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Rapid Communication

First verified record of *Anolis sagrei* Cocteau in Duméril and Bibron, 1837 from the central Pacific coast of Mexico

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Abstract

The occurrence of the invasive Brown anole, *Anolis sagrei* from the Pacific coast of Mexico is confirmed based on squamation and the use of morphological characters. A PCA was performed to explore the morphological differences between the invasive anole and the native Clouded anole *Anolis nebulosus*. Some of the potential implications for dry tropical ecosystems and native anoles are discussed.

Key words: Anole, distribution, invasive species, Jalisco, morphology, taxonomy

Introduction

The Brown anole *Anolis sagrei* Cocteau in Duméril and Bibron, 1837 is a lizard species native to Cuba, the Bahamas, and some adjacent islands in the Caribbean (Schwartz and Thomas 1975). This species has invaded parts of the Americas and several islands in the Pacific region such as Hawaii, Singapore, and recently Taiwan (Norval et al. 2002; Mautz and Shaffer 2011; Tan and Lim 2012). In the Neotropics, most records of *A. sagrei* are from the Gulf of Mexico and Caribbean lowlands from Tamaulipas, Mexico, to Central America. Garman (1887) first reported the occurrence of the Brown anole outside its native distribution more than 130 years ago in Florida; since then, the reported localities of the Brown anole have increased; however, there are no reported occurrences on the Pacific side of North America. Recently, Amador et al. (2017) reported the occurrence of the Brown anole in the city of Guayaquil, Ecuador, which suggests that this species may be colonizing not only South America but also the Pacific region, and that it will spread more widely in the future. The occurrence of *A. sagrei* on the central Pacific coast of Mexico is verified herein, based on

Figure 1. Records (square = first record on the Pacific coast, circles = previous records) of *Anolis sagrei* in Mexico.

squamation and a morphometric analysis. Some of the ecological implications for native lizards are also discussed.

Materials and methods

Five anoles were collected on 4 May and 11 May 2017 on Cuale River Island (20°36′21.10″N; 105°14′10.90″W; Datum: WGS84; elev. < 5 m a.s.l.; Figure 1), Puerto Vallarta, Jalisco, Mexico. Anoles were captured at less than 1.5 m above the ground near a water source (Figure 2). We confirmed the identity of the five individuals from Cuale River Island (hereafter referred to as Cuale) as Brown anoles (*A. sagrei*) based on external morphological diagnostic traits. We compared the external morphology of the native species *Anolis nebulosus* (Wiegmann, 1834) with that of *A. sagrei*. Eleven individuals of *Anolis nebulosus* were measured. These specimens had been captured in Bahía de Banderas region in previous years, preserved and stored in the Centro Universitario de la Costa, Universidad de Guadalajara. Twenty-six *A. sagrei* were captured in the Banco Chinchorro Biosphere Reserve and measured by Charruau et al. (2015), who provided the morphological data with which to conduct the morphological analyses in this study. The specimens of *A. sagrei* reported in this study are deposited in the Chamela Biological Collection (EBCH), Instituto de Biología, Universidad Nacional Autónoma de México.

All individuals captured were sexed using external sex-specific characteristics (size of the dewlap, mainly). In general, five morphological

Figure 2. *Anolis sagrei* perched on a palm trunk on Cuale River Island, Puerto Vallarta. Photograph by Francis N. Pazos Nava.

traits were measured (Williams 1995): snout-vent length (SVL), from the tip of the snout to the anterior margin of cloaca; head length (HL), from the tip of the snout to the anterior margin of the ear; head width (HW), measured at the widest point of the head; humerus length (HuL), from the point at which the forelimb enters the body to the elbow; and femur length (FL), from the insertion in the body wall to the knee. All measurements were made using digital calipers to the nearest 0.1 mm; means ± standard deviations are provided. To remove body size effects from those of morphological traits, regressions were run on each morphological trait against snout-ventral length (SVL), and residuals for each trait were used in subsequent analyses. Principal components analyses (PCA) were done to explore the structure of the morphometric data. In addition, the derived discriminant functions using SVL and HW/HL ratio were used to quantify the percentages of taxon assignment.

Results and discussion

Of the five individuals captured on 4 May 2017 at Cuale, three were female and two male. The SVL of females ranged from 43.0 to 46.9 mm, with a mean (± SD) of 44.5 ± 2.1 mm. HL ranged from 13.2 to 13.6 mm, with a mean of 13.4 ± 0.2 mm. HW ranged from 7.0 to 7.8 mm, with a mean of 7.5 ± 0.5 mm. HuL ranged from 8.0 to 8.2 mm, with a mean of 8.2 ± 0.1 mm, and FL ranged from 10.7 to 11.9 mm, with a mean of 11.8 ± 1.1 mm. One male had a small dewlap with colors ranging from yellow-orange to orange-red with a yellow edge (SVL: 64.2 mm, HL: 17.6 mm, HW: 10.4 mm, HuL: 9.9 mm, FL: 14.1 mm; Figure 3), and also had a crest along the top of the body. The other male had a bigger dewlap with similar colors but with

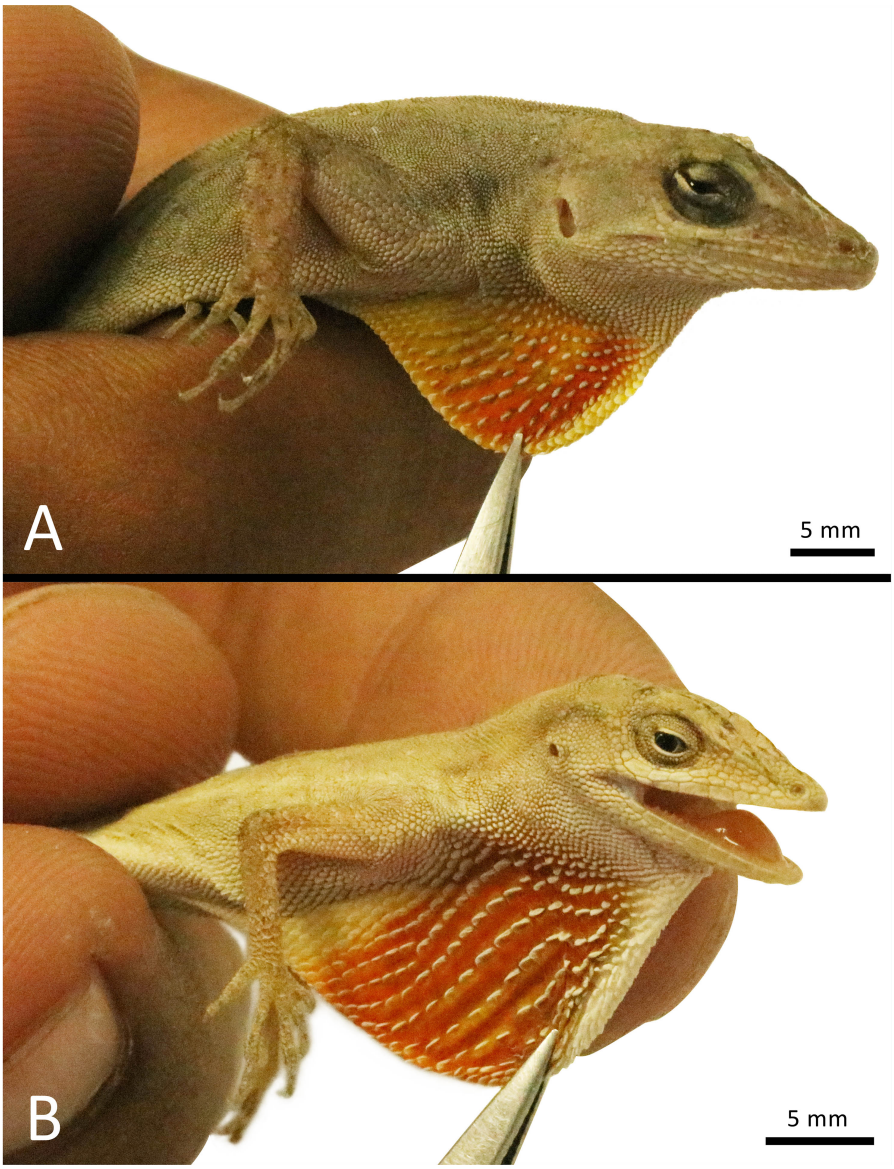

Figure 3. Comparison of dewlap folds between male specimens of *Anolis sagrei* (A) and *A. nebulosus* (B) from Cuale River Island. Specimens collected on 4 May 2017. Photographs by Armando H. Escobedo Galván.

dark rows (SVL: 45.1 mm, HL: 12.0 mm, HW: 6.9 mm, HuL: 7.0 mm, FL: 9.1 mm). Females had a dorsal pattern with diamonds and/or a stripe running down their back.

During the current study, the first challenge was to correctly identify the Brown anole *Anolis sagrei*. Therefore, to confirm the occurrence of non-native anoles in Puerto Vallarta, a principal components analysis was performed showing a separation between *Anolis sagrei* and *A. nebulosus* (Figure 4). The first two components explain 98.3% of the variance in morphological traits. Snout-ventral length had the highest influence on the first component, while HuL and FL had a significant influence on the second component. The results of a derived discriminant functional analysis (SVL and HW/HL ratio) show that at least one individual from Cuale could be correctly attributed to *A. sagrei* (Figure 4).

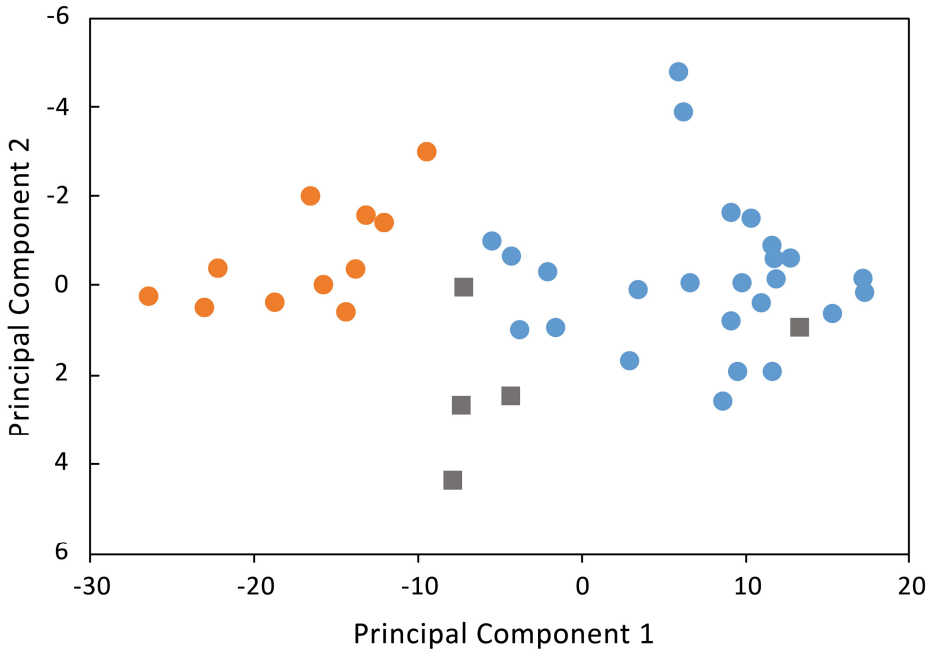

Figure 4. Principal components scores derived from the structure of the morphological data for *Anolis nebulosus* (orange dots = data from this study) and *Anolis sagrei* (blue dots = data obtained from Charruau et al. 2015; gray squares = data from this study).

Recently, updated information regarding the herpetofauna checklist from different states on the Pacific side of Mexico became available, yet for none of the localities was the presence of Brown anoles recorded (Oaxaca, Mata-Silva et al. 2015; Chiapas, Johnson et al. 2015; Nayarit, Woolrich-Piña et al. 2016; Jalisco, Cruz-Sáenz et al. 2017). However, iNaturalist.org has photographic records of the invasive anole for the Pacific coast of Jalisco, Oaxaca, Guerrero, and Chiapas. Therefore, this is the first verified record of *A. sagrei* in the Mexican Pacific region, based on morphometric analysis.

The main hypothesis about the wide colonization of *Anolis sagrei* suggests that this species is a human commensal that is frequently transported intentionally or unintentionally to new localities, potentially due to the nursery trade or potted landscaping vegetation (Kraus 2009; Granatosky and Krysko 2013). Acosta-Morán et al. (2016) determined that 36 of the 63 tree species in the urban parks of Puerto Vallarta are non-native, suggesting the frequent transportation of ornamental plants from different origins and via different pathways (e.g., airplanes, motor vehicles, maritime cargo ships). Granatosky and Krysko (2013) recorded the presence of an *A. sagrei* in North Carolina that had been found on an ornamental plant transported by motor vehicle from Miami, Florida. We suggest that in Puerto Vallarta *A. sagrei* was introduced by cargo ships because if the species had been transported by land, it probably would have been reported previously in other mainland areas of Mexico. To our knowledge, the species is only present in the coastal regions of the Yucatán Peninsula and Gulf of Mexico (Toscano-Flores and Calzada-Arciniega 2015; Charruau et al. 2015). Determining the exact site of origin for the Brown

anole captured in Puerto Vallarta would be difficult. An mtDNA analysis showed that the established populations of *A. sagrei* in Florida are composed of five different native range sources (Kolbe et al. 2004, 2007a). In addition, non-native populations of *A. sagrei* have shown genetic and phenotypic plasticity compared with native range populations. Introduced populations have increased the haplotype diversity, and some changes in morphological traits have even been observed (Kolbe et al. 2007b). The adaptive benefits of genetic and phenotypic plasticity of *A. sagrei* can be explained primarily by their rapid and successful establishment in new environmental conditions (e.g, Norval et al. 2014). The establishment of non-native ranges of *A. sagrei* populations has resulted in the displacement of native anoles such as the Green anole *A. carolinensis* Voigt, 1832 in the southeastern United States (Gerber 1991; Campbell 2000) and the Silky anole *A. sericeus* Hallowell, 1856 in the lowlands of the Gulf of Mexico (Vogt et al. 1997). Additionally, negative effects on the trophic network have been reported, such as the alteration of the community structure of ants (Huag et al. 2008a, b) and saurophagy on both native and non-native vertebrates (Norval 2007). We suggest that, in the future, populations of *A. nebulosus* might be impacted by the presence of the Brown anole. Future work should address how the presence of *A. sagrei* influences not only the phenological but also the behavioral patterns of *A. nebulosus*. This information would expand our understanding of the ecological consequences of invasive species in the Pacific coastal ecosystems, and particularly in the dry forest regions.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Georeferenced records of *Anolis sagrei*.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2019/Supplements/BIR_2019_Pazos-Nava_etal_Table_S1.xlsx