among four groups, with *C. p. pricei* SMOc North having the smallest ratio (0.08) and *C. p. miquihuanus* with the largest (0.114); *C. p. pricei* SMOc South and *C. pricei* from Aguascalientes had intermediate values (0.084 and 0.098, respectively).

Activity patterns and habitat use.—We encountered *C. pricei* from June to November (Fig. 3) and the months

with the most records were July, August, and September, when we found five snakes in each month. We found individuals of *C. pricei* from 1000–1800 with two activity peaks between 1201–1600 (Fig. 4), where we were able to locate 16 of the 19 snakes. The average air temperature at which we found snakes was  $23.02^\circ \pm 4.16^\circ$  C (range,  $17^\circ$ –30.1° C), the mean relative humidity was  $48.1\% \pm$ 17.64 (range, 19–68%), and the canopy cover was 5.54%  $\pm$  3.81 (range, 0.03%–11.8%). All individuals were located no farther than 10 m from temporary streams: five of them were actively moving on leaf litter; 12 were coiled among leaf litter (pine and oak) or bunchgrass; and

**TABLE 3.** Comparison of morphological characters among Twin-spotted Rattlesnake (*Crotalus pricei*) populations across its range: SMOc North = *C. p. pricei* from the northern end of the Sierra Madre Occidental, Mexico; SMOc South = *C. p. pricei* from the central and southern end of the Sierra Madre Occidental, Mexico; this study = *C. pricei* from the southern end of the Sierra Madre Occidental in Comunidad Indigena Monte Grande, Aguascalientes, Mexico; *C. p. miquihuanus* in the Sierra Madre Oriental (SMOr). Data for SMOc North from McCranie (1980), Campbell and Lamar (2004), and Prival and Schroff (2012), for SMOc South from unpublished personal notes from L.M. Klauber (1935–1954), and for *C. p. miquihuanus* from Axtell and Sabath (1963), McCranie (1980), and Campbell and Lamar (2004). Abbreviations are VE = number of ventral scales, ICS = intercanthal scales, TL:T = tail length:total length ratio, DS = dorsal spots, and NA = information not available.

	SMOc North	SMOc South	this study	C. p. miquihuanus
Character	n = 304	n = 16	n = 24	n = 3
VE (females)	157–171	157–163	143–153	143–145
VE (males)	149–162	153–163	148–156	135–141
ICS	0-9 (usually 4-6)	4	2–4	0–3
TL:T	0.08	0.084	0.098	0.114
DS	Generally separated	NA	Generally fused	Generally fused



**FIGURE 3.** Number of Twin-spotted Rattlesnakes (*Crotalus pricei*) found per month at Aguascalientes, México, 2019–2020.

two of them were basking in open rocky areas. There were 11 plant species associated with the specimens of *C. pricei* (Fig. 5): Red Oak (*Quercus jonessi*), *Pinus duranguensis*, and muhly grass (*Muhlenbergia* sp.) were the most common species.

*Notes on reproduction and behavior.*—One female encountered during the surveys gave birth in the lab to four neonates 12 August 2020 during the time we held it to obtain measurements and biological samples. Another female deposited six unfertilized ova 28 August 2020. Most of the individuals of *C. pricei* that we found behaved quite peacefully in comparison with the snakes of other species present in the area (*C. lepidus* and *C. molossus*). Only two individuals of *C. pricei* struck the



FIGURE 5. The number of Twin-spotted Rattlesnake (*Crotalus pricei*) found associated with different plant species in Aguascalientes, México, 2019–2020. Plant species are Red Oak (*Quercus jonessi*), Durango Pine (*Pinus durangensis*), muhly grass (*Muhlenbergia* sp.), stevia (*Stevia* sp.), Texas Madrone (*Arbutus xalapensis*), Hierba Dulce (*Stevia purpussi*), Madrone (*Comarostaphylis polifolia*), Durango Juniper (*Juniperus duranguensis*), Netleaf Oak (*Quercus rugosa*), and Eggleaf Silktassel (*Garrya ovata*).



**FIGURE 4.** Number of the Twin-spotted Rattlesnake (*Crotalus pricei*) found per hour interval in Aguascalientes, Mexico, 2019–2020.

herpetological hook while being manipulated. When first encountered, the individuals of *C. pricei* would stay coiled in the substrate and some of them would try to escape among the leaf litter or shrubs, sometimes rattling for a few seconds. The same behavior was observed upon release of the individuals.

