Anolis duellmani was described in 1973 based on four specimens collected on the southern slope of Volcán San Martín, in the Los Tuxtlas region of Veracruz, Mexico. Despite the disputed phylogenetic position of this anole, since that time no additional morphological or ecological information has been reported. This species apparently is locally abundant on the continental slopes of the mountains in the Los Tuxtlas region. *Anolis duellmani* is one of several species in this area in risk of extinction, given the ongoing rate of habitat destruction. © Adam Clause

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Morphological variation and natural history of *Anolis duellmani* (Squamata: Dactyloidae)

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Abstract: We increase information on the morphological variation of *Anolis duellmani* based on 31 specimens collected since the species was described. We also provide some observations on the natural history of the species. Our sample showed greater variation in diagnostic characters than originally recorded, but the expanded range of characters still diagnose the species. The possibility of synonymy with a similar species, *A. pygmaeus*, requires further investigation. *Anolis duellmani* might be at risk of extinction due to ongoing habitat destruction in its restricted geographic range, given that we found this species only in relatively well-preserved forest patches, which rapidly are disappearing.

Key Words: *Anolis pygmaeus*, lizards, Los Tuxtlas, Mexico, morphology, variation

Resumen: Incrementamos la información disponible de la variación morfológica de *Anolis duellmani* con base en 31 especímenes colectados desde que la especie fue descrita. También proveemos algunas observaciones de historia natural de la especie. Nuestra muestra mostró mayor variación en los caracteres diagnósticos que la originalmente reportada, pero el rango expandido de caracteres sigue diagnosticando a la especie. La posibilidad de sinonimia con una especie similar, *A. pygmaeus*, requiere de más investigación. *Anolis duellmani* pudiera estar en riesgo de extinción debido a la continua destrucción del hábitat en su restringido rango geográfico, dado que sólo encontramos esta especie en parches de bosque relativamente bien conservados, los cuales rápidamente están desapareciendo.

Palabras Claves: *Anolis pygmaeus*, lagartijas, Los Tuxtlas, México, morfología, variación

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INTRODUCTION

Fitch and Henderson (1973) described *Anolis duellmani* on the basis of four adult male specimens from the southern slope of Volcán San Martín Tuxtla, Veracruz, Mexico, at elevations from 800 to 1,150 m. Since that time, additional morphological variation has not been reported for this species.

In recent years, opposing views regarding the generic arrangement of the family Dactyloidae have been presented. While some have used the genus *Norops* for nearly all the species of Mexican anoles (e.g., Guyer and Savage, 1986; Nicholson, 2002; Nicholson et al., 2012, 2014), others have maintained the use of *Anolis* (Cannatella and De Queiroz, 1989; Williams, 1989; Poe, 2013). A discussion of this issue is beyond the scope of this work, and herein we chose to maintain use of the generic name *Anolis*.

Anolis duellmani has been placed in the *schiedii* species group (Guyer and Savage, 1986; Campbell et al., 1989; Savage and Guyer, 1989; McCranie et al., 1993 a,b; Lieb, 2001), but its position in the genus also has been regarded as uncertain (Nieto-Montes de Oca, 2001), or has been placed within a more inclusive *auratus* group (Nicholson et al., 2012).

Herein, we report information on morphological variation for *A. duellmani* based on a sample of 31 additional specimens, including males and females, juveniles and adults. Additionally, we provide some observations on this species' natural history.

MATERIALS AND METHODS

We examined 31 specimens of *Anolis duellmani* from the Los Tuxtlas region of Veracruz, Mexico. Fourteen of the specimens were collected by Joseph R. Mendelson III from 22 to 27 July 1998; seven by Adrián Nieto-Montes de Oca on 22 April 1998; seven by us from 22 to 25 February 2013; and three by Uri O. García-Vázquez from 14 to 15 March 2005. We provide locality data for the specimens, in this order, in Appendix 1.

We scored all of the diagnostic characters for the species provided by Fitch and Henderson (1973), and follow the character terminology of Fitch and Hillis (1984) and Köhler (2014). We performed scale counts with the aid of a dissecting microscope, scored bilateral characters on both sides, used digital calipers for most measurements (to the nearest 0.01 mm), and recorded scale measurements at their maximum with the aid of an ocular micrometer in a dissecting microscope. We measured head length from the tip of the snout to the anterior edge of the ear opening, head width at the broadest portion of the head, and provide snout–vent length (SVL) in mm. We follow the color code in Köhler (2012) for the dewlap, indicate geographical coordinates in decimal degrees (datum = WGS84), and follow Sabaj Pérez (2010) in the use of acronyms for collections. We made our natural history observations during fieldwork conducted from 22 to 25 February 2013.

