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New state record and potential distribution of the snake *Sibon nebulatus* (Dipsadidae) from Mexico

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Abstract.—We report the northernmost Atlantic Coast record of the Cloudy Snail Sucker (*Sibon nebulatus*) from the state of Hidalgo, at a straight-line distance of about 185-km from the nearest historical locality in Sierra Norte de Puebla, Mexico. We assess the potential distribution of this species and compare morphological characteristics of specimens from Mexico and Central America. No significant morphometric or meristic differences were found. A species distribution model suggests that *S. nebulatus* is widely distributed on both coasts of Mexico, with a high probability of occurrence at a wider range of latitudes than current records indicate.

Resumen.—Reportamos el registro más norteño para la vertiente del Atlántico de la Serpiente Caracolera Jaspeada (*Sibon nebulatus*) en el estado de Hidalgo, el cual se encuentra approximadamente a 185 km de distancia en línea recta de la localidad histórica más cercana en la Sierra Norte de Puebla, México. Evaluamos la distribución potencial de esta especie y comparamos características morfológicas con especímenes de México y América Central, sin encontrar diferencias morfométricas o merísticas significativas. El modelo de distribución de especies sugiere que *S. nebulatus* está ampliamente distribuida en ambas costas de México, con una alta probabilidad de ocurrencia en latitudes mayores de la que indican los registros actuales.

Sibon Fitzinger (1826) is a Neotropical genus of snakes comprising 16 species specialized for eating terrestrial gastropods (Rovito et al. 2012, Uetz and Hosek 2016). *Sibon nebulatus* (Linnaeus 1758) is the most widely distributed species and the northernmost representative of the genus. This species has been reported at low and middle elevations (0–1690 m asl) from Mexico to Ecuador and Brazil (Lee 2000, Lotzkat et al. 2012). In Mexico, *S. nebulatus* occurs from Nayarit to Chiapas on the Pacific versant and from the Sierra Norte of Puebla to Quintana Roo on the Atlantic versant (Lee 2000, CONABIO, 2011).

Herein, we document 2 new records of *S. nebulatus* for the state of Hidalgo. Additionally, we construct a species distribution model to estimate the potential distribution of this species within Mexico, and we compare morphometric and lepidotic characteristics of specimens from Mexico and Central America.

During monitoring of amphibians and reptiles in the municipality of Tepehuacán de Guerrero, Hidalgo, México, on 21 September 2016, we found 2 specimens of *S. nebulatus* (Fig. 1A, 1B) on the road between the towns of Tamala and San Simón. One was an active adult male encountered at 22:40 (21°00′39.87″N, 98°48′08.37″W; elevation 330 m). The second was an adult female encountered dead on the road (DOR) at 23:15 (21°00′44.69″N, 98°49′21.40″W; elevation 392 m). The vegetation type in both locations is tropical semideciduous forest. The DOR specimen was collected under scientific permit SEMARNAT/SGPA/DGVS/04287/16. This individual was fixed in 10% formaldehyde, stored in 70% ethanol (Casas-Andreu et al. 1991), and catalogued in the Collection of Amphibians and Reptiles at the Centro de Investigaciones Biológicas (CIB), Universidad Autónoma del Estado de Hildago (UAEH) (CIB-5081). Both specimens were photographed and their morphological features and meristic counts recorded (Savage 1973, Rovito et al. 2012).

Peters (1960) proposed 4 subspecies for *S. nebulatus* based on scutellation and distri-

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Fig. 1. *Sibon nebulatus* from Tepehuacán de Guerrero, Hidalgo: **A,** male (uncollected); **B,** female (CIB-5081).

bution. Kofron (1990) did not elevate these taxa to species level due to insufficient morphological and genetic evidence. Sheehy (2012) identified 2 well-defined genetic groups—"Centroamerica" (Guatemala, Honduras, Mexico, and Nicaragua) and "Sudamerica" (Colombia, Ecuador, Panamá, and Trinidad and Tobago)—using molecular phylogenetic techniques and including samples obtained from throughout most of the distribution. Smith and Taylor (1950) restricted the type locality of *S. nebulatus* to Veracruz, Mexico, such that, should their restriction be accepted and the 2 lineages of Sheehy (2012) be recognized, the northern populations ("Centroamerica") would retain the original name.

