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UN LLAMADO NEOTROPICAL: REPOSITORIOS ACÚSTICOS DE LA HERPETOLOGÍA LATINOAMERICANA

A CALL FOR CALLS: ACOUSTIC REPOSITORIES BASED IN LATIN AMERICA

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Abstract.— In recent decades, the development of new sampling techniques has allowed us to more easily collect novel samples that enrich our knowledge of the specimens we study. In this sense, audiovisual samples, especially acoustic signal recordings, have become an essential part of herpetological research. The correct storage of these specimens is key to strengthening scientific research. However, the vast majority of publicly accessible audiovisual repositories are located in countries of the Global North, which restricts scientific work in Latin countries. The use of local or regional repositories opens the possibility of storing the diversity of scientific samples generated in the region, making them easily accessible to regional researchers and the dissemination of local science. This letter is an urgent call to the herpetological community in Latin America to take three main actions as a community to increase the accessibility, reproducibility and growth of Neotropical amphibian bioacoustic research: 1) researchers should deposit recordings used in published research in national or regional acoustic repositories, 2) publishers and paper reviewers should require authors to provide deposit numbers of all files used in any acoustic research and the correct referencing of the collections used in order to accept manuscripts and, 3) the managements of regional institutions with repositories should ensure that institutional acoustic repositories are strengthened and maintained in the long term.

Keywords.— Anura, bioacoustics, digital repositories

Resumen.— En las últimas décadas, el desarrollo de nuevas técnicas de muestreo nos ha permitido recolectar con mayor facilidad diversas evidencias que enriquecen el conocimiento de los especímenes que estudiamos. En este sentido, las muestras audiovisuales, sobre todo las grabaciones de señales acústicas, se han convertido en parte esencial de la investigación herpetológica. El correcto almacenamiento de estas muestras es clave para fortalecer la investigación científica. Sin embargo, la gran mayoría de repositorios audiovisuales de acceso público se encuentran en países del Norte Global, lo cual puede restringir la labor científica en países latinos.

El uso de repositorios locales o regionales abre la posibilidad de almacenar la diversidad de muestras científicas generadas en la región, haciéndolas fácilmente accesibles a los investigadores regionales y a la divulgación de la ciencia local. Esta carta es un llamado urgente a la comunidad herpetológica en Latinoamérica para que se tomen tres acciones principales como comunidad para aumentar la accesibilidad, reproducibilidad y crecimiento de la investigación bioacústica de anfibios neotropicales: 1) los investigadores deben depositar las grabaciones usadas para investigaciones publicadas en repositorios acústicos nacionales o regionales, 2) las editoriales y revisores de revistas científicas deben exigir a los autores los números de depósito de todos los archivos utilizados en cualquier investigación acústica y la correcta referenciación de las colecciones usadas para poder aceptar los manuscritos y, 3) las directivas de las instituciones regionales con repositorios deben garantizar el fortalecimiento y mantenimiento a largo plazo de los repositorios acústicos institucionales.

Palabras clave.— Anura, bioacústica, repositorios digitales.

Resumo — Nas últimas décadas, o desenvolvimento de novas técnicas de amostragem nos permitiu coletar com mais facilidade diferentes tipos de amostras que enriquecem o conhecimento das espécies estudadas. Nesse sentido, as amostras audiovisuais, principalmente as gravações sonoras, tornaram-se parte essencial da pesquisa herpetológica. O armazenamento e o cuidado correto com esses arquivos são fundamentais para fortalecer a pesquisa científica. No entanto, a grande maioria das coleções audiovisuais de acesso público estão em países do Hemisfério Norte, o que restringe o trabalho científico em países latino-americanos. A utilização e valorização de coleções locais ou regionais abrem a possibilidade de armazenar a diversidade de amostras científicas geradas na região, tornando-as facilmente acessíveis aos pesquisadores regionais e à divulgação da ciência local. Esta carta é um apelo à comunidade herpetológica na América Latina para realizar três ações principais, para aumentar a acessibilidade, reprodutibilidade e crescimento da pesquisa bioacústica em anfíbios e répteis neotropicais: 1) os pesquisadores devem depositar as gravações citadas em pesquisas científicas em coleções sonoras nacionais ou regionais, principalmente naquelas com acesso público; 2) os editores e revisores de revistas científicas devem exigir dos autores os números de tombo/códigos de depósito de todos os arquivos utilizados em qualquer pesquisa acústica e a correta citação das coleções utilizadas, para a aceitação dos manuscritos e; 3) os coordenadores das instituições regionais com coleções bioacústicas devem garantir o reforço e manutenção das coleções nas respectivas instituições, de forma a garantir a acessibilidade de longo prazo a esses arquivos.

Palavras-chave — Anura, bioacústica, repositórios digitais.

Los especímenes depositados en colecciones biológicas convencionales permiten conocer la morfología y otros aspectos del relacionamiento intra e interespecífico, como su condición reproductiva o la presencia de patógenos. Las colecciones científicas, en particular las colecciones públicas de universidades, entidades gubernamentales u organizaciones privadas sin ánimo de lucro, son actores importantes en el papel de conservación del material y disponibilidad para consulta, puesto que promueven la reproducibilidad y accesibilidad de los datos de la investigación, lo cual es esencial para el método científico. De hecho, la importancia de las colecciones de historia natural como una fuente valiosa de datos para todo tipo de investigación biológica ha sido resaltada en las últimas décadas (por ejemplo, Suárez & Tsutsui, 2004; Winker, 2004; Pyke & Ehrlich, 2010; Toledo et al., 2015; Dena et al., 2018; Funk, 2018; Dena et al., 2020). Los especímenes más comunes son las pieles y los ejemplares completos preservados en etanol, sin embargo, algunos rasgos conductuales y ecológicos a menudo no se documentan o no se logran conservar adecuadamente al preservar el ejemplar por sí mismo (Webster, 2017), perdiendo detalles de las interacciones biológicas (Alström & Ranft, 2003; Ranft, 2004; Schindel & Cook, 2018). En este sentido, la investigación biológica incluye la recolección de otro tipo de muestras biológicas, denominadas "especímenes extendidos" (Webster, 2017). Algunas de estas muestras son tangibles como los sus tejidos, diafanizaciones o nidos, mientras otras son digitales como secuencias de ADN, fotografías, videos o audios (Fig. 1).

El sonido juega un papel muy importante en la comunicación tanto intra como interespecífica (Farina, 2014, Acevedo-Charry et al., 2021). La comunicación acústica es uno de los cuatro tipos de comunicación comúnmente usados por los organismos y utiliza señales auditivas de largo y corto alcance, asociados al contexto comunicativo público o privado, respectivamente (Larsen 2020). Se ha documentado el uso de la comunicación acústica en escenarios de forrajeo, defensa de territorio, selección de pareja y cuidado parental, entre otros (Clemens et al., 2017). Las vocalizaciones (e incluso las señales vibratorias no propiamente acústicas, Frommolt et al., 2019; Narins, 2019)

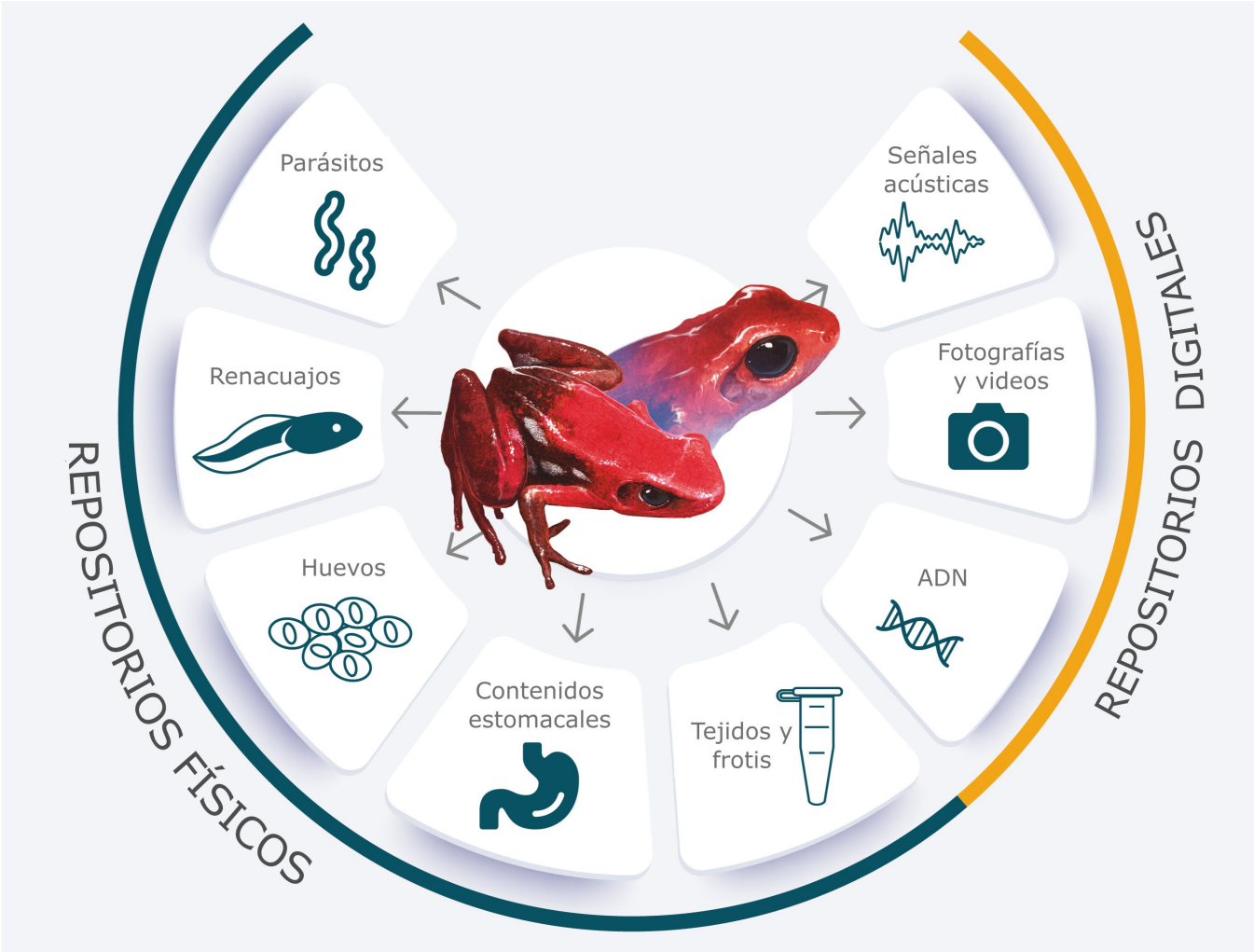

Figure 1. Besides complete specimens, there are diverse elements, known as extended specimens that should be stored in biological collections to ensure the long-term availability of the information. Extended specimens can be physical (like eggs, dry skeletons and diaphaniations, stomachal contents, tissues) and digital (like DNA sequences, pictures, videos and acoustic signals among others).

Figura 1. Além dos espécimes completos, existem vários itens, conhecidos como espécimes estendidos, que devem ser armazenados em coleções biológicas para garantir a disponibilidade de informações a longo prazo. Os espécimes estendidos podem ser físicos (como ovos, esqueletos secos e diafanizações, conteúdo estomacal, tecidos) e digitais (como sequências de DNA, fotografias, vídeos e sinais acústicos, entre outros).

Figura 1. Además de los especímenes completos, existen diversos elementos, conocidos como especímenes extendidos, que deben almacenarse en colecciones biológicas para garantizar la disponibilidad de la información a largo plazo. Los especímenes extendidos pueden ser físicos (como huevos, esqueletos secos y diafanizaciones, contenidos estomacales, tejidos) y digitales (como secuencias de ADN, fotografías, vídeos y señales acústicas, entre otros).

están presentes en procesos tanto ecológicos como evolutivos lo que las hace una característica de historia natural sumamente valiosa de colectar en campo. En grupos como los anuros, donde las señales acústicas median las interacciones reproductivas, las vocalizaciones tienden a ser altamente estereotipadas. Esto se debe a que son vitales para discriminar entre conespecíficos e individuos de otras especies (Okamoto & Grether, 2013), evitando así los costos energéticos asociados a cruces inviables con heteroespecíficos (Kelley, 2004). Esto convierte a los anuros en modelos ideales para los estudios comparativos a excluir la variación cultural por aprendizaje, facilitando la detección del impacto de los restantes parámetros en la variación de estas señales (Gerhard, 1994). Dada esta alta especificidad, la variación geográfica de las vocalizaciones puede representar un mecanismo de aislamiento reproductivo (Lee et al., 2016)

que puede llegar a tener implicaciones evolutivas, favoreciendo incluso el proceso de especiación (Clemens et al., 2017).

Aunado a esto, el estudio de las vocalizaciones desde la ecología de la conducta y con una perspectiva de conservación puede ayudarnos a identificar perturbaciones en los ecosistemas en etapas tempranas (Herrera Montes, 2018) así como facilitar los esfuerzos de reintroducción y traslocación de especies en peligro (Durant et al., 2019). La baja variación intraespecífica facilita la detección de especies en el monitoreo acústico pasivo al reducir la curva de aprendizaje en el *Machine Learning* (Aide et al., 2013; Ospina et al., 2013, pero ver Rivera-Correa et al., 2017). Dado que la mayoría de las especies de anuros emiten señales acústicas, el seguimiento y la comparación de sus diferentes señales frente al cambio climático, los invasores biológicos y las enfermedades también pueden mejorar los estudios de conservación, algo extremadamente importante, ya que se trata de uno de los grupos más amenazados entre todos los animales (Collins & Storfer, 2003; Sodhi et al., 2008).

El avance en nuevos desarrollos de tecnologías en la toma de datos, almacenamiento y accesibilidad a la información permite formalizar los esfuerzos de registro conductual en medios audiovisuales, de modo que puedan garantizar su acceso para futuras consultas (Acevedo-Charry et al., 2021). Una de las ventajas de los especímenes multimedia (como las grabaciones de audios) es la disponibilidad de generar múltiples copias o duplicados, por lo que un mismo archivo puede ser almacenado en diferentes colecciones institucionales y a la vez los investigadores pueden conservar los archivos originales en sus unidades personales para uso personal. Junto con el estallido de la tecnología de grabación y procesamiento de audio, en los últimos cincuenta años se han producido cambios drásticos en la forma de administrar las colecciones científicas. La mayoría de la información de las colecciones está pasando a un formato digital, respondiendo a nuevos retos como la necesidad de datos holísticos que requiere la investigación interdisciplinar (Schindel & Cook, 2018). Teniendo en cuenta la naturaleza de las colecciones completamente digitales, estas garantizan que sus activos digitales sean Encontrables, Accesibles, Interoperables y Reutilizables (conocida como FAIRness por sus siglas en inglés; Wilkins et al., 2016). Para garantizar la correcta conservación de las grabaciones, una condición importante para las colecciones es que deben ser capaces de asegurar la actualización y el mantenimiento de las bases de datos, y en especial en esta era de grandes conjuntos de datos, el acceso público a los datos biológicos es un requisito para el desarrollo de estudios a gran escala. En este sentido, el conocimiento sobre bioacústica se ha visto favorecido por el trabajo colectivo, que ha dado lugar a bases de datos organizadas y públicas (por ejemplo, biblioteca Macaulay, Xeno-canto, WikiAves), permitiendo incluso la creación de herramientas especializadas para trabajar de forma automatizada en la identificación y procesamiento de una gran cantidad de datos sonoros (por ejemplo, el paquete de R WarblerR, Araya-Salas & Smith-Vidaurre, 2017; Animal Sound Identifier en MatLab, Ovaskainen et al., 2018; o scikit-maad en Python, Ulloa et al., 2021). De esta manera, la información disponible en estos repositorios puede ser utilizada no sólo como referencia para la identificación y comparación de especies *per se*, sino para estudios a gran escala en monitoreo, evolución de señales, procesos macroecológicos, entre otros (i.e. Mikula et al., 2021).

Dada la suma importancia para el avance de la ciencia neotropical, los investigadores deberían archivar las grabaciones de audio en repositorios acústicos, de forma similar a lo que se hace con los especímenes de museo y las secuencias de ADN (Toledo et al., 2015; Dena et al., 2018; Dena et al., 2020). Lamentablemente, el depósito de grabaciones sonoras de anuros en repositorios institucionales aún no es una práctica habitual (Dena et al., 2020) y las publicaciones aún no exigen esta práctica como requisito para sustentar la información que respalde las investigaciones (Toledo et al., 2015). La principal justificación de los investigadores para no depositar los archivos de audio es la falta de tiempo para prepararlos (Dena et al., 2020). No depositar las grabaciones en los repositorios acústicos pone en peligro el almacenamiento a largo plazo, la posibilidad de compartirlas y también podría implicar una apropiación indebida de recursos públicos al perderse el esfuerzo (salarios de investigadores, compra de equipos, gastos de salidas de campo) financiado por dichos recursos (Dena et al., 2020).

Debido a esta falta de información pública, los investigadores interesados en la bioacústica o ecoacústica han tenido que hacer un esfuerzo extra contactando a diferentes investigadores y apelando a su buena voluntad para compartir los archivos de audio generados en estudios a veces ya publicados. Este trabajo es más difícil cuando existen conflictos personales entre los líderes de los laboratorios, poniendo en desventaja a los estudiantes que no han formado parte de dichos conflictos, o para aquellas instituciones pequeñas que no forman parte de ciertas redes de trabajo, lo cual aumenta la desigualdad y falta de representatividad.

A pesar de que en América Latina existen varios repositorios acústicos con grabaciones herpetológicas, permanentemente vinculados a institutos de investigación y universidades, los especímenes digitales se encuentran en su mayoría en institutos

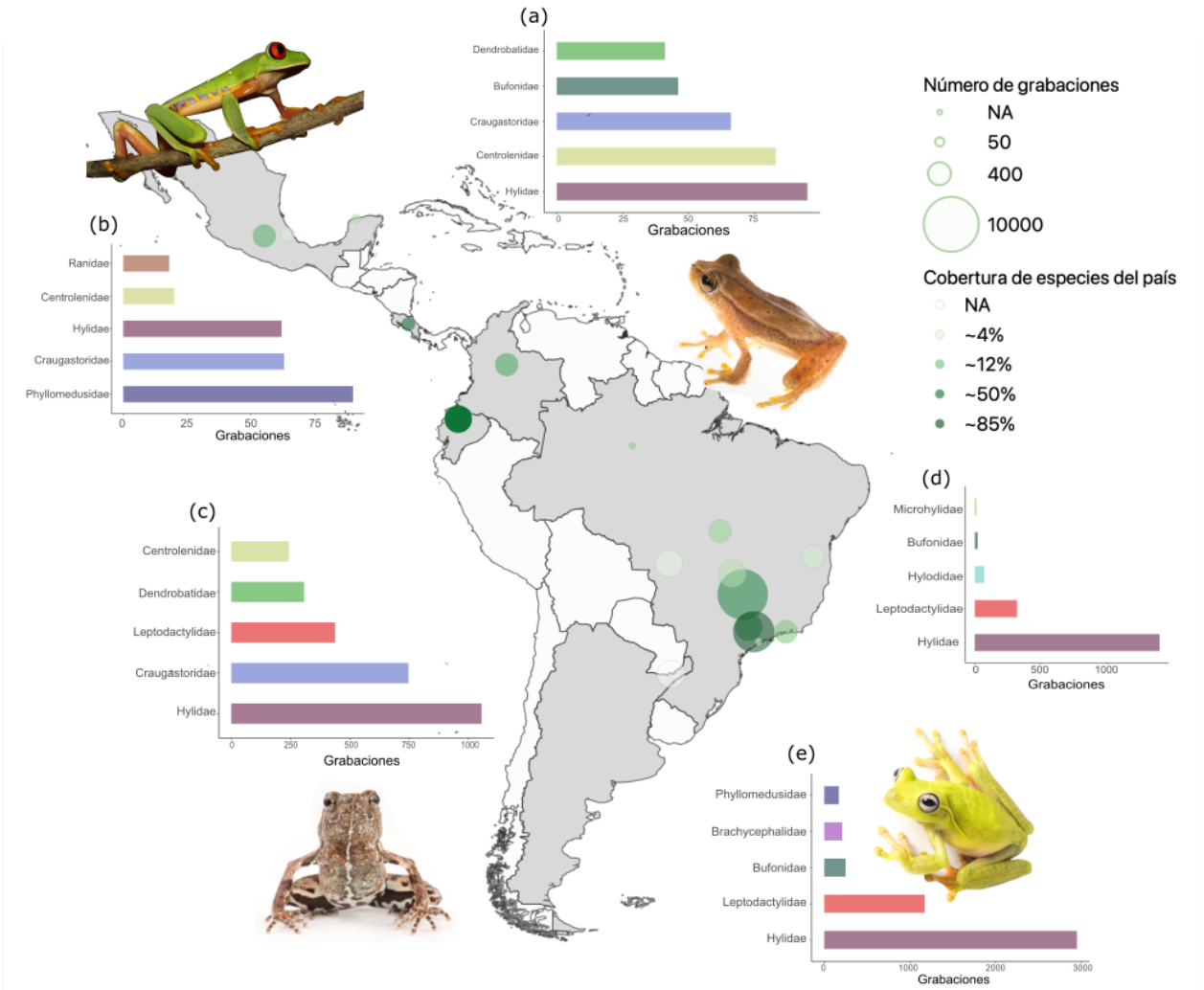

Figure 2. Location and taxonomical coverage of anuran sound repositories in Latin America. The size of each point represents the number of recordings until 31 may 2021 and the opacity represents the species coverage with respect to the total number of species in each country. Countries in gray color have at least one repository with anuran recordings. Bar plots indicate the number (N) of recordings of the most common families in some repositories. a = Colección de Sonidos Ambientales Mauricio Álvarez Rebolledo, b = Fonoteca de Anfibios de México, c = combined information of collections in Quito, d = Fonoteca da Universidade Federal de Goiás y e = Fonoteca Neotropical Jacques Vielliard. Complete information of repositories is available in Appendix 1. Pictures: *Agalychnis taylori* (Angela M. Mendoza-Henao), *Dendropsophus microcephalus* (Felipe Villegas), *Engystomops petersi* (Alejandro Arteaga) and *Boana albomarginata* (Victor Fávaro Augusto).

Figura 2. Localização e representatividade taxonômica dos repositórios sonoros de anuros na América Latina. O tamanho de cada ponto representa o número de registros até 31 de maio de 2021 e a opacidade mostra a representatividade das espécies em relação ao total de espécies em cada país. Os países em cinza contêm pelo menos uma coleção com sons em anuros. Os gráficos de barras indicam o número (N) de registros das famílias mais comuns em alguns repositórios. a = Colección de Sonidos Ambientales Mauricio Álvarez Rebolledo, b = Fonoteca de Anfibios de México, c = Quito, d = Fonoteca da Universidade Federal de Goiás y e = Fonoteca Neotropical Jacques Vielliard. As informações completas dos repositórios estão disponíveis na Apéndice 1. Fotografias das espécies com mais registros em alguns repositórios: *Agalychnis taylori* (Angela M. Mendoza-Henao), *Dendropsophus microcephalus* (Felipe Villegas), *Engystomops petersi* (Alejandro Arteaga) e *Boana albomarginata* (Victor Fávaro Augusto).

Figura 2. Ubicación y cobertura taxonómica de los repositorios de sonidos de anuros en América Latina. El tamaño de cada punto representa el número de grabaciones hasta el 31 de mayo de 2021 y la opacidad representa la cobertura de especies respecto al total de especies en cada país. Países en color gris contienen al menos una colección con sonidos en anuros. Los gráficos de barras indican el número (N) de grabaciones de las familias más comunes en algunos repositorios. a = Colección de Sonidos Ambientales Mauricio Álvarez Rebolledo, b = Fonoteca de Anfibios de México, c = total de cantos de las cuatro colecciones de Quito, d = Fonoteca da Universidade Federal de Goiás y e = Fonoteca Neotropical Jacques Vielliard. La información completa de los repositorios está disponible en la Apéndice 1. Fotografías de las especies con más grabaciones en algunos repositorios: *Agalychnis taylori* (Angela M. Mendoza-Henao), *Dendropsophus microcephalus* (Felipe Villegas), *Engystomops petersi* (Alejandro Arteaga) y *Boana albomarginata* (Victor Fávaro Augusto).

de investigación ubicados en países del Norte Global. En este trabajo logramos identificar un total de 20 repositorios en seis países (Fig. 2; Apéndice 1). Algunos de ellos surgen como iniciativas personales, y con el paso del tiempo y con el apoyo institucional respectivo, los repositorios logran contar con los estándares de curación que garanticen el correcto almacenamiento y acceso público a largo plazo. En este momento, siete de los repositorios institucionales en Latinoamérica cuentan con estándares internacionales de curación: incluyen un sitio web con la información de las vocalizaciones disponibles en la colección, cuentan con un sistema de catálogo, permiten el libre depósito de cantos y acceso a los metadatos y tienen personal dedicado a las colecciones de sonidos. El uso de repositorios locales o regionales abre la posibilidad de almacenar la diversidad de muestras científicas generadas en la región, garantizando la gobernabilidad de los territorios sobre sus propios recursos naturales, haciéndolas fácilmente accesibles a los investigadores regionales y al público no especializado. Así mismo, la divulgación de la ciencia allí generada (en sus respectivos idiomas locales) permite una relación más estrecha entre la academia y el resto de la sociedad.

La democratización de la ciencia requiere, entre otras cosas, un fácil acceso a las muestras (Toledo et al., 2015); y esto sólo es posible a través de la inversión en instalaciones o desarrollos que aseguren el mantenimiento a largo plazo de dichas muestras. Recientes iniciativas institucionales apuntan a mejorar este panorama en un futuro próximo (Apéndice 1), con lo cual se espera mejore el relacionamiento entre la sociedad y la naturaleza. Esta carta es un llamado urgente a la comunidad herpetológica para que se tomen tres acciones principales para aumentar la accesibilidad y reproducibilidad de la investigación bioacústica de anuros neotropicales. Estas acciones son:

• Los investigadores deben depositar las grabaciones de sus investigaciones publicadas y en preparación en repositorios acústicos nacionales o regionales. Aquellos investigadores con grabaciones son bienvenidos a contactar a las instituciones para resolver sus dudas sobre los protocolos de depósito y préstamo de grabaciones.

• Los editores y revisores de revistas deben exigir a los autores los números de depósito de todos los archivos utilizados en cualquier investigación acústica y la correcta referenciación de las colecciones usadas antes de aceptar los manuscritos.

• Las directivas de instituciones regionales deben asegurar el fortalecimiento y mantenimiento a largo plazo de los repositorios acústicos institucionales.

Afortunadamente se está entendiendo la importancia de estas acciones y un número considerable de investigadores ya ha apoyado con su firma a esta misiva (Apéndice 2). Aun así, es importante identificar los retos implicados para lograr dichas acciones. Los investigadores y los estudiantes han declarado que no están familiarizados con los protocolos de depósito (Dena et al., 2020), de modo que proporcionar protocolos sencillos y accesibles en los sitios web de las colecciones puede fomentar la participación y facilitar este proceso. En el aspecto metodológico, existen trabajos recientes en inglés y en español (Köhler et al., 2017; Acevedo-Charry et al., 2021) donde esa información ya está sistematizada; sin embargo, consideramos importante divulgar por diferentes medios algunos elementos claves para facilitar su acceso a las personas interesadas en esta área. Así mismo, algunos herpetólogos han expresado su preocupación por los derechos de autor de sus materiales audiovisuales una vez que los depositan en los repositorios (Dena et al., 2020). Las colecciones deberían hacer lo más visible posible las declaraciones de derechos de autor para certificar la transparencia en el envío de las grabaciones.

Cabe resaltar que esta situación no es exclusiva para el estudio de la bioacústica de anuros sino que se extiende también a otros grupos taxonómicos (ej. Lozano-Flórez et al., 2021; Martínez-Medina et al., 2021). El trabajo colaborativo entre investigadores, editores de revistas y directivas institucionales es fundamental para reforzar el estudio en bioacústica en el Neotrópico. El fortalecimiento y mantenimiento de los repositorios acústicos institucionales es importante para que los repositorios logren asegurar la correcta preservación y uso a corto, mediano y largo plazo, junto con la actualización de sus instalaciones. De este modo, se pueden establecer buenas prácticas para proporcionar de manera pública información clara sobre el proceso de curación y garantizar la transparencia en la preservación y manejo de las grabaciones.

Agradecimientos.— Agradecemos a dos revisores anónimos por sus comentarios al documento.

INFORMACIÓN SUPLEMENTARIA

Apéndice 1. Repositorios acústicos encontrados con grabaciones herpetológicas. https://drive.google.com/drive/folders/1JAGktlo9XRusOnIykvA-nI1ek7DPM494?usp=sharing

Apéndice 2. Firmas de apoyo obtenidas.

Apéndice 3. English version of this document.

Apéndice 4. Versão em português deste documento.

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APÉNDICE 2. FIRMAS DE APOYO OBTENIDAS

Como investigador/a a depositar correctamente y referenciar los archivos bioacústicos en repositorios regionales / As a researcher, to correctly deposit and reference bioacoustic archives in regional repositories. / Como um pesquisador(a), para depositar e referenciar corretamente arquivos bioacústicos em coleções regionais

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Como directiva institucional a garantizar el fortalecimiento y mantenimiento de los repositorios acústicos institucionales / As an institutional directive to ensure the strengthening and maintenance of institutional acoustical repositories/ Como coordenação de coleção científica audiovisual, para garantir o fortalecimento e manutenção das coleções acústicas institucionais
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APPENDIX 3. A CALL FOR CALLS: ACOUSTIC REPOSITORIES BASED IN LATIN AMERICA

Specimens deposited in conventional biological collections provide information on morphology and other aspects of intra- and interspecific relationships, reproductive status, or the presence of pathogens. Scientific collections, particularly public collections of universities, governmental entities, or private non-profit organizations, are important actors in the role of material preservation and availability for consultation since they promote reproducibility and accessibility of research data, which is essential for the scientific method. The debate on the importance of natural history collections as a valuable source of data for all types of biological research has been increasing in recent decades (e.g., Suarez & Tsutsui, 2004; Winker, 2004; Pyke & Ehrlich, 2010; Toledo et al., 2015; Funk, 2018; Dena et al., 2018; 2020). The most common samples are complete specimens, however some behavioral and ecological traits are often not documented or fail to be adequately stored by preserving the specimen by itself (Webster, 2017), losing details of biological interactions (Alström & Ranft, 2003; Ranft, 2004; Schindel & Cook, 2018). In this sense, biological research includes the collection of other types of biological samples, termed "extended specimens" (Webster, 2017). Some of these samples are tangible such as their tissues, diaphanizations, or nests, while others are digital such as DNA sequences, photographs, videos, and audios (Fig. 1).