RESULTS

Morphological Variation (Fig. 1; Table 1)

Some of the scalation characters we examined showed no variation, as follows: the loreals are smooth or keeled in the same specimen, with the smallest scales smooth and larger ones keeled; the supraorbital semicircles, postrostrals, internasals, and supraoculars are distinctively keeled; the enlarged dorsals are keeled, and the remaining dorsals granular; the postcloacal scales are not enlarged. The characters showing variation are as follows: the postrostrals are 5–8 ($\bar{x}$ = 6.19); the internasals are 7–9 ($\bar{x}$ = 7.90); the loreal scale rows below the 2nd canthal are 5–9 ($\bar{x}$ = 7.74); the supralabials are 8–12 ($\bar{x}$ = 9.89); the enlarged canthals are 3–6 ($\bar{x}$ = 4.47); the scales between the supraorbital semicircles are 1–3 ($\bar{x}$ = 1.68); the enlarged superciliaries are 1–5 ($\bar{x}$ = 2.60); the enlarged supraoculars are 6–11 ($\bar{x}$ = 8.16); the enlarged supraoculars are in narrow (n = 5) or moderate (n = 26) contact with the supraorbital semicircles; the scales between the supraorbital semicircles and the interparietal are 2–5 ($\bar{x}$ = 3.23); the infralabials are 8–13 ($\bar{x}$ = 9.61); the middorsals between levels of the axilla and the groin are 35–58 ($\bar{x}$ = 44.55); the enlarged dorsal scale rows are 10–15 ($\bar{x}$ = 11.90); the midventrals between levels of the axilla and the groin are 41–60 ($\bar{x}$ = 49.94); the ventrals are weakly (n = 14) or distinctly keeled (n = 17); the scales around midbody are 88–109 ($\bar{x}$ = 98.23); and the subdigital lamellae below the 2nd and 3rd phalanges are 11–15 ($\bar{x}$ = 13.10).

Fig. 1. *Anolis duellmani* in life: adult female in dorsolateral (top) and ventral (middle) views, and adult male dewlap (bottom).

We recorded the following dewlap characters in nine adult males (SVL = 33.17–38.56; $\bar{x}$ = 35.04): the dewlap extends posteriorly to the level of the axilla (n = 3), slightly beyond the axilla (n = 4), or to the anterior one-fourth of the body (n = 2); the gorgetal-sternal rows are 5–9 ($\bar{x}$ = 7.11); the average number of scales in the middle gorgetal-sternal rows are 20–30 ($\bar{x}$ = 26.00); the transverse scale rows along the dewlap margin are 47–59 ($\bar{x}$ = 50.44); the dewlap color in life (recorded during our fieldwork) was Pale Purple (Color 223).

The SVL (n = 31) is 21.73–40.59 ($\bar{x}$ = 31.75). Six females that showed follicular development were longer (SVL = 32.94–40.59; $\bar{x}$ = 36.81) than those not showing it. Nine males (SVL = 33.17–38.56; $\bar{x}$ = 35.04) were longer than the shortest female showing follicular development. We consider these 15 specimens to be adults. We only considered adult specimens for the following morphometric characters: the head length/SVL ratio is 0.27–0.29 ($\bar{x}$ = 0.28); the head width/SVL ratio is 0.17–0.19 ($\bar{x}$ = 0.18); the ear opening height/interparietal length ratio is 1–1.86 ($\bar{x}$ = 1.28); the adpressed hind limb extends approximately to the middle of the orbit (n = 4), or to the anterior margin of the orbit (n = 11); the shank length transposed from the snout tip and posteriorly onto the head extends halfway between the orbit and the ear opening (n = 8), three fourths of the way between orbit and the ear opening (n = 2), just prior to the ear opening (n = 2), to the anterior margin of the ear opening (n = 2), or to the posterior margin of the ear opening (n = 1); the head length/shank length ratio is 0.94–1.16 ($\bar{x}$ = 1.07); and the tail length/SVL ratio for the five adult specimens with a complete tail is 1.54–1.79 ($\bar{x}$ = 1.67).

Live individuals showed profuse (Fig. 1) to barely noticeable orange speckling through their entire ventral surface. The following description is based on preserved specimens: the

degree and pattern of dark pigmentation on the ventral surface of the head and neck are variable, and show disperse infralabial and gular speckling (n = 14) or moderately profuse infralabial and gular speckling (n = 17); longitudinal dark lines are present on the ventral surface of neck in four specimens, and all show profuse infralabial and gular speckling; the degree and pattern of dark pigmentation on the ventral surface of body are variable, and show disperse dark speckles throughout the venter (n = 8); disperse dark speckles clumping together to form disperse spots (n = 12); disperse dark speckles clumping together to form a large blotch at the middle of the body (n = 5); or profuse dark speckling throughout the venter (n = 6).

Table 1. Morphological variation of selected characters in *Anolis duellmani*. We show morphometric characters only for adults.

Character	Reported	Specimens Examined	Mean and Standard Deviation of Specimens Examined
Loreal scale rows	7	5–9	7.74 ± 0.89
Scales between supraocular semicircles	2	1–3	1.68 ± 0.54
Scales between supraorbital semicircles and interparietal	3–4	2–5	3.23 ± 0.56
Middorsal scales	86–91 (between levels of nape and rear thigh)	35–58 (between levels of axilla and groin)	45.55 ± 6.11
Midventral scales	61–70 (between levels of axilla and vent)	41–60 (between levels of axilla and groin)	49.94 ± 4.13
Enlarged dorsal scale rows	10–14	10–15	11.90 ±1.27
Scales around midbody	92–108	88–109	98.23 ± 6.28
Ventral keeling	Weakly keeled	Weakly keeled (n = 14), distinctly keeled (n = 17)	—
SVL	36–37	32.94–40.59	35.75 ± 2.47
Ear opening height/interparietal length ratio	Ear opening larger than interparietal	1–1.86	1.28 ± 0.21
Head length/shank length ratio	Shank slightly exceeds head length	0.94–1.16	1.07 ± 0.06
Anteriormost reach of adpressed hindlimb	Beyond ear to anterior margin of orbit	Anterior margin (n = 11), middle of orbit (n = 4)	—
Tail length/SVL ratio (when tail complete)	ca. 1.67	1.54–1.79	1.67 ± 0.11

Natural History

The specimens we examined were collected on the continental slopes of Volcán San Martín and the Cordillera de Santa Marta, at elevations ranging approximately from 833 to 1,450 m (Fig. 2). The climate in these areas has been described as warm, with a monsoon influence during the summer rains (Am of the Köppen-Geiger Climate Classification System as modified by García, 1964; Soto, 2004). All of the individuals found during the day were active on the ground or on low-lying logs. Those found at night were sleeping on shrubs ca. 2 m above the ground or lower. We collected both adults and juveniles. This species seems to prefer shadowed, humid, and rather cool microhabitats, as we did not find any lizards in open or dry areas, or exposed to direct sunlight (see images on Introductory Page). During our fieldwork we saw only one other species of anole, *Anolis sericeus*, in this type of microhabitat, represented by a single individual. We also found individuals of *A. laeviventris*, *A. lemurinus*, and *A. petersii* near the vicinity of collecting sites for *A. duellmani*, but always occupying different microhabitats.

Six of the nine specimens we confidently sexed as females showed evidence of follicular development; their SVL was 32.94–40.59, ($\bar{x}$ = 36.81). The SVL for the two females without evidence of follicular development was 28.77–30.32 ($\bar{x}$ = 29.55). Five juveniles could not be sexed with confidence (SVL = 21.73–27.06; $\bar{x}$ = 24.52). We provide the number of follicles, their stage of maturation, and the length of vitellogenic follicles and eggs for each of the first six females in Table 2. We did not score the length of the previtellogenic follicles.

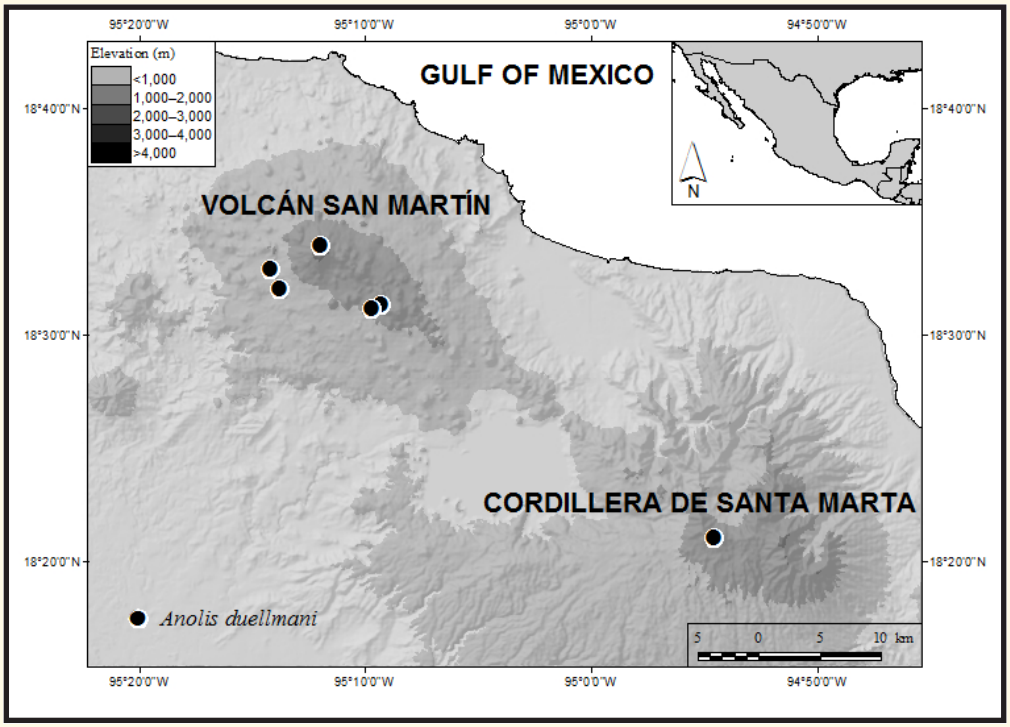

Fig. 2. Collecting localities for the specimens of *Anolis duellmani* we examined.

Table 2. Specimen number, collecting date, SVL, supposed maturity state of follicles, and the number and length number of follicles in six females of *Anolis duellmani*. We did not measure previtellogenic follicles.

Museum Specimen Numbers	Collecting Date	SVL (mm)	Maturity State of Follicles	Number of Follicles	Length of Follicles (mm)
MZFC 10599	27 June 1998	33.86	Pitellogenic Previtellogenic	1 6	3
MZFC 10601	27 June 1998	38.89	Vitellogenic Previtellogenic	1 2	4
MZFC 28748	23 February 2013	37.37	Egg	2	10
MZFC 28751	14 March 2005	32.94	Egg Vitelogenic	1 1	8 4
MZFC 28752	15 March 2005	40.59	Egg	2	7–10
MZFC 28753	15 March 2005	37.2	Egg	1	8

DISCUSSION

We found *Anolis duellmani* to show variation in some of the diagnostic character states, as previously reported. Despite this variation, the diagnostic characters used for *A. duellmani* continue to effectively separate this species from all other Mexican anoles. The most similar species, *A. pygmaeus*, differs from *A. duellmani* by the presence of rather flat and feebly keeled head scales (vs. distinctively keeled head scales in *A. duellmani*) and a pale red dewlap (vs. a Pale Purple, Color 223, dewlap in *A. duellmani*). Additionally, these species appear to be allopatric. *Anolis pygmaeus*, however, was described by Álvarez del Toro and Smith (1956) on the basis of a single specimen from El Ocote, Chiapas, and recently was collected in the Los Chimalapas region of northeastern Oaxaca (L. Canseco-Márquez, pers. comm.), which is not far (ca. 190 km) from the Los Tuxtlas region. Furthermore, preliminary molecular

phylogenetic analyses reveal a close relationship between both species (A. Nieto-Montes de Oca, S. Poe, pers. comm.). *Anolis duellmani* apparently is distributed at moderately high elevations within Los Tuxtlas. Accordingly, the populations from Volcán San Martín and Sierra de Santa Marta are isolated. Urbina-Cardona et al. (2006) reported two specimens of anole from an elevation between 30 and 275 m, which they referred to as "*Anolis* cf. *duellmani*." Conversely, *A. pygmaeus* has been reported from an elevation of 600 m (Álvarez del Toro and Smith, 1956). If the specimens reported by Urbina-Cardona et al. (2006) represent *A. duellmani*, then the existence of intermediate populations between Los Chimalapas and Los Tuxtlas is likely. The apparent allopatry could correspond to deficient sampling or may be due to habitat loss. A study of variation in *A. pygmaeus* and fieldwork in distributional gaps between the known ranges of both species hopefully will clarify this issue.

Anolis duellmani shows most of the diagnostic characters of the *schiedii* group as defined by Nieto-Montes de Oca (1994), even though he decided not to include this species in the group. He defined the *schiedii* group by the following set of characteristics: 23 or fewer presacral vertebrae (we did not score this character in *A. duellmani*); ventral scales smooth or faintly keeled (keels usually more pronounced on chest and sides of belly, especially in females); numerous enlarged supraoculars (about 15) arranged in three or more longitudinal rows on each side; supraorbital semicircles and largest suproculars in contact or separated by one circumorbital row usually including some moderately enlarged scales, and minute dorsals. *Anolis duellmani* differs from this definition because distinctly keeled ventrals are present in some individuals, and the median rows of dorsals are enlarged in all the specimens examined. The first condition also is found in *A. cuprinus*, which Nieto-Montes de Oca (1994) included in the *schiedii* group. Therefore, we tentatively agree with the previous assignment of *A. duellmani* to the *schiedii* group. Hopefully, future molecular analyses will help to confidently infer the position of *A. duellmani*.