#### DISCUSSION

*Survey effort and detection rate.*—Our study represents the first data systematically gathered for *C. pricei* in Aguascalientes. The first specimen in Aguascalientes was collected in 1953 by E.T. Hooper (UMMZ–110878). The second was collected by I.E. Pinedo-Rodríguez in 1983 (UANL–4277) and Campbell and Lamar (1989) commented on the identity of the individuals from 1953 and 1983. The third recorded specimen was collected by V. Villalobos-Sánchez in 1998 (UAA–REP–290), while two more individuals were found but not collected in 2004 by H. Bárcenas and 2009 by R. Valencia-Villegas. The last recorded specimen before this study was found by R. Reyes-Ardit in 2011 (UAA–REP–377), all this despite intensive efforts made to find more individuals (Sigala-Rodríguez 2008).

Considering the scarcity of previous records, it was surprising that 19 individuals were encountered, given that the species is considered one of the rarest rattlesnakes in Aguascalientes (Vázquez-Díaz and Quintero-Díaz 2005; Sigala-Rodríguez 2008; Carbajal-Márquez and Quintero-Díaz 2016). In contrast, Armstrong and Murphy (1979) stated that *C. pricei* is probably the most common rattlesnake at higher elevations within its range, which is consistent with our sampling effort being concentrated in Pine-oak Forest, which are usually the locations with highest elevation in the study area. Another idea worth considering is that climate change and human perturbation might be restricting C. pricei to these few areas with the highest elevation within the limits of its distribution, as has been the case for other similar species (Davis et al. 2015); hence, the reason why other species of rattlesnakes (probably more tolerant of these changes) appear to be more common in lower elevations and C. pricei is only found at high elevations. During our study period, we found almost the same number of individuals of C. lepidus (24) as C. pricei, but just two C. molossus specimens. We expected to find more rattlesnakes of those species and just a few of C. pricei because the former two tend to be more common at lower elevations in the study area (Vázquez-Díaz and Quintero-Díaz 2005). We assume that the low numbers of individuals of C. pricei is because we were at the limits of its southern distributional range, so we did not expect it to be as frequent as in other areas where it occurs (Gaston 2000). Additionally, the population is numerically small, occupies a restricted area in Aguascalientes, and with limited prior information on its natural history in this Mexican State, in stark contrast with the populations that occur in the northern limits of its distribution, where the species is more abundant and occurs in four mountain systems (Prival and Schroff 2012).

Although we surveyed eight places in Monte Grande and found at least one C. lepidus in six of them, we located all C. pricei individuals in but one of the eight sites within an area of 10 ha. Therefore, it is difficult to estimate the population size of C. pricei in the study area, as they tend to concentrate into semi-discrete populations instead of being uniformly distributed throughout the landscape (Prival and Schroff 2012). This is also consistent with the small home range reported for this species: 0.16 ha for females and 2.29 ha for males (Prival et al. 2002). The effort needed to find C. pricei in Monte Grande (55.5 search-hours per snake) is further evidence of the low abundance of the species in the study area, particularly if compared with the study of Prival and Schroff (2012) in the Chiricahua Mountains in Arizona, USA, where they reported an encounter rate of one C. pricei every eight search-hours in one of their sites and 4.7 search-hours per snake in the other. This information is important for species with low capture rates, as it can help differentiate between true rarity and inadequate sampling (Shelton et al. 2017) and stresses the importance of local studies instead of just generalizing and extrapolating from studies in other areas. In the case of C. pricei from Aguascalientes, we can confirm that it is indeed a rare species, given the difference in the encounter rate between our results and the ones presented by Prival and Schroff (2012); however, more monitoring of this population

would confirm increases or decreases in detectability considering different environmental conditions in different years.

Morphology and population structure.—The characteristics of the individuals from this study are similar to what is known about the species; however, we can highlight some unique findings. The mean SVL we obtained is slightly smaller than that reported by Prival and Schroff (2012), which could be due to the difference in sample size (n = 304 versus n = 24). Sexual dimorphism in C. pricei was as expected, with males having longer tails and more subcaudal scales. Prival et al. (2002) pointed out that, in most rattlesnake species, adult males tend to be larger than adult females. That was not the case, however, for C. pricei in Aguascalientes. Although males were usually larger than females in T, the mean SVL difference between sexes was not pronounced. This was also confirmed by the SSD index (-0.005), which is consistent with the results of Shine (1994) for the species, although our results must be interpreted with caution given the low number of individuals reported here.