Sound plays a very important role in both intra- and interspecific communication (Farina, 2014, Acevedo-Charry et al., 2021). Acoustic communication is one of the four types of communication commonly used by organisms and uses long-range and short-range auditory signals, associated with the public or private communicative context, respectively (Larsen, 2020). The use of acoustic communication has been documented in foraging, territory defense, mate selection, and parental care scenarios, among others (Clemens et al., 2017). Vocalizations are present in both ecological and evolutionary processes making them an extremely valuable natural history feature to collect in the field.

In groups like anurans, where acoustic signals mediate reproductive interactions, vocalizations tend to be highly stereotyped. This is because they are vital for discriminating between conspecifics and individuals of other species (Okamoto & Grether, 2013), thus avoiding the energetic costs associated with infeasible crosses with heterospecifics (Kelley, 2004). This makes anurans ideal models for comparative studies, since we can exclude cultural variation by learning, and thus, facilitating the detection of the impact of the remaining parameters on the variation of these signals (Gerhard, 1994). Given this high specificity, geographic variation in vocalizations may represent a reproductive isolation mechanism (Lee et al., 2016). These variations in acoustic structure may even have evolutionary implications, favoring the process of speciation (Clemens et al., 2017).

In addition, the study of vocalizations from a behavioral ecology and conservation perspective can help us to identify disturbances in ecosystems at early stages (Herrera Montes, 2018) as well as facilitate reintroduction and translocation efforts of endangered species (Durant et al., 2019). Low intraspecific variation facilitates species detection in passive acoustic monitoring by reducing the learning curve in Machine Learning (Ospina et al., 2013; Aide et al., 2013, but see Rivera-Correa et al., 2017). Since most anuran species emit acoustic signals, tracking and comparing their different signals in the face of climate change, biological invaders and diseases can also improve conservation studies, which is extremely important, as this is one of the most threatened groups among all animals (Collins & Storfer, 2003; Sodhi et al., 2008).

Advances in new technology developments in data collection, storage, and accessibility of information make it possible to formalize behavioral recording efforts in audiovisual media so that they can guarantee access for future reference (Acevedo-Charry et al., 2021). One of the advantages of storing multimedia specimens (such as vocalization recordings) is the availability of generating multiple copies or duplicates so that the same file can be stored in different institutional collections while researchers can keep the original files on their personal drives for personal use. Along with the explosion of audio recording and processing technology, the last fifty years have seen dramatic changes in the way scientific collections are managed. The majority of information in collections is moving to a digital format, responding to new challenges such as the need for holistic data required for interdisciplinary research (Schindel & Cook, 2018). Considering the nature of fully digital collections, they ensure that their digital assets are Findable, Accessible, Interoperable, and Reusable (known as FAIRness; Wilkins et al., 2016). In this era of large databases, public access to biological data is a requirement for the development of large-scale studies. In this sense, knowledge on bioacoustics has been favored by collective work, which has given rise to organized and public databases (e.g., Macaulay Library, Xeno-Canto, WikiAves), even allowing the creation of specialized tools to work in an automated way in the identification and processing of a large amount of sound data (e.g., the R package WarblerR, Araya-Salas & Smith-Vidaurre, 2017; Animal Sound Identifier in MatLab, Ovaskainen et al., 2018; or scikit-maad in Python, Ulloa et al., 2021). In this way, the information available in these repositories can be used not only as a reference for species identification and comparison per se but also for large-scale studies in monitoring, signal evolution, macroecological processes, among others (i.e. Mikula et al., 2021).

Given the utmost importance for the advancement of Neotropical science, researchers should archive audio recordings in acoustic repositories, similar to what is done with museum specimens and DNA sequences (Toledo et al., 2015; Dena et al., 2018; 2020). Unfortunately, depositing anuran sound recordings in institutional repositories is not yet a standard practice (Dena et al., 2020) and publications do not yet require this practice as a requirement to validate information to support research (Toledo et al., 2015). The main justification of researchers for not depositing audio files is the lack of time to prepare them (Dena et al., 2020). Not depositing recordings in acoustic repositories jeopardizes long-term storage, the possibility of sharing them, and could also imply misappropriation of public resources by losing the effort (researchers' salaries, purchase of equipment, field trip expenses) funded by those resources (Dena et al., 2020).

Due to this lack of public information, researchers interested in bioacoustics or ecoacoustics have had to make an extra effort by contacting different researchers and appealing to their goodwill to share audio files generated in studies sometimes already published. This work is more difficult when there are personal conflicts between laboratory leaders, putting students who have not been part of such conflicts at a disadvantage, or for those small institutions that are not part of certain networks, which increases inequality and lack of representativeness.

Although there are several acoustic repositories with herpetological recordings in Latin America, permanently linked to research institutes and universities, digital specimens are mostly found in research institutes located in countries of the Global North. In this work, we were able to identify a total of 20 repositories in six Latinamerican countries (Fig. 2; Appendix 1). Some of them arise as personal initiatives, and with the

passage of time and with the respective institutional support, the repositories manage to have the curation standards that guarantee the correct long-term storage and public access. At present, seven of the institutional repositories in Latin America have international curation standards: they contain a website with information on the vocalizations available in the collection, have a catalog system, allow free deposit of calls and access to metadata, and have hired staff in charge of the collection. The use of local or regional repositories opens the possibility of storing the diversity of scientific samples generated in the region, guaranteeing the governance of the territories over their own natural resources, making them easily accessible to regional researchers and the non-specialized public. Likewise, the dissemination of the science generated there (in their respective local languages) allows for a closer relationship between academia and the rest of society.

The democratization of science requires, among other things, easy access to samples (Toledo et al., 2015); and this is only possible through investment in facilities or developments that ensure the long-term maintenance of such samples. Recent institutional initiatives aim to improve this scenario in the near future (Appendix 1), which is expected to improve the relationship between society and nature. This letter is an urgent call to the herpetological community to take three main actions to increase the accessibility and reproducibility of bioacoustic research on Neotropical anurans. These actions are:

- Researchers should deposit recordings of their published and forthcoming research in national or regional acoustic repositories. Researchers with recordings are welcome to contact the institutions with questions about the protocols for depositing and lending recordings.

- Journal editors and reviewers should require authors to provide deposit numbers of all files used in any acoustical research and the correct referencing of the collections used before accepting manuscripts.

- Managers of regional institutions should ensure that institutional acoustical repositories are strengthened and maintained.

Fortunately, the importance of these actions is being understood and a considerable number of researchers have already supported this letter with their signatures (Appendix 2). Even so, it is important to identify the challenges involved in achieving such actions. Researchers and students have stated that they are unfamiliar with deposition protocols (Dena et al., 2020), so providing simple and accessible protocols on collection websites may encourage participation and facilitate this process. In the methodological aspect, there are recent works in English and Spanish (Köhler et al., 2017; Acevedo-Charry et al., 2021) where such information is already systematized; however, we consider important to disseminate by different means some key elements to facilitate its access to people interested in this area. Likewise, some herpetologists have expressed concern about the copyright of their audiovisual materials once they deposit them in repositories (Dena et al., 2020). Collections should make copyright statements as visible as possible to certify transparency in the submission of recordings.

It should be noted that the problematic acknowledge here is not exclusive to the study of bioacoustics in anurans since it extends to most taxonomic groups (e.g. Lozano-Flórez et al., 2021, Martínez-Medina et al., 2021), so collaborative work between researchers, journal editors, and institutional managers is essential to strengthening the study of bioacoustics in the Neotropic. The strengthening and maintenance of institutional acoustic repositories are important for the repositories to ensure the correct preservation and use in the short, medium, and long term, together with the updating of their facilities, so that good practices can be established to provide clear public information on the curation process and ensure transparency in the preservation and management of the recordings.

APENDICE 4. UM CHAMADO NEOTROPICAL: COLEÇÕES SONORAS HERPETOLÓGICAS LATINO-AMERICANAS

Os espécimes depositados em coleções biológicas convencionais permitem conhecer a morfologia e outros aspectos das relações intra e interespecíficas, como sua condição reprodutiva ou a presença de patógenos. As coleções científicas, em particular as coleções públicas de universidades, entidades governamentais ou organizações privadas sem fins lucrativos, são atores importantes na conservação do material e disponibilização para consulta, uma vez que promovem a reprodutibilidade e acessibilidade dos dados da pesquisa e dos métodos. Na verdade, a importância das coleções de história natural como uma fonte valiosa de dados para todos os tipos de pesquisa biológica tem sido destacada nas últimas décadas (por exemplo, Suárez & Tsutsui, 2004; Winker, 2004; Pyke & Ehrlich, 2010; Toledo et al., 2015; Dena et al., 2018; Funk, 2018; Dena et al., 2020). No entanto, alguns traços comportamentais e ecológicos muitas vezes não são documentados ou não podem ser adequadamente conservados preservando a amostra por si só (Webster, 2017) e ficam faltando detalhes de interações biológicas (Alström & Ranft, 2003; Ranft, 2004; Schindel & Cook, 2018). Nesse sentido, a pesquisa biológica também inclui a coleta de outros tipos de amostras biológicas, denominados "espécimes estendidos" (Webster, 2017). Algumas dessas amostras são tangíveis, como seus tecidos, diafanizações ou ninhos, enquanto outras são digitais, como sequências de DNA, fotografias, vídeos ou áudios (Fig. 1).

O som desempenha um papel muito importante na comunicação intra e interespecífica (Farina, 2014, Acevedo-Charry et al., 2021). A comunicação acústica é um dos quatro tipos de comunicação comumente usados pelos organismos e utiliza sinais acústicos de longo e curto alcance, associados ao contexto da comunicação pública ou privada, respectivamente (Larsen, 2020). O uso da comunicação acústica foi documentado em contextos de forrageamento, defesa de território, seleção de parceiros e cuidados parentais, entre outros (Clemens et al., 2017). As vocalizações estão presentes em processos ecológicos e evolutivos, o que as torna uma característica da história natural extremamente valiosa para coleta no campo.

Em grupos como os anuros, onde os sinais acústicos mediam as interações reprodutivas, as vocalizações tendem a ser altamente estereotipadas. Isso porque eles são vitais para discriminar entre coespecíficos e indivíduos de outras espécies (Okamoto & Grether, 2013), evitando assim os custos de energia associados a cruzamentos inviáveis com heteroespecíficos (Kelley, 2004). Isso torna os anuros modelos ideais para estudos comparativos, excluindo a variação cultural pelo aprendizado e facilitando a detecção do impacto dos parâmetros restantes na variação desses sinais (Gerhard, 1994). Dada esta alta especificidade, a variação geográfica das vocalizações pode representar um mecanismo de isolamento reprodutivo (Lee et al., 2016). Essas variações na estrutura acústica podem ter implicações evolutivas, favorecendo até mesmo o processo de especiação (Clemens et al., 2017).

Além disso, o estudo das vocalizações a partir da ecologia do comportamento e com uma perspectiva de conservação pode nos ajudar a identificar distúrbios em ecossistemas em estágios iniciais (Herrera Montes, 2018), bem como facilitar esforços de reintrodução e translocação de espécies ameaçadas de extinção (Durant et al., 2019). A baixa variação intraespecífica facilita a detecção de espécies no monitoramento acústico passivo, reduzindo a curva de aprendizado na técnica de aprendizado de máquinas (Aide et al., 2013; Ospina et al., 2013, mas ver Rivera-Correa et al., 2017). Como a maioria das espécies de anuros emite sinais acústicos, monitorar e comparar seus diferentes sinais frente as mudanças climáticas, invasores biológicos e doenças também podem melhorar os estudos de conservação, o que é extremamente importante, pois envolve um dos grupos mais ameaçados de todos os animais (Collins & Storfer, 2003; Sodhi et al., 2008).

Avanços em novos desenvolvimentos de tecnologias de coleta de dados, armazenamento e acessibilidade à informação permitem formalizar esforços de registro comportamental em meios audiovisuais, de forma que possam garantir seu acesso para futuras consultas (Acevedo-Charry et al., 2021). Armazenar espécimes multimídia (como gravações de áudio), a disponibilidade de gerar múltiplas cópias ou duplicatas, de forma que o mesmo arquivo possa ser armazenado em diferentes coleções institucionais e ao mesmo tempo os pesquisadores possam manter os arquivos originais em suas unidades pessoais para uso pessoal, juntamente com a explosão de tecnologias de processamento e gravação de áudio, os últimos cinquenta anos viram mudanças drásticas no forma de gestão de coleções científicas. A maioria das informações nas coleções está mudando para o formato digital, respondendo a novos desafios, como a necessidade de dados holísticos que

a pesquisa interdisciplinar (Schindel & Cook, 2018). Dada a natureza das coleções totalmente digitais, eles garantem que seus ativos digitais sejam localizáveis, acessíveis, interoperáveis e reutilizáveis (conhecido como FAIRness; Wilkins et al., 2016). Nesta era de grandes conjuntos de dados, o acesso público aos dados biológicos é um requisito para o desenvolvimento de estudos em grande escala. Nesse sentido, o conhecimento sobre bioacústica tem sido favorecido pelo trabalho coletivo, que tem dado origem a bases de dados organizadas e públicas (por exemplo, biblioteca Macaulay, Xeno-Canto, WikiAves), permitindo inclusive a criação de ferramentas especializadas para o trabalho de forma automatizada, na identificação e processamento de uma grande quantidade de dados sonoros (por exemplo, o pacote de R WarblerR, Araya-Salas & Smith-Vidaurre, 2017; Animal Sound Identifier in MatLab, Ovaskainen et al., 2018; ou scikit-maad em Python, Ulloa et al., 2021). Dessa forma, as informações disponíveis nesses repositórios podem ser utilizadas não apenas como referência para a identificação e comparação das espécies em si, mas também para estudos em larga escala em monitoramento, evolução de sinais, processos macroecológicos, entre outros. (por exemplo, Mikula et al., 2021).

Dada a extrema importância para o avanço da ciência neotropical, os pesquisadores devem arquivar as gravações de áudio em repositórios acústicos, semelhante ao que é feito com espécimes de museu e sequências de DNA (Toledo et al., 2015; Dena et al., 2018; Dena et al., 2020). Infelizmente, o depósito de gravações sonoras de anuros em repositórios institucionais não é uma prática muito comum (Dena et al., 2020) e as publicações ainda não exigem essa prática como um requisito para apoiar as informações que sustentam a pesquisa (Toledo et al., 2015). A principal justificativa dos pesquisadores para não depositar os arquivos de áudio é a falta de tempo para prepará-los (Dena et al., 2020). O não depósito das gravações em repositórios acústicos compromete o armazenamento de longo prazo, a possibilidade de seu compartilhamento e também pode implicar no desvio de recursos públicos quando o esforço é perdido (salários de pesquisadores, compra de equipamentos, despesas com viagens de campo) (Dena et al., 2020).

Devido a esta falta de informação pública, pesquisadores interessados em bioacústica ou ecoacústica frequentemente tem que entrar em contato com diferentes pesquisadores e apelar para sua boa vontade para compartilhar os arquivos de áudio gerados em estudos às vezes publicados. Este trabalho é mais difícil quando há conflitos pessoais entre chefes de laboratório, colocando em desvantagem alunos que não fizeram parte desses conflitos, ou para aquelas pequenas instituições que não fazem parte de determinadas redes de trabalho, o que aumenta a desigualdade e a falta de representação.

Apesar de na América Latina existirem vários repositórios acústicos com registros herpetológicos, permanentemente vinculados a institutos de pesquisa e universidades, a maioria dos espécimes digitais encontra-se em institutos de pesquisa localizados em países do Norte Global. Neste trabalho conseguimos identificar um total de 20 repositórios em seis países (Fig. 2; Apêndice 1). Alguns deles surgem como iniciativas pessoais e, com o passar do tempo e com o apoio institucional, os repositórios conseguem ter padrões de curadoria que garantem o correto armazenamento e o acesso público a longo prazo. Atualmente, sete dos repositórios institucionais da América Latina possuem padrões de curadoria internacional: contêm um site com as informações sobre as vocalizações disponíveis na coleção, possuem um sistema de catálogo, permitem o depósito gratuito das gravações, acesso aos arquivos e metadados e tem pessoal dedicado para colecções sonoras. A utilização de repositórios locais ou regionais abre a possibilidade de armazenar a diversidade de amostras científicas geradas na região, garantindo a governabilidade dos territórios sobre os seus próprios recursos naturais, tornando-os facilmente acessíveis aos pesquisadores regionais e ao público não especializado. Da mesma forma, a divulgação da ciência aí gerada (em seus respectivos idiomas locais) permite uma relação mais estreita entre a academia e a sociedade.

A democratização da ciência requer, entre outras coisas, fácil acesso às amostras (Toledo et al., 2015), e isso só é possível através do investimento em instalações ou empreendimentos que garantam a manutenção a longo prazo de tais amostras. Iniciativas institucionais recentes visam aprimorar esse panorama em um futuro próximo (Apêndice 1), o que se espera melhorar a relação entre a sociedade e a natureza. Esta carta é um apelo urgente à comunidade herpetológica para tomar três ações principais para aumentar a acessibilidade e reprodutibilidade da pesquisa bioacústica de anfíbios neotropicais. Essas ações são:

Os pesquisadores devem depositar as gravações de suas pesquisas publicadas e em preparação em repositórios acústicos nacionais ou regionais. Pesquisadores com gravações podem entrar em contato com as instituições para esclarecer dúvidas sobre os protocolos de depósito e empréstimo da gravação.

Os editores e revisores de periódicos devem exigir dos autores os números de depósito de todos os arquivos utilizados em qualquer pesquisa acústica e a correta referenciação das coleções utilizadas antes de aceitar os manuscritos.

As diretrizes das instituições regionais devem garantir o fortalecimento e manutenção dos repositórios acústicos institucionais.

Felizmente, a importância dessas ações está sendo compreendida e um número considerável de pesquisadores já assinou esta carta (Apêndice 2). Ainda assim, é importante identificar os desafios envolvidos na concretização dessas ações. Pesquisadores e estudantes afirmaram não estar familiarizados com os protocolos das coleções (Dena et al., 2020), portanto, fornecer protocolos simples e acessíveis nos sites de coleções pode incentivar a participação e facilitar esse processo. No aspecto metodológico, há trabalhos recentes em inglês e espanhol (Köhler et al., 2017; Acevedo-Charry et al., 2021) onde essas informações já estão sistematizadas; no entanto, consideramos importante divulgar alguns elementos-chave por diversos meios para facilitar o seu acesso às pessoas interessadas nesta área. Da mesma forma, alguns herpetólogos expressaram preocupação com os direitos autorais de seus materiais audiovisuais, uma vez que eles são depositados nos repositórios (Dena et al., 2020). As coleções devem tornar as declarações de direitos autorais o mais visíveis possível para certificar a transparência no envio das gravações.

Deve-se notar que esta situação não é exclusiva do estudo da bioacústica em herpetologia, mas também se estende a outros grupos taxonômicos (por exemplo, Lozano-Flórez et al., 2021, Martínez-Medina et al., 2021), portanto, o trabalho colaborativo entre pesquisadores, editores de periódicos e diretrizes institucionais para fortalecer o estudo da bioacústica na Região Neotropical é essencial para fortalecer este campo de estudo. O reforço e manutenção do repositórios acústicos institucionais são importantes para que os repositórios garantam a correta preservação e utilização a curto, médio e longo prazo, juntamente com a atualização das suas instalações. Dessa forma, boas práticas podem ser estabelecidas para fornecer publicamente informações claras sobre o processo de curadoria e garantir transparência na preservação e manuseio das gravações.

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NEW VISUAL RECORDS OF PLANTS CONSUMED BY 10 LIZARD SPECIES ON ISLANDS OF THE GULF OF CALIFORNIA, AND IMPLICATIONS FOR THE INSULAR ECOLOGY AND TROPHIC WEBS

NUEVOS REGISTROS VISUALES DE PLANTAS CONSUMIDAS POR 10 ESPECIES DE LAGARTIJAS EN ISLAS DEL GOLFO DE CALIFORNIA, E IMPLICACIONES PARA LA ECOLOGÍA INSULAR Y LAS REDES TRÓFICAS

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Resumen.— Presento una lista inédita de 59 especies de plantas de 19 familias que constituyen una fuente de alimento para los reptiles insulares *Ctenosaura conspicuosa, C. hemilopha, Sauromalus varius, S. hispidus, S. slevini, S. klauberi, S. ater, Dipsosaurus dorsalis, D. catalinensis,* y *Petrosaurus thalassinus* en 15 islas del Golfo de California basada en 711 observaciones directas de eventos alimenticios. Dos especies trepan a los ápices de las pencas de cardón con el propósito de alimentarse de sus flores y frutos, y al hacerlo accidentalmente desprenden partes de la planta que subsidian parcialmente a los organismos terrestres; el resto forrajea en el suelo, pero muestran tendencias evolutivas, ecológicas y conductuales marcadas para trepar a los arbustos y árboles para comer sus hojas, flores y frutos. Los hábitos alimenticios de estos reptiles repercuten hacia e influyen a otras poblaciones, especies, niveles tróficos e incluso a la comunidad insular completa, tanto hacia arriba (a depredadores) y hacia abajo (a productores y consumidores primarios) como horizontalmente (a competidores). Las lagartijas insulares herbívoras y omnívoras, en su papel de consumidores primarios y secundarios, e incluso como depredadoras, están en medio de complejas redes tróficas. En estas interacciones destaca el cardón por las masivas cantidades de biomasa y energía que proporciona a las comunidades insulares completas.

Palabras clave.— Lagartijas insulares herbívoras, lagartijas insulares omnívoras, redes tróficas, especies estructurales, subsidios marinos, cardón.

Abstract.— I present an unpublished list of 59 plant species of 19 families that constitute a source of food for the insular reptiles *Ctenosaura conspicuosa, C. hemilopha, Sauromalus varius, S. hispidus, S. slevini, S. klauberi, S. ater, Dipsosaurus dorsalis, D. catalinensis*, and *Petrosaurus thalassinus* on 15 islands of the Gulf of California based on 711 direct observations of feeding events. Two reptile species climb to the tops of cardon cacti branches to purposely eat flowers and fruits and accidentally dislodge plant parts that partially subsidize ground organisms; the rest forage mainly on the ground, but do show a strong evolutionary, ecological, and behavioral tendency to climb on low trees and bushes to eat leaves and flowers. The reptiles' food habits influence other populations, species, trophic levels, and even the whole insular communities, both up (to predators), down (to producers and primary consumers) and horizontally (to competitors). Insular herbivorous and omnivorous lizards, as primary and secondary consumers, and even as predators, are in the middle of complex food webs. In these interactions, the cardon cactus provides vast amounts of biomass and energy to the whole insular communities.

Keywords.— Insular herbivorous lizards, insular omnivorous lizards, food webs, structural species, marine subsidies, cardon cactus.

INTRODUCTION

The islands of the Gulf of California, Mexico, support diverse flora and fauna assemblages with interesting evolutionary histories that include plate tectonics-background settings, diverse paleogeographic scenarios, vicariance and dispersal events, adaptive radiations, convoluted phylogeographic and phylogenetic patterns, genetic and phenotypic diversity, cryptic diversity, endemism, varied habits and lifestyles, and evolutive trends (i.e. character release, change in form, secondarily adaptations) resulting in complex, even perplexing, distributions and ancestry relations with still unresolved taxonomies (Savage, 1960; Soulé & Sloan, 1966; Murphy & Otley, 1984; Murphy & Crabtree, 1985; Grismer, 1999; Riddle et al., 2000; Case et al., 2002; Douglas et al., 2006; Riddle & Hafner, 2006; Hafner & Riddle, 2011; Cruz-Andrés, 2014; Meik et al. 2015; Alencar et al., 2016; Harrington et al., 2017; Meik et al., 2018; Ruíz-Sánchez et al., 2019; Ramírez et al., 2020).

The reptiles, being abundant and conspicuous in these arid habitats, have attracted more attention than other vertebrates and today we have a reasonably complete picture of at least which species are on which islands (Case, 2002). Lovich et al. (2009) have noted that the Baja California Peninsula and associated gulf and Pacific islands contain 167 species of native amphibians and reptiles with native reptiles comprising 50 genera and 149 species (8 turtles, 86 lizards, one amphisbaenid, and 54 snakes). Among these, there are five species of sea turtles and the sea snake *Pelamis platurus* (Lovich et al., 2009). In addition, 54 islands in the gulf are inhabited by 276 populations of reptiles of 94 species, which represent an assemblage of continental and peninsular components, plus the endemics that have originated *in situ* (Murphy & Aguirre, 2002).

Studies on the cited topics at the beginning of this section have been conducted for diverse reptile taxa, especially genetic and molecular ones, e. g. on rattlesnakes of the genus *Crotalus* (in prep.), to the point of finding new species (*C. polisi* and *C. thalassophorus*) based on biological data including mitochondrial nSNP trees, as recently as 2018 (Meik et al., 2018).

However, natural history research related to Baja California reptiles has been slower and less often reported. Most studies have focused on the endemic, insular rattlesnakes (Avila-Villegas et al., 2007; Arnaud et al., 2008; Martins et al., 2008; García-Padilla, 2010). Many aspects of reproduction, growth, population dynamics, behavior and feeding are still unknown for most reptile species, although several researchers have studied and compiled information on various aspects of lizard biology and ecology, and Grismer (2002), in his book of Baja Californian reptiles and amphibians, included what was known about their Natural History up to 2002.

The food of insular lizards is the focus of this paper. A literature review on dietary habits and feeding behavior of Sonoran Desert lizards reveals that most research has been done on continental ones, although a few, very specialized studies have been done on insular ones (see below). Among the continental representatives that have been studied, two species that have island populations in the Gulf of California (*Sauromalus ater* and *Dipsosaurus dorsalis*), have attracted much attention. These two continental/insular species are useful to illustrate the broad spectrum of diets available for herbivorous and omnivorous lizards in the Sonoran Desert realm and are presented in a summarized form in Table 1.

In relation to feeding behavior, few authors have focused on the climbing behavior of lizards. Johnson (1965), in his ecological study of continental *Sauromalus ater*, noted that individuals of this species either ate small annuals and shrubs on the ground, or climbed onto the higher shrubs to get flowers. Lizards of both sexes were observed feeding on the same bush simultaneously, showing both the climbing tendency of the species and its gregariousness.

The island forms of widespread lizards have received much less attention than the continental ones. The dietary habits and feeding behavior of only four insular, endemic species have been studied (Table 1), though three have been studied intensively. For *Dipsosaurus catalinensis* on Santa Catalina island, Grismer (2004) reported that, at certain times of the year, groups of two to six animals feeding communally on the fallen fruits of *Pachycereus pringlei* was a common occurrence. Individuals feeding on ripened fruits of *Stenocereus gummosus* were observed as high as one meter above the ground.

Without any doubt the champion of intensive chuckwalla (*Sauromalus sp*.) research on islands of the Gulf of California was Ted J. Case. In 1979, he initiated the first, and to date the only, ecological study of *Sauromalus varius* and *Ctenosaura hemilopha* (= *C. conspicuosa* [Grismer, 1999, 2002]) on San Esteban Island, and *S. hispidus* on Angel de la Guarda and satellite islands. Case (1982) found on Ángel de la Guarda, that *Sauromalus hispidus* was the most arboreal chuckwalla of all *Sauromalus* species, with 45% of juveniles (in one of his studied locations) observed on *Dalea, Hyptis, Acacia* and other perennials bushes at a height of 1.5 to 3.0 m, maneuvering to the end of flowering stems to eat the blossoms, but the global arboreal preference of juveniles was unknown. Only 10% of the adults were sighted in arboreal situations and

Tabla 1. Dietas comparativas de seis especies de lagartos de tierra firme e islas según lo informado en la literatura revisada.

Table 1. Comparative diets of six lizard species of mainland and islands as reported in the reviewed literature.

Lizard species	Location	Technique	Plant food	Reference
Sauromalus ater	Borrego Mountains, California	Stomach analysis	*Phacelia* sp. *Ambrosia dumosa* *Encelia farinosa* *Erigonum* *Ditaxis lanceolata* *Larrea tridentata* *Fouquieria splendens* *Encelia farinosa* *Lotus* sp. *Phacelia* sp. *Festuca* sp. *Cryptantha* sp. *Lotus strigosus* *Chenactis* sp. *Cryptantha* sp. *Tropidocarpum gracile*	Shaw, 1939
	Tubbs Canyon, California			
	Palm Canyon			
Sauromalus ater	Western Mojave Desert	Observation	*Cryptantha* sp. *Isomeris arborea* *Eriogonum fasciculatum* *Stephanomeria pauciflora*	Johnson, 1965
Sauromalus ater	Grand Wash Cliffs, Grand Canyon	Fecal pellet analysis	*Sphaeralcea ambigua* *Ambrosia dumosa* *Acacia gregii* *Lotus strigosus* *Coldenia hispidissima*	Hansen, 1974
Sauromalus ater	Colorado Desert of Southern California	Observation	*Plantago insularis* *Perityle emoryi* *Phacelia crenulata, Erigonum inflatum* *Mirabilis bigelovi* *Sphaeralcea ambigua* *Chaenictis carphoclina* *Ambrosia dumosa* *Fagonia chilensis* *Bebbia juncea* *Pectis papposa* *Euphorbia polycarpa*	Abts, 1985

Tabla 1 (cont.). Dietas comparativas de seis especies de lagartos de tierra firme e islas según lo informado en la literatura revisada.

Table 1 (cont.). Comparative diets of six lizard species of mainland and islands as reported in the reviewed literature.

Lizard species	Location	Technique	Plant food	Reference
Sauromalus ater	Santan Mountains, South Mountains, and Phoenix Mountains, Arizona	Observation	*Cercidium microphylum* *Sphaeralcea ambigua* *Trixis califórnica* *Viguiera deltoidea* *Fouquieria splendens* *Hyptis emoryi* *Lycium* sp.	Kwiatkowski and Sullivan, 2002
Dipsosaurus dorsalis	Dry areas of California	Observation	*Lupinus sparsiflorus* *Chaenactis fremontii* *Larrea tridentata* *Olneya tesota*	Howland, 1988
Dipsosaurus dorsalis	Mainland	Observation, fecal pellet analysis	*Omnivorous (herbivorous and insectivorous)*	Norris, 1953
Dipsosaurus catalinensis	Santa Catalina Is., Gulf of California	Observation	*Pachycereus pringlei* *Stenocereus gummosus*	Grismer, 2004
Sauromalus varius	San Esteban Island	Observation	*Macrocereus* sp. *Cercidium* sp. *Prosopis* sp. *Olneya* sp.	Case, 1982
Ctenosaura conspicuosa	San Esteban Island		*Cactus fruits* *Assorted perennial flowers*	
Sauromalus hispidus	Angel de la Guarda Island	Observation	*Dalea* sp. *Hyptis* sp. *Acacia* sp. *Jatropha* sp. Cholla Cardon	Case, 1982
Sauromalus varius	San Esteban Island	Fecal pellet analysis	22 plant species of 12 families, with "large amounts of shrubs, forbs and tree leaves and fruits"	Sylber, 1988
Sauromalus hispidus	San Lorenzo Sur, Angel de la Guarda and Mejia Islands		35 plants species of 20 families, including *Cressa truxilliensis, Amaranthus palmeri, Ferocactus peninsulae, Opuntia echinocarpa, Agave deserti, Asclepias subulata*	
Sauromalus hispidus	Rasa Island	Observation	*Cressa truxilliensis*	Velarde, pers. com., 2014
Sauromalus hispidus	Rasa Island	Fecal pellet analysis	*Cressa truxilliensis*	Cerdá, unpubl. data

usually at about 1 m in height in shorter, sturdier shrubs. On the other hand, *Sauromalus varius* adults were not inclined to climb vegetation, with only a 3% of his global sightings in such situations. A 53% of the individuals were sighted in vegetation. Like *S. hispidus* on Ángel de la Guarda island, ctenosaurs (members of the genus *Ctenosaura*) occasionally perched on the top of cardons to bask and feed.