Historical records for Mexico show that *S. nebulatus* has a disjunct distribution across the Pacific and Atlantic versants. Species distribution models (SDMs) allow us to make predictions about the potential distributional extent of *S. nebulatus,* which then permit a more accurate and efficient assessment of its actual distribution. The current peripheral records of *S. nebulatus* are important in delimiting the species' complete range, and an SDM based on fundamental niche modeling (Peterson et al. 2016) can help identify cryptic species by indicating climatic barriers that may limit gene flow between populations (Wiens and Graham 2005, Elith et al. 2010).

The SDM was constructed based on our new records and on 163 historical records obtained from public databases (CONABIO [www.gob.mx/conabio], GBIF [www.gbif.net], VertNet [www.vertnet.org]) and published records (Peters 1960, Lee 2000, Peréz-Higareda et al. 2007, Sheehy 2012). We employed a minimum convex polygon within the distribution area, using the most extreme records to select environmental variables to use in the SDM. One-thousand background points were randomly located within the polygon. From these points, data on 19 environmental variables at 30 arcseg (1 km) were obtained from WorldClim (2016) using ArcMap v. 10.1 (ESRI 2012). Subsequently, a bivariate correlations analysis was performed using the software SPSS v. 18.0 (SPSS Inc. 2009) to select environmental variables with $R^2 = 0.7$ ($P = 0.05$; Elith et al. 2010). Finally, 9 environmental variables were selected to build the SDM: 6 related to temperature (average annual temperature, maximum temperature of the warmest month, average temperature of the fourth wettest month, average temperature of the fourth driest month, average temperature of the fourth hottest month, average temperature of the fourth coolest month) and 3 related to humidity (annual precipitation, precipitation of the wettest month, and seasonal precipitation). We calibrated the model following methods of Muscarella et al. (2014) using the package ENMeval in program R v. 3.3.1 (R Core Team 2016). This step is fundamental because data sets that have sampling bias need an adequate calibration of the model to avoid under- or overestimates (Muscarella et al. 2014). The SDM was constructed with the program MaxEnt v. 3.3.3 (Phillips et al. 2004, 2011) by using the values obtained with the calibration ($\Delta AIC_c = 0$; characteristics = L,Q; multiple regularization = 1) and considering 25% of the points for the randomization test

TABLE 1. Morphological data of specimens examined in this study and those reported in the literature: Veracruz, México (Pérez-Higareda et al. 2007); Panama (Lotzkat et al. 2012); Costa Rica (Solórzano 2012). A hyphenated pair of numbers indicates the number of scales on each side of the head (right-left). ND = no data.

	Specimens				
Characteristics	Uncollected specimen	CIB-5081	Veracruz, Mexico, *n* = 2	Panama, *n* = 7	Costa Rica, *n* = 15
Loreals	1-1	1-1	1-1	ND	ND
Preoculars	1	1	ND	ND	ND
Postoculars	2-3	2-2	2-2	1-2	2-2
Supralabials	7-7	7-7	7-7	7-8	7-8
Supralabials in contact with eye	2	2	2	2	2
Infralabials	10-10	9-9	8-8	8-9	8-10
First pair of infralabials in contact	Yes	Yes	Yes	Yes	Yes
Temporals	1+2	1+2	1+2	1+2	1+2
Pairs of chin shields	3	2	4	3	3
Scale rows	16-15-15	15-15-15	15-15-15	15-15-15	15-15-15
Vertebral scales	175	179	ND	ND	ND
Ventral scales	175	180	172-174	184-195 males, 179-188 females	159-193 (unidentified sex)
Caudal scales	74	62	ND	87-94 males, 80-93 females	70-114 (unidentified sex)
Dorsal patches	44	38	>30	ND	ND
Ventral patches	32	32	>15	ND	ND
Snout–vent length (mm)	498	491	>500	267-612 (unidentified sex)	ND
Tail length (mm)	178	173	25%	87-197 (unidentified sex)	ND

(Phillips and Dudik 2008). Fifteen replicates were made with these values (Becerra-López et al. 2014). We selected the model with the greatest area under the curve (AUC). In generating the presence-absence map, the cutoff point of distribution was determined according to the value obtained in the maximum sensitivity test.