Crotalus pricei specimens from Aguascalientes were not considered in the mitochondrial phylogeny done by Bryson et al. (2011b), and we think that this population is important because it is geographically the closest population of C. p. pricei to C. p. miquihuanus; therefore, it could bring new insights into the evolutionary history of the species. Bryson et al. (2011b) suggested that the two subspecies of C. pricei possibly diverged in the Pleistocene, and that each subspecies contains distinct geographically delineated groups: Northern SMOc (C. p. pricei), Southern SMOc (C. p. pricei) and Northern SMOr (C. p. miquihuanus). Regarding scalation of specimens of C. pricei from Aguascalientes, we did not find marked differences compared to other populations of both subspecies of C. pricei. The evolutionary history of C. pricei is interesting as it is one of the smallest rattlesnakes and may be morphologically and ecologically similar to early rattlesnakes (Prival et al. 2002). In addition, organisms with low vagility are particularly well-suited for studies of speciation because their populations tend to be more exposed to geographic isolation, and as a consequence, this leads to reductions in gene flow and population divergence (Davis et al. 2015; Schield et al. 2018). Further, C. pricei is restricted to montane habitats, which are discontinuously distributed across Mexico. Under this scenario of geographic isolation, different populations of the same species became allopatric, and this gene flow break might have led to speciation (Jezkova and Wiens 2018). This lack of gene flow may be why we cannot find similarities among the characteristics of the different groups of C. pricei given the biogeographic history of the species. Although they may not represent different species, differences among isolated populations that are also represented in the phylogeny of the group are observable (Bryson et al. 2011b).

There are some characters that help us to differentiate C. p. pricei from C. p. miquihuanus (Axtell and Sabath 1963; McCranie 1980). Crotalus p. pricei tends to have a higher number of VE than C. p. miquihuanus, and the female specimens from Aguascalientes overlap with the values reported for C. p. miquihuanus; meanwhile, the range in males is similar to C. p. pricei. The number of ICS was uninformative, as all values overlapped in all of the groups. The TL:T ratio of our individuals (0.098) is above the known ratio for C. p. pricei (0.080; 0.084) and is lower than the reported for C. p. miquihuanus (0.114). Axtell and Sabath (1963) mentioned that the TL:T ratio could be the best character to differentiate between C. pricei subspecies. Finally, the DS of our specimens were usually fused, and although this is a common pattern for C. p. miquihuanus, this characteristic is not conclusive evidence to differentiate between subspecies (Axtell and Sabath 1963). Although this comparison does not define subspecies adscription for the individuals collected in Aguascalientes, they are more similar to C. p. miquihuanus, than C. p. pricei. Molecular analysis could shed light on this issue in the future.

Activity patterns and habitat use.--We primarily found C. pricei in our study area on grassy slopes with leaf litter, and all of them were found near temporary streams. One reason for the association with temporary streams could be that these streams carry and accumulate the leaf litter that the snakes use as shelter. Although the importance of streams (or water bodies in general) for animals is well known, it may have been overlooked for rattlesnakes, although it has been mentioned for other vipers (Roth 2005). In other areas of the SMOc, the presence of C. pricei is usually associated with rocky places and occasionally canyon bottoms, but it can also be found in grassy mountain valleys, basking in the open, moving across rocks, or coiled under rocks or vegetation (Armstrong and Murphy 1979; Prival et al. 2002; Bryson et al. 2011a; Grabowsky and Mackessy 2019).

We only found two *C. pricei* individuals in rocky areas despite considerable effort searching in this type of habitat; *C. lepidus* was far more abundant in these rocky habitats. It is therefore important to know the characteristics of the life history of different populations of the same species (Beaupre 1995; Mata-Silva et al. 2018), given that in other parts of its distribution *C. pricei* can be found primarily in rocky habitats (Armstrong and Murphy 1979; Prival et al. 2002). The assumption that the preferences of the species are always the same in all regions can lead to false absences

(Shelton et al. 2017; Burns et al. 2019) and increasing difficulty of detecting the species in different habitats in its distributional range (Baxley et al. 2011; Triska et al. 2017). The brief description of the vegetation associated with C. pricei presented here increases our understanding of the type of habitat in which the species is found through its southern range of distribution, which is essential to inform management strategies and conservation planning (Degregorio et al. 2011; Burns et al. 2019). Although habitat type concurs with previous studies (Pine-oak Forest), the species and microhabitats vary from what was described by Prival and Schroff (2012). Additionally, most of the snakes that we found were in areas where canopy cover was very low; the highest value that we recorded was 11.8%. This is consistent with the work of Johnson et al. (2016), who indicated that rattlesnakes tend to be more frequent in sites with low levels of canopy cover.