Sylber (1988) conducted the first and most comprehensive research on the feeding habits of insular lizards. He collected 1875 fecal pellets of *Sauromalus varius* and *S. hispidus* on four islands of the midriff region of the Gulf of California (Table 1). A total of 48 species representative of 25 plant families were in the diets of adult *Sauromalus*. For *S. varius* he found a diet consisting of 22 plant species of 12 families, whereas that of *S. hispidus* was made of 35 plant species from 20 families. When the diet was subdivided into plant types, shrubs were the most frequently eaten food item (40.4%), followed by forbs (32.4%), tree leaves and fruits (18.8%), cactus flowers and fruits (6.6%), and grasses (1.2%). If plants parts were considered, seeds made up the largest portion of the diet (46%), followed by leaves (36%), flowers (10%), and stem (7%). Notably, no halophytes (*i.e. Abronia* sp., *Artiplex* sp., *Suaeda* sp., and *Allenrolfea* sp.) were obtained in the fecal analyses, except *Cressa truxilliensis* and *Amaranthus palmeri*, consumed by *S. hispidus*.

Traditionally, analysis of stomach contents has been the main way to determine the dietary habits of many animal species, but this implied the killing of individuals, including rare, unique, scarce, or endangered ones; or the dissecting of museum specimens. More recently, scat collection and analysis has become the most effective technique (Hansen, 1974), but also requires enormous reference plant collections (with flowers, fruits and seeds) and laboratory work. Although still applicable and effective, the feces analyses can be complemented with direct observation of feeding events in the field (empirical evidence *ad oculos*), that may also render other valuable information like behavior. Photography can reinforce these observations. By simply observing, there is no need to collect, kill or disturb any of the insular lizards, which have in the past been catastrophically decimated by introduction of feral species and are now in the process of population recovery after eradication of invasive, non-native species on some islands (Cerdá-Ardura, 2019).

By previous observations (made in 1986 and 1987 during eight scientific, one month-long cruises), I assumed that native, insular lizards had a wide range of food items available for consumption along the seasons, and that they probably displayed adaptive behaviors to do so. Accordingly, the objectives of my research were: 1) to visually record the plant species the lizards consumed by direct, field observations and plant identification *in situ*; 2) the recording of feeding behavior; and 3) to make some assumptions, based on results, about lizards' position and importance into the insular food webs.

MATERIAL AND METHODS

Based on 711 visual records, I obtained the feeding habits for 10 lizard species from 24 years (from December 1995 to April 2019) of visiting diverse islands of the Gulf of California in winter, spring, early summer, and in some cases in mid-late summer. Most of the visits consisted in 4-hours long walks in the morning and/or afternoon on seven-day long trips, yielding a minimum observation time of 24 hours per week, 288 hours per season (year), and 6900 hours in the whole period of 24 years and more than 1500 days of navigation and exploration. I tried to cover most habitats and as many physiognomic landscapes as possible, e.g. arroyos, foothills, mountains, beaches, sand dunes, berms, and mangroves in different locations of the following 15 islands: Ángel de la Guarda, Carmen, Cerralvo, Coronado, Danzante, Espíritu Santo-Partida Sur (herein referred as Espíritu Santo), Monserrat, Rasa, San Francisco, San Esteban, San José, San Lorenzo Sur, San Marcos, Santa Catalina, and Tiburón.

All visits were made aboard touristic cruise ships belonging to Lindblad Expeditions/National Geographic. Disembarking was made on Zodiac-type and DIB rubber boats. The walks were of different lengths, but the majority was 2-4 km long following linear transects across different landforms (e.g. arroyos, foothills), and investing the same searching effort. Field notes on Natural History of the species (e.g. behavior, measurements, etc.), and photographs, when possible, were taken. Samples include N= >1000 individuals of the different chuckwalla species (*Sauromalus* sp.), N= >300 iguanas (*Ctenosaura* sp.), N= >200 desert iguanas (*Dipsosaurus* sp.) and N= <150 rock lizards (*Petrosaurus thalassinus*). No feces were collected for this report although feces have been collected in other, specifically oriented studies, but will not be reported here (*cf.* Cerdá & Langarica, 2018). Photographs are presented as a way of documenting the behavior of some of these species and their feeding habits, as well as to present aspects of morphology of buds, flowers, and fruits of some plants.

RESULTS

Plants and feeding preferences. Table 2 presents the list of the 15 islands visited during this long-term data recording, arranged by increasing area, and the numbers of plant and reptile species

Tabla 2. Islas visitadas con área informada y número de especies de plantas y reptiles (Case, Cody & Ezcurra, 2002).

Table 2. Islands visited with reported area and numbers of plant and reptile species (Case, Cody & Ezcurra, 2002).

	Island	Area in km²	Number of plant species	Number of reptile species
1	RASA	0.68	14	2
2	SAN FRANCISCO	4.49	109	10
3	DANZANTE	4.64	128	16
4	CORONADO	9.13	127	15
5	MONTSERRAT	19.86	127	13
6	SAN MARCOS	30.07	142	22
7	SAN LORENZO SUR	33.03	82	7
8	SAN ESTEBAN	40.72	123	9
9	SANTA CATALINA	40.99	122	10
10	ESPÍRITU SANTO	96.26	249	21
11	CERRALVO	136.50	232	20
12	CARMEN	143.03	195	16
13	SAN JOSÉ	187.16	219	22
14	ÁNGEL DE LA GUARDA	936.04	199	15
15	TIBURÓN	1223.53	298	29

as reported in literature (from Carreño & Helens, 2002; Cody et al., 2002; and Murphy & Aguirre, 2002, respectively). The general geological, ecological and biogeographic features of these islands of the Gulf of California and their locations can be reviewed in Carreño and Helenes (2002) and Álvarez-Borrego (2002). For identification, measurements, morphology, taxonomy, distribution and natural history of the reptiles treated below, see Grismer (2002). All plants mentioned here were identified in situ using the Baja California Plant Guide by Rebman and Roberts (2012).

From Table 2 I must emphasize the great variation in size of these islands: they range from Rasa, with only 0.68 km² of extension and only 14 plant species (Velarde et al., 2014) and two reptile species (Murphy & Aguirre, 2002), to Tiburón, the largest island of Mexico, with 1223.53 km² (Carreño & Helenes, 2002) and as many as 298 plant species (Cody et al., 2002) and 29 reptiles (Murphy & Aguirre-León, 2002; Grismer, 2002). In addition to a small area, Rasa is low and flat, presenting few habitats for reptiles (Cerdá & Langarica, 2018), whereas Tiburón is high (1218 m) (Murphy et al., 2002) and with multiple habitats. These features make the future research on insular reptiles' diet highly promising.

I visually recorded 10 lizard species feeding directly on plants. From these, *Sauromalus* species are classically regarded as strict herbivorous lizards (Sylber, 1988; Hollingsworth, 2004), with the iguanas *C. conspicuosa, C. hemilopha, Dipsosaurus dorsalis* and *D. catalinensis*, and the rock lizard *Petrosaurus thalassinus* being omnivorous (Grismer, 2002, 2004). A total of 711 observations of exclusively feeding events were retrieved from my general records.

Table 3 gives a summarized, composite view of the reptile species recorded, the plants they consumed, the number of times they were observed feeding on each plant, and the island or group of islands were this behavior occurred. The 711 feeding observations correspond as follows: 81 to *Ctenosaura conspicuosa*; two to *C. hemilopha*; 51 to *S. varius*; 22 to *S. hispidus*; six to *S. slevini*; 100 to S. klauberi; 411 to S. ater; 20 to *Dipsosaurus dorsalis*; 16 to *D. catalinensis*, and eight to *Petrosaurus thalassinus*.

As many as 59 plant species were found to be consumed by these 10 reptile species on the 15 islands of the Gulf of California. The maximum number of records of a single reptile species eating a single plant species corresponds to *Ctenosaura conspicuosa*, with 52 feeding times on *Pachycereus pringlei*, followed by *Sauromalus varius* to *P. pringlei* in 41 times. Also meaningful are the records of *S. klauberi* with 18 feeding observations on *Ferocatus diguetii*, 19 times on *Hyptis emoryi*, and 15 times on *P. pringlei*; and *S. ater*, with 17 records of feeding on *Bebbia juncea*, 17 on *H. emoryi*, 21 on *P. pringlei*, 25 on *Perytile californica*, 17 on *Jacquemontia eastwoodiana*, and 17 on *Trixis californica*. Some of the reptile species were observed feeding on different plant species only once, and the one of *Mardsenia* sp. is uncertain as I had difficulties in correctly identifying the plant. Table 3 is also useful to compare the whole diversity of plants available for the reptiles, their preferences, and the intensity with which they feed on them. In the case of *Cressa truxilliensis*, the record correspond to what was published by Velarde el al. (2008), and Cerdá and Langarica (2018), plus 43 *Sauromalus hispidus* feces I collected on Rasa, feces that were not included in the general counting and are presented just as one plant record. Another interesting fact derived from Table 3 is that *S. ater*, as the reptile species with wider distribution

Tabla 3. Tabla compuesta para las 10 especies de reptiles encontradas durante este estudio, con las especies de plantas que consumieron, el número de veces que se observó que cada especie de reptil comía cada especie de planta y las islas donde se realizaron las observaciones combinadas.

Table 3. Composite table for the 10 reptile species found during this study, with the plant species they consumed, the number of times each reptile species was observed eating each plant species, and the islands where the combined observations were made.

Reptile species	Consumed plant species	No. of times seen eating the plant	Islands
Ctenosaura conspicuosa	*Lysiloma candidum*	9	San Esteban
	Olneya tesota	8	
	Pachycereus pringlei	52	
	Stenocereus gummosus	9	
	Stenocereus thurberi	3	
C. hemilopha	*Lysiloma candidum*	1	Cerralvo
	Pachycereus pringlei	1	
Sauromalus varius	*Ambrosia ambrosioides*	3	San Esteban
	Echinocereus grandis	2	
	Pachycereus pringlei	41	
	Stenocereus gummosus	5	
S. hispidus	*Atriplex sp.*	2	Ángel de la Guarda, San Lorenzo Sur, Rasa
	Cressa truxilliensis *	N/A	
	Encelia farinosa	12	
	Pachycereus pringlei	6	
	Suaeda nigra	2	
S. slevini	*Amauria rotundifolia*	4	Carmen, Monserrat, Coronado
	Pachycereus pringlei	2	
S. klauberi	*Bursera hindsiana*	3	Santa Catalina
	Bursera microphylla	2	
	Euphorbia polycarpa	3	
	Ferocactus diguetii diguetii	18	
	Gossypium davidsonii	4	
	Hyptis emoryi	19	
	Lysiloma candidum	2	
	Melochia tomentosa	8	
	Pachycereus pringlei	15	
	Parkinsonia microphylla	1	
	Pythecellobium confine	3	
S. klauberi	*Ruellia californica*	13	Santa Catalina
	Simmondsia chinensis	3	
	Stenocereus gummosus	5	
	Stenocereus thurberi	1	
S. ater	*Acacia goldmanii*	1	Espíritu Santo, San Francisco, San José, Danzante, Península, San Marcos, Tiburón
	Amarathus fimbriatus	12	
	Ambrosia dumosa	2	
	Antigonon leptopus	5	
	Atriplex sp.	3	
	Bacharis salicifolia	6	
	Bajacalia crassiflora	11	
	Bebbia juncea	17	
	Bursera hindsiana	4	
	Bursera microphylla	6	
	Calliandra californica	15	
	Celtis pallida	1	
	Cordia curassavica	3	
	Coulterella capitata	9	
	Croton californicus	3	
	Cylindropuntia alcahes	7	
	Cylindropuntia cholla	9	
	Ditaxis lanceolata	1	
	Encelia farinosa	11	
	Eucnide aurea	6	
	Eucnide cordata	5	
	Euphorbia misera	3	
	Ficus palmeri	3	
	Gossypium davidsonii	14	
	Heliotropum curassavicum	7	
	Hoffmeisteria fasciculata	9	
	Hyptis emoryi	17	
	Jacquemontia abutiloides	11	
	Jacquemontia eastwoodiana	17	
	Jatropha cuneata	2	
	Lophocereus schottii	5	
	Mammillaria albicans	7	
	Mammillaria dioica	13	
	Mardsenia sp. **	1	

Tabla 3 (cont.). Tabla compuesta para las 10 especies de reptiles encontradas durante este estudio, con las especies de plantas que consumieron, el número de veces que se observó que cada especie de reptil comía cada especie de planta y las islas donde se realizaron las observaciones combinadas.

Table 3 (cont.). Composite table for the 10 reptile species found during this study, with the plant species they consumed, the number of times each reptile species was observed eating each plant species, and the islands where the combined observations were made.

Reptile species	Consumed plant species	No. of times seen eating the plant	Islands
S. ater	*Melochia tomentosa*	15	Espíritu Santo, San Francisco, San José, Danzante, Península, San Marcos, Tiburón
	Merremia aurea	6	
	Opuntia tapona	6	
	Pachycereus pringlei	21	
	Parkinsonia praecox	2	
	Passiflora palmeri	14	
	Perityle aurea	11	
	Perityle californica	25	
	Ruellia californica	14	
	Simondsia chinensis	4	
	Stenocereus gummosus	4	
	Stenotis mucronata	16	
	Trixis californica	17	
Dipsosaurus dorsalis	*Pachycereus pringlei*	18	Ángel de la Guarda, Carmen, San Marcos, San José, Espíritu Santo
	Simmondsia chinensis	2	
D. catalinensis	*Ferocactus diguetii var. diguetti*	7	Santa Catalina
	Pachycereus pringlei	9	
Petrosaurus thalassinus	*Ficus palmeri*	3	Espíritu Santo
	Pachycereus pringlei	5	

* Records from Velarde et al. (2008); Cerdá and Langarica (2018), and feces collection (Cerdá, unpubl. data).

* * Plant species identification uncertain.

(occupying naturally at least 14 islands; Grismer, 2002), repeated the consumption of plants species on different islands: nine plant species were consumed in series of two out of six islands, and 4 plant species were consumed in series of three out of six islands; the remaining 32 plant species were consumed on only one of the six single, different islands. These 59 plant species belong to 19 families arranged in alphabetical order in Table 4. All were Eudicots (Rebman & Roberts, 2012). Table 4 indicates the families represented in the 711 observations, the list of plant species per family, and the total number of species per family. Asteraceae is the best represented, with 12 species, followed by 11 species of the Cactaceae, and then Fabaceae (seven) and Euphorbiaceae (five).

This is not surprising as the sunflowers and daisies, either as annuals or perennials, can be abundant in most islands, especially after the winter rains, and produce numerous flowers and leaves (*pers. obs*.). Also, the Cactaceae, with 105 species in the area (Rebman and Roberts, 2012), can be abundant and more important than other type of plants.

Tabla 4. Especies de plantas consumidas por reptiles, ordenadas por familia.

Table 4. Plant species consumed by reptiles, arranged by family.

Family	Species	Number of plant species per family
ACANTHACEAE	*Ruellia californica*	1
AMARANTHACEAE	*Amarathus fimbriatus*	4
	Atriplex sp.	
	Suaeda niigra	
APOCYNACEAE	*Mardsenia sp.*	1
ASTERACEAE	*Amauria rotundifolia*	12
	Ambrosia ambrosioides	
	Ambrosia dumosa	
	Bacharis salicifolia	
	Bajacalia crassiflora	
	Bebbia juncea	
	Coulterella capitata	
	Encelia farinosa	
	Hoffmeisteria fasciculata	
	Perityle aurea	
	Perityle californica	
	Trixis californica	
BORAGINACEAE	*Cordia curassavica*	2
	Heliotropum curassavicum	
BURSERACEAE	*Bursera hindsiana*	2
	Bursera microphylla	
CACTACEAE	*Cylindropuntia alcahes*	11
	Cylindropuntia cholla	

Tabla 4 (cont.). Especies de plantas consumidas por reptiles, ordenadas por familia.
Table 4 (cont.). Plant species consumed by reptiles, arranged by family.

Family	Species	Number of plant species per family
CACTACEAE	*Echinocereus grandis*	11
	Ferocactus diguetii var. diguetti	
	Lophocereus schottii	
	Mammillaria albicans	
	Mammillaria dioica	
	Opuntia tapona	
	Pachycereus pringlei	
	Stenocereus gummosus	
	Stenocereus thurberi	
CANNABACEAE	*Celtis pallida*	1
CONVOLVULACEAE	*Cressa truxilliensis*	4
	Jacquemontia abutiloides	
	Jacquemontia eastwoodiana	
	Merremia aurea	
EUPHORBIACEAE	*Croton californicus*	5
	Ditaxis lanceolata	
	Euphorbia misera	
	Euphorbia polycarpa	
	Jatropha cuneata	
FABACEAE	*Acacia goldmanii*	7
	Calliandra californica	
	Lysiloma candidum	
	Olneya tesota	
	Parkinsonia microphylla	
	Parkinsonia praecox	
	Pithecellobium confine	
LAMIACEAE	*Hyptis emoryi*	1
LOASACEAE	*Eucnide aurea*	2
	Eucnide cordata	
MALVACEAE	*Gossypium davidsonii*	2
	Melochia tomentosa	
MORACEAE	*Ficus palmeri*	1
PASSIFLORACEAE	*Passiflora palmeri*	1
POLYGONACEAE	*Antigonon leptopus*	1
RUBIACEAE	*Stenotis mucronata*	1
SIMMONDSIACEAE	*Simmondsia chinensis*	1

Table 5 resumes the 10 reptile species with the total number of plant species consumed by each reptile species, and the families that the plants belong to. It is possible to observe that *S. ater* consumed 47 plants, representative of all the 19 families recorded, becoming the more varied diet of all the reptile species analyzed; and *S. klaubery* consumed 15 representatives of eight families. The remnant reptiles consumed two to five representatives of as much as four families, mostly of two, and *Dipsosaurus catalinensis* consumed only two plant species of one family (Cactaceae).

Tabla 5. Resumen de especies y familias de plantas consumidas por las 10 especies de reptiles.
Table 5. Summary of plant species and families consumed by the 10 reptile species.

Reptile species	Number of plant species consumed	Number of plant species per family
Ctenosaura conspicuosa	5	2
C. hemilopha	2	2
Sauromalus varius	4	2
S. hispidus	5	4
S. slevini	2	2
S. klauberi	15	8
S. ater	47	19
Dipsosaurus dorsalis	2	2
D. catalinensis	2	1
Petrosaurus thalassinus	2	2

Table 6 presents the number of single observations per plant, their relative frequency of occurrence, the number of reptile species feeding on them, and the individual reptile species that feed on each plant. As can be seen, *Pachycereus pringlei* was the most consumed plant, with 168 observations (frequency, f = 0.236), followed by *Hyptis emoryi* with 36 observations (f = 0.051), and six plant species with 23 to 27 records and f = 0.032 to 0.038. Also, 13 plant species were recorded between 11 and 19 times, with f = 0.015 to 0.025; and 37 species had less than 10 observations (1-9), and frequencies below 0.015 (=1.5 % representation in the total sample of N = 711). In Table 6, *Pachycereus pringlei*, the elephant cactus or cardon, is consumed by all 10 reptile species, followed by *Stenocereus gummosus* (galloping cactus), consumed by four species, and *Lysiloma candidum* (Palo Blanco) and *Simmondsia chinensis* (Jojoba), both consumed by four reptile species. The other 55 plants are consumed by one or two lizard species. This table shows the relevance of the cardon and other seven plant species (with 18 to 36 records) as a source of food.

Tabla 6. Disposición jerárquica de plantas por número de veces que fueron consumidas (en orden decreciente), más frecuencia de consumo, número de especies de reptiles que consumieron cada especie de planta y especies de lagarto que consumieron cada especie de planta.

Table 6. Hierarchical arrangement of plants by number of times they were consumed (in decreasing order), plus frequency of consumption, number of reptile species that consumed each plant species, and lizard species that consumed each plant species.

	Plant species	Number of times observed being consumed	Frequency	Number of reptile species consuming the plant	Reptile species consuming the plant
1	*Pachycereus pringlei*	168	0.236	10	All 10 species
2	*Hyptis emoryi*	36	0.051	2	*S. ater, S. klauberi*
3	*Ruellia californica*	27	0.038	2	*S. ater, S. klauberi*
4	*Perityle californica*	25	0.035	1	*S. ater*
5	*Ferocactus diguetii var. diguetti*	25	0.035	2	*S. klauberi, D. dorsalis*
6	*Stenocereus gummosus*	23	0.032	4	*C. conspicuosa, S. ater, S. klauberi, S. varius*
7	*Melochia tomentosa*	23	0.032	2	*S. ater, S. klauberi*
8	*Encelia farinosa*	23	0.032	2	*S. ater, S. hispidus*
9	*Lysiloma candidum*	18	0.025	3	*C. conspicuosa, C. hemilopha, S. klauberi*
10	*Gossypium davidsonii*	18	0.025	2	*S. ater, S. klauberi*
11	*Trixis californica*	17	0.024	1	*S. ater*
12	*Jacquemontia eastwoodiana*	17	0.024	1	*S. ater*
13	*Bebbia juncea*	17	0.024	1	*S. ater*
14	*Stenotis mucronata*	16	0.022	1	*S. ater*
15	*Calliandra californica*	15	0.021	1	*S. ater*
16	*Passiflora palmeri*	14	0.020	1	*S. ater*
17	*Mammillaria dioica*	13	0.018	1	*S. ater*
18	*Amarathus fimbriatus*	12	0.017	1	*S. ater*
19	*Perityle aurea*	11	0.015	1	*S. ater*
20	*Jacquemontia abutiloides*	11	0.015	1	*S. ater*
21	*Bajacalia crassiflora*	11	0.015	1	*S. ater*
22	*Simmondsia chinensis*	9	0.013	3	*S. ater, S. klauberi, D. dorsalis*
23	*Hoffmeisteria fasciculata*	9	0.013	1	*S. ater*
24	*Cylindropuntia cholla*	9	0.013	1	*S. ater*
25	*Coulterella capitata*	9	0.013	1	*S. ater*
26	*Olneya tesota*	8	0.011	1	*C. conspicuosa*
27	*Bursera microphylla*	8	0.011	2	*S. ater, S. klauberi*
28	*Mammillaria albicans*	7	0.010	1	*S. ater*
29	*Heliotropum curassavicum*	7	0.010	1	*S. ater*
30	*Cylindropuntia alcahes*	7	0.010	1	*S. ater*
31	*Bursera hindsiana*	7	0.010	2	*S. ater, S. klauberi*

Tabla 6 (cont.). Disposición jerárquica de plantas por número de veces que fueron consumidas (en orden decreciente), más frecuencia de consumo, número de especies de reptiles que consumieron cada especie de planta y especies de lagarto que consumieron cada especie de planta.

Table 6 (cont.). Hierarchical arrangement of plants by number of times they were consumed (in decreasing order), plus frequency of consumption, number of reptile species that consumed each plant species, and lizard species that consumed each plant species.

	Plant species	Number of times observed being consumed	Frequency	Number of reptile species consuming the plant	Reptile species consuming the plant
32	*Opuntia tapona*	6	0.008	1	*S. ater*
33	*Merremia aurea*	6	0.008	1	*S. ater*
34	*Ficus palmeri*	6	0.008	2	*S. ater, P. thalassinus*
35	*Eucnide aurea*	6	0.008	1	*S. ater*
36	*Bacharis salicifolia*	6	0.008	1	*S. ater*
37	*Lophocereus schottii*	5	0.007	1	*S. ater*
38	*Eucnide cordata*	5	0.007	1	*S. ater*
39	*Atriplex sp.*	5	0.007	2	*S. ater, S. hispidus*
40	*Antigonon leptopus*	5	0.007	1	*S. ater*
41	*Stenocereus thurberi*	4	0.006	2	*C. conspicuosa, S. klauberi*
42	*Amauria rotundifolia*	4	0.006	1	*S. slevini*
43	*Ambrosia ambrosioides*	3	0.004	1	*S. varius*
44	*Pithecellobium confine*	3	0.004	1	*S. klauberi*
45	*Euphorbia polycarpa*	3	0.004	1	*S. klauberi*
46	*Euphorbia misera*	3	0.004	1	*S. ater*
47	*Croton californicus*	3	0.004	1	*S. ater*
48	*Cordia curassavica*	3	0.004	1	*S. ater*
49	*Suaeda nigra*	2	0.003	1	*S. hispidus*
50	*Parkinsonia praecox*	2	0.003	1	*S. ater*
51	*Jatropha cuneata*	2	0.003	1	*S. ater*
52	*Echinocereus grandis*	2	0.003	1	*S. varius*
53	*Ambrosia dumosa*	2	0.003	1	*S. ater*
54	*Mardsenia sp.*	1	0.001	1	*S. ater*
55	*Celtis pallida*	1	0.001	1	*S. ater*
56	*Parkinsonia microphylla*	1	0.001	1	*S. klauberi*
57	*Ditaxis lanceolata*	1	0.001	1	*S. ater*
58	*Acacia goldmanii*	1	0.001	1	*S. ater*
59	*Cressa truxilliensis*	N/A		1	*S. hispidus*
	Total frequency		**1.0**		
	Total observations	**711**			

Tabla 7. Especies de plantas por familia consumidas por cada especie de reptil. / **Table 7.** Plant species per family consumed by each reptile species.

Reptile species	Plant Family	Number of plants species per family consumed by each reptile species
Ctenosaura conspicuosa	Cactaceae	3
	Fabaceae	2
C. hemilopha	Cactaceae	1
	Fabaceae	1
Sauromalus varius	Asteraceae	1
	Cactaceae	3
S. hispidus	Amaranthaceae	2
	Asteraceae	1
	Cactaceae	1
	Convolvulaceae)	1
S. slevini	Asteraceae	1
	Cactaceae	1
S. klauberi	Acanthaceae	1
	Burseraceae	2
	Cactaceae	4
	Euphorbiaceae	1
	Fabaceae	3
	Lamiaceae	1
	Malvaceae	2
	Simmondsiaceae	1
S. ater	Acanthaceae	1
	Amaranthaceae	2
	Apocynaceae	1
	Asteraceae	10
	Boraginaceae	1
	Burseraceae	2
	Cactaceae	8
	Cannabaceae	1
	Convolvulaceae	3
	Euphorbiaceae	4
	Fabaceae	2
	Lamiaceae	1
	Loasaceae	2
	Malvaceae	1
	Moraceae	2
	Passifloraceae	1
	Polygonaceae	1
	Rubiaceae	1
	Simmondsiaceae	1
Dipsosaurus dorsalis	Cactaceae	1
	Simmondsiaceae	1
D. catalinensis	Cactaceae	2
Petrosaurus thalassinus	Cactaceae	1
	Moraceae	1

Finally, Table 7 presents a combined set of the 10 reptile species with the total number of plant species that they consume per plant family. *Sauromalus ater* stands out by eating 10 species of the family Asteraceae, eight of the Cactaceae, and four of Euphorbiaceae. None of the other lizard species consumes more than three species of a family, except *S. klauberi*, who consumes as many as four species of the Cactaceae.

Feeding behavior. The endemic San Esteban Island Spiny-Tailed Iguana (*Ctenosaura conspicuosa*) has become an icon of San Esteban Island for its behavior of climbing upon the cardon cactus branches (Figs. 1a, b and c); while on top, it is a main attraction for visitors because of its beautiful, sculptured poses (Fig. 2). This behavior was first reported by Banks and Farmer (1963) on Cerralvo, and later (as "occasional") by Case (1982, 2002) and then by Grismer (2002).

In this study, I observed that this climbing tendency is very strong and common among *Ctenosaura*. I found that this species also shows a remarkable capability to climb upon the *Stenocereus thurberi* (organ pipe) and galloping cacti. Mature and juvenile individuals show this climbing behavior for feeding purposes, protection and thermoregulation.

In many cases the juveniles are expelled (but not aggressively) from the cardon by occupant or arriving adults. Thus, juveniles move down to the ground and then climb upon galloping and organ pipe cacti (Fig. 3a), iron wood (*Olneya tesota*) (Fig. 3b), and palo blanco (*Lysiloma candidum*) (Fig. 3c). As famous for visitors to San Esteban as it has been, the behavior of the spiny-tailed iguana can also be taken as a symbol or a model of the reptile-cardon mutualist interaction and seed dispersal in some islands of the Gulf of California.