The absence of other anole species (except for *A. sericeus*) in the same microhabitat as *A. duellmani* suggests that this species might be a strong competitor. Two distantly related species (A. Nieto-Montes de Oca, S. Poe, pers. comm.) in the Los Tuxtlas region share similar habits with *A. duellmani*: *A. tropidonotus* and *A. uniformis*. We noted that the southwestern slopes of the volcanoes in the Los Tuxtlas region are not as wet and humid as those on the coastal sides. *Anolis tropidonotus* and *A. uniformis* might prefer the wetter, more humid forest in the coastal region. Additional surveys in the area might determine whether *A. duellmani* can be found in sympatry with either of those species, which are remarkably similar in appearance and habitat preference.

Anolis duellmani might be sensitive to habitat modification, since individuals only were collected in relatively well preserved forest patches. Urbina-Cardona et al. (2006) reported "*Anolis* cf. *duellmani*" from forest-edge and forest interior habitats, but not from pasture (their observations, however, were based on only two specimens). The creation of private reserves by the villagers of the Los Tuxtlas region can have a critical impact on this situation (Arroyo-Rodríguez et al., 2009). Actions must be taken, as *A. duellmani* and other species from Los Tuxtlas may depend on these small forest patches for their survival.

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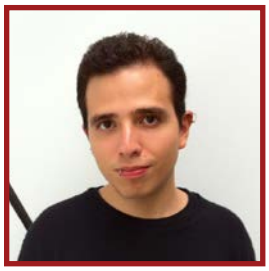
Appendix 1. Specimens examined.

Anolis duellmani: MEXICO: VERACRUZ: "Primero de Mayo" Ranch, about 12.3 km ENE Tapalapan, SW slope of Volcán San Martín, 18.54855° N, 95.2363° W (MZFC 10458–10466, 10598–10601); between Tapalapan and Madero, SW slope of Volcán San Martín, 18.54855° N, 95.2363° W (MZFC 10593); "Primero de Mayo" area, end of trail from Tatalpan to Volcán San Martín, near town of Madero, SW slope, 18.54855° N, 95.2363° W (MZFC 10632–10634, 10636–10637, 10639); SW slope of Volcán San Martín, 18.5358° N, 95.2363° W (MZFC 10575); along road to San Martín, NE of San Andres Tuxtla, 18.51979° N, 95.16216° W (MZFC 28744–28746); trail along road NE from San Andres Tuxtla, 18.52274° N, 95.15539° W (MZFC 28747–28750); Volcán San Martín, Los Tuxtlas, 18.56667° N, 95.2° W (MZFC 28751); El Bastonal, Volcán Santa Marta, Los Tuxtlas (MZFC 28752–28753).



Carlos J. Pavón-Vázquez is a Mexican herpetologist interested in the systematics, biogeography, population genetics, and evolutionary ecology of the Mexican herpetofauna. Born in Mexico City, he obtained a Bachelor of Science degree in 2013 at the Universidad Nacional Autónoma de México, where he has taught classes in systematics and currently is involved in a Master's degree program. His primary focus is in studying the systematics of the squamate genera *Anolis*, *Geophis*, and *Plestiodon*; his work with *Geophis* has resulted in the description of two new species from central Mexico.

Israel Solano-Zavaleta is a herpetologist born in Mexico City, who is interested in the systematics, ecology, natural history, geographic distribution, and conservation of amphibians and reptiles in Mexico and Latin America. Israel currently is a Ph.D. student at the Universidad Nacional Autónoma de México, where he conducts research primarily on the species limits and systematics of the lizard genera *Abronia* and *Mesaspis*. To date, he has authored or co-authored 15 peer-reviewed scientific publications.

Levi N. Gray grew up on a ranch in northern California, where he gained an appreciation for the local herpetofauna. After receiving a Bachelor of Science degree at the University of California, Davis, for several years Levi was a lab technician in Dr. Bradley Shaffer's lab, where he worked primarily on the California Tiger Salamander (*Ambystoma californiense*). Currently a Ph.D. student in Dr. Steven Poe's lab at the University of New Mexico, Levi's research focuses on speciation, systematics, and biogeography. Although generally interested in amphibians and reptiles, his dissertation work focuses on anoline lizards in Mexico, with an emphasis on the state of Chiapas.