During our field surveys in 2019 and 2020, we were able to find 12 and seven snakes, respectively. Although the conditions in the study site were favorable, these years were the driest in Aguascalientes in the last 5 y (https:// smn.conagua.gob.mx/es/climatologia/temperaturasy-lluvias/resumenes-mensuales-de-temperaturas-ylluvias). According to Prival and Schroff (2012), the best predictor to account for the detectability of C. pricei is the humidity through the year and this could explain the fact that all the snakes were found near temporary streams and leaf litter because these places provide high levels of humidity. Taking this into account, we can assume that in a more humid year in Aguascalientes, we could be able to find even more individuals of C. pricei. Therefore, the number of individuals that we found in drier years, compared with previous efforts, could be a good sign for the conservation status of this species in this locality, because species detectability is intimately related to abundance, and it becomes even more important with rare species (Holycross and Goldberg 2001). This prediction, however, should be tested by comparing the abundance of the species in subsequent years. Related to this, Smith et al. (2019) documented that dry years directly affect the population levels of the Copperhead (Agkistrodon contortrix) by decreasing the number of offspring that females could bear, hence the importance of continuing to monitor the population of C. pricei reported in this study to evaluate their responses to dry and humid years.

Regarding activity patterns, we found 15 of the 19 individuals from July to September. The earliest encounter with *C. pricei* in our study site was after 1000 and the period of time with the most individuals registered was between 1501-1600 (n = 6) followed by 1201-1300 (n = 5). Prival and Schroff (2012) report that these snakes are more active in the summer, mainly after late July, which is consistent with our findings. They

also point out that the snakes start basking between 0800–0900, but we did not observe individuals at that time interval. Axtell and Sabath (1963) observed one individual of *C. p. miquihuanus* at 1100 on a sunny day in July 1961, which falls between the intervals in which we were able to find our snakes. There are no reports of nocturnal activity for this species in the literature and we did not detect activity of *C. pricei* during our nocturnal surveys.

Reproduction and behavior .--- We recorded one female giving birth to four neonates 12 August 2020, and one female deposited six unfertilized ova 28 August 2020, the later representing the first report of an event like this for C. pricei. This is consistent with previous observations: mating occurs generally in August and September and parturition occurs in the summer of the following year with litter size ranging from three to eight neonates (Armstrong and Murphy 1979; Liner and Chaney 1986; Goldberg 2000; Prival and Schroff 2012). Pérez-Mendoza et al. (2018) reported the passing of unfertilized ova for Mexican Dusky Rattlesnake (C. triseriatus). As previously mentioned, the snakes that we encountered principally tried to escape among the leaf litter or they would rattle for a few seconds, and this behavior is consistent with the characterization of C. pricei being a rather shy rattlesnake (Armstrong and Murphy 1979).

*implications*.—In **Conservation** the current biodiversity crisis, we need to understand how species survive in fragmented, marginal, and peripheral populations over long time periods, despite the negative impacts on population size and genetic structure predicted to occur in isolation (Gaston 2000; Burbrink 2010). Therefore, information about the ecology of a given species is crucial to elaborate plans that promote its conservation (Seigel 1986; Prival et al. 2002). The information presented here is important to begin to understand the life-history strategies and conservation requirements of C. pricei in the southern extreme of its distributional range. Identifying populations that might be declining or that are at elevated extinction risk allows conservation efforts to be implemented before precipitous declines occur. This type of information is well documented in several vertebrate groups, with the notable exception of reptiles, including most rattlesnakes (Campbell and Flores-Villela 2008; Shelton et al. 2017). In our study area we could observe potential threats to the conservation of this population of C. pricei, such as presence of livestock and motorcycle riders. We must also consider the threat represented by the current trend of climate change, which has been documented to affect rattlesnakes inhabiting high altitudes (Davis et al. 2015). Therefore, additional research is needed concerning

natural history and evolution of *C. pricei* to allow us to develop appropriate management strategies.