Ctenosaura conspicuosa consumes five plants species of two families on San Esteban. There is also another species, *Echinocereus grandis*, an endemic little cactus, whose flowers and fruits are available in spring-summer, but I have not been able to verify directly the consumption. I observed spiny-tailed

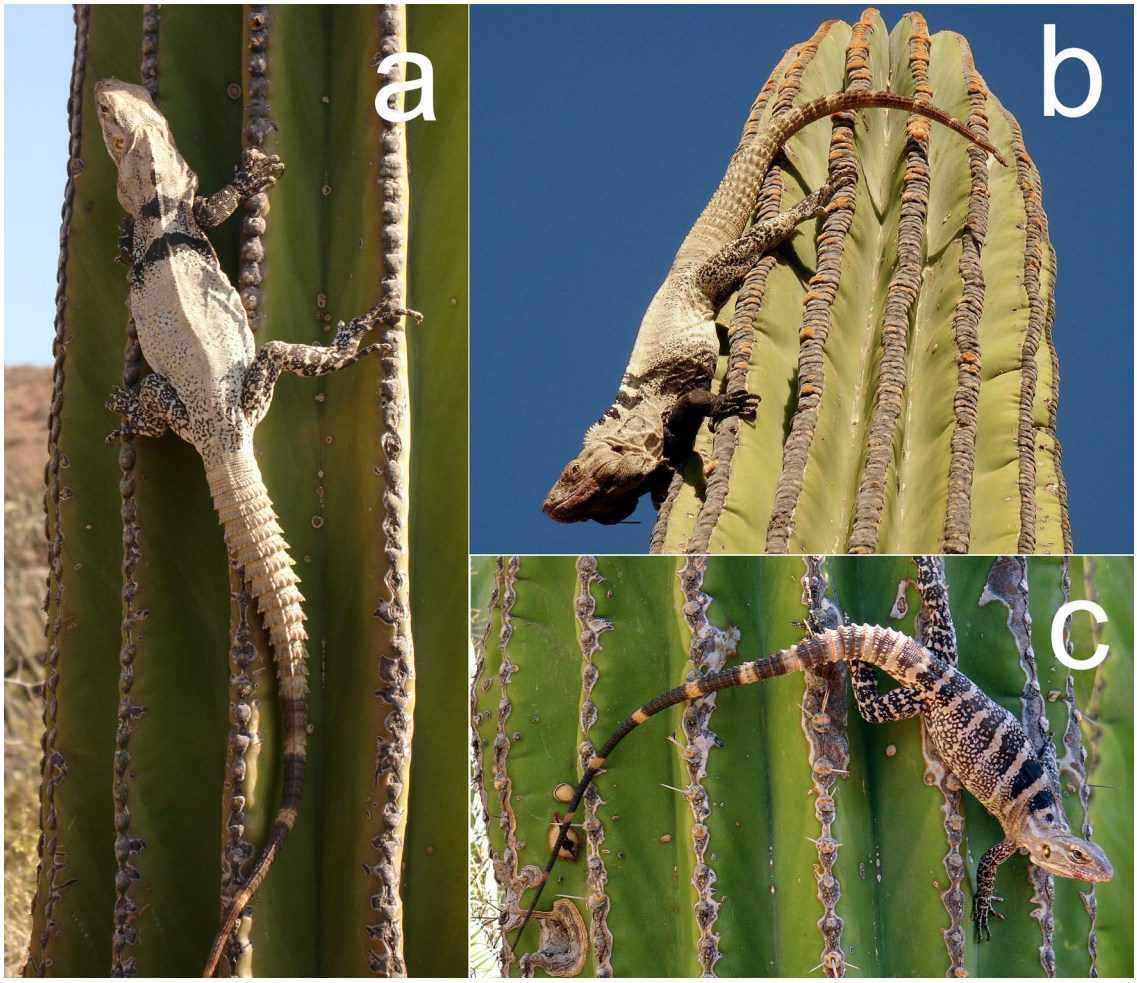

Figura 1. Son notables las capacidades escaladoras de *Ctenosaura conspicuosa*; a) hembra adulta subiendo; b) macho, descendiendo después de alimentarse; c) individuo inmaduro descendiendo después de alimentarse de los frutos del cardón.

Figure 1. The climbing capabilities of *Ctenosaura conspicuosa* are remarkable; a) adult female going up; b) male, descending after feeding; c) immature individual going down after eating on cardon fruit.

Figura 2. Los ctenosaurios de la isla San Esteban Island son icónicos, en parte por sus poses escultóricas sobre los ápices de las pencas de cardón.

Figure 2. Ctenosaurs on San Esteban Island are iconic partly for their sculptured poses on cardon tops.

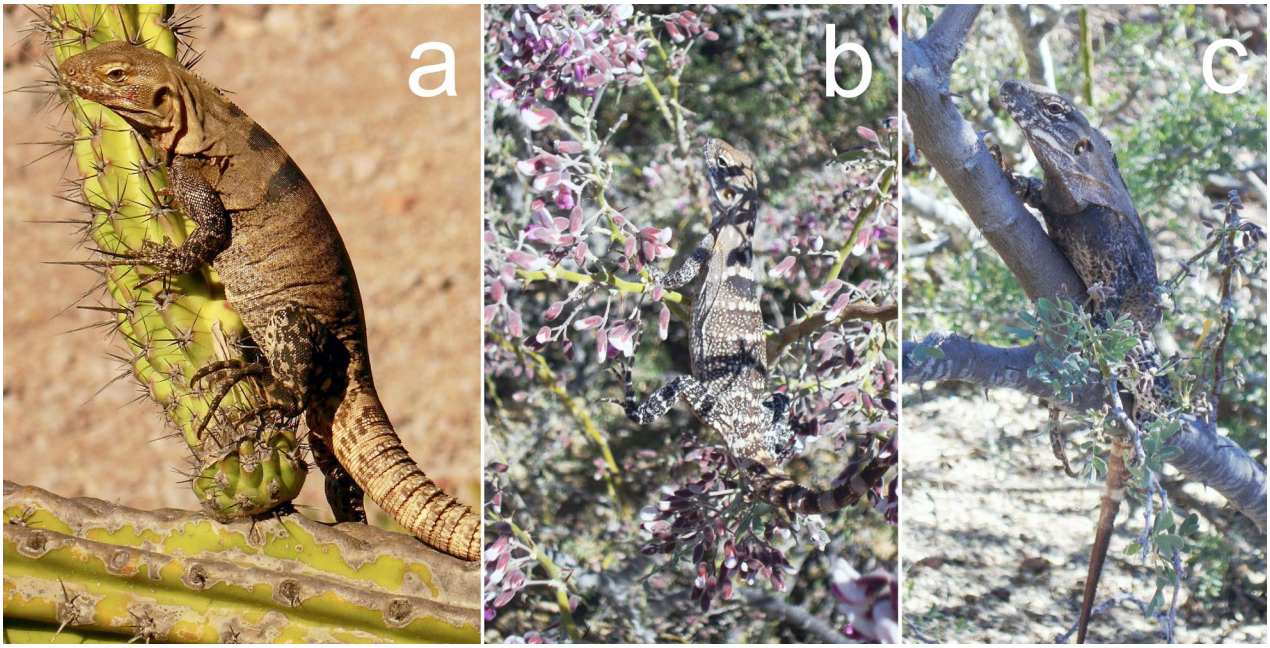

Figura 3. Usualmente, los ctenosaurios inmaduros se alimentan de diversas plantas, aunque los adultos también lo hacen; a) juvenil sobre pitahaya agria (*Stenocereus gummosus*); b) juvenil sobre palo fierro (*Olneya tesota*); c) adulto sobre palo blanco (*Lysiloma candidum*).

Figure 3. Usually, immature ctenosaurs are found feeding on diverse plants, but adults do so too; a) juvenile on galloping cactus (*Stenocereus gummosus*); b) juvenile on ironwood (*Olneya tesota*); c) adult on palo blanco (*Lysiloma candidum*).

iguanas, or ctenosaurs, climbing upon cardon branches but, in the way up, the individuals may feed on the lowest buds (Fig. 4). They take only the upper part of these buds, rejecting the rest, but they can dislodge, accidentally, the eaten buds, or the whole ones when moving around. When ctenosaurs get to a branch top, they feed on what is present at that moment (Fig.5). If they feed on opened flowers, they mostly eat the corolla with petals and the upper portions of sexual organs (Fig. 6). Rarely, the iguanas eat the whole flower structure. If there are fruits on the cardon branch top, the iguanas feed on the ripened ones, whose abundant pulp is crimson-colored. The evidence that they have been feeding on pulp is the color around the mouths of adults and juvenile iguanas (Fig. 7a), as with other lizard species (e.g. *Sauromalus klauberi* in Fig. 7b, and *S. slevini*, in Fig. 7c). A still undetermined number of flowers and fruits are dislodged in these ways and provide valuable food for juvenile iguanas and, importantly, for chuckwallas, which are not strict climbers.

Once satisfied, the iguanas remain on the tops for as long as 30 minutes, or they jump to another branch to seek more food (Fig. 8). When feeding on fruits and flowers, the iguanas may inadvertently consume some of the insects present into those structures as well, especially *Drosophila* flies, wasps and bees, ingesting additional protein. The carnivorous habit of *C. conspicuosa* also has been recorded, especially the consumption of hatchlings and juveniles of the sympatric, gigantic chuckwalla (Case, 2002). Thus, the role of the iguana goes beyond a simple herbivory to a more complex trophic level.

Also endemic to San Esteban, the Piebald Chuckwalla (*Sauromalus varius*) (Fig. 9a) is not a climber but a ground and saxicolous lizard (Grismer, 2002). This is the largest of all chuckwalla species (Case, 1982; Hollingsworth, 2004) and is highly conspicuous for its yellow to orange and black coloration and its habit of seeking shelter under cholla cacti. *Sauromalus varius* benefits directly from cardon flowers and fruits either dislodged by iguanas or falling naturally, and feeds on leaves, flowers and fruits of other plant species (Case, 2002; Grismer, 2002). I have observed this species feeding on four plant species: leaves and flowers of canyon ragweed (*Ambrosia ambrosioides*),

Figura 4. En su camino a los ápices de los cardones, y en su descenso, los ctenosaurios se detienen a alimentarse de botones y flores bajos, de los que sólo comen las corolas, pero a veces pueden desprender las estructuras que serán consumidas por los organismos terrestres.

Figure 4. On their way up a cardon, and going down too, the ctenosaurs stop to feed on the lowest buds and flowers from which they only take the corolla and doing so they may dislodge some that eventually are eaten by ground organisms.

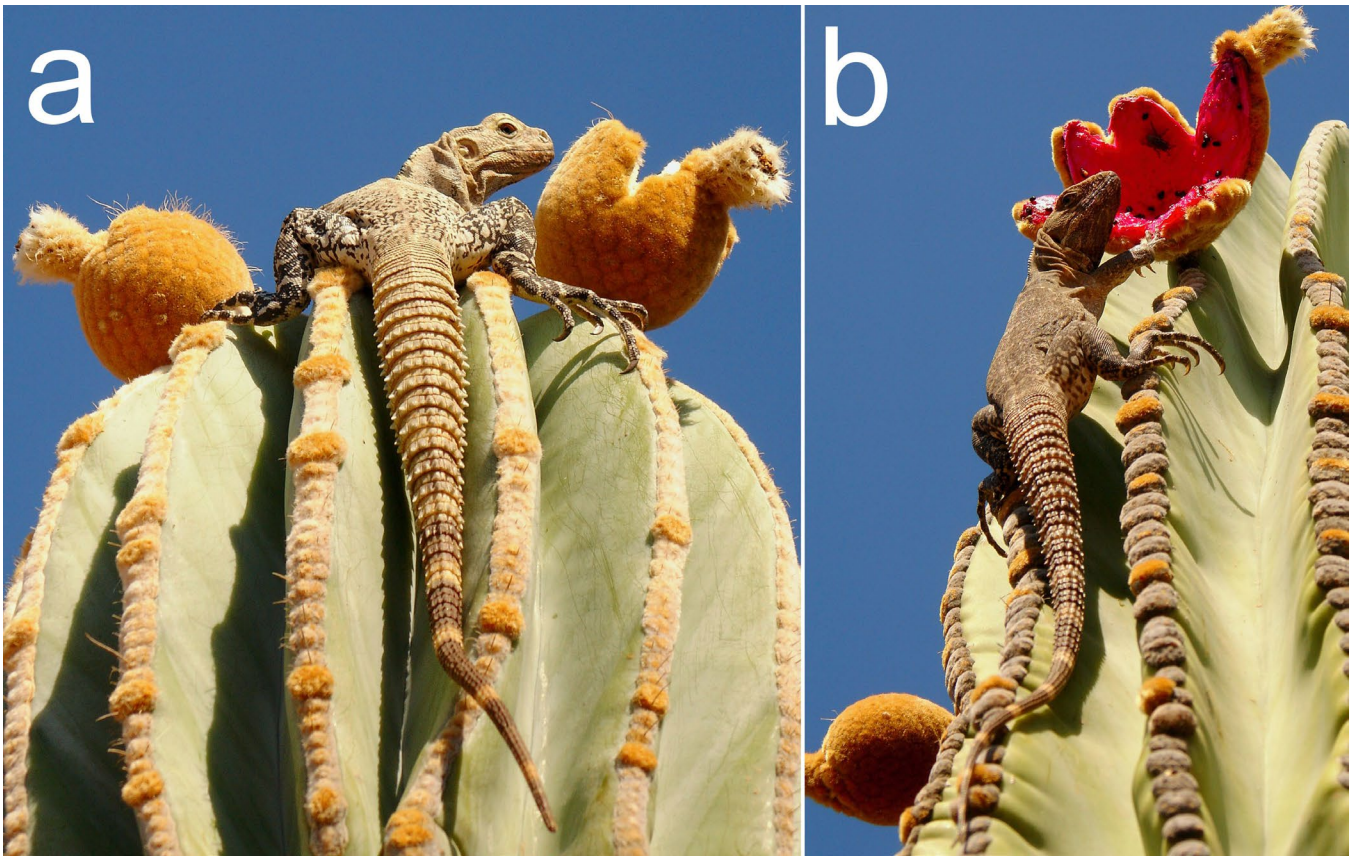

Figura 5. Iguanas de cualquier edad y sexos escalas los cardones para comer lo que está disponible al momento; a) juvenile listo para comer la pulpa de un fruto maduro y abierto; b) un pequeño juvenil ha comido casi toda la pulpa del fruto.

Figure 5. Iguanas of all ages and sexes climb cardon cacti to feed on what is available there; a) a juvenile ready to feed on a ripe fruit; b) a young juvenile has taken almost all the pulp from the cardon fruit.

flowers and fruits of the endemic San Esteban hedgehog cactus (*Echinocereus grandis*), which is small and within the reach of chuckwallas, and flowers and fruits from cardon and galloping cacti. Due to the presence of carotenoids in the fruit's pulp, a typical crimson coloration is also present in the chuckwalla's mouth.

This chuckwalla does not show aggressive behavior while feeding, neither towards their congeners nor towards iguanas. This tolerance contrasts with the behavior of *S. klauberi*, as will be described later. I have seen young *S. varius* as well as large adults (Fig. 9b) on the upper stems of densely stemmed cacti, behavior reported before (Case, 1982, 2002; Grismer, 2002).

Figura 6. Iguana adulta; a) ha mordido la corolla de una flor; b) deglutiendo la corola.

Figure 6. Adult iguana; a) it has bitten the corolla of a flower; b) swallowing the corolla.

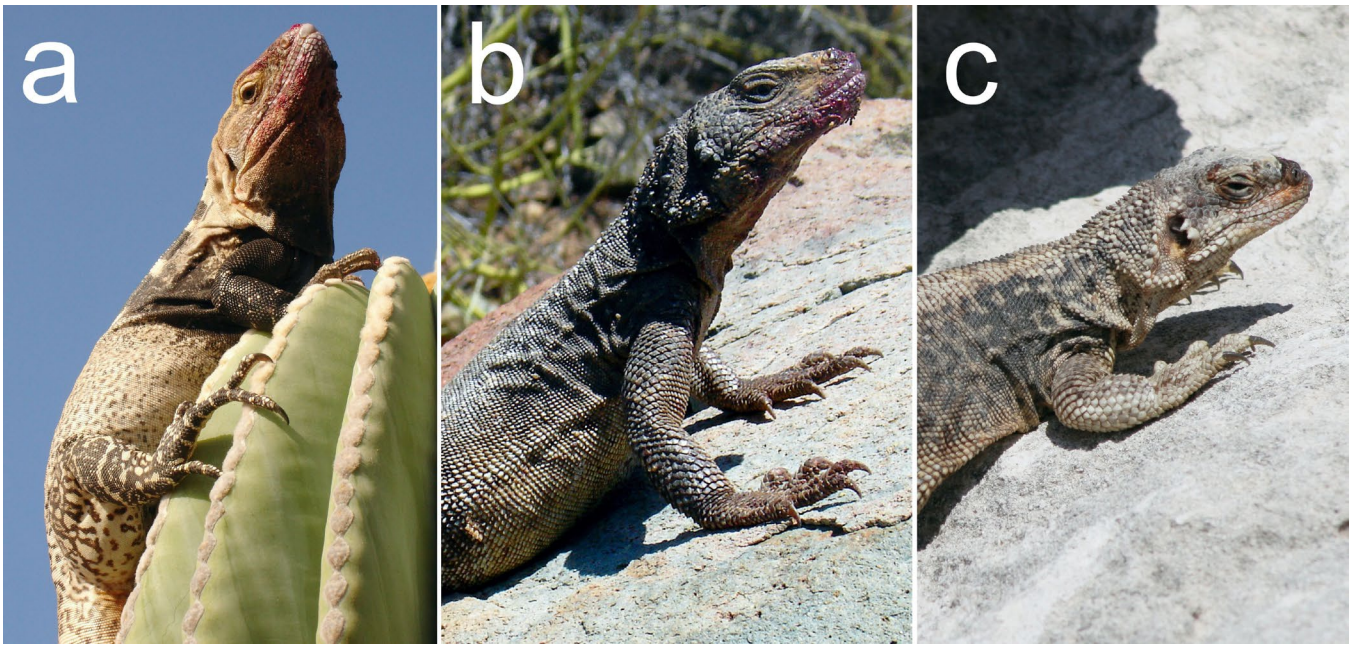

Figura 7. Después de comer la pulpa de un fruto, un color carmesí tiñe las escamas de la boca de los saurios; a) *Ctenosaura conspicuosa*; b) *Sauromalus klauberi*; c) *Sauromalus slevini*.
Figure 7. After eating the fruit's pulp, a crimson coloration remains on the scales around the mouth of lizards; a) *Ctenosaura conspicuosa*; b) *Sauromalus klauberi*; c) *Sauromalus slevini*.

Figura 8. Si las iguanas no obtienen suficiente comida en una rama de cardón, saltan a otra, haciendo que su comportamiento sea aún más llamativo. Foto: Carlos Navarro.
Figure 8. If the iguanas do not get enough food on a cardon branch, they jump to another, making their behavior even more attractive. Photo: Carlos Navarro.

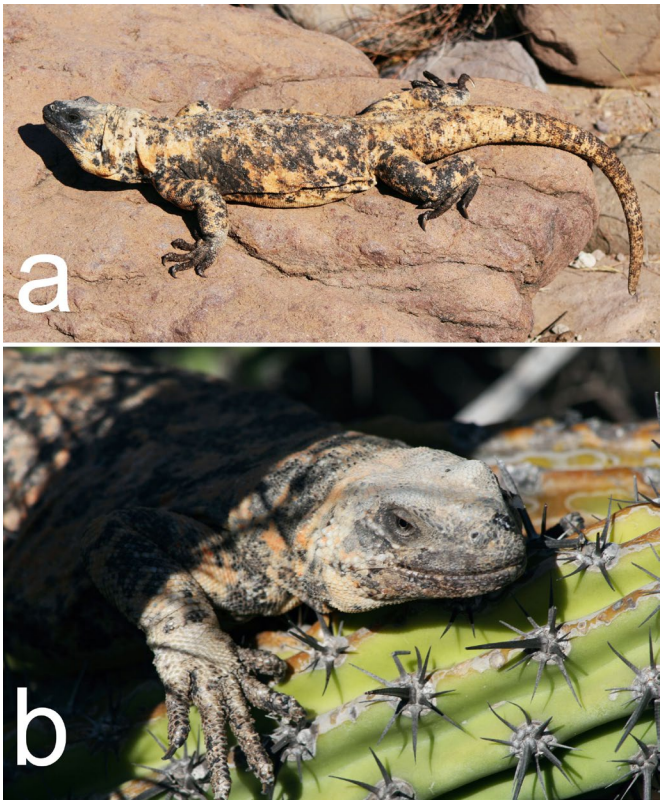

Figura 9. *Sauromalus varius* de la isla San Esteban Island es la especie más grande del género; a) es, básicamente, de hábitos terrestres; b) algunos individuos, en este caso un adulto, pueden ser vistos perchados en pitahayas agrias y otras cactáceas con el propósito de alimentarse.

Figure 9. *Sauromalus varius* of San Esteban Island is the largest of all chuckwalla species; a) it is, basically, a ground dweller; b) some individuals, in this case an adult, can be seen perched on galloping and other cacti for feeding purposes.

I have recorded the black chuckwalla (*Sauromalus hispidus*) (Fig. 10a) more often on Ángel de la Guarda island, especially in the northern part (called Puerto Alcatraz), where *P. pringlei* is moderately abundant. My views of *S. hispidus* (both adults and juveniles) are while feeding on cardon fallen products and eating saltbush (*Atriplex* sp.) and flowers of brittlebush (*Encelia farinosa*) and *Suaeda nigra*, in which they tend to climb upon (Fig. 10b). On Rasa island, where the species never existed but has been reported recently (Velarde et al., 2008; Reynoso et al., 2017; Cerdá & Langarica, 2018), the single extant individual feeds on alkali weed (*Cressa truxilliensis*), which abounds in a small patch of the Tapete Verde Valley. In San Lorenzo Sur my records represent the feeding on cardon fruits only.

The Slevin's Chuckwalla (*S. slevini*) is inhabitant of Carmen, Monserrat and Coronado islands (Fig. 11a) and feeds on leaves and flowers of different perennial and annual shrubs and bushes on the three islands, but unfortunately, I was able to identify only the Baja California Rock Daisy, *Amauria rotundifolia* and the cardon flowers and fruits on the ground, so I provide only six feeding records. This species has a strong tendency to climb upon bushes and small cacti and trees, regardless of its saxicolous habit (Fig. 11b and c), and also can be gregarious.

The Santa Catalina island holds the one-island endemic Santa Catalina Island Chuckwalla (*Sauromalus klauberi*) (Fig. 12a), for which I have records of feeding on fallen cardon buds, flowers and fruits (Fig.12b), as well as on leaves, flowers and fruits of the plants listed in Table 3, for a total of 15 plant species in eight families. The special fact, not previously reported, was the observation of feeding on fallen flowers and fruits of the endemic Santa Catalina Barrel Cactus (*Ferocactus diguetii* var. *diguetii*), that ravens or other organisms may accidentally dislodge from this up-to-four-meters high cactus, or may fall naturally.

The chuckwallas can also reach fruits by climbing on the smaller cacti (from 0.70 m to 2.60 m) *Stenocereus gumossus* and *S. thurberi*. *Sauromalus klauberi* has a strong tendency to climb upon bushes too, and I recorded their efforts to climb upon the cardon cactus (Fig. 12c). This is the only chuckwalla species from which I have seen agonistic behavior towards congeners in association to the feeding of cardon structures on the ground (Fig. 12b), behavior not previously reported by other researchers: when an adult finds a good spot with buds, flowers and/or fruits, it chases away other individuals, either adults or juveniles, that may come close. The aggressive chase is short in distance (1-4 m maximum) and in time (few seconds). Then, the individual concentrates itself in a fast feeding event, being always alert. This species seems to be more solitary than the others, for all records made on Santa Catalina Island by the author are of single individuals, and never have seen it sharing a rock or a crack like in other species.

For *Sauromalus ater* (Fig. 13a), *Dipsosaurus dorsalis* (Fig. 13b) and *D. catalinensis* (Fig. 13c) my records showed a strong tendency for arboreal feeding on the different islands they inhabit, apart from the ground foraging. For *Petrosaurus thalassinus* (Fig. 13d) I recorded individuals feeding on several unidentified plants plus flowers and fruit of cardon and figs of *Ficus palmeri* (that usually grows on the boulders the lizards use as home and territory).

DISCUSSION

Plants consumed. To my knowledge, this report constitutes to date the only first-hand, totally field-based and non-invasive, extant list on the dietary habits of 10 lizard species on islands

Figura 10. a) Un adulto de *Sauromalus hispidus* de la isla Ángel de la Guarda; b) *Sauromalus hispidus* sobre un arbusto.

Figure 10. a) An adult *Sauromalus hispidus* from Angel de la Guarda Island; b) *Sauromalus hispidus* upon a bush.

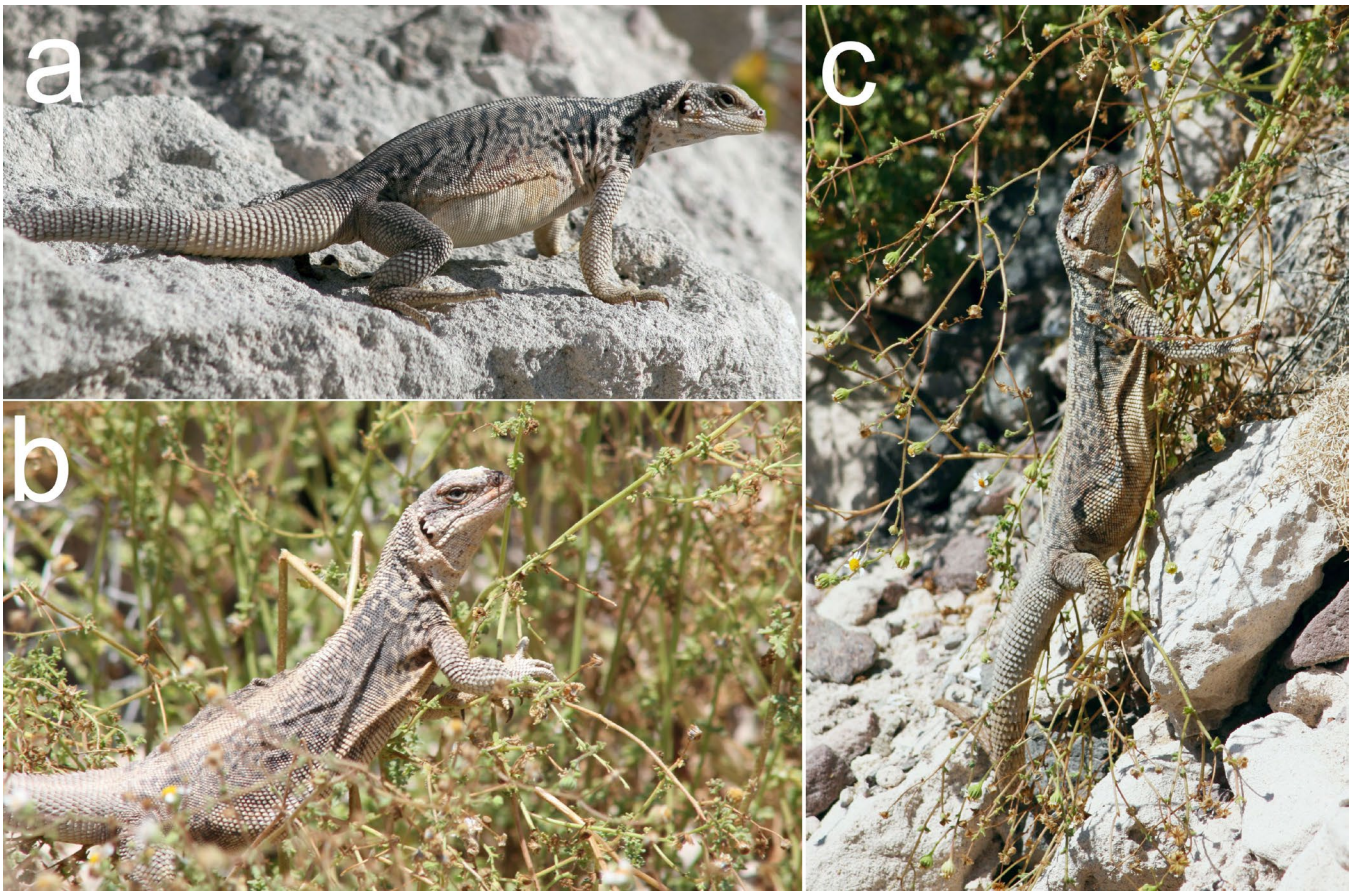

Figura 11. *Sauromalus slevini* de la isla Carmen. A pesar de sus hábitos saxícolas (a) esta especie muestra una fuerte tendencia a escalar sobre los arbustos de los que se alimenta, especialmente margaritas (b y c).

Figure 11. *Sauromalus slevini* from Carmen island. Despite its saxicolous habits (a), this species shows a strong climbing tendency upon bushes it feeds on, especially daisies (b and c).

of the Gulf of California observed directly. Certainly, this is not a finite list; with time, more plant species will be added up. For example, there is a great number of plants that, because of time constraints and my own lack of professional training in botanical taxonomy, I was unable to identify, but may account for several dozen more species to be included in this list; or the new records I obtained in the winter 2019-2020 (which was extremely wet due to summer storms and winter rains) that are not included here but may account for other 10 to 15 plant species, mainly Asteraceae (both annuals and perennials), that were extremely abundant and flowering on islands and the peninsula of Baja California.

For the plant diversity, Table 2 summarizes the number of species that have been recorded in the 15 islands I visited (from Cody et al., 2002). Reptiles have much more options for feeding in the medium-to-large islands, so my contribution here is just a minimal part of what can be expected. As an example, in San Esteban island a total of 123 plants have been recorded; I only report seven species (5.7%) being consumed by *C. conspicuosa* and *S. varius*. On Santa Catalina Island, of a total of 122 plants recorded, 15 species (12.3%) are reported here to be consumed by *S. klauberi* and *D. catalinensis*. For an estimate of 3000 to 4000 plant species for the peninsula and adjacent islands (Rebman & Roberts, 2012), the 59 plants recorded in this study account for only 1.5 to 2%. And for the 649 plant species reported solely for the gulf islands by Cody et al. (2002), my list accounts for a 9% plant species consumed by 10 lizard species. Taking into consideration all my unidentified plant species, and the new records from the winter 2019-2020, I estimate that the herbivorous and omnivorous lizards could eat a minimum of 20 to 30 % of the 649 plant species reported on islands.

Figura 12. a) El cachorón de roca *Sauromalus klauberi* de isla Santa Catalina, y de hábitos saxícolas, muestra una gran preferencia a ser solitario. b) *Sauromalus klauberi* alimentándose de un fruto de cardón en el suelo, situación en la que los individuos muestran comportamiento agresivo hacia sus congéneres. c) Algunos cachorones de Santa Catalina a veces tratan de subir sobre un cardón; a veces son exitosos, otras veces fracasan.

Figure 12. a) The saxicolous chuckwalla *Sauromalus klauberi* from Santa Catalina Island, shows a strong tendency to be solitary. b) *Sauromalus klauberi* feeding on a fallen cardon fruit on the ground, situation in which individuals show aggressive behavior towards congeners. c) Chuckwallas from Santa Catalina Island sometimes try to climb upon cardon cacti; sometimes they are successful, sometimes they are not.

Feeding behavior. The strong climbing tendency detected in chuckwallas must be emphasized. All the species of *Sauromalus* described in this report, at least in the juvenile stage, have been observed climbing upon small bushes and even small trees and cacti. In most circumstances, the animals stand up on their hind limbs to reach leaves, flowers and fruits, climbing upon most plants. Medium-sized *Sauromalus varius* and *S. hispidus* have been seen perched on branches of galloping cacti at more than 1.5 m from the ground. *S. klauberi* has shown a peculiar and strong tendency to climb upon cardon. I have seen its efforts repeatedly in Santa Catalina (Fig. 12c). Not all individuals doing this could climb at all, although many were successful, by holding the cardon's cuticle with their claws. The other chuckwalla species climb a lot too. *Dipsosaurus* species do not hesitate in climbing bushes in order to get food as well (Fig. 13b).