The record of *S. nebulatus* (Linnaeus 1758) for the state of Hidalgo increases the number of genera and species of snakes in this state to 45 and 88, respectively (Lemos-Espinal and Smith 2015, Fernández-Badillo et al. 2017). These new records are 185 km from the nearest historical locality near Yaonáhuac, Sierra Norte of Puebla (García-Vázquez et al. 2009, Canseco-Marquez personal communication). The Hidalgo records represent the most northern distribution of the species on the Atlantic versant. Both specimens are similar in their morphological characteristics and color patterns to other specimens from Mexico, Panamá, and Costa Rica (Lotzkat et al. 2012, Solórzano 2012; Table 1). These data corroborate molecular studies that suggest that populations from Mexico and Central America form a monophyletic group that could be genetically different from populations in South America (Sheehy 2012). However, an exhaustive review of the genetic and external morphology is needed, along with an assessment of hemipenial characteristics of populations assigned to *S. nebulatus* (Linnaeus 1758), to reach an adequate conclusion about whether this taxon represents more than a single species.

In the SDM for *S. nebulatus*, mean annual precipitation showed the greatest contribution (49.8%), followed by temperature of the fourth coldest month (18.1%). The model showed an AUC of 0.802. On the Pacific Coast, a high percentage of predicted suitability (66.3%–100%) was observed for the species' presence from southern Sinaloa to southern Chiapas (Fig. 2); while the Atlantic coast showed 20%–100% predicted suitability from the southeastern of Tamaulipas to west of Tabasco. On the Yucatán Peninsula, there are areas of high predicted suitability in the northwestern region, but the presence of the species in parts of the central and north part of the peninsula (Fig. 2) is doubtful because of unsuitable environmental conditions (Lee 2000).

Based on our SDM, it is highly probable that *S. nebulata* occurs at higher latitudes in

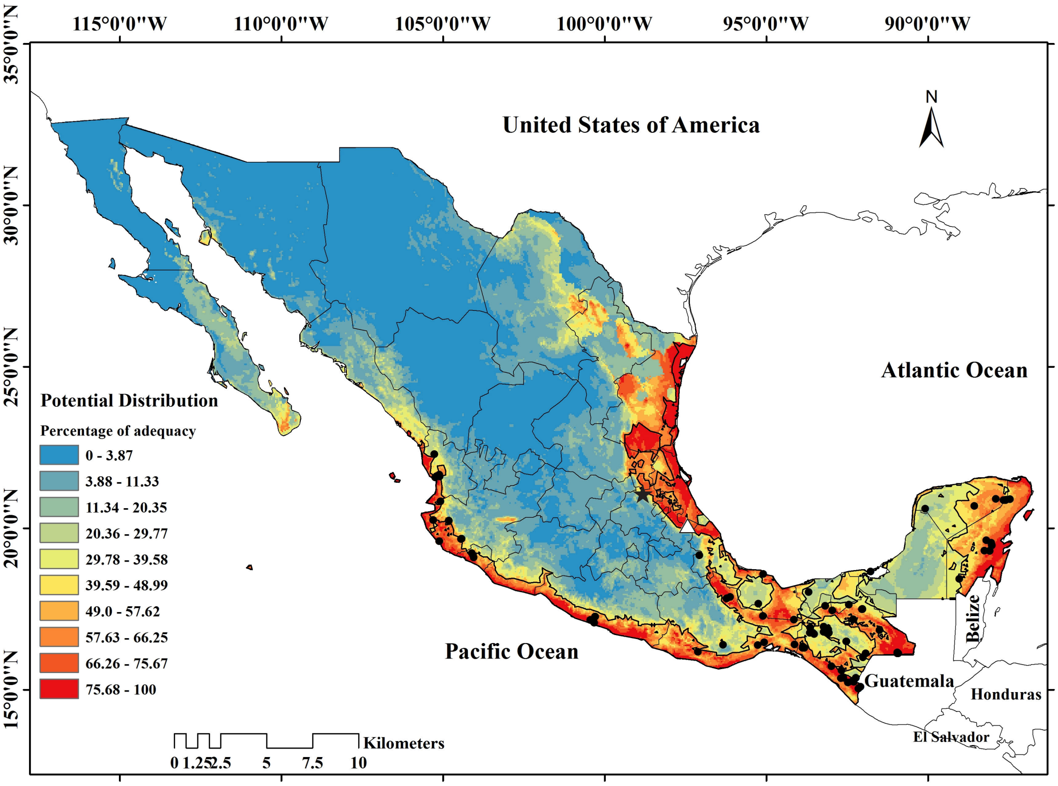

Fig. 2. Distribution model of *Sibon nebulatus* in Mexico. Black star = new records for the state of Hidalgo, Mexico; white triangle = nearest historical locality (Yaonáhuac, Sierra Norte de Puebla); black dots = historical records. Potential distribution is expressed as a heat map, with warm colors representing an increasing percentage of suitability for the species' presence; a thin, dark black line outlines the potential distribution of the species (maximum sensitivity test = 0.408).

the states of San Luis Potosí and Tamaulipas. The SDM showed that within the Mexican Republic there is a probability of occurrence similar to those observed for our site records. Possibly, in this region, the canyons and basins provide an environment similar to the coasts (Morrone 2005), and these physical features may act as corridors into the interior of the country. The paucity of records of *S. nebulatus* may be a reflection that the appropriate climatic conditions are found only in a relatively small area on the Atlantic slope. Additionally, the nocturnal and cryptic habits of this species reduce the possibility of encountering it, as observed and reported in other species from tropical environments of central Mexico (Monroy-Vilchis et al. 2014). According to the MaxEnt analysis, mean annual precipitation is an important factor (49.8%) in the distribution of this species. Mean annual precipitation may be closely linked with the snake's prey distribution, because *S. nebulatus* has a specialized diet of terrestrial gastropods (Kofron 1990, Lee 2000), certain species of which may be more abundant or restricted to places with high humidity. In conclusion, SDMs that include recent peripheral records can serve to assess distributions that have conservation implications (Liu et al. 2016).

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LITERATURE CITED

BECERRA-LÓPEZ, J.L., U. ROMERO-MÉNDEZ, J.D. ANADÓN-HERRERA, AND G. GARCÍA-DE LA PEÑA. 2014. Modelo de nicho potencial de las madrigueras de *Gopherus* *flavomarginatus* en la Reserva de la Biosfera de Mapimí. Revista Mexicana de Biodiversidad 85: 523–531.

CASAS-ANDREU, G., G. VALENZUELA-LÓPEZ, AND A. RAMÍREZ-BAUTISTA. 1991. Cómo hacer una colección de anfibios y reptiles. Cuadernos del Instituto de Biología 10. Universidad Nacional Autónoma de México, México.

[CONABIO] COMISIÓN NACIONAL PARA EL CONOCIMIENTO Y USO DE LA BIODIVERSIDAD. 2011. La biodiversidad de Puebla: Estudio de estado. México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Gobierno del Estado de Puebla, Benemérita Universidad Autónoma de Puebla, México.

ELITH, J., M. KEARNEY, AND S. PHILLIPS. 2010. The art of modelling range-shifting species. Methods in Ecology and Evolution 1:330–342.

ESRI. 2012. ArcGIS, version 10.1. Esri, Redlands, CA; [accessed June 2012]. www.esri.com

FERNÁNDEZ-BADILLO, L., S.Y. VALDEZ-RENTERÍA, C.R. OLVERA-OLVERA, G. SÁNCHEZ-MARTÍNEZ, N.L. MANRÍQUEZ-MORÁN, AND I. GOYENECHEA. 2017. The snake *Lampropeltis annulata*, Kennicott, 1861, in Hidalgo, Mexico. Mesoamerican Herpetology 4:502–506.

FITZINGER, L.J.F.J. 1826. Neue Classification der Reptilien nach ihren Naturlichen Verwandtschaften: nebst einer Verwandtschafts-tafel und einem Verzeichnisse der Reptilien-Sammlung des K. K. zoologischen Museum's zu Wien. J.G. Heubner, Vienna.

GARCÍA-VÁZQUEZ, U.O., L. CANSECO-MÁRQUEZ, G. GUTIÉRREZ-MAYEN, AND M. TRUJANO-ORTEGA. 2009. Actualización del conocimiento de la fauna herpetológica en el estado de Puebla, México. Boletín de la Sociedad Herpetológica Mexicana 17:12–36.

KOFRON, C.P. 1990. Systematics of Neotropical gastropod-eating snakes: the *dimidiatus* group of the genus *Sibon,* with comments on the *nebulatus* group. Amphibia-Reptilia 11:207–223.

LEE, J.G. 2000. A field guide to the amphibians and reptiles of the Maya World. Cornell University Press, Ithaca, NY.

LEMOS-ESPINAL, J.A., AND G.R. SMITH. 2015. Amphibians and reptiles of the state of Hidalgo, Mexico. Check List 11(3):1642.