Although the species is protected in Mexico, the population of *C. pricei* inhabiting Aguascalientes indicates that this species may be even more vulnerable than previously thought. It persists in the few remaining patches of high elevation Pine-oak Forests but at low densities, and in specialized niches that might be threatened by climate change. In addition, rattlesnakes are frequently threatened by humans because they are venomous. The information presented in this study represents the first attempt to describe the natural history, morphology, and taxonomic status of the population of *C. pricei* occurring in Aguascalientes. We hope that this information leads to additional natural history studies of this species and that time and funds are spent in monitoring programs.

Acknowledgments.—Part of this project was conducted thanks to the support provided by the Ph.D. program of Biological Sciences of the Universidad Autónoma de Aguascalientes and a fellowship from the Consejo Nacional de Ciencia y Tecnología (CONACYT) to J.J. Ayala-Rodríguez. We would like to thank the community of Monte Grande for letting us do field work on their land, especially Ma. Elvia R. Esparza Villegas and Luis Manuel Suárez Rojas. We also thank Elena Quiroz, Ramsés Rosales, Rogelio Rosales, Cristian Servín, Eduardo Díaz, Jeny Aguilar, Israel Elizalde, Carlos Ayala, Fernanda Chávez Samayoa and Iván Villalobos and countless others for their support during field surveys and gathering of data. We thank Alondra Encarnación and Rámses Rosales for their comments to improve this paper, to Iván Esteban Pinedo Rodríguez, Víctor Villalobos, Horacio Bárcenas, José Roberto Valencia, Raramuri Reyes and for collecting previous individuals of C. pricei from Aguascalientes, to Harry W. Greene and Kelly R. Zamudio for help and encouragement in the early phases of this study. We also thank the following curators in collections for access and information provided: David Lazcano Villarreal (Universidad Autónoma de Nuevo Léon), Gilfredo de la Riva (Universidad Autónoma de Aguascalientes), Jose Rosado (Museum of Comparative Zoology Harvard University), Ron Nussbaum and Greg Schneider (University of Michigan Museum of Zoology). Collecting was carried out under permits SEMARNAT SGPA/DGVS/7494/19 to Jesus Sigala-Rodríguez.

### LITERATURE CITED

Alvarado-Díaz, J., and J.A. Campbell. 2004. A new montane rattlesnake (Viperidae) from Michoacán, México. Herpetologica 60:281–286.

- Armstrong, B.L., and J.B. Murphy. 1979. The natural history of Mexican rattlesnakes. University of Kansas Museum of Natural History Publications 5:1–88.
- Arriaga, L., J.M. Espinoza, C. Aguilar, E. Martínez, L. Gómez, and E. Loa. 2000. Regiones terrestres prioritarias de México. Comisión Nacional para el Conocimiento y uso de la Biodiversidad (CONABIO), México, Distrito Federal, México.
- Axtell, R.W., and M.D. Sabath. 1963. Crotalus pricei miquihuanus from the Sierra Madre of Coahuila, México. Copeia 1963:161.
- Baxley, D., G.J. Lipps, and C.P. Qualls. 2011. Multiscale habitat selection by Black Pine Snakes (*Pituophis melanoleucus lodingi*) in southern Mississippi. Herpetologica 67:154–166.
- Beaupre, S.J. 1995. Comparative ecology of the Mottled Rock Rattlesnake, *Crotalus lepidus*, in Big Bend National Park. Herpetologica 51:45–56.
- Bryson, R.W., R.W. Murphy, M.R. Graham, A. Lathrop, and D. Lazcano. 2011b. Ephemeral Pleistocene woodlands connect the dots for highland rattlesnakes of the *Crotalus intermedius* group: diversification of montane rattlesnakes. Journal of Biogeography 38:2299–2310.
- Bryson, R.W., R.W. Murphy, A. Lathrop, and D. Lazcano-Villareal. 2011a. Evolutionary drivers of phylogeographical diversity in the highlands of México: a case study of the *Crotalus triseriatus* species group of montane rattlesnakes: phylogeography of the *Crotalus triseriatus* group. Journal of Biogeography 38:697–710.
- Burbrink, F.T. 2010. Historical versus contemporary migration in fragmented populations. Molecular Ecology 19:5321–5323.
- Burns, P.A., C. McCall, K.C. Rowe, M.L. Parrott, and B.L. Phillips. 2019. Accounting for detectability and abundance in survey design for a declining species. Diversity and Distributions 25:1655–1665.
- Campbell, J.A., and O. Flores-Villela. 2008. A new long-tailed rattlesnake (Viperidae) from Guerrero, México. Herpetologica 64:246–257.
- Campbell, J.A., and W.W. Lamar. 1989. The Venomous Reptiles of Latin America. Comstock/Cornell University Press, Ithaca, New York, USA.
- Campbell, J.A., and W.W. Lamar. 2004. The Venomous Reptiles of the Western Hemisphere. Cornell University Press, Ithaca, New York, USA.
- Carbajal-Márquez, R.A., and G.E. Quintero-Díaz. 2016. The herpetofauna of Aguascalientes, México. Revista Mexicana de Herpetología 2:1–30.
- Contreras-Lozano, J.A., D. Lazcano, and A.J. Contreras-Balderas. 2012. Herpetofauna of the Cerro El Potosi Natural Protected Area of Nuevo Leon, México: status of the ecological and altitudinal distribution. Natural Areas Journal 32:377–385.

- Cruz, E., S. Gibson, K. Kandler, G. Sanchez, and D. Chiszar. 1987. Strike-induced chemosensory searching in rattlesnakes: a rodent specialist (*Crotalus viridis*) differs from a lizard specialist (*Crotalus pricei*). Bulletin of the Psychonomic Society 25:136–138.
- Davis, M.A., M.R. Douglas, C.T. Webb, M.L. Collyer, A.T. Holycross, C.W. Painter, L.K. Kamees, and M.E. Douglas. 2015. Nowhere to go but up: impacts of climate change on demographics of a shortrange endemic (*Crotalus willardi obscurus*) in the Sky-Islands of southwestern North America. PLoS ONE 10:e0131067. https://doi.org/10.1371/journal. pone.0131067.
- DeGregorio, B.A., B.J. Putman, and B.A. Kingsbury. 2011. Which habitat selection method is most applicable to snakes? Case studies of the Eastern Massasauga (*Sistrurus catenatus*) and Eastern Fox Snake (*Pantherophis gloydi*). Herpetological Conservation and Biology 6:372–382.
- Gaston, K.J. 2000. Global patterns in biodiversity. Nature 405:220–227.
- Gibbons, J.W., and J.E. Lovich. 1990. Sexual dimorphism in turtles with emphasis on the Slider Turtle (*Trachemys scripta*). Herpetological Monographs 4:1–29.
- Goldberg, S.R. 2000. Reproduction in the Twin-spotted Rattlesnake, *Crotalus pricei* (Serpentes: Viperidae). Western North American Naturalist 60:98–100.
- Grabowsky, E.R., and S.P. Mackessy. 2019. Predatorprey interactions and venom composition in a high elevation lizard specialist, *Crotalus pricei* (Twinspotted Rattlesnake). Toxicon 170:29–40.
- Hammerson, G.A., J. Vázquez-Díaz, and G.E. Quintero-Díaz. 2007. *Crotalus pricei*. The IUCN Red List of Threatened Species 2007. International Union for Conservation of Nature. http://www.IUCN.org.
- Holycross, A.T., and S.R. Goldberg. 2001. Reproduction in northern populations of the Ridgenose Rattlesnake, *Crotalus willardi* (Serpentes: Viperidae). Copeia 2001:473–481.
- Jezkova, T., and J.J. Wiens. 2018. Testing the role of climate in speciation: new methods and applications to squamate reptiles (lizards and snakes). Molecular Ecology 27:2754–2769.
- Johnson, B.D., J.P. Gibbs, T.A. Bell, and K.T. Shoemaker. 2016. Manipulation of basking sites for endangered Eastern Massasauga rattlesnakes. Journal of Wildlife Management 80:803–811.
- Klauber, L.M. 1972. Rattlesnakes: Their Habits, Life Histories, and Influence on Mankind. 2nd Edition. University of California Press, Berkeley, California, USA.
- Lillywhite, H.B. 2010. Focus on snake conservation. BioScience 60:315–317.

- Liner, E.A., and A.H. Chaney. 1986. *Crotalus pricei miquihuanus* reproduction. Herpetological Review 17:89.
- Mata-Silva, V., D.L. DeSantis, A.E. Wagler, and J.D. Johnson. 2018. Spatial ecology of Rock Rattlesnakes (*Crotalus lepidus*) in far West Texas. Herpetologica 74:245–254.
- McCranie, J.R. 1980. *Crotalus pricei*. Catalogue of American Amphibians and Reptiles 266:1–2.
- Meik, J.M., E. Mociño-Deloya, and K. Setser. 2007. New distribution records for the Querétaro Dusky Rattlesnake *Crotalus aquilus* (Viperidae), with comments on morphology and habitat use. Western North American Naturalist 67:601–604.
- Minton, S.A., and S.A. Weinstein. 1984. Protease activity and lethal toxicity of venoms from some little known rattlesnakes. Toxicon 22:828–830.
- Pérez-Mendoza, H.A., S.R. Sanabria-Tobón, J.L. Jaramillo-Alba, I. Solano-Zavaleta, L.F. Vázquez-Vega, and A.H.D. de la Vega-Pérez. 2018. Reproductive traits of Dusky Rattlesnakes (*Crotalus triseriatus*) in Central México. Journal of Herpetology 52:6–11.
- Place, A.J., and C.I. Abramson. 2004. A quantitative analysis of the ancestral area of rattlesnakes. Journal of Herpetology 38:152–156.
- Prival, D.B., and M.J. Schroff. 2012. A 13-year study of a northern population of Twin-spotted Rattlesnakes (*Crotalus pricei*): growth, reproduction, survival, and conservation. Herpetological Monographs 26:1–18.
- Prival, D.B., M.J. Goode, D.E. Swann, C.R. Schwalbe, and M.J. Schroff. 2002. Natural history of a northern population of Twin-spotted Rattlesnakes, *Crotalus pricei*. Journal of Herpetology 36:598–607.
- R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project. org.
- Reyes-Velasco, J., C.I. Grünwald, J.M. Jones, M.S. Price, and J.T. Fisher. 2012. New distributional records for the herpetofauna of Mexico. Herpetological Review 43:455–457.
- Roth, E.D. 2005. Buffer zone applications in snake ecology: a case study using Cottonmouths (*Agkistrodon piscivorus*). Copeia 2005:399–402.
- Schield, D.R., R.H. Adams, D.C. Card, A.B. Corbin, T. Jezkova, N.R. Hales, J.M. Meik, B.W. Perry, C.L. Spencer, L.L. Smith, et al. 2018. Cryptic genetic diversity, population structure, and gene flow in the Mojave Rattlesnake (*Crotalus scutulatus*). Molecular Phylogenetics and Evolution 127:669–681.
- Secretaria de Medio Ambiente y Recursos Naturales, México (SEMARNAT). 2010. Norma Oficial Mexicana NOM-059SEMARNAT-2010, Protección ambiental - Especies nativas de México de

flora y fauna silvestres - Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio - Lista de especies en riesgo. Diario Oficial de la Federación. 30 de diciembre de 2010, Segunda Sección, México.

- Seigel, R.A. 1986. Ecology and conservation of an endangered rattlesnake, *Sistrurus catenatus*, in Missouri, USA. Biological Conservation 35:333– 346.
- Shelton, M.B., R.L. Goldingay, and S.S. Phillips. 2017. Population ecology of a cryptic arboreal snake (*Hoplocephalus bitorquatus*). Australian Journal of Zoology 65:383–390.
- Shine, R. 1994. Sexual size dimorphism in snakes revisited. Copeia 1994:326–346.
- Sigala-Rodríguez, J.J. 2008. La serpiente de cascabel *Crotalus pricei* (Serpentes: Viperidae) en Aguascalientes: ¿Especie rara o en peligro de extinción? Pp. 147 *In* La Biodiversidad en Aguascalientes: Estudio de Estado. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), Instituto del Medio Ambiente del Estado de Aguascalientes (IMAE), Universidad Autónoma de Aguascalientes (UAA), Aguascalientes, México.
- Siqueiros-Delgado, M.E., J.A. Rodríguez-Ávalos, J. Martínez-Ramírez, and J.C. Sierra-Muñoz. 2016. Situación actual de la vegetación del estado de Aguascalientes, México. Botanical Sciences 94:455 -470.
- Siqueiros-Delgado M.E., J.A. Rodríguez-Ávalos, J. Martínez-Ramírez, J.C. Sierra-Muñoz, and G. García-Regalado. 2017. Vegetación del Estado de Aguascalientes. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Universidad Autónoma de Aguascalientes, México.
- Smith, C.F., G.W. Schuett, R.S. Reiserer, C.E. Dana, M.L. Collyer, and M.A. Davis. 2019. Droughtinduced suppression of female fecundity in a capital breeder. Scientific Reports 9:15499.
- Triska, M.D., M.D. Craig, V.L. Stokes, R.P. Pech, and R.J. Hobbs. 2017. Conserving reptiles within a multiple-use landscape: determining habitat affiliations of reptile communities in the northern jarrah forest of south-western Australia. Australian Journal of Zoology 65:21–32.
- Van Denburgh, J. 1895. Description of a new rattlesnake (*Crotalus pricei*) from Arizona. Proceedings of the California Academy of Sciences 5:856–857.
- Vázquez-Díaz, J., and G.E. Quintero-Díaz. 2005. Anfibios y reptiles de Aguascalientes. 2nd Edition. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Centro de Investigaciones y Estudios Multidisciplinarios de Aguascalientes, México.

Wilson L.D., and J.R. McCranie. 1979. Notes on the herpetofauna of two mountain ranges in México (Sierra Fría, Aguascalientes, and Sierra Morones, Zacatecas). Journal of Herpetology 13:271–278. Wilson, L.D., J.D. Johnson, and V. Mata-Silva. 2013. A conservation reassessment of the amphibians of México based on the EVS measure. Amphibian & Reptile Conservation 7:97–127.



**JUAN J. AVALA-RODRÍGUEZ** is a doctoral student in Biological Sciences at the Universidad Autónoma de Aguascalientes (UAA), at Aguascalientes, México. He has a degree in Biology from the same institution. He is interested in the study of ecology, evolution, and conservation of reptiles, and in recent years has participated in field research focused on gathering information about rare species of reptiles. He also worked for a short period of time on animal rescue programs in northern México. (Photographed by Juan J. Ayala-Rodríguez).



**J. JE**SÚS **SIGALA-RODRÍGUEZ** is a Professor at Universidad Autónoma de Aguascalientes, Mexico, and a Co-Chair of the Viper Specialist Group (VSG) of the International Union for the Conservation of Nature. He is interested in macroecological patterns, natural history, and conservation of viperid snakes. Jesús enjoys field work and has done it looking for vipers in every state of México and several in the USA. He values teaching and outreach, and he has taught 36 different courses and given more than a hundred professional presentations. Jesús was President of the Mexican Zoological Society and has done academic stays in the USA and Ecuador. (Photographed by Jesús Sigala-Rodríguez).



**GILBERTO A. OCAMPO-ACOSTA** is currently an Associate Professor at Universidad Autónoma de Aguascalientes, Mexico, with a Ph.D. degree in Botany from the California Botanic Garden and the Claremont Graduate University, Claremont, California, USA. He is a council member of the Sociedad Botánica de México, and his research interests cover topics such as plant taxonomy and nomenclature, phylogenetics, systematics, and evolution. (Photographed by Patricia García).



**JAIME A. ESCOTO-MORENO** is a Full Professor at Universidad Autónoma de Aguascalientes, Mexico. He is an entomologist with a Doctoral degree in Biodiversity and Conservation and a member of the Mexican Society of Entomology and National System of Researchers in México. His current research interests focus on taxonomy, diversity, biogeography, and conservation of Odonata. Throughout his career, Jaime has attempted to combine research, teaching, and service, involving undergraduate as well as graduate students. He has participated in 33 congresses and has published 24 scientific articles and chapters. (Photographed by Jaime Escoto Rocha).



**RUBÉN A. CARBAJAL-MÁRQUEZ** received his Bachelor's degree in Biology from Universidad Autónoma de Aguascalientes (UAA), Mexico, his Master's degree from the Centro de Investigaciones Biológicas del Noroeste (CIBNOR), at La Paz, Baja California Sur, Mexico, and his Doctoral degree from El Colegio de la Frontera Sur (ECOSUR), Chetumal, Quintana Roo, México. He is currently a postdoctoral fellow at UAA. He is member of Conservación de la Biodiversidad del Centro de México A.C. and of the Viper Specialist Group of the International Union for the Conservation of Nature/Species Survival Commission. His research interests include natural history, diversity, ecology, systematics, and conservation of the herpetofauna of México. (Photographed by Tania Ramírez Valverde).