Therefore, climbing by lizards is only one of their many amazing adaptations to the harsh, insular environments of the gulf, and may have important evolutionary implications. Just like what has happened to some reptile species (e.g. insular chuckwallas) in terms of body change (i.e. gigantism, dwarfism [Case, 1976, 1978, 1982, 2002; Tracy, 2004]), to plants (habit

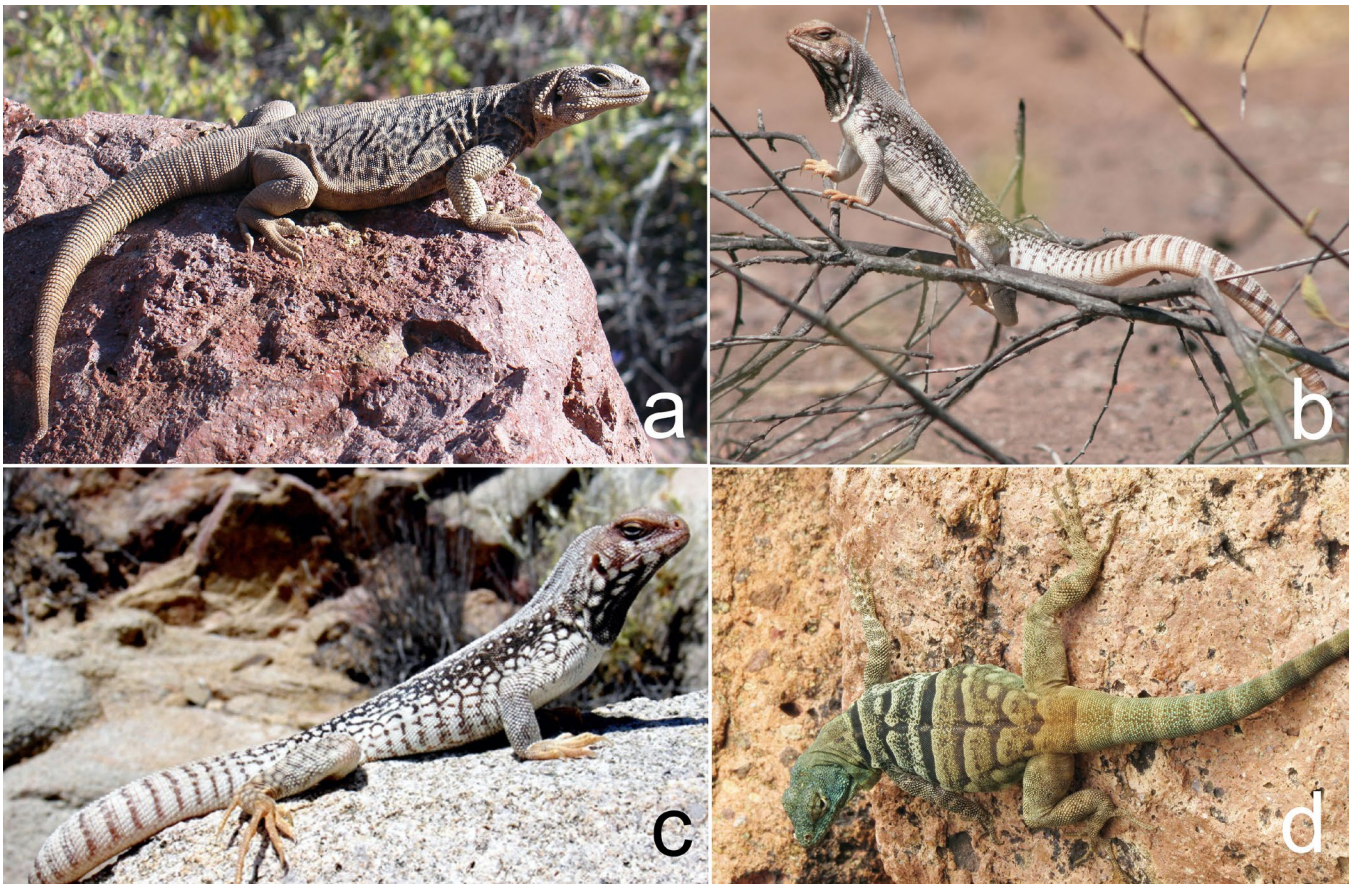

Figura 13. a) *Sauramalus ater*, isla Danzante; b) *Dipsosaurus dorsalis*, isla Carmen; c) *D. catalinensis*, isla Santa Catalina; y d) *Petrosaurus thalassinus* de la isla Espiritu Santo.

Figure 13. a) *Sauramalus ater*, Danzante island; b) *Dipsosaurus dorsalis*, Carmen Island; c) *D. catalinensis*, Santa Catalina Island; and d) *Petrosaurus thalassinus* from Espiritu Santo Island.

change, i.e. bush to tree, woodiness [Carlquist, 1965, 1974]), to tortoises (gigantism [Carlquist, 1965, 1974]), beak shape and size in Darwin's finches (Grant, 1986), changes in mammalian body size and shape on Mediterranean islands (Van der Geer et al., 2010), or change from terrestrial to aquatic as a secondarily adaptation in Mexican box terrapin (Pritchard, 1979), I hypothesize that insular chuckwallas as well as desert iguanas (*Dipsosaurus*) have a tendency to climb because they are passing through a process of shifting from terrestrial to partially arboreal habit as a secondarily adaptation (or a new one) for exploitation of a new ecological space through habitat partitioning that may explain too their high densities.

Habitat partitioning has been demonstrated to be a driver of population densities on small and isolated islands by 'density compensation' (Case, 1975, 1983), a result of the depressed number of predator and competing species that lead to ecological release and increased population densities (MacArthur & Wilson, 1967; Buckley & Jetz, 2007). Density compensation is a general and global phenomenon: it has been found that, on average, lizards on islands have population densities that are over an order of magnitude higher than on the mainland ($N_{island} \approx 10^{1.31 \pm 0.08}$; Buckley & Jetz, 2007). Lizards may have an exceptional potential to reach high densities following predator and competitor release due to their relative low energetic costs (up to 10 times lower than those of endotherms), and may also increase their densities by diversifying their diets (Buckley & Jetz, 2007) and by habitat partitioning.

Diversification of diets has been investigated by Olesen and Valido (2003) as well, finding that this island phenomenon occurs because island lizards reach very high densities by experiencing a lower predation risk than do those on the mainland (density compensation). Consequently, they can expand their diet to include nectar, pollen and fruit.

Olesen and Valido also stated that there are four potential reasons for why island lizards might include more floral

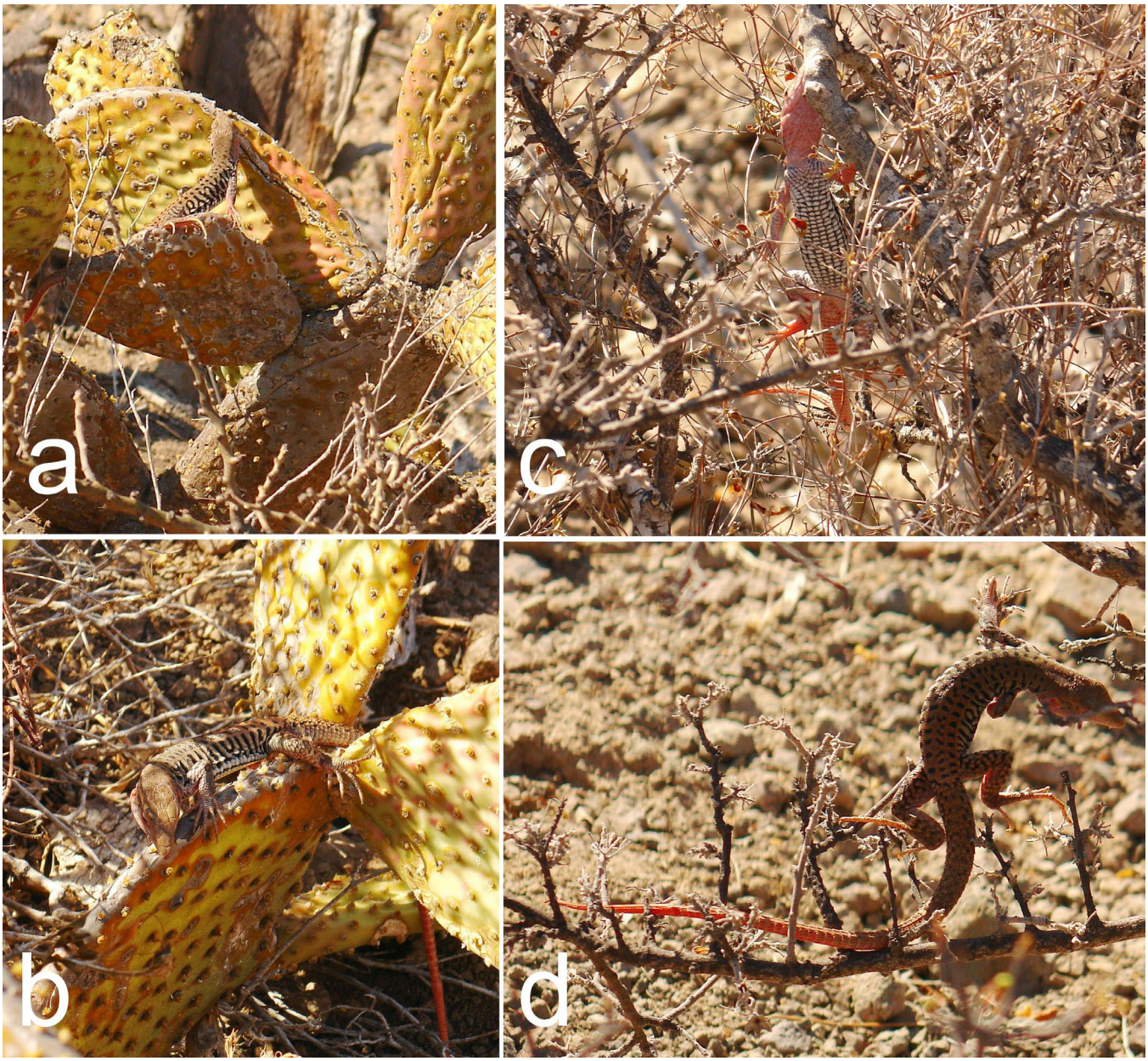

Figura 14. a-d. *Aspidoscelis rubidus*, de isla Danzante, frecuentemente se encarama sobre los arbustos y cactáceas buscando insectos y agallas de insectos. Este comportamiento incrementa sus posibilidades de encontrar alimento y expande su nicho terrestre típico hacia uno arbóreo.

Figure 14. a-d. *Aspidoscelis rubidus*, from Danzante Island, frequently climbs upon bushes and cacti while looking for insects and insect galls. This behavior increases its possibilities to find more food and expands its typical ground niche to an arboreal one.

resources and fruit into their diet compared with adjacent mainland species. Islands might have: (1) a surplus of floral food and fruit for herbivorous lizards (2) a scarcity of arthropod for insectivorous lizards; (3) larger lizards pre-adapted to a herbivorous diet; and (4) a reduced predation risk (Olesen & Valido, 2003). All these topics are still open for investigation on the gulf islands.

As an interesting example of an arboreal habit tendency in mostly ground lizards, in 2006 I observed an individual of *Aspidoscelis rubidus* on Danzante Island, climbing upon prickly pears and other plants in search of insects and insect galls (Fig. 14a-d), which is reported here for the first time. I have recorded this behavior some other times too.

Ecological implications. From literature data and the results of this study it seems clear that saurian communities on islands consume much more plant species than was known, and the niches they occupy are varied and complex, both temporarily and spatially. The plants consumed by lizards at different times of the year have different impacts on different stages of the lizards' life cycles. Some plants may be important for growing and re-gaining weight and a good health condition after the dry portion of the year, and others might be important for reptiles' reproduction, especially in the summer months (Case, 2002). Berry (1974) reported on the importance of food availability for growing of hatchlings during their first winter for *S. ater* at Lone Butte, California. Unfortunately, information about ontological parameters is still nonexistent for most insular reptiles (but see Cerdá-Ardura, 2019).

The ecological implications of the reptiles' feeding habits also go far beyond their own ontogenetic development and life cycles: I show here that their food habits have spatial, wide-range importance since they influence other populations and species, and even the whole insular community, both up (to predators) and down (to producers and primary consumers), as well as horizontally (to competitors and symbionts) for the reasons given below with one single example. Before going further, it is useful to remember that food webs are special descriptions of biological communities focusing on trophic interactions between consumers and resources, and ultimately represent transfer rates of energy and matter, thus they require tools to translate resource availability to energy supply, *i.e.* known biomass of both producers and consumers should be translated into growing and respiration rates (De Ruiter, Wolters and Moore, 2005). For insular reptiles, food webs have not been analytically constructed yet due to the lack of physiological studies.

I can exhibit the complexity of food webs in insular lizards with the single example of ctenosaurs by three observations. First, in a small, local scale, *Ctenosaura conspicuosa* of San Esteban Island feeds profusely on cardon buds, flowers and fruits on the highest branches, playing the role of a primary arboreal consumer and seed disperser in this niche that is shared with frugivorous and nectarivores birds, insects, and pollinating bats; in consequence, *C. conspicuosa* establishes horizontal, symbiotic interactions with the other animals by competition, and acts as a symbiotic seed disperser for the cardon but also altering or controlling consumption, pollination and seed dispersal rates of the plant.

Second, the ctenosaurs dislodge flowers and fruits adding biomass to ground dwellers (other reptiles species and, possibly, rodents and insects); with this, ctenosaurs partially subsidize the trophic level of the totally ground-based primary consumers in the same ecosystem but in a different niche. Subsidies of different types play an important role in general feeding ecology (sensu Huxel & McCann, 1988; Leroux & Loreau, 2008). As Barret el al. (2005) pointed out, ecosystems, even those with seemingly distinct borders, rarely function independently of other adjacent ecosystems, and ecologists are increasingly recognizing the important effects that cross-ecosystem transport of energy and nutrients have on plant and animal population, food webs and community patterns. The transport of energy and nutrients occurs from organisms that travel across ecosystem boundaries or from abiotic factors such as wind, tidal action, or watershed drainage. When materials move from a highly productive system to a relatively unproductive system, they have the greatest potential to alter plant and animal population and community dynamics.

Third, ctenosaurs are partially carnivorous of chuckwallas hatchlings and juveniles (Case, 1982, 1992), controlling at least minimally the *Sauromalus*' population recruitment and its juveniles' ecological distribution by displacing them to other niches, a consequence of predatory avoidance (i.e. to foothills). Therefore, I propose that ctenosaurs move in a tri-dimensional habitat with two functional niches: one niche represented by the ground (where they consume primary producers, and prey upon chuckwallas), and the other niche represented by the cardon, other cacti and non-cactus species (where ctenosaurs act as arboreal consumers and competitors for pollinating bats, birds and arthropods), providing important subsidies to the ground dwellers.

In turn, ctenosaurs, chuckwallas, desert iguanas and banded-rock lizards are subject to predation by raptors (i.e. red-tailed hawks, kestrels), owls, ravens, great blue herons, gulls, snakes, other lizards (e.g. the predatory genus *Gambelia, per. obs.*) and ring-tailed cats. For ring-tailed cats (*Bassariscus astutus sexicolus*), Sansores (2016), from 90 fecal samples in Espíritu Santo island, recorded the following reptiles as part of its diet: *Chilomeniscus punctatissimus, Masticophis* sp., *Aspidoscelis* sp., *Dipsosaurus dorsalis*, *Sauromalus ater, Sceloporus* sp., *Urosaurus nigricaudus*, and *Uta stansburiana)*. Ctenosaurs do not occur on this island.

It is then not an excess to state that herbivorous and omnivorous insular lizards, as primary and secondary consumers and in some cases also predatory, are in the middle of complex food webs (*sensu* Lindeman, 1942), topology strengthened by the arboreal tendency that most of the studied species show, and the occurrence of subsidies. The arboreal habit, strong in ctenosaurs

and less marked in chuckwallas, may be an expansion of their ecological and evolutionary adaptations to survive, and in this way the reptiles get involved in more complex energy transfers that exert influences on: (1) the plants' cycles by means of consumption; (2) the ecological symbiosis with plants, either as pollinators or seed dispersers, influencing their phenology and population dynamics; (3) the ecological symbioses with other organisms that share the same habitats (i.e. by competing with frugivorous bats, birds and insects, and with bird and mammalian seed dispersers; and with insectivorous bats and birds); (4) the ecosystem functioning, possibly controlling parts of it (*sensu* Paine, 1966, 1980).

Simultaneously, strict insectivorous invertebrates and vertebrates, and omnivorous lizards like *Dipsosaurus dorsalis, D. catalinensis,* and *Petrosaurus thalassinus* benefit from inputs from other ecosystems, or subsidies. Barret el al. (2005) demonstrated that materials are transferred from the ocean onto the islands and mainland coast by two mechanisms: 1) tidal activity, that washes large algal mats and marine carrion onto the beaches of the islands and mainland; and 2) seabirds, which feed exclusively in the marine system and transport marine derived nutrients onto the islands when they return to roost and nest. These nutrients may be in the form of guano, fish scraps, eggs, or bird carcasses. Marine materials have been found to subsidize insular and coastal communities including plants, detritivores beetles, rodents, spiders, and scorpions.

Barret el al. found that populations of *Uta stansburiana*, from 20 islands in the Gulf of California and coastal mainland of Mexico, benefit by consuming materials derived from the extremely productive marine system, and these food subsidies alter lizard abundance, as was derived from analyses of stable isotopes of C and N from lizard tissues to determine if lizard diets are ultimately based in the marine food web where subsidies are available (Barret el al., 2005). Polis and Hurd (1995) provided a notable example of these subsidies by marine input in relation to the extraordinary abundance of spiders on island of the Gulf of California, and Cerdá-Ardura (*in prep*.) shows the importance of marine subsidies for coyotes (*Canis latrans*) on Magdalena island.

The cardon cactus as a structural species. It has been found that, in food webs, there are few 'structural species' (Winemiller & Layman, 2005) which determine the production dynamics and ecosystem processes. In many ecosystems, according to these authors, certain plants and herbivores clearly support most of the consumers biomass, and certain consumers strongly influence biomass and production dynamics at lower levels. In many of the gulf islands, one conspicuous plant dominates the biomass of the whole land system: it is the cardon cactus. Therefore, this cactus can be considered as such.

The cardon dominates the landscape from the southern ranges in latitude 22° 54' N to 31° N on both sides of the Gulf of California to many of its islands (Medel-Narváez, 2003). The cardon possesses great symbiotic relevance (Franklin et al., 2016). For example, Delgado-Fernández et al. (2017) recorded 61 species of different taxonomic groups involved in 83 types of interactions with cardon as a source of food and shelter on the peninsula of Baja California. It is important to notice that these authors recorded only two reptile species involved in those biotic relations.

According to results in this study, the cardon is the most consumed plant by all the reptile species accounted for, at least during the flowering and fruiting seasons, with 168 observations. As a consequence of the great density of cardon, and the number of buds, flowers, fruits, pollen and nectar it produces (Fleming, 2002; Medel-Narváez, 2008), this plant constitutes one of the structural species for many herbivorous reptiles, birds, insects and mammals, including nectarivores and fruit-eaters of all sorts (*pers. obs.*).

By taking the figures provided by Fleming (2002) for this cactus (all averages: fruit mass = 78.9 g; seed mass = 52.2 mg; seeds per fruit = 1,329; flowers per season per plant = 872; fruits per season per plant = 170; seeds per season per plant = 225,930), and applying basic math to them, we can then obtain the following (all calculations mine): from a simple flower mass of 40.9 g existent in 1,329 flowers produced per season per plant, we obtain 54.3 kg of flower mass per plant per season. If we take the average 288 cardon/ha given by Medel-Narváez (2008), it results that, in a hectare, there are 15,638.4 kg of flowers available for herbivorous organisms.

Given the 170 fruits per season per plant contained in 288 ind./ha, we obtain 48,960 fruits/ha/year, or a fruit mass of 3,862.9 kg per ha/year. Thus, these 3,862.9 kilograms of fruit would theoretically be available for 1.4 to 44.3 *S. hispidus* per ha found by Case (2002), and to 8.3 to 45.4 individuals per ha of *S. varius*. In other words, for the lowest density of *S. hispidus* (1.4 indiv./ha), there would be 2,759 kg of fruit mass/year/ha per individual, and 465 kg of fruit mass/year/ha/ per individual for *S. varius* (8.3 indiv./ha); on the other hand, for the highest number of *S. hispidus* (44.3 indiv./ha), there would be 87 kg of fruit mass/year/ha per individual, and 81 kg of fruit mass/year/ha per individual of *S. varius* (45.4 indiv./ha).

This great theoretical amount of food potentially available for herbivorous lizards and for fruit flies, bees, wasps, lepidopterans, birds, bats, rodents, lagomorphs, deer and bighorn sheep, among many other, can be significantly increased by obtaining, from field data, the contributions of the other cacti and plant species. Thus, the energy that circulates from insular producers to primary consumers could be very large from an estimate of 649 species of plants reported for islands in the gulf (Cody et al., 2002). Unfortunately, for none, except cardon and cholla, biomass has been estimated in the field. The same occurs with physiological characteristics, like CO_2 consumption and conversion rates, which are necessary parameters that can be obtained either in the field or in laboratory. For some cacti, Nobel (2002) offers an excellent overview on physiological ecology of columnar cacti, and among other things, estimated a maximal rate of net CO_2 uptake of 8 $\mu mol \cdot m^{-2} \cdot s^{-1}$ for *Stenocereus queretaroensis, Carnegiea gigantea* and *P. pringlei* at night, which is immediately incorporated into phosphoenolpyruvate which leads to the formation of an organic acid such as malate, and only fixed during the day into photosynthetic products such as the sugars glucose and sucrose.

Case (1982, 2002) reported that, for *Sauromalus hispidus*, population density in one locality was around 52 animals/hectare (about 1/3 were juveniles); on San Esteban was about 12.4 animals/hectare with no juveniles. The biomass maintained by the insular endemic chuckwallas was large: 20.8 kg/hectare for *S. hispidus* and 7.8 kg/hectare for *S. varius.* The *Ctenosaura* of San Esteban probably added at least another 5 kg/hectare. In relation to plants, in the same studies, Case found that the average number of buds, flowers and fruits on individual cholla in 1979 yielded 205 potential fruit/cholla. The average number of ripe edible fruits produced per cholla was 305. Using 18 gr/fruit and 1.8 Kcal/g dry weight and 41 plants/ha over a 6-month period, 122,500 Kcal of cholla fruit would be produced by hectare. The amount of this energy consumed by *Sauromalus* (assuming cholla fruit is all that they ate) was only about 23% of that produced. Since at least 30% of the chuckwallas diet consisted of other plant species, they alone did not appear to be making a severe dent in the total food supply. The diet of sympatric *Ctenosaura hemilopha* (= *C. conspicuosa* [Grismer, 1999]) was nearly identical to that of *S. varius. Ctenosaura* appeared to be almost as numerous. Both iguanids together may have eaten at most 46 % of the available energy tied up in cholla fruit during the moderately 1979 activity season.

As it can be derived from the above calculations, the flora of the islands of the Gulf of California holds a huge amount of energy available for organisms, and represent a treasure to be investigated by field biologist to fully understand the food webs, energy flux, population dynamics, and other topics in ecology and Natural History. This knowledge may have a great impact in the conservation actions for the insular environments.

CONCLUSIONS

A list of 59 plants of 19 families consumed by 10 herbivorous and omnivorous lizard species on 15 islands of the Gulf of California is available for the first time in literature, number that represents a 9.1% of the 649 plant species reported for these islands. *Sauromalus ater*, a widespread species with insular, peninsular and mainland representatives, has the most varied diet, consuming 47 plants of 19 families. All lizard species normally forage in the ground, but nine (the exception being *Petrosaurus thalassinus*) show a very marked tendency to climb upon bushes and small trees to get food, thus exploiting temporarily a new niche by becoming partially arboreal as a secondary, or maybe totally new, adaptation for survival.

The spiny-tailed iguana *Ctenosaura conspicuosa* from San Esteban Island, a mostly ground dweller but also with semiarboreal habits climbs to the cardon branches to feed, but frequently and accidentally dislodges buds, flowers and fruits that fall to the ground. Therefore, ctenosaurs function as important food-suppliers or subsidizers for other saurian species that forage on the ground, impacting their population biology and possibly their evolutionary histories. For their herbivory and for their habit of preying on chuckwalla hatchings, the iguanas occupy an important position in the insular food web, inhabiting a tri-dimensional habitat with ground and arboreal niches. The insular herbivorous and omnivorous lizards may also exploit other resources subsidized by the sea and may be preyed by different island predators. As a result, the 10 reptile species are entangled into complex food webs.

The cardon cactus, the most consumed plant in this study, produces vast amounts of flowers and fruits (representing vast amounts of biomass, energy, and water), and thus I consider it a structural species that support many different organisms, including herbivorous reptiles, at least during 3 to 4 months, time period that embraces the breeding season for some of the lizards reported here. The other 58 plant species, belonging to diverse families of vascular plants, also play a vital role in providing a still unknown amount of biomass whose availability throughout the year may substantially influence the rate of growing of hatchlings and juvenile herbivorous lizards before reaching sexual maturity.

Field observation is still a very powerful tool to understand the biology and ecology of organisms and provide qualitative and quantitative information that can be used for modelling and testing, and for conservation.

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A NEW SPECIES PREVIOUSLY CONFUSED WITH *CAECILIA PACHYNEMA* (GÜNTHER, 1859) (AMPHIBIA: GYMNOPHIONA: CAECILIIDAE) FROM THE CORDILLERA CENTRAL OF COLOMBIA

UNA NUEVA ESPECIE PREVIAMENTE CONFUNDIDA CON *CAECILIA PACHYNEMA* (GÜNTHER, 1859) (AMPHIBIA: GYMNOPHIONA: CAECILIIDAE) DE LA CORDILLERA CENTRAL DE COLOMBIA

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Resumen.— *Caecilia pachynema* es una especie con una coloración llamativa, conocida del occidente de Ecuador y supuestamente de una población remota al norte de la Cordillera Central de Colombia. Previamente se había reconocido que aquellas poblaciones colombianas de "*C. pachynema*" pertenecen a una especie no descrita. El material obtenido durante los últimos veinte años nos permite describir esta especie nueva y restringir la distribución de *C. pachynema* a Ecuador.

Palabras clave.— Cecilias, Dimorfismo sexual, Fosorial, Neotropical, Taxonomía.

Abstract.— *Caecilia pachynema* is a distinctively colored species known from western Ecuador and supposedly from a remote population in the northern Cordillera Central of Colombia. Previously it had been detected that the Colombian populations of "*C. pachynema*" were likely an undescribed species. Material gathered over the past twenty years allows us to describe this new species and restrict the known distribution of *C. pachynema* to Ecuador.

Keywords.— Caecilians, Fossorial, Neotropical, Sexual dimorphism, Taxonomy.

INTRODUCTION

Caecilia pachynema (Günther, 1859) is a large, stout caecilian with large, recurved dentary teeth, known from western Ecuador in the provinces of Azuay, El Oro, Intac, Pallatanga, and Pichincha. This species bears a particular color pattern of white rectangles on the annuli, subdivided by dark grooves, constituting a broad "ventrolateral stripe" along the body. Taylor (1968) remarked that this species inhabited the Pacific drainages of Ecuador, the Caribbean drainages of Colombia, and considered that it might extend into Peru. Our results indicate this species is restricted to western Ecuador as it has not been found in the neighboring Pacific lowlands of Colombia. Furthermore, the Peruvian record was subsequently designated as the holotype of *C. inca* by Taylor (1973).

The presence of *C. pachynema* in Colombia was first reported by Dunn (1942), who provided a brief taxonomic account but had a mixed series that comprised more than a single species. Later, Taylor (1968, 1973) named *C. attenuata* Taylor, 1968, *C. crassisquama* Taylor, 1968, and *C. tenuissima* Taylor, 1973, which were taken from the type series of Dunn's *C. pachynema*. Lynch (2000)

detected an undescribed species misidentified as '*C. pachynema*' known from around Medellín, Antioquia, Colombia, and attributed the taxonomic confusion to the recurrent presence of similar coloration patterns (like that of *C. pachynema*) in various Colombian species of *Caecilia* (i.e. *C. occidentalis* Taylor, 1968 and *C.* sp.) but deferred from describing it until further material became available. Over the past twenty years, enough material has become available for a robust taxonomic assessment of this new species and its intraspecific variation.

MATERIALS AND METHODS

All groove counts were performed under a stereoscope and repeated at least twice for each individual. Entomological pins were used to demarcate and differentiate primary and secondary grooves in order to avoid misrepresenting their individual counts. Careful incisions to the mouth's commissure were performed using a razor blade in order to fully open the mouth and access dentition, choanae, and tongue when necessary. A sharp pin was used to open the pockets where the primary grooves concealed their dermal scales. Once these were obtained, they were described in shape and size and put back in their respective positions so no material would be lost or damaged. Subdermal scales were searched by partial dissection of the annuli close to mid-body point and removing a section of epidermis to expose the connective tissue and determine their presence or absence.

Sex was determined through direct examination of gonads by performing a ventral longitudinal incision posterior to the mid-body point and anterior to the vent to look for testis in males and ovaries in females; if mature testis or ovaries were found, these were considered to be adults. Juveniles are much smaller than adults, have undefined collars, and bear an incomplete dentition. Diagnosis and description follow Taylor (1968) and Maciel & Hoogmoed (2018) with some modifications. All measurements were performed under a Zeiss stereoscope; these were taken to the nearest 0.1 mm using a Neiko digital caliper with the exception of total length, which was determined using a measuring tape.

Comparisons of groove counts were made using Taylor's (1968) species accounts or their respective original descriptions for those species of *Caecilia* described after 1968. Museum abbreviations are as follows: Colección de Anfibios, Museo de Historia Natural C.J. Marinkelle, Universidad de Los Andes, Bogotá, Colombia (ANDES), British Museum of Natural History (BMNH), now Natural History Museum, London, U.K., Colegio San José, Medellín, Colombia (CSJ), now Instituto Tecnológico de Medellín, Colección de Anfibios, Instituto Alexander von Humboldt, Villa de Leyva, Boyacá, Colombia (IAvH), Colección de Anfibios, Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá, Colombia (ICN), Museo de Herpetología, Universidad de Antioquia, Medellín, Colombia (MHUA), Museo de Herpetología, Universidad del Cauca, Popayán, Colombia (MHUC), Colección de Anfibios, Museo La Salle, Universidad de La Salle, Bogotá, Colombia (MLS), Colección de Anfibios, Pontificia Universidad Javeriana, Bogotá, Colombia (MUJ), Colección de Anfibios, Universidad Industrial de Santander, Bucaramanga, Colombia (UIS), Museo de Zoología, Pontificia Universidad Católica del Ecuador, Quito (QCAZ), National Museum of Natural History, Smithsonian Institution, Washington, D.C., U.S.A. (USNM), and Colección de Herpetología, Universidad del Valle, Cali, Colombia (UVC).