LINNAEUS, C. 1758. Systema naturae. Reginum anmale. Tomus I. Editio decima, reformata. Laurentii Salvii, Holmiae, Sweden.

LIU, X., B. PETITPIERRE, O. BROENNIMANN, X. LI, A. GUISAN, AND Y. LI. 2016. Realized climatic niches are conserved along maximum temperatures among herpetofaunal invaders. Journal of Biogeography 2016:1–11.

LOTZKAT, S., A. HERTZ, AND G. KÖHLER. 2012. A new species of *Sibon* (Squamata: Colubroidea: Dipsadidae) from the Cordillera Central of western Panama, with comments on other species of the genus in the area. Zootaxa 3485:26–40.

MONROY-VILCHIS, O., H. DOMÍNGUEZ-VEGA, AND F. URBINA. 2014. Primer registro de *Coleonyx elegans nemoralis* (Lacertilia: Eublepharidae) para el Estado de México, México. Revista Mexicana de Biodiversidad 85:318–321.

MORRONE, J.J. 2005. Hacia una síntesis biogeográfica de México. Revista Mexicana de Biodiversidad 76: 207–252.

MUSCARELLA, R., P.J. GALANTE, M. SOLEY-GUARDIA, R.A. BORIA, J.M. KASS, M. URIARTE, AND R.P. ANDERSON. 2014. ENMeval: an R package for conducting spatially independient evaluations and estimating optimal model complexity for MaxEnt ecological niche models. Methods in Ecology and Evolution 5:1198–1205.

PÉREZ-HIGAREDA, G., M.A. LÓPEZ-LUNA, AND M.A. SMITH. 2007. Serpientes de la región de Los Tuxtlas, Veracruz, México. Guía de identificación ilustrada. Instituto de Biología, Universidad Nacional Autónoma de México, México.

PETERS, J.A. 1960. The snakes of the subfamily Dipsadinae. Miscellaneous Publications, Museum of Zoology, University of Michigan 114:1–224.

PETERSON, A.T., M. PAPES, AND J. SOBERÓN. 2016. Mechanistic and correlative models of ecological niches. European Journal of Ecology 1:28–38.

PHILLIPS, S.J., AND M. DUDIK. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 31:161–175.

PHILLIPS, S.J., M. DUDIK, AND R.E. SCHAPIRE. 2004. A maximum entropy approach to species distribution modeling. *In:* Proceedings of the 21st International Conference on Machine Learning. ACM Press, New York, NY.

PHILLIPS, S.J., M. DUDIK, AND R.E. SCHAPIRE. 2011. Maxent software for modeling species niches and distributions. Version 3.3.3 [released October 2011]. https://biodiversityinformatics, amnh.org/open_source/maxent

R CORE TEAM. 2016. R: a language and environment for statistical computing. Version 3.3.1. R Foundation for Statistical Computing, Vienna, Austria; [accessed March 2017]. www.R-project.org

ROVITO, S.M., T.J. PAPENFUSS, AND C.R. VAZQUEZ-ALMAZAN. 2012. A new species of *Sibon* (Squamata: Colubridae) from the mountains of eastern Guatemala. Zootaxa 3266:62–68.

SAVAGE, J.M. 1973. A revised terminology for plates in the loreal region of snakes. British Journal of Herpetology 5:360–362.

SHEEHY, C.M. 2012. Phylogenetic relationships and feeding behavior of Neotropical snail-eating snakes (Dipsadinae, Dipsadini). Doctoral dissertation, University of Texas at Arlington, Arlington, TX.

SMITH, H.M., AND E.H. TAYLOR. 1950. Type localities of Mexican reptiles and amphibians. University of Kansas Science Bulletin 33:313–380.

SOLÓRZANO, A. 2012. Una nueva especie de serpiente del género *Sibon* (Serpentes: Colubridae) de la vertiente del Caribe de Costa Rica. Revista de Biología Tropical 49:1111–1120.

SPSS INC. 2009. PASW Statistics for Windows. Version 18.0. Chicago, IL.

UETZ, P., AND J. HOSEK. 2016. The reptile database. [Accessed 8 April 2017]. www.reptile-database.org

WIENS, J.J., AND C.H. GRAHAM. 2005. Niche conservatism: integrating evolution, ecology and conservation biology. Annual Review of Ecology, Evolution, and Systematics 36:519–539.

WORLDCLIM. 2016. WorldClim – Global Climate Data: free climate data for ecological modeling and GIS. Version 1. www.worldclim.org

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