RESULTS

Caecilia goweri sp. nov.

Caecilia pachynema Dunn, 1942: Taylor (1968: 425), Lynch (2000: 327)

Holotype. MHUA 3241, an adult male from vereda Potreritos, San Antonio del Prado, Medellín, Antioquia, 6°10'55.74" N, 75°39'49.8" W, 1800 meters above sea level (m a.s.l.) by C. Cuartas in 2003 (Fig. 1).

Paratypes (n = 12). MHUA 3915, an adult female collected by Mauricio Rivera-Correa in 1998 in Altos del Castillo, Belén, Medellín, Antioquia, Colombia, 6°14'07.0" N, 75°36'58.0" W, 1600 m a.s.l.; MHUA 6296, a juvenile obtained by O. Ortiz in 2009 in Alto de Mercado, Marinilla, Antioquia, 6°10'46.0" N, 75°18'13.0" W, 2200 m a.s.l.; MHUA 8115, an adult male obtained by Juan Manuel Daza in 9 January 2014 in Finca El Recuerdo, San Juan, San Roque, Antioquia, 6°27'49.3" N, 75°2'56.5" W, 1500 m a.s.l. (Figs. 2–3); MLS 46, an adult male obtained in Carolina del Principe, Antioquia, 6°43'21.0" N, 75°17'03.0" W, 1800 m a.s.l. in 28 November 1971; MLS 48–49, small juveniles collected in Caldas, Bellavista, Antioquia, 6°05'15.2" N, 75°38'03.0" W, 1750 m a.s.l. in December 1967 by Hermano José Ignacio Isaza; MLS 50, an adult female obtained in San Pedro, Antioquia, 6°15'53.0" N, 75°37'18.8" W, 1620 m a.s.l. in 10 May 1967; MLS 51, an adult male obtained at San Antonio del Prado, Medellín, Antioquia, 6°10'53.9"N, 75°38'9.6"W, 1700 m a.s.l. in 20 May 1971; MLS 52, an adult female obtained by Hermano Marco Antonio Serna in San Antonio del Prado, Medellín, Antioquia, 6°10'53.9"N, 75°38'9.6"W, 1700 m a.s.l. in 10 May 1967; MLS 53, an adult female from Caldas, La Tablaza, Antioquia, 6°6'53.47"N, 75°38'17.71"W, 1750 m a.s.l. by Hermano Marco Antonio Serna in January 1969; UVC 7376,

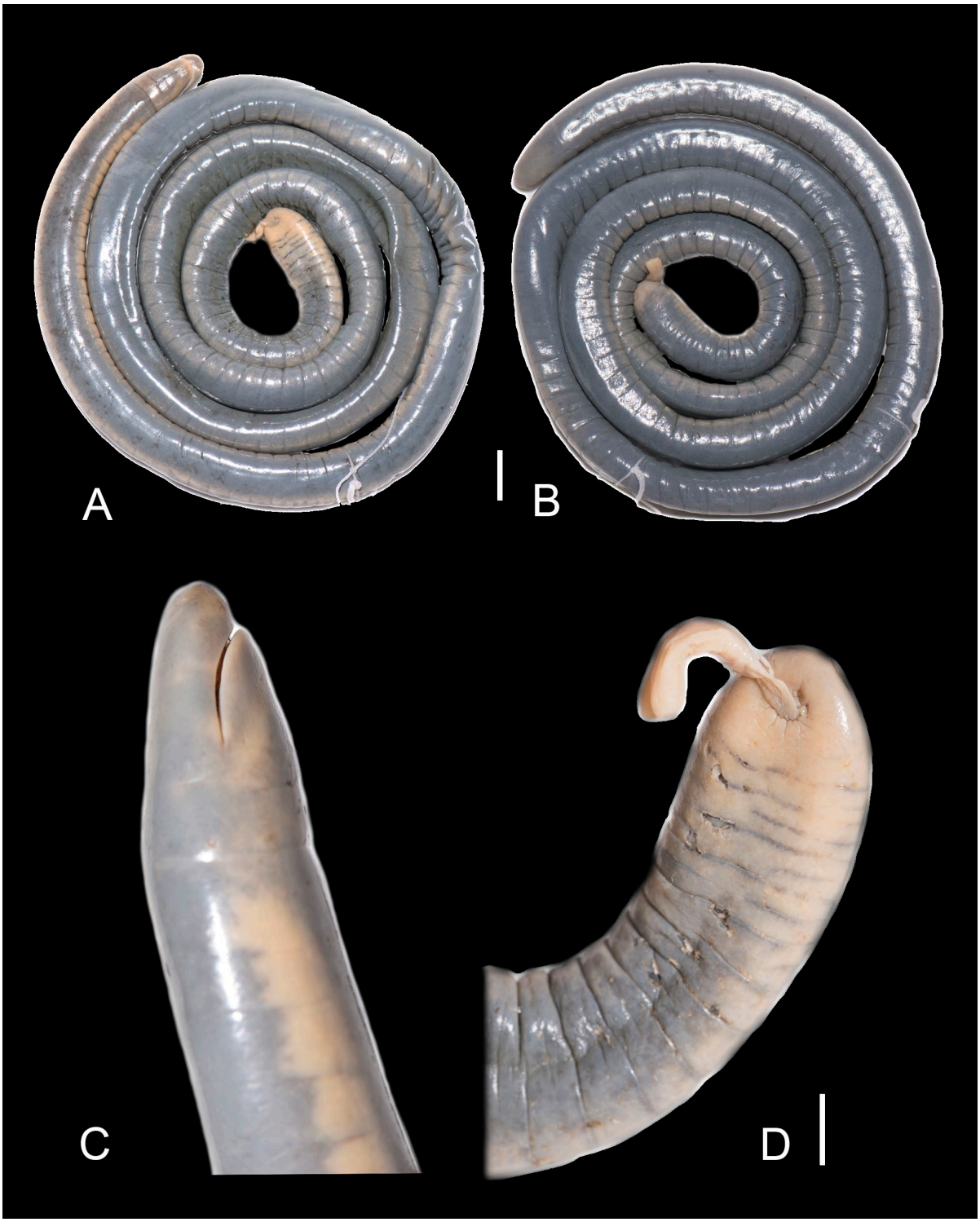

Figura 1. Holotipo de *Caecilia goweri* (MHUA 3241). (A) Vista ventral y (B) dorsal del especimen; la escala equivale a 8 mm. (C) Vista lateral de la cabeza y (D) vista ventral del término y el phallodeum; la escala equivale a 3mm.

Figure 1. Holotype of *Caecilia goweri* (MHUA 3241) (A) Ventral and (B) dorsal views, respectively, of whole specimen; scale bar equals 8 mm. (C) Lateral view of the head and (D) ventral view of the terminus and phallodeum; scale bar equals 3 mm.

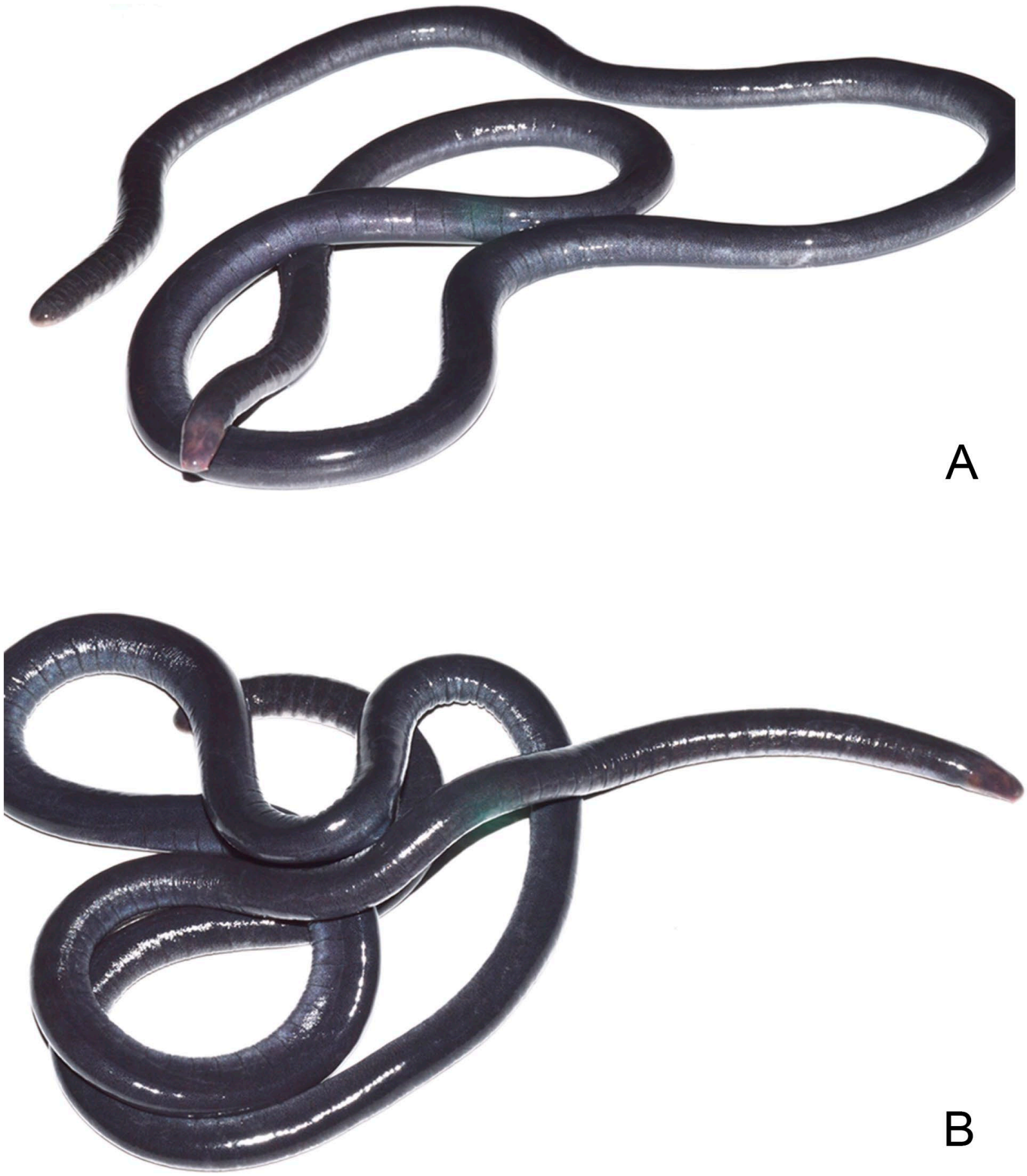

Figura 2. (A-B) Vista general del cuerpo de *Caecilia goweri* (MHUA 8115) en vida. Fotografías por el Dr. Juan Manuel Daza del MHUA.

Figure 2. (A-B) General body views of *Caecilia goweri* (MHUA 8115) in life. Photographs by Dr. Juan Manuel Daza of MHUA.

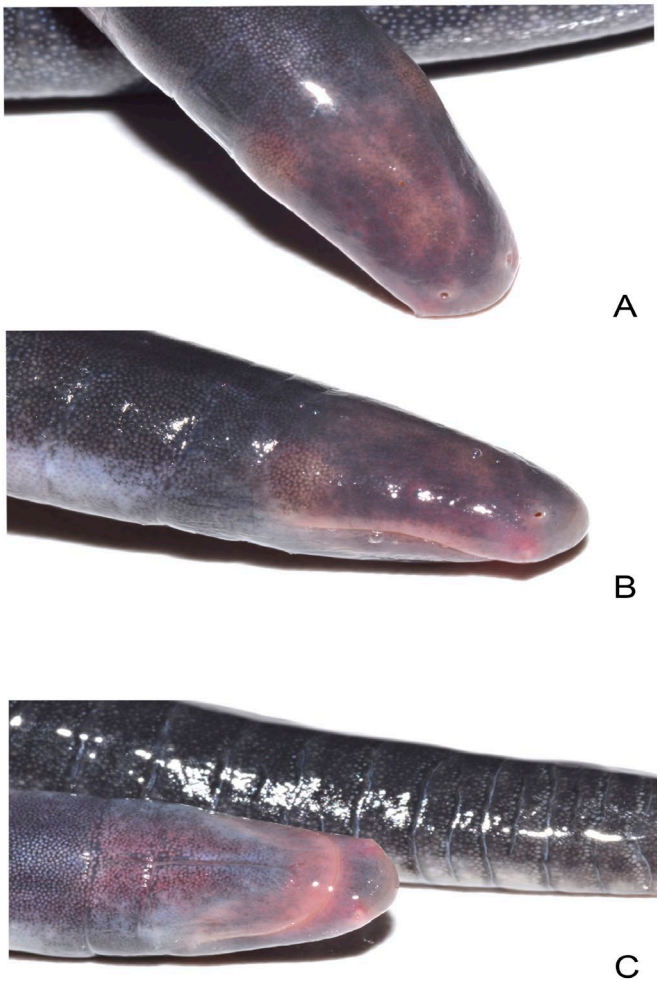

Figura 3. Cabeza de *Caecilia goweri* (MHUA 8115) en vista (A) dorsal, (B) lateral y (C) ventral, en vida. Fotografías por el Dr. Juan Manuel Daza del MHUA.

Figure 3. Head of *Caecilia goweri* (MHUA 8115) in (A) dorsal, (B) lateral, and (C) ventral views, in life. Photographs by Dr. Juan Manuel Daza of MHUA.

an adult female and UVC 77, an adult male obtained in Caldas, Antioquia, 6°06'01.0" N, 75°37'26.0" W, 1750 m a.s.l. by Hermano Marco Antonio Serna in July 1968.

Referred specimens (n = 4). CSJ 710, 711, 1141 and 1507 from Medellín, Antioquia, Colombia. All examined by J.D. Lynch in 1999.

Distribution. Known only from the northern Cordillera Central of Colombia in the Altiplano region of Medellín, Antioquia, in the municipalities of Caldas, Carolina del Principe, Marinilla, San Antonio del Prado, San Pedro, San Roque and San Vicente; as well as in the city of Medellín, ranging from 1500–2200 m a.s.l.

Diagnosis. Differs from *C. attenuata*, *C. caribea* Dunn, 1942, *C. corpulenta* Taylor, 1968, *C. crassisquama*, *C. degenerata* Dunn, 1942, *C. guntheri* Dunn, 1942, *C. inca* Taylor, 1973, *C. occidentalis*, *C. orientalis* Taylor, 1968, *C. pachynema* (Figs. 4–5), *C. pulchraserrana* Acosta-Galvis, Torres & Pulido-Santacruz, 2019, and *C. subdermalis* Taylor, 1968, because unlike these species, it bears secondary grooves.

Caecilia disossea Taylor, 1968 (216–262 primary grooves), *C. gracilis* Shaw, 1802 (183–204), *C. occidentalis* (191–221), and *C. thompsoni* Boulenger, 1902 (187–240) are the only member of the genus that have higher counts of primary grooves than *C. goweri* (156–193 primary grooves and 7–20 secondaries), while *C. abitaguae* Dunn, 1942 (137–148 primaries and 0–5 secondaries), *C. albiventris* Daudin, 1803 (144–147 primaries and 45–53 secondaries), *C. dunni* Hershkovitz, 1938 (124), *C. guntheri* (111–132), *C. isthmica* Cope, 1877 (131–147), *C. leucocephala* Taylor, 1968 (118–142), *C. mertensi* Taylor, 1973 (142), *C. museugoeldi* Maciel & Hoogmoed, 2018 (152), *C. perdita* Taylor, 1968 (139–152), *C. tentaculata* Linnaeus, 1758 (122–137), and *C. volcani* Taylor, 1969 (112–124) all have lower counts of primary grooves than the new species.

Caecilia antioquiaensis Taylor, 1968 (171 primary grooves and 4 secondary grooves) and *C. armata* Dunn, 1942 (186 primaries and 92 secondaries) have overlapping counts of primary grooves but these differ in their counts of secondary grooves. *Caecilia bokermanni* Taylor, 1968 (180–192 primaries and 15–21 secondaries) has overlapping counts of primary and secondary grooves but these differ in their number of splenial teeth, which is 1-1 in *C. bokermanni* and up to 4-4 in the new species. *Caecilia gracilis* (183–204 primaries and 11–21 secondaries) also has overlapping counts of primary and secondary grooves with the new species but lacks subdermal scales within the connective tissue of the skin and has more denticulations on the anterior (6) and posterior margins (6) of the vent versus 4 anterior and 5 posterior denticulations in the new species.

Caecilia abitaguae (137–148 primaries and 0–5 secondaries), *C. subterminalis* Taylor, 1968 (170 primaries and 16 secondaries), and *C. tenuissima* (186 primaries and 10 secondaries) have overlapping counts of primary grooves but many fewer secondary grooves or none at all. *Caecilia flavopunctata* Roze & Solano, 1963 (155 primaries and 27 secondaries) has overlapping counts of grooves but its characteristic "funnel-shaped", truncated head (Taylor, 1968: 382: Fig. 199 B-D) differs from that of *C. goweri*, which is rounded. *Caecilia nigricans* Boulenger, 1902 also has overlapping counts of primary grooves (157–189) but higher counts of secondary grooves (32–62) furthermore, *C. nigricans* entirely

Figura 4. Vista ventral del holotipo de *Caecilia pachynema* (BMNH 1946.9.6.83.) de Intac, Ecuador. Fotografía por Martín R. Bustamante.

Figure 4. Ventral view of the holotype of *Caecilia pachynema* (BMNH 1946.9.6.83.) from Intac, Ecuador. Photograph by Martín R. Bustamante.

lacks an unsegmented terminal shield (Taylor, 1968; 409), unlike the new species. *Caecilia subnigricans* Dunn, 1942 has overlapping counts of grooves (151–161 primaries and 17–31 secondaries) but it differs from the new species in the shape of its dermal scales, which are thin and mostly rounded in *C. goweri*, but thick and straight at the margin of inception with the scale pocket but with a rounded terminal margin in *C. subnigricans* (Taylor, 1972: 1118: Fig. 73).

The new species most closely resembles *C. pachynema* and *C. occidentalis*, mainly because these *Caecilia* are very elongate, bear subdermal scales within the connective tissue of the skin, have few (or no) secondary grooves, and bear a series of light colored ventrolateral rectangles subdivided by the primary grooves throughout their body lengths. Discerning *C. goweri* from *C. pachynema* could be difficult given that both species have overlapping counts of teeth on all four series, overlapping counts

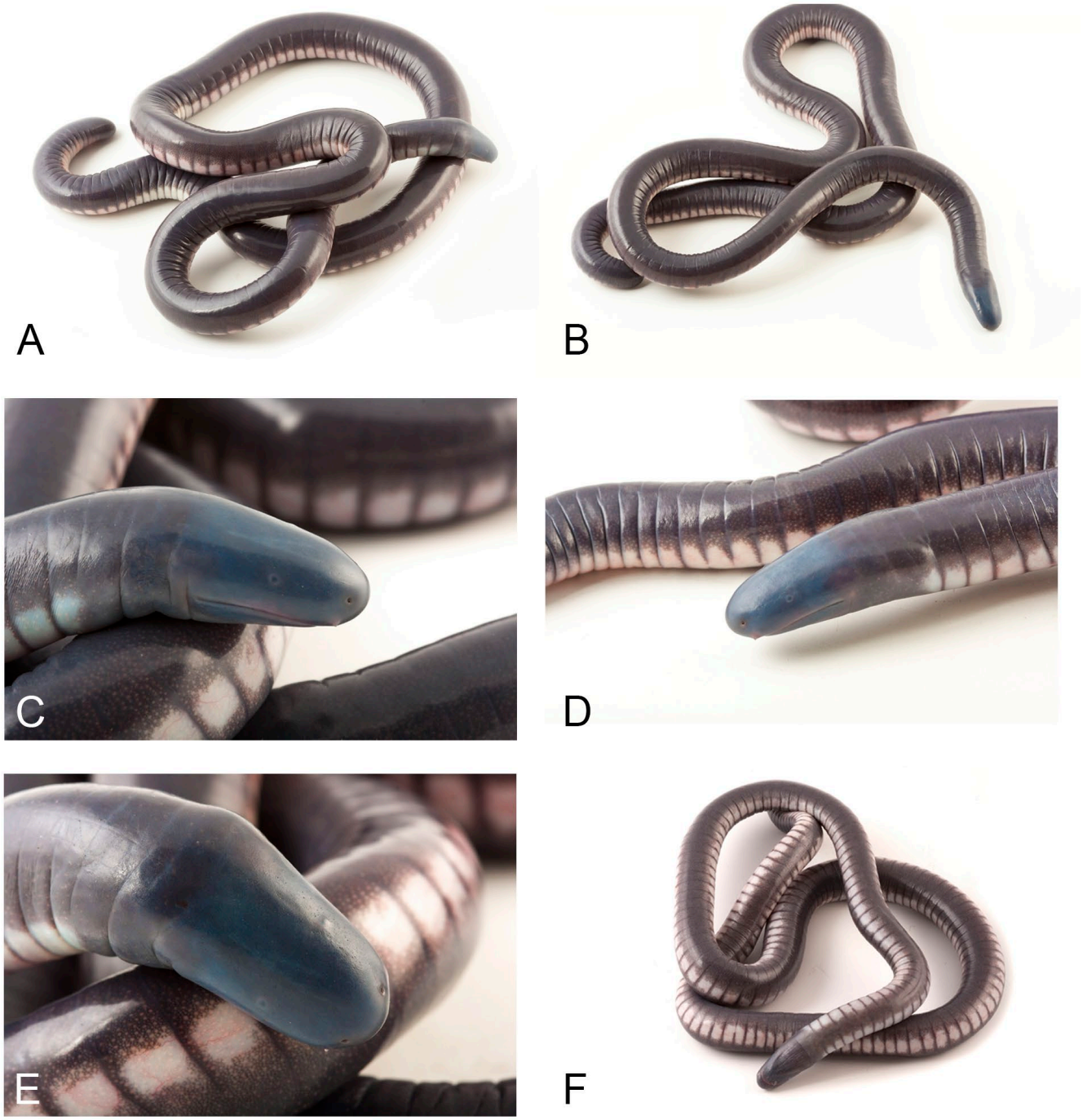

Figura 5. *Caecilia pachynema* (QCAZA 46983) del Río Chipla, provincia Azuay, en la vía entre Molleturo y La Costa Pacífica. A-B) Vista general del cuerpo; C-E) Vistas dorso-laterales de la cabeza; F) Vista ventral de la cabeza y el cuerpo. Todas las fotografías por el Dr. Santiago R. Ron del QCAZ.

Figure 5. *Caecilia pachynema* (QCAZA 46983) from Río Chipla, Azuay Province, on the road between Molleturo and the Pacific coast. A-B) General body views; C-E) Dorsolateral views of the head; F) Ventral view of the head and body. All photographs by Dr. Santiago R. Ron of QCAZ.

of primary grooves and a similar color pattern. Still, *C. pachynema* tends to have a lower count of primary grooves (150–163) and its teeth are much more recurved than those of *C. goweri* (Taylor, 1968: 428: Fig. 228 C). Dermal scales are present in both species (contra Taylor, 1968) and these tend to be subrectangular in *C. pachynema* (Taylor, 1973: 1113: Fig. 68) but clearly rounded in the new species. Some individuals of *C. pachynema* lack secondary grooves entirely but others have up to 11 secondaries; in contrast, all individuals of *C. goweri* bear secondary grooves (7–20). The last primary and secondary grooves dorsally encompass the terminal portion of *C. goweri* but these do not extend onto the ventral surfaces of the terminus, hence it has a small terminal shield, while *C. pachynema* bears a large, notable, completely unsegmented terminal shield (Taylor, 1968: 428: Fig. 228 D-E) (Fig. 4).

To a certain degree, *C. occidentalis* is easier to discern from *C. goweri* because *C. occidentalis* has an even higher count of primary grooves (191–221) (Taylor, 1969) and because the nuchal collars of *C. occidentalis* are not clearly demarked as those of C. *goweri*; in *C. occidentalis* the third nuchal groove is complete (Taylor, 1969: 787: Fig. 1) while it is only complete ventrally in the new species. Dermal scales of *C. occidentalis* seemingly vary in shape from subtriangular, to subrectangular to oval *sensu* Taylor (1972: 1022: Fig. 67) but these are circular in *C. goweri*. The new species has larger premaxillary-maxillary teeth than *C. occidentalis*, their dentary teeth are slightly recurved and of very similar proportions in both species, however these are well spaced from each other in *C. goweri* but set closer together in *C. occidentalis*, where the first 3-3 are set further from each other and the posterior 5-5 are closer together.

Description of the holotype. General condition is poor given that there are a few scratches on the surface of the skin, a constriction caused by an over-tightened tag on the 34th primary groove and an aggressive bend of the spine between primary grooves 37–50; a few dermal pockets were opened towards the terminus to check for dermal scales. Still, all usual measurements and counts can be made. An adult male with a total body length of 680 mm and a body width of 10 mm at mid-body point, length divided by width is 68 times. Head (7.3 mm) narrower than the body. In lateral view top of head sloping (not straight), margins of the

Tabla 1. Variación merística y datos morfométricos de la serie tipo de *Caecilia goweri*.
Table 1. Meristic variation and morphometric data of the type series of *Caecilia goweri*.

	MHUA 3241	MHUA 3915	MHUA 6296	MHUA 8115	MLS 46	MLS 48	MLS 49	MLS 50	MLS 51	MLS 52	MLS 53	UVC 7376	UVC 7377
Total length (mm)	680	560	180	630	480	125	115	580	530	390	410	320	380
Width at mid-body (mm)	10	8.6	4.6	8	8	2.4	2.3	8.3	11	5.9	8.1	5.5	5.4
Length/width	68	65.1	39	78.7	60	52.1	50	69.9	48.2	66.1	50.6	58.2	70.4
Snout projection (mm)	2.5	1.9	0.9	2.2	1.7	1.1	0.9	1.7	2.1	1.6	1.4	1.6	1.6
Eye-mouth commissure distance (mm)	3.8	2.5	1.6	3.1	2.8	1.8	1.6	2.8	3.6	2.1	1.9	2.4	3.0
Eye-nostril distance (mm)	3.8	3.0	1.6	3.1	2.8	1.7	1.5	3.1	3.4	2.6	2.3	2.7	3.0
First scale found at groove no.	1	1	166	1	74	167	156	127	108	119	55	4	17
Primary grooves	168	168	169	193	165	172	159	169	158	171	160	156	157
Secondary grooves	14	13	18	7	14	13	11	13	12	13	13	17	20
Grooves interrupted by vent	7	4	3	7	4	3	3	7	5	4	4	4	5
Premaxillary-maxillary teeth	4-1-4	5-4	5-1-4	4-1-4	5-5	1-1	7-1-7	9-1-9	6-1-6	6-1-6	6-6	6-5	6-5
Prevomeropalatine teeth	5-5	10-1-9	6-1-5	9-1-9	7-1-9	10-8	7-1-6	9-1-9	6-1-6	8-1-8	4-4	7-1-9	11-8
Dentary teeth	5-6	7-7	6-6	5-4	5-6	0	6-6	6-6	6-8	9-8	9-8	10-11	6-6
Splenial teeth	3-2	2-2	3-2	2-1	4-3	4-4	4-3	4-3	3-2	3-3	4-3	3-2	3-3

mouth deeply curved and downturned from the commissure of the mouth to the anterior margin of the mouth.

Snout rounded in dorsal and ventral view but blunt in profile; it projects 2.5 mm beyond the mouth. Nostrils clearly visible in dorsal view and in profile but not visible in ventral view; these are circular in shape and much closer to the tentacular opening than to eye. Distance between nostril and tentacular opening 1.9 mm, that between nostril and eye 3.8 mm. Eyes small, 0.6 mm in diameter, partially concealed by very translucent epidermis and resemble white dots. Distance between eye and commissure of mouth 3.8 mm. Interorbital distance 5.3 mm and the distance between snout tip and eye 4.9 mm. Tentacular openings oval in outline, elevated above skin, positioned below and slightly posterior to nostril, equidistant to margin of mouth and nostril; not visible in dorsal view but prominent in ventral and lateral views. First nuchal collar smaller than second; both nuchal collars bear a very faint nuchal groove dorsally and ventrally; third nuchal groove is complete ventrally but incomplete dorsally. Width of body increasing past the nuchal collars onto the fourth fifth of the total body length, it then tappers slightly only to become stouter onto the final fifth of the total body length, the terminus is stouter than the width of the head. Primary grooves 168, mostly incomplete, only the last 14 completely encircle the body near the terminus; secondary grooves 14, these are short and barely extend onto the ventral surfaces. Vent transverse, of moderate size, of same color as surrounding skin, bearing small denticulations, 4 anteriorly and 5 posteriorly, seemingly no anal glands on the anterior margin of the vent, but phallodeum was badly extruded and this could have hidden them.

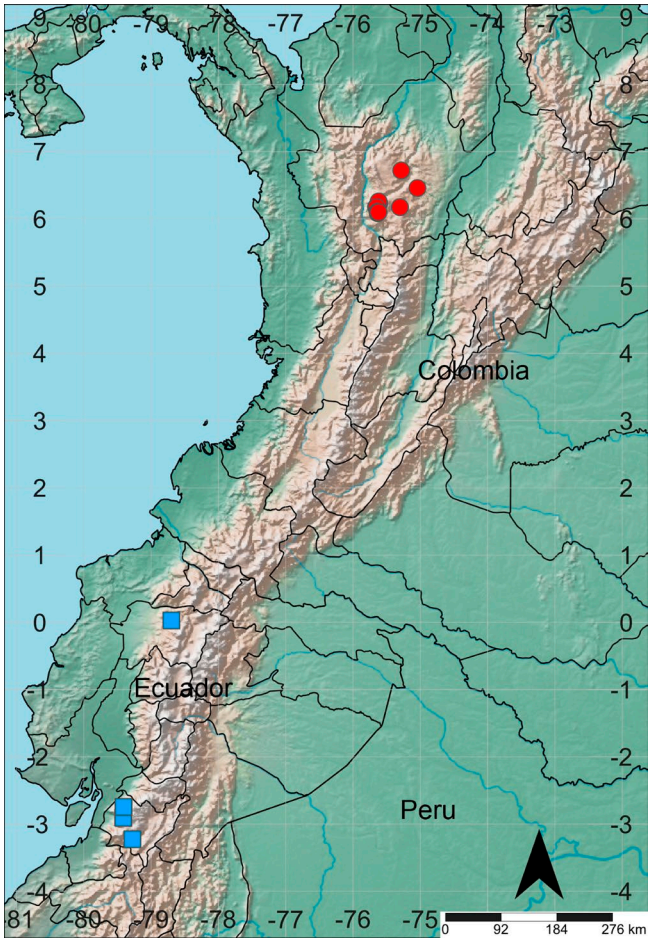

Figura 6. Distribución geográfica de *Caecilia goweri* (círculos rojos) y *C. pachynema* (cuadrados azules).

Figure 6. Geographic distribution of *Caecilia goweri* (red circles) and *C. pachynema* (blue squares).

A small, unsegmented terminal shield, given that it is dorsally interrupted by the last short primary and secondary grooves even though these do not extend onto the ventral surfaces of the terminus. Dermal scales first appear at the first primary groove, where they are small, slightly oval, and folded upon (misshapen) but those found towards the terminus are circular and slightly thicker at the insertion margin; these are present up to the last primary groove. Dermal scales closer to the venter are larger in size. Many subdermal scales are found in the connective tissue of the skin. All teeth are thin, monocuspid, pointed, and slightly recurved; those on the premaxillary-maxillary and prevomeropalatine series are smaller in overall size than those on the dentary series; splenial teeth are of moderate size and not concealed by the tongue or gums. The premaxillary-maxillary bears 4-1-4 teeth that are well spaced and large but decreasing in size posteriorly; the prevomeropalatine series has 5-5 teeth, which also decrease their overall size posteriorly; the dentary has 5-6 teeth on each side and splenials are 3-2, straight and pointed. Teeth in dentary series more recurved than those on premaxillary-maxillary and prevomeropalatine series. Choanae oval transversally in shape, the maximum diameter of one choana is 0.6 mm, and the space separating them is 1.3 mm, tongue with protruding narial plugs, which are darker than the coloration of the tongue. Teeth replacement is evident in the gums.

Coloration in preservative. Coloration in life is unknown. In preservative, coloration is bright gray dorsally, followed by a cream median "lateral stripe", which extends along the total body length, more evident anteriorly than posteriorly, ventrally same color as dorsum but paler. The color of the terminus is bright cream against the dull cream color of the ventrolateral rectangles (Fig. 1A-D).

Variation. There is slight variation in the color pattern because the ventrolateral rectangles are more prominent in some individuals (such as the holotype) than in others such as MHUA 8115 (Fig. 2). In some individuals such as the holotype (MHUA 3241) (Fig. 1C) and paratype MHUA 8115 (Fig. 2) the eyes are concealed by translucent epidermis to a higher degree than in others, such as MHUA 3915 and MHUA 6296. Dermal scales can be rounded (as in MHUA 3241, 3915, 6296 and 8115) or very slightly more oval (UVC 7376–77). Juveniles (MLS 48–49 and MHUA 6296) are very small (115–180 mm total length), have undefined nuchal collars, and bear an incomplete dentition with only 2 premaxillary-maxillary teeth and no dentary teeth although traces of emerging teeth can be seen within the gums. Adult males of *C. goweri* tend to have the eye located equidistant between the commissure of the mouth and the nostril, while adult females tend to have the eye located closer to the commissure of the mouth than to the nostril, suggesting sexual dimorphism (Table 1).

Etymology. We name this species after Dr. David J. Gower, merit researcher at the Natural History Museum in London, U.K., for all his contributions to the anatomy, evolution, systematics, and taxonomy of caecilians and snakes.

Remarks. Coloration in life is unknown for the holotype of *C. goweri*, but paratype MHUA 8115 is mostly dark gray or slate along the dorsal surfaces of the body, paler gray or slate on the flanks with purple hues and pale cream ventrally, which appears even paler (close to white) on the last 30 primary grooves and the terminus; head, tentacles, lips and nostrils are salmon pink surrounded by shades of dark blueish gray (Figs. 2–3).

DISCUSSION

Taylor (1968: 431) paid close attention to the color pattern of *C. pachynema* (Figs. 4–5) and described it as "Ventrolaterally there is a brownish cream stripe ranging from the first collar to very near vent-level but broken by dark lines in the grooves, leaving quadrangular marks on each annulus. A median ventral stripe of grayish-slate, lighter than the dorsum" (Fig. 4). We consider that neither *C. goweri* nor *C. pachynema* bears a true ventrolateral stripe —such as those found in *Epicrionops* Boulenger, 1883, *Ichthyophis* Fitzinger, 1826, and *Rhinatrema* Duméril & Bibron, 1841— but instead these *Caecilia* bear a series of light-colored rectangles interrupted by dark grooves, hence not touching each other. Lynch's assertion that the dermal scales of *C. goweri* are only found within the secondary grooves is wrong (Lynch, 2000: 327), because we have confirmed their presence in both the primary and secondary grooves (as is the case for all Colombian *Caecilia* with secondary grooves).

Taylor (1968: 426) claimed not to have examined any Peruvian specimens of *C. pachynema* (Fig. 6) but still provided an illustration is of a specimen taken from "Fundo Sinchono", Loreto, Peru (Fig. 226). This specimen (USNM 119008) was later designated as the holotype of *C. inca* and, according to Taylor (1973), the differences in coloration, adult size, and presence of scales throughout most of the body separate it from *C. pachynema*. Based on their original descriptions, we find it difficult to discern these two species given that their groove counts overlap and differences in coloration can be attributed to variation. Furthermore, we have found dermal scales in other supposedly scale-less *Caecilia* and the average adult size can only be gauged if a series of specimens is available.

Some individuals of *C. pachynema* may not have secondary grooves fide Taylor (1968), a peculiarity that we corroborated during a recent visit to QCAZ, Ecuador in 2019. Variation in secondary groove number, ranging from zero to 11, could challenge the efforts to diagnose other *Caecilia* with overlapping counts of primary grooves, hence dentition, squamation, cephalic and terminal morphology should be examined in detail to discern other similar species. Nonetheless, *C. pachynema* is not the only *Caecilia* known for variation in the presence and number of secondary grooves, as it is also known to occur in *C. abitaguae*, *C. guntheri*, *C. occidentalis*, *C. orientalis*, and *C. subdermalis* (*unpublished data*).

Recently, Restrepo et al., (2017) provided a list of the amphibians and reptiles collected from 2006–2016 in two hydroelectric projects on the eastern versant of the Cordillera Central of Colombia in Antioquia, namely Jaguas (1100–1300 m a.s.l.) and San Carlos (600–950 m a.s.l.). Their efforts yielded collections of *C. guntheri* (ICN 58446 and MHUA 3566, 6631), *C. thompsoni* (MHUA 7115 and 7192), *E. parkeri* (Dunn, 1942) (MHUA 7191 and 10720), and *Microcaecilia pricei* (Dunn, 1944) (MHUA 10728, though not examined). *Caecilia goweri* is seemingly restricted to higher elevations (1500–2200 m a.s.l.), as it was not found within these collection sites.

Aside from the collecting efforts of Hermano Nicéforo María in Pensilvania, Caldas, in the 1940s, those of Hermano Marco Antonio Serna in the Altiplano de Medellín during the 1960s, those of Restrepo et al., (2017) during 2006–2016, and more recently those of Dr. Mauricio Rivera-Correa in Valdivia, Antioquia, much of the montane forests of the northern Cordillera Central of Colombia (Fig. 6) have not been adequately sampled for caecilians and as a result it would seem that only seven species (*C. caribea*, *C. guntheri*, *C. occidentalis*, *C. goweri*, *C. subdermalis*, *E. bicolor* Boulenger, 1883 and *M. pricei*) occur near

the 2000 m mark. Still, we are confident that as the rate of collections increases so will the number of caecilian species in these mountains.

The adjacent lowlands of the Magdalena River Valley have not been sufficiently sampled for caecilians either, despite past efforts by Dr. Juan Manual Daza, Mariela Osorno-Muñoz, José Vicente Rueda-Almonacid, Andrés R. Acosta-Galvis, Diego Gómez Sánchez, Esteban Alzate, Dr. Marco Rada, and us. These have yielded collections of *C. guntheri*, *C. subnigricans*, *C. thompsoni*, *E. parkeri*, *M. nicefori* (Barbour, 1924), *M. pricei*, *Oscaecilia polyzona* (Fischer, 1880) and *Typhlonectes natans* (Fischer, 1880). Given that the Magdalena River Valley lowlands become considerably drier southward past the Cundinamarca-Tolima boundary (around 4.5° N) in the Upper Magdalena River Valley, we have higher expectations for taxonomic novelties along the northern portion in the Middle and Low Magdalena River Valley.

Acknowledgments.— Dr. Fernando Sarmiento and Maria Fernanda Lozano permitted various visits to the Amphibian Collection at Museo La Salle, Universidad de La Salle, Bogotá (MLS), as well as various loans of specimens under their care. Professors Raul Sedano and Wilmar Bolivar (UVC) allowed us to examine the material deposited at Colección de Anfibios, Universidad del Valle, Cali, Valle del Cauca. Professors Mauricio Rivera-Correa and Juan Manuel Daza at Universidad de Antioquia (MHUA) gave us access to the caecilians under their care, lent us their photographs for this article, and offered us ample working space during our visits; their student Daniel Bocanumenth assisted J.D. Fernández with photographing many specimens at MHUA. Dr. Santiago R. Ron at Pontificia Universidad Católica del Ecuador, Quito, Ecuador (QCAZ) allowed us to examine specimens of *C. pachynema* and permitted us to use his photographs of this species for this manuscript.

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APPENDIX 1. EXAMINED MATERIAL.

Countries are indicated in bold capitals, departments and provinces in regular capitals, municipalities and localities in plain text.

***Caecilia goweri* (n= 13) COLOMBIA:** ANTIOQUIA: Bellavista: MLS 48–49; Caldas: UVC 7376–77; Carolina del Principe: MLS 46; La Tablaza: MLS 53; Marinilla, Alto de Mercado: MHUA 6296; Medellín, Belén: MHUA 3915; San Antonio del Prado: MHUA 3241, MLS 51–52; San Roque, San Juan, Finca El Recuerdo: MHUA 8115; San Pedro: MLS 50.

***Caecilia guntheri* (n= 21) COLOMBIA:** ANTIOQUIA: Anorí: MHUA 6631; Frontino: IAvH 14557, MHUA 11565; Maceo: MHUA 3566; Sonsón: ICN 58446; Valdivia, San Fermín, Reserva La Selva: Mauricio Rivera Correa (MRC) 1485 and 1533 (to be catalogued at MHUA). CAUCA: El Tambo, PNN Munchique, sector La Cueva: ICN 58402, 58404. CHOCÓ: Arusí: ANDES-A 4451; vía Cartago-San José del Palmar: UVC 8499. NARIÑO: Barbacoas: ICN 53580, 53766, 53793; Francisco Pizarro, Salahonda: ICN 57211; Ricaurte, Chucunes, Reserva La Planada: MHUA 4003, UVC 6070. VALLE DEL CAUCA: Bajo Calima: ICN 58411, UVC 8564; Buenaventura, Aguaclara: UVC 9881; Serranía de los Paraguas, vía El Cairo-Las Amarillas: UVC 7113.

Caecilia occidentalis **(n= 7) COLOMBIA:** ANTIOQUIA: Yarumal: MLS 45; CAUCA: Popayán: ICN 43526, 41225 and MHUC 93–95; VALLE DEL CAUCA: Pance, near Río Pance: UVC 6567.

Caecilia pachynema **(n= 5) ECUADOR:** AZUAY: Río Chipla, vía Molleturo-La Costa por la carretera pequeña: QCAZA 46983, QCAZA 46938; San Antonio de Chaucha: QCAZA 31720; Santa Isabel, El Unión, Reserva Yunguilla, Fundación Yotoco: QCAZA 33235; PICHINCHA: Reserva Puyucunapi-Mindo Cloudforest Foundation: QCAZA 75976.

Caecilia thompsoni **(n= 38) COLOMBIA:** ANTIOQUIA: San Carlos, Juanes. Puente Roto: MHUA 7115, Quebrada el Jordán: MHUA 7192; San Roque, Estación Piscícola Universidad de Antioquia: MHUA 5157; Yondó, Reserva El Silencio: ICN 58437. BOYACÁ: Humbo, Estación de Policía de Quípama: MLS 21–22. CALDAS: La Victoria, El Llano, Quebrada Casanguillas: MHUA 4247, 4432; Corinto, Charco Azul: ICN 43668; Norcasia: ANDES-A 4458, MUJ 7368, La Miel: IAvH 9688; Samaná, Tasajos: ICN 41233. CUNDINAMARCA: Mesitas del Colegio: ANDES-A 1904; Nilo: ICN 11763, 47997; La Esperanza: ICN 21431. SANTANDER: Betulia, vereda Aguamieluda: UIS-A 5753; Floridablanca, barrio Bucarica: UIS-A 5190; Lebrija UIS-A 5189, vereda Portugal: UIS-A 20; Piedecuesta, vereda Monterredondo: UIS-A 6427; Rionegro: UIS-A 4938–40, 4943–44, 4946, 6201; San Vicente de Chucurí: vereda La Colorada, UIS-A 5378, 6865. TOLIMA: Carmen de Apicalá, vereda Cuatro Esquinas: ANDES-A 4448–49, 4462, ICN 58509; Chaparral: MLS 23, MHUA 6611; Ibagué: MLS 34.

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NEONATAL GROWTH IN CAPTIVE DUSKY RATTLESNAKES (*CROTALUS TRISERIATUS*) FROM TWO POPULATIONS IN CENTRAL MÉXICO

CRECIMIENTO NEONATAL DE LA SERPIENTE DE CASCABEL TRANSVOLCÁNICA (*CROTALUS TRISERIATUS*) CAUTIVAS DE DOS POBLACIONES DEL CENTRO DE MÉXICO

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Resumen.— En las serpientes, el tamaño corporal tiene implicaciones importantes en su ecología, y éste a su vez, depende de la tasa de crecimiento de los individuos. En este estudio, analizamos el primer año de crecimiento en cautiverio de individuos de dos poblaciones de la víbora de cascabel transvolcánica (*Crotalus triseriatus*). Empleamos modelos lineales para estimar las tasas de crecimiento individual, así como para comparar estas tasas entre poblaciones y sexos. La talla al nacer fue mayor en machos que en hembras, y este patrón se mantuvo a lo largo de todo el experimento. La tasa de crecimiento promedio para todos los individuos fue de 7.66 mm/mes. Mientras que el cambio absoluto promedio fue de 79.8 mm. No se detectaron diferencias significativas en las tasas de crecimiento entre poblaciones ni entre sexos. Esto podría indicar que la variación en este atributo puede ser mayor dentro de poblaciones que entre poblaciones.

Palabras clave.— Tamaño corporal, crecimiento corporal, víbora de cascabel, cautiverio, experimento.

Abstract.— Body size has important effects on snake ecology, and in turn, body size is dependent on the rate at which individuals grow. In this study, we analyzed first year captive growth of individuals from two populations of the Mexican dusky rattlesnake (*Crotalus triseriatus*). We used linear models to estimate individual growth rates as well as to compare growth rates between populations and sexes. Birth body size was greater in males than in females, and this pattern remained throughout the experiment. Average growth rate for all individuals was 7.66 mm/month. While the average absolute change was 79.8 mm. No statistical differences were detected in growth rates between populations or sexes. This could indicate that the variation in this attribute may be greater within populations than between populations.

Keywords.— body size, body growth, captivity, rattlesnake, experiment.

INTRODUCCION

Body size shapes many aspects of the ecology of organisms (Calder, 1996). In animals, body size is related to the survival and reproduction of individuals (Stearns, 1992; Roff, 2002). Particularly in reptiles, it is related to reproductive effort in females and reproductive success in males (Shine, 2003; 2005). Characterizing the body size that individuals maintain throughout their life cycle is thus important for the study of the life history and ecology of reptiles.

Ecology and life history data are sometimes difficult to obtain for many snake species in the field because of their secretive nature and low densities (Seigel et al., 1987). Our knowledge of snake ecology has grown extensively in recent years, and there are now several taxa that are well studied (e. g. Bonnet et al., 2001a; Baron et al., 2010; Michel & Bonnet, 2010; Luiselli et al., 2011; Madsen et al., 2020). However, most of these studies have been conducted in North American, European, and Australian snake species (Mullin & Seigel, 2011). Basic data on snake body growth are always valuable to collect because helps to understand the variation in population dynamics and determining how natural selection shapes life history strategies.

Individual body growth is determined by genetic factors, as well as environmental factors such as food availability and, especially in reptiles, environmental temperature (Andrews, 1982; Calder, 1996). Due to behavioral thermoregulation, growth in snakes can vary widely between and within populations (Andrews, 1982). Life-history traits are highly related to fitness. Different environments can favor either slow or fast growers for different selective causes (Ferguson & Brockman, 1980). Nevertheless, phenotypic variation in different environments may not be good evidence for genotypic difference due to genotype-environment interactions. Hence, experimental studies that control environmental conditions are of great importance for evolutionary biology (Stearns, 1992).

Crotalus triseriatus (Wagler, 1830) is a rattlesnake that lives in the mountains of the Trans-Volcanic Mexican Belt (TVMB; Bryson et al., 2014). It inhabits an altitudinal range from 2500 to around 4000 m a.s.l., which is dominated by coniferous forests and subalpine grasslands (Campbell & Lamar, 2004). Consequently, most of its populations are isolated in the mountains of the TMVB, separated by the valleys of central Mexico. This geographic isolation results in little to no genetic flow between distant populations within its distribution (Sunny et al., 2015; 2018; 2019). These characteristics make it a great system for exploring variation in life history strategies between populations living at different, isolated sites, as isolation might lead to changes in life history traits, such as individual body growth rates, between populations. This type of intraspecific variation in life history traits has been documented in populations of other species of reptiles (Ferguson & Brockman, 1980; Gregory & Larsen, 1993; Tinkle et al., 1993; Plummer, 1997; Bronikowski & Arnold, 1999; Aldridge et al., 2008; Hileman et al., 2010).

Currently, no studies have characterized body growth in *Crotalus triseriatus* in the field nor in captivity. Here, we analyze first-year growth in captivity of individuals from two populations of *C. triseriatus*. Although individuals experienced the same conditions in captivity (temperature, quantity and frequency of food), due to a degree of potential genetic determination, we expect that there might be differences in the growth rates in individuals from different populations.

MATERIAL AND METHODS

Study species and sites. Crotalus triseriatus is a small-sized rattlesnake species, adults commonly exceed 600 mm snout-vent lenght (SVL) (Campbell & Lamar, 2004). It occurs from central Veracruz to east Michoacán and is considered locally abundant (Bryson et al., 2014; Pérez-Mendoza et al., 2018). *Crotalus triseriatus* holds the highest-altitude record for a snake in the Americas, reaching 4,573 m a.s.l. (Mani & Giddings, 1980). We worked with two populations. Site 1 (Cumbres del Ajusco National Park; 19.22° N, -99.28° W) is located within the limits of Mexico City and corresponds to the mountain chain that closes the southern part of the Valley of Mexico. Site 2 (La Malinche National Park; 19.24° N, -97.99° W) is located in the state of Tlaxcala, bordering the state of Puebla. This National Park covers the area of a volcano isolated from other mountain formations, making it an island for high mountain flora and fauna in the region.

Sampling. During late winter and spring of 2015 (late stage of gestation; Campbell & Lamar, 2004), we collected pregnant females of *C. triseriatus* in both study sites (5 from site 1 and 5 from site 2). These were kept in the laboratory until parturition. The size and weight of the neonates were recorded (between 0 and 5 days later; reproductive traits of these litters are reported in Pérez-Mendoza et al., 2018). Forty randomly selected newborns were kept in captivity for the experiment (11 from site 1 and 29 from site 2).

The snakes were kept individually in 40×20×20 cm plastic terrariums with ad libitum access to water. The air temperature in captivity was maintained between 20–30°C for all individuals throughout the study, and the light cycle was 12 h light: 12 h

dark. The neonates were fed every twelve days with mice (*Mus musculus*; average mice weight: 2.8 g, standard error: 0.04 g; range of weights through the study: 1.08-8.04 g); these were introduced alive to stimulate feeding. A record was kept of the amount and weight of the food items consumed to ensure that the individuals consumed the same amount of food throughout the experimental period. Snout-vent length (SVL), tail length, total length (TL) and mass were measured monthly from June–July 2015 (depending on the date of birth) until June 2016.

Figura 1. Imagen de muestra que muestra cómo se tomaron las medidas del tamaño corporal de un *Crotalus triseriatus* juvenil utilizando un software de procesamiento de imágenes.

Figure 1. Sample image demonstrating how measurements of body size were taken from a juvenile *Crotalus triseriatus* using image processing software.

All measurements were made by the first author. Tail length was measured to the nearest mm with a Vernier caliper. To avoid excessive handling of individuals, the total length was obtained through photographic records and analysis in an image processing software (Snake Measure Tool; downloaded in https://sourceforge.net/projects/snakemt/). Photographs were taken from a 90° angle to minimize errors in measurements (Astley et al., 2017; e.g., Figure 1). SVL was calculated by subtracting the tail length from total length. Mass was determined on a precision scale to the nearest 0.01 g. The birth characteristics of the neonates' part of this study were published in Pérez-Mendoza et al. (2018).

Statistical analysis. The growth rate analysis was carried out by means of linear models. We used the method called "Derived variable statistics," also known as "response variable analysis" (Crowder & Hand, 1990; Diggle et al., 1994; Davis, 2003). We performed linear regressions for each of the individuals with time as the independent variable and the SVL or mass as dependent variables. The slopes (β) obtained were taken as the individual growth rates; these were grouped by population and sex, and differences were evaluated by Student's t-tests (parametric assumptions were met). Also, growth rates (β) were analyzed by a generalized linear model with population and sex as factors to evaluate interactive effects.

In addition, we analyzed growth using two other methods: the absolute change in SVL (ABS = final SVL - initial SVL) and the relative change in SVL (REL = [final SVL - initial SVL] / initial SVL) of the individuals. Since growth could vary as a function of initial size and the amount of food consumed, we performed correlation tests between these variables and the ABS and REL growth variables. If there was a correlation, we used the initial size or the amount of food as a covariate in the following analyzes (GLM's). We analyzed these variables (ABS and REL) using Student's t-tests and generalized linear models to test for population and/or sex effects. We decided to execute these last analyzes only with the SVL and not the mass because SVL is a better indicator of growth in this group. Analyses were performed with package "stats" in R version 4.1.0. (R Development Core Team 2020).

RESULTS

Eight snakes died during the study; thus, the analyses were restricted to the remaining 32 individuals, who were healthy and active throughout the experiment (8 from site 1 and 24 from site 2). Although the data were normally distributed, we also performed the non-parametric version of the t-test (Mann-Whitney U) in addition to the GLM's because of the small sample sizes. As the results of all analyses were consistent in terms of the statistical decision, we only report the results of the parametric and GLM analyses. We found a barely significant relationship between mortality and size at birth ($t = 2.09$, $P = 0.04$). On average, individuals who died before the end of the experiment had a lower SVL at birth. We did not find a relationship between mortality and sex ($\chi^2 = 5.67e\text{-}32$, $P \approx 1$).

Most of the neonates showed strong feeding responses during the experiment. During the first 3 feeding events, some individuals that did not react to food after one complete day were force-fed. After the fourth feeding event, all individuals ate on their own. The average weight of the mice consumed throughout the study did not vary significantly between populations or sexes ($t_{pop} = 0.89$, $df = 7.09$, $P = 0.39$; $t_{sex} = -0.17$, $df = 13.68$, $P = 0.86$).

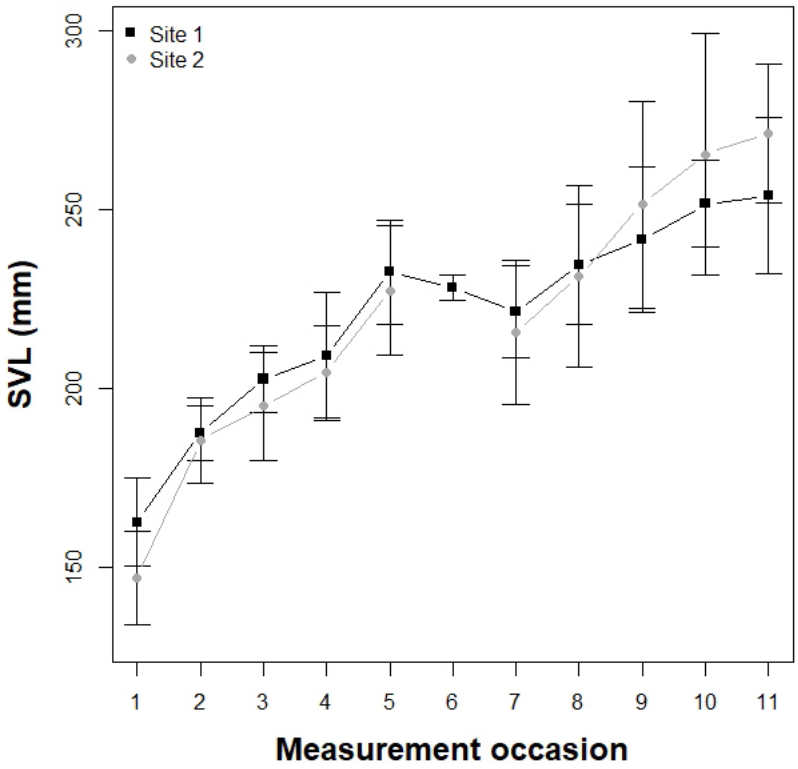

Figura 2. Trayectorias de crecimiento en cautiverio de neonatos de *Crotalus triseriatus* de dos sitios de estudio.

Figure 2. Growth trajectories of captive neonates of *Crotalus triseriatus* from two study sites.

Tabla 1. Medias de la LHC inicial y final, la longitud de la cola, la tasa de crecimiento de la LHC, la tasa de crecimiento de la masa, el cambio absoluto (ABS), y relativo (REL) en la LHC de neonatos de *Crotalus triseriatus*..

Table 1. Mean of initial and final SVL, tail length, SVL growth rate, mass growth rate, and absolute (ABS) and relative (REL) change in SVL for neonates of *Crotalus triseriatus*.

Site	N	Initial tail length (mm)	Final tail length (mm)	Initial SVL (mm)	Final SVL (mm)	SVL growth rate (mm/m)	Mass growth rate (gr/m)	ABS
1	8	24.33	29.33	168.83	254.16	9.32	1.24	77.6
2	24	21.32	28.76	185.22	271.38	7.11	1.06	80.6
Sex								
F	12	20.93	24.77	180.97	258.38	9.04	1.06	0.77
M	20	24.02	32.08	186.23	271.92	9.39	1.29	0.82

Tail size did not differ between populations or sexes at birth (t_{sex} = 1.92, P = 0.07; t_{pop} = -2.25, P = 0.05; $t_{pop*sex}$ = 1.78, P = 0.09). Nevertheless, it did vary between sexes at the end of the experiment (t_{sex} = 4.00, P = 0.001; t_{pop} = -0.23, P = 0.81; $t_{pop*sex}$ = 1.03, P = 0.31). At birth, the average SVL was higher in males than in females (t = -6.20, df = 13.38, P < 0.001), and this pattern held until when the last measurements were taken (t = -3.21, df = 7.89, P = 0.012; Table 1). The individual SVL range varied little during the study. In general, the longest snakes at the beginning of the study remained the longest at the end. Moreover, the initial SVL of the individuals was correlated with their final SVL (r^2 = 0.51, P = 0.01).

The average SVL growth rate for all individuals was 7.66 mm/month (SE = 0.85). The average SVL growth rates for sites 1 and 2 were 9.32 and 7.11 mm/month, respectively (SE1 = 0.63, SE2 = 0.91). The female growth rate was 9.04 mm/month, and the male growth rate was 9.39 mm/m (SEf = 0.77, SEm = 0.70). However, no significant differences were detected in the SVL growth rates between populations or between sexes (t_{pop} = 1.72, df = 25.94, P = 0.09; Fig 2; t_{sex} = -0.32, df = 14.13, P = 0.74). The monthly increase in mass varied less, which was 1.24 and 1.19 gr / m for sites 1 and 2, respectively (SE1 = 0.10, SE2 = 0.14; t_{pop} = -0.32, df = 14.13, P = 0.74), and 1.06 and 1.29 gr / m for females and males, respectively (t_{sex} = -1.66, df = 15.84, P = 0.11; Table 1).

No significant effects for the population × sex interaction on the SVL growth rates ($t_{pop*sex}$ = -0.12, P = 0.90) or mass ($t_{pop*sex}$ = 0.009, P = 0.99) were detected by the GLMs. Furthermore, there were no significant differences between populations and sexes in the SVL growth rate (t_{pop} = 0.59, P = 0.55; t_{sex} = 0.26, P = 0.79).

The average absolute change in SVL was 79.8 mm, and the relative change was 0.43 mm. The absolute and relative changes in SVL also did not show significant differences between populations or sexes (ABS: t_{pop} = -0.33, df = 8.27, P = 0.74; t_{sex} = -0.46, df = 12.02, P = 0.64; REL: t_{pop} = 0.69, df = 7.81, P = 0.50; t_{sex} = -0.09, df = 11.48, P = 0.92; Table 1; Figure 2).

DISCUSSION

The mortality observed during the experiment was mainly associated with individuals who did not feed on their own or were delayed in feeding on their own. We do not assume that this was associated with the type of food offered during the experiment because most of the neonates fed without difficulty. Most rattlesnake species are known to prefer feeding on rodents, although they are often generalists in early life stages (Campbell & Lamar, 2004).

It has been documented that the first three months in captivity are the most critical in terms of survival and adaptation in wild caught snakes (Braz et al., 2012). Although born in captivity, we observed this pattern with *Crotalus triseriatus*, the frequency of mortality was higher during the firsts months after birth. The inability to adapt to the captive environment, known as Maladaptation syndrome, has been recognized as the major cause of death in captive reptiles (Cowan, 1980). This syndrome is defined as the pathological effects of stress on an animal related to the captive environment (Cowan, 1968), and it may cause anorexia and emaciation among other consequences. We found that on average, individuals with smaller SVL at birth were more likely to die than larger individuals (P = 0.04). However, there were relatively small individuals who survived the entire study and individuals with higher SVL at birth who did not.

We found that size at birth was higher in males than in females, and this difference was maintained throughout the experiment. Sexual dimorphism in SVL has been observed in neonates of *Storeria dekayi* and *Thamnophis sirtalis*. Females exceeded males in SVL in *S. dekayi*, while males exceeded females in *T. sirtalis* (King et al., 1999; Krause & Burghardt, 2007). In rattlesnakes, Beaupre et al. (1998) did not find sexual dimorphism in SVL in neonates of *Crotalus atrox*, and Taylor & Denardo (2005) later confirmed this pattern. We did not find sexual dimorphism in tail length in neonate rattlesnakes; however, there were differences in tail length at the end of the experiment. In the last measurement, males had longer tails than females (Table 1). Many snake species exhibit sexual dimorphism in adult stages; however, it is not as common at birth (King, 1989; Shine, 1993; Bonnet et al., 2011). Sexual dimorphism in tail size is related to the caudal position of the hemipenis, and this pattern is consistent in most species (Shine, 1993).

There was a decrease in average SVL in individuals from both snake populations on two measurement occasions (Fig. 2). This may have been caused by measurement error; however, all measurements were made by the same observer and with the same methodology. These observations occurred during the winter period (from January to February); some reptiles have been observed to decrease in size under suboptimal conditions (Wikelski & Thom, 2000), such as low temperatures and food scarcity. Nevertheless, studies in snakes are not conclusive on whether they can shrink; in most cases, apparent shrinkage is a result of measurement error (Madsen & Shine, 2001a; Blouin-Demers, 2003; Luiselli, 2005). We evaluated intra-observer error by analyzing the variances of each measurement occasion with ANOVA, and found no significant differences. The laboratory conditions were identical for all the individuals within the

experiment, however there was a small variation in temperature in the winter period, in which lower temperatures in the laboratory (closer to 20 °C) were detected more frequently than during the other seasons of the year.

Individual growth rates are determined by extrinsic and intrinsic factors. In this experiment, we reduced as possible the environmental factors (extrinsic) that affect growth under natural conditions to detect differences in factors related to the genetics of individuals (intrinsic), such as belonging to a particular population or to a certain sex, which we hypothesized might shape differences in growth rates. However, our results did not support this hypothesis. This might be explained for two reasons. First, because sample sizes were small and unequal between sites, we might not have had sufficient statistical power to resolve intrinsic differences in growth rates. Ideally, the effects of population, sex and litter would be tested simultaneously. However, we did not include litter as a factor because of the low sample size. Second, with the exception of mass at birth (Pérez-Mendoza et al., 2018), no local adaptation in growth rates has been observed in the studied sites, in contrast to other life history attributes in these same populations (e.g., litter size, size at birth).

In snakes, these attributes can be highly plastic and vary widely within and between populations (Ford & Seigel, 1989; Gregory & Larsen, 1993; Gregory & Prelypchan, 1994; Gregory & Farr, 2018). Under the same captivity conditions, we did not find differences in neonatal growth rates between the two populations studied. Growth plasticity in snakes may be an adaptation to variable environments and might be more responsive to resource availability (Forsman & Lindell, 1996; Bonnet et al., 2001b; Taylor & Denardo, 2005).

Although the differences between population growth rates were not statistically significant (P = 0.095), there was a slight difference in growth rates between populations. Specifically, individuals from site 1 grew slightly faster on average (GRS1 = 9.3 mm / year; GRS2 = 7.1 mm / year). Site 1 (Ajusco National Park) has lower operative temperatures and therefore habitat with lower thermal quality (Jaramillo-Alba et al., 2020). Such thermal conditions might favor the selection of fast-growing individuals even under harsh conditions or that optimizes growth under the time windows when conditions are optimal; whereas, other populations inhabiting sites with higher thermal quality, such as site 2, may not favor faster or slower growth, as thermal environmental is optimal during longer periods (Jaramillo-Alba et al., 2020). However, this hypothesis needs to be tested with a greater number of populations and a larger sample size while controlling for other factors that might affect individual growth rate variation. As most life history theory has been derived from interspecies studies; intraspecies-level patterns of variation are expected to not be as predictable based on current theory (Dunham et al., 1988). Studies between populations of the same species are particularly important, as such studies permit genetic and non-genetic factors to be distinguished. Widely distributed species or species with isolated populations are particularly valuable because they may show greater diversity in life history attributes (Gregory & Larsen, 1993).

Studies that have analyzed rattlesnake body growth in the wild have shown that this attribute can be highly variable. Macartney et al. (1990) found differences in growth rates between sexes in *Crotalus viridis*, males grew at a higher rate than females. In addition, they found differences in growth between different populations, growth rates varied in relation to latitude (differences in activity and hibernation periods between southern and northern populations). They also reported differences in growth rates between years related to variation in annual precipitation. Wittenberg & Beaupre (2014) reported differences in growth rates between populations of *Crotalus horridus*. They report that prey abundance had the strongest effect in growth rates. Other studies have indicated that prey availability has a greater effect on snake growth than genetic differences among individuals (Madsen & Shine, 1993, 2000; Forsman & Lindell, 1996). Field studies are needed to determine the relative magnitude of these effects in *Crotalus triseriatus*.

Data on rattlesnake growth rates for both neonates and adults are especially useful. Few studies have analyzed individual growth in snakes (especially in tropical areas; e.g., Madsen & Shine, 2000; Madsen & Shine, 2001b; Brown et al., 2017), and studies in such regions are particularly important because variation in individual growth between size classes is key for understanding population growth rates.

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ANFIBIOS Y REPTILES DEL ESTERO DE PUNTA BANDA, ENSENADA, BAJA CALIFORNIA, MÉXICO

AMPHIBIANS AND REPTILES OF THE PUNTA BANDA ESTUARY, ENSENADA, BAJA CALIFORNIA, MEXICO

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Abstract.— The Estero Punta Banda in Bahia Todos Santos, Baja California, is a coastal wetland of international importance considered a RAMSAR site and a priority area for biodiversity conservation. However, no formal studies have been carried out on the richness and diversity of amphibians and reptiles at this site, focused on knowing their richness and diversity. We selected five sampling sites on coastal dunes, crop fields, and riparian areas. Arrays of pit-fall traps with drift fences were implemented, as well as diurnal and nocturnal visual encounter surveys. The herpetofauna of Estero Punta Banda is composed of 15 species of amphibians and reptiles, belonging to 13 genera and 10 families. The best-represented families were Phrynosomatidae and Colubridae, with the lizards *Uta stansburiana*, *Aspidoscelis hyperythrus*, and *Sceloporus zosteromus* being the most abundant. Ten species previously recorded in scientific collections were not observed in the field, it is possible that the alteration of habitat and threats in the area are causing the extirpation of species. We suggest carrying out actions to control exotic plant species, and avoid the spread of the urban area to prevent the loss of biodiversity at this site.

Keywords.— Conservation, herpetofauna, coastal wetland, RAMSAR site.

Resumen.— El Estero de Punta Banda en la Bahía Todos Santos, Baja California, es un humedal de importancia internacional considerado sitio RAMSAR, prioritario para la conservación de la biodiversidad. En el caso del grupo de los anfibios y reptiles, no se han realizado estudios formales enfocados a conocer sus valores de riqueza ni de diversidad. Se establecieron cinco sitios de muestreo en tres ambientes: dunas costeras, campos de cultivo y zonas riparias. Los muestreos fueron indirectos, con sistemas de trampas de caída y nasas, y directos, mediante una búsqueda por transectos. La herpetofauna del Estero de Punta Banda está conformada por 15 especies de anfibios y reptiles, 13 géneros y 10 familias. Las familias mejor representadas fueron Phrynosomatidae y Colubridae, y las especies más abundantes *Uta stansburiana*, *Aspidoscelis hyperythrus* y *Sceloporus zosteromus*. Diez especies registradas previamente en colecciones científicas no fueron observadas en campo, es posible que la alteración de hábitat y amenazas de la zona estén provocando la extirpación de especies. Sugerimos realizar acciones de control de plantas exóticas y evitar la propagación de la mancha urbana para evitar la pérdida de biodiversidad en el sitio.

Palabras clave.— Conservación, herpetofauna, humedal costero, sitio RAMSAR.

INTRODUCCIÓN

La herpetofauna de México es una de las más diversas del mundo, con alrededor de 1,292 especies, de las cuales 394 son anfibios y 898 son reptiles (Johnson et al., 2017). El estado de Baja California cuenta con un registro estimado de 113 especies de reptiles y 20 especies de anfibios (incluyendo ocho especies no nativas) (Hollingsworth et al., 2015), sin embargo, la información acerca de la completitud para la herpetofauna en el estado, aún se desconoce, siendo ejemplo de ello, el Estero de Punta Banda (EPB).

Este lugar forma parte del Programa de Regiones Prioritarias para la Conservación de la Biodiversidad de México (Arriaga et al., 2000), como un sitio prioritario para la conservación a nivel estatal y nacional debido a la presencia de endemismos y riqueza de especies. También fue designado como sitio Ramsar desde 2006 debido a su variedad de ambientes como marismas, planicies lodosas, dunas, entre otros, permitiendo con ello una diversidad de flora y fauna endémica para este sitio (Arriaga et al., 2000; Martínez-Ríos, 2006; Granillo et al., 2012).

Dada su categoría como sitio Ramsar ha sido de interés para la realización de distintos estudios (Pritchard et al., 1978; Ibarra-Obando & Escofet, 1987; Ibarra-Obando & Poumian-Tapia, 1991; Massey & Palacios, 1994; Jiménez-Pérez et al., 2009). Sin embargo, y pesar de ello, no se cuenta con trabajos que analicen los valores de riqueza para los anfibios y reptiles en el EPB. A la falta de trabajos formales, se añade, la presión por el desarrollo turístico y urbano, el cual se estima que está presente en el 70% de la barra arenosa, lo que ha provocado la pérdida del hábitat y, por ende, ocasiona afectación a la biodiversidad local (Escofet, 1988; Jiménez-Pérez et al., 2009).

Realizar estudios de línea base, como lo son listados herpetofaunísticos, permite sentar las bases para estudios posteriores (García-Grajales et al., 2016). Así mismo, las políticas de conservación se basan en información disponible de las especies, por lo que es necesaria, tanto la investigación biológica como ecológica que guíe las acciones de conservación al área de estudio (Goodland, 1988; Bojórquez-Tapia et al., 1995).

El presente estudio tiene como finalidad conocer la riqueza y composición de la herpetofauna en el EPB, dado que estos organismos son parte fundamental de las interacciones ecológicas y procesos evolutivos de los ecosistemas costero-lagunar. Este estudio permitirá identificar prioridades de investigación y conservación ad hoc para las especies de herpetozoos en el sitio de estudio.

MATERIALES Y MÉTODOS

Área de estudio

El Estero de Punta Banda, es un humedal sub-estuarino (Dugan, 1992), ubicado 13 km al sur de la ciudad de Ensenada, Baja California, México (31.7333° N, 116.6333° O; Fig. 1) con un área de 2,390 ha (incluyendo planicies de marea, planicies fangosas, marismas, dunas costeras y planicies perturbadas). Dicho sitio es un cuerpo de agua en forma de "L", separada del mar por una barra arenosa de aproximadamente 7 km de largo (Jiménez-Pérez et al., 2009). Los principales hábitats que pueden distinguirse son las planicies lodosas, marisma, dunas costeras, canales de marea, zonas de pastos marinos y zonas riparias, lo que le confiere el carácter de ambiente costero-lagunar (Ibarra-Obando & Escofet, 1987; Martínez-Ríos, 2006; Jiménez et al., 2009).

La vegetación que predomina en las zonas riparias de las desembocaduras de los arroyos San Carlos y Las Ánimas son el sauce (*Salix* sp.), romerillo (*Baccharis sarothroides*), aliso (*Platanus racemosa*) y algunas plantas no nativas como el tabaquillo (*Nicotiana glauca*) y el pino salado (*Tamarix* sp). En la barra arenosa, predomina la vegetación de dunas costeras como la verbena de arena (*Abronia maritima*) y algunos elementos de matorral costero de los géneros *Acalypha, Artemisia, Euphorbia*, y *Lycium*, así como especies no nativas como el rábano de mar (*Cakile maritima*) y los deditos (*Carpobrotus edulis* y *C. chilensis*) (Martínez-Ríos et al., 2012).

Trabajo en campo

Previo al trabajo de campo, se buscaron registros de anfibios y reptiles para el EPB, en bases de datos electrónicas como VertNet (vertnet.org) y el Global Biodiversity Information Facility (gbif.org), así como en la literatura (Grismer, 2002), para conocer las especies potenciales a encontrar en el EPB.

Se seleccionaron cinco sitios de muestreo incluyendo hábitat de dunas costeras, campos de cultivo y zona riparia, que son los distintos hábitats terrestres detectados en el área de estudio. (Fig. 1). En cada sitio se instaló un sistema de trampas de caída con cercos de desvío. Cada sistema consistió en cuatro trampas de caída utilizando cubetas de 19 L enterradas al nivel del suelo ubicadas en los extremos de los cercos de desvió y tres trampas de embudo para serpientes colocadas en medio de los cercos de desvío (Fisher & Rochester, 2012). Debido a que el sitio cuenta con la desembocadura de un arroyo de aguas tratadas de manera semipermanente, se colocaron tres trampas tipo nasa de 45 cm de diámetro y 1 m de longitud cebadas con sardinas para la detección de tortugas dulceacuícolas (Bury et al., 2012).

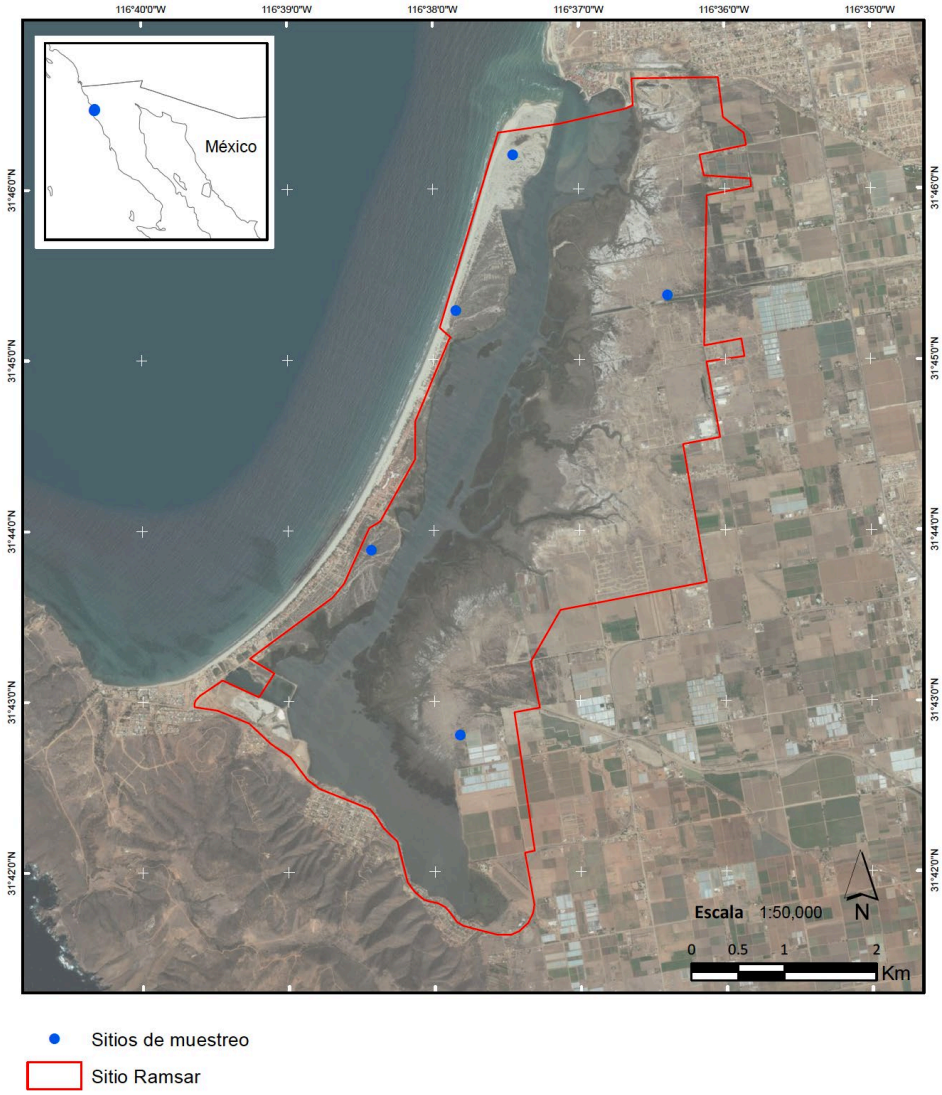

Figure 1. Location of the survey sites in the Punta Banda Estuary, Ensenada, Baja California.

Figura 1. Ubicación de los sitios de muestreo en el Estero de Punta Banda, Ensenada, Baja California.

Los muestreos se llevaron a cabo cada mes, a lo largo de nueve meses de monitoreo, de julio a octubre de 2018 y de abril a agosto de 2019 con un total de 45 días de muestreo. Cada muestreo se realizó a lo largo de cinco días y cuatro noches, y las trampas se revisaron cada 24 horas. Cada individuo capturado fue identificado a nivel de especie y después liberado en el sitio de captura.

Los muestreos se complementaron con transectos de encuentros visuales diurnos y nocturnos a pie (Foster, 2012), de 1 a 1.5 km de longitud en los distintos hábitats, realizados por 3-4 personas, entre 10:00–13:00 h y 20:00–22:00 h respectivamente. También se tomaron en cuenta los registros incidentales de organismos que se encontraron muertos o atropellados en caminos de acceso. Estos ejemplares fueron colectados, fijados con formaldehído al 10%, después preservados en alcohol etílico al 70% y finalmente depositados en la Colección Herpetológica de la Facultad de Ciencias de la Universidad Autónoma de Baja California en Ensenada. Para el caso, se contó con el permiso de colecta científica SGPA/DGVS/04457/19, otorgado por la Dirección General de Vida Silvestre, de la SEMARNAT.

Análisis de datos

Con los datos de los registros obtenidos del trabajo de campo, se generó una curva de acumulación de especies, utilizando los estimadores no paramétricos ACE y Chao 1 (1987), con la

variante Chao 1 (Chao, 1987; Cruz-Elizalde & Ramírez-Bautista, 2012; Rioja-Paradela et al., 2013). El análisis para la curva de acumulación de especies se efectuó con el programa EstimateS versión 9.1.0 (Colwell, 2013).

Para evaluar la riqueza de especies del EPB, se utilizó el índice de Margalef mediante la ecuación $DMg = S\text{-}1 / LnN$, dónde: S es el número de especies presentes en el sitio y N es el número total de individuos encontrados (Magurran, 2004).

Para comparar la abundancia entre especies, se elaboraron curvas de rango-abundancia, en las que se ordena a las especies de acuerdo a sus valores de abundancia proporcional (Feinsinger, 2003; Magurran, 2004). Los datos fueron graficados de acuerdo con el logaritmo de la proporción de cada especie ($p = [n/N]$), y posteriormente ordenados de la especie más abundante a la menos abundante. Adicionalmente, se identificó el estado de conservación de las especies mediante tres indicadores de riesgo: 1) Norma Oficial Mexicana (NOM-059-SEMARNAT-2010), 2) Lista Roja de la UICN, y 3) EVS (valor de vulnerabilidad ambiental; Wilson et al., 2013a, b).

RESULTADOS

La búsqueda en colecciones científicas arrojó 31 registros de tres especies de anfibios y 60 registros de 16 especies de reptiles colectados entre 1937 y 1971 (Apéndice 1). En el trabajo de campo se obtuvieron en total 549 registros/observaciones de 13 especies de anfibios y reptiles. Dos especies mas fueron detectadas incidentalmente poco después de terminado el trabajo de campo, sumando un total de 15 especies para el EPB (13 especies nativas y dos no nativas), pertenecientes a 13 géneros y 10 familias (Tabla 1). Cabe señalar que estas dos últimas especies detectadas (*Crotalus ruber* y *Hemidactylus turcicus*), se incluyeron en el listado total pero no fueron incluidos en los análisis. Las familias mejor representadas fueron Colubridae y Phrynosomatidae con cuatro y tres especies, respectivamente.

La curva de acumulación de especies estimó una completitud del 86.6% y 90.2% para los estimadores Chao1 y ACE. El estimador Chao1 predijo 15 especies, en tanto que ACE, 14 especies (Fig. 2), por lo que se requeriría un mayor esfuerzo de muestreo para alcanzar la asíntota y una completitud del inventario del 100%. Respecto a la diversidad verdadera, basada en la abundancia relativa de las especies se obtuvo un valor $DMg = 1.9$.

Las curvas de intervalo-abundancia indicaron que las especies más abundantes en el Estero de Punta Banda fueron *Uta stansburiana* seguida de *Aspidoscelis hyperythrus* y *Sceloporus zosteromus*. Mientras que las especies menos abundantes fueron las serpientes *Arizona elegans*, *Masticophis lateralis* y la tortuga *Trachemys scripta* (Fig. 3).

De las 15 especies registradas en este estudio, el 40% (6 especies) se encuentran en alguna categoría de la NOM-059-SEMARNAT-2010, de las cuales dos (*U. stansburiana* y *A.*

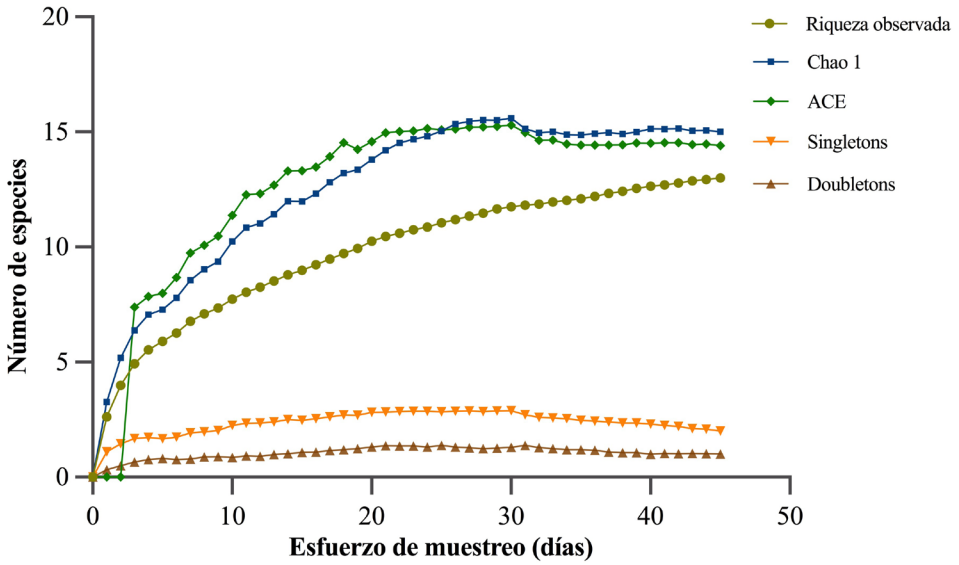

Figure 2. Accumulation curve of observed and expected amphibian and reptile species (Chao1 and ACE) in the Estero Punta Banda, Ensenada, Baja California.

Figura 2. Curva de acumulación de especies de anfibios y reptiles observados y esperados (Chao1 y ACE) en el Estero de Punta Banda, Ensenada, Baja California.

Table 1. Amphibian and reptile species recorded at Estero Punta Banda, Baja California. Conservation status according to IUCN's Red List (LC= Least concern); Nom-059-SEMARNAT-2010 (A= Threatened, Pr= Subject to special protection, NL= Not listed); and Environmental Vulnerability Score (EVS; Wilson et al. 2013a,b): Low (B: 3-9), Medium (M: 10-13) y High (A: 14-20). Non-native species marked with +, of which conservation status is not included (N/A).

Tabla 1. Especies de anfibios y reptiles registrados en el Estero de Punta Banda, Ensenada, Baja California. Estatus de conservación de acuerdo con la Lista Roja de la IUCN (LC= Preocupación menor); Nom-059-SEMARNAT-2010 (A= Amenazada, Pr= Sujeta a protección especial, NL= No enlistada); y Puntaje de Vulnerabilidad Ambiental (EVS; Wilson et al., 2013a,b): Bajo (B: 3-9), Medio (M: 10-13) y Alto (A: 14-20). Especies no nativas marcadas con +, de las cuales no se incluye el estatus de conservación (N/A).

Especies	Acrónimo	N	Estatus de conservación		
			IUCN	NOM-059	EVS
AMPHIBIA					
Bufonidae					
Anaxyrus boreas	ANBO	26	LC	NL	B(8)
Hylidae					
Pseudacris hypochondriaca	PSHY	4	N/A	NL	B(9)
REPTILIA					
Emydidae					
Trachemys scripta+	TRSC	1	N/A	N/A	N/A
Anguidae					
Elgaria multicarinata	ELMU	4	LC	Pr	M(10)
Anniellidae					
Anniella stebbinsi	ANST	3	LC	Pr	M(12)
Gekkonidae					
Hemidactylus turcicus+	HETU	1	N/A	N/A	N/A
Phrynosomatidae					
Sceloporus occidentalis	SCOC	9	LC	NL	M(12)
Sceloporus zosteromus	SCZO	52	LC	Pr	M(12)
Uta stansburiana	UTST	354	LC	A	B(7)
Teiidae					
Aspidoscelis hyperythrus	ASHY	67	LC	A	M(10)
Colubridae					
Arizona elegans	AREL	1	LC	NL	B(5)
Masticophis fuliginosus	MAFU	22		NL	B(9)
Masticophis lateralis	MALA	1	LC	NL	M(10)
Pituophis catenifer	PICA	3	LC	NL	B(9)
Viperidae					
Crotalus ruber	CRRU	1	LC	Pr	B(9)

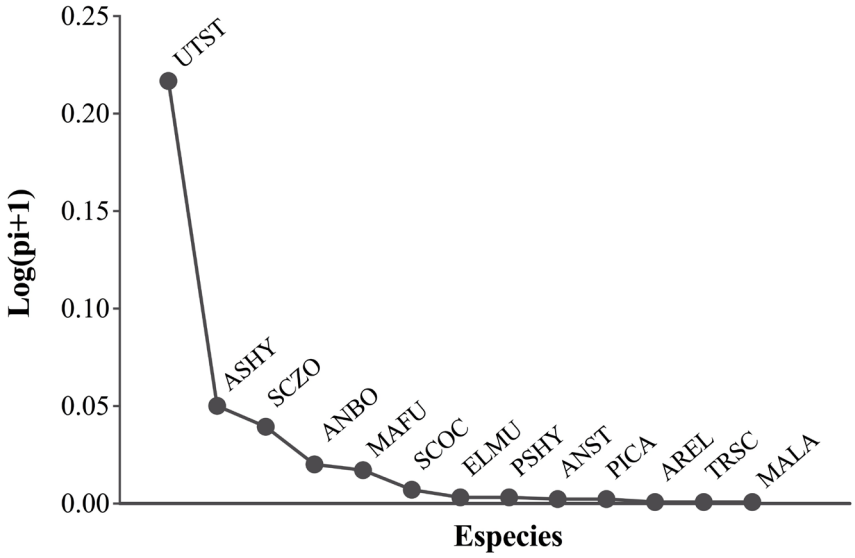

Figure 3. Rank abundance curve of the herpetofauna in the Estero Punta Banda. Species abbreviations are listed in Table 1.

Figura 3. Curva de intervalos de abundancia de la herpetofauna en el Estero de Punta Banda. Los acrónimos en la Tabla 1 representan a las especies.

hyperythrus) se encuentran en la categoría de amenazada y cuatro (*Anniella stebbinsi, Elgaria multicarinata, S. zosteromus* y *Crotalus ruber*) en la categoría de sujetas a protección especial (Fig. 4). Respecto a la lista roja de la IUCN, todas las especies registradas se encuentran en la categoría de preocupación menor. De acuerdo con el puntaje de vulnerabilidad ambiental (EVS), siete especies presentaron valores de vulnerabilidad bajos, seis especies valores intermedios y ninguna presentó un puntaje de vulnerabilidad alto.

DISCUSIÓN

La importancia de realizar estudios basados en muestreos para generar listados de especies, recae en que estos proporcionan información sólida y confiable que permite conocer la biodiversidad de un lugar determinado, además, son útiles para sentar las bases de estudios posteriores sobre conservación e historia natural que puedan ser enfocados a especies o grupos de especies (García-Grajales et al., 2016).

De acuerdo al esfuerzo de muestreo en el EPB, los estimadores de Chao1 y ACE mostraron una completitud de 86.6% y 90.2% respectivamente (Fig. 2), y aunque esta completitud se considera un porcentaje aceptable (Cruz-Elizalde & Ramírez-Bautista, 2012), se requiere mayor esfuerzo de muestreo para alcanzar una completitud del 100%. Esto se pudo comprobar cuando se registró la presencia de *C. ruber* en visitas posteriores al área de estudio, corroborando los resultados de los estimadores los cuales predijeron un mayor número de especies (Fig. 2).

Excluyendo a las dos especies exóticas, el listado de especies en el área de estudio aumentó a 23 especies (13 registros de este estudio y 10 en colecciones científicas). Estos datos contrastan con los estimadores de completitud del muestreo, los cuales estiman un total de 15 especies en la zona de estudio, existiendo así una discrepancia de ocho especies entre los estimadores y el número de registros totales. Los resultados de los estimadores, aunado a la antigüedad de los registros (<1971) y a la pérdida y alteración del hábitat que ha sufrido el área (Jiménez-Pérez et al., 2009), puede indicar la posibilidad de que algunas de las especies faltantes hayan sido extirpadas.

Entre las especies presentes en colecciones científicas, pero no observadas en el EPB, seis son serpientes (*Crotalus oreganus, Lampropeltis californiae, Lichanura trivirgata, Rhinocheilus lecontei, Rena humilis* y *Tantilla planiceps*), las últimas dos especies son de hábitos fosoriales, por lo que es raro observarlas y posiblemente sigan presentes en el área de estudio (Grismer, 2002). Sin embargo, *C. orgenaus, L. californiae* y *R. lecontei* son consideradas especies comunes en la región, y la falta de registros puede indicar su posible extirpación de la zona. Cabe mencionar que los métodos de captura empleados en este estudio, han demostrado ser muy eficaces para detectar especies crípticas que no se detectan por otros medios de muestreo (Case & Fisher, 2012),

Figure 4. Representative species of amphibians and reptiles from the Estero Punta Banda, Ensenada, Baja California. A) *Anaxyrus boreas*, B) *Anniella stebbinsi*, C) *Elgaria multicarinata*, D) *Aspidoscelis hyperythrus*, E) *Sceloporus zosteromus*, F) *Uta stansburiana*, G) *Masticophis fuliginosus*, H) *Crotalus ruber*.

Figura 4. Especies representativas de anfibios y reptiles del Estero Punta de Banda, Ensenada, Baja California. A) *Anaxyrus boreas*, B) *Anniella stebbinsi*, C) *Elgaria multicarinata*, D) *Aspidoscelis hyperythrus*, E) *Sceloporus zosteromus*, F) *Uta stansburiana*, G) *Masticophis fuliginosus*, H) *Crotalus ruber*.

por lo que no creemos que la falta de detección de estas especies se deba a los métodos de captura utilizados en este estudio. Las serpientes son propensas a múltiples amenazas, como carreteras, crecimiento urbano, muerte incidental por desechos de pesca (Moreno-Higareda et al., 2020) o muerte directa por lugareños, como lo indicó la presencia de serpientes muertas (n=6); el único ejemplar de *Masticophis lateralis* se encontró atropellado en la carretera y dos ejemplares de *Pituophis catenifer* se encontraron muertos colgados en un cerco.

Dada la geografía del EPB, las poblaciones pueden quedar aisladas dado que el único sitio de entrada resulta ser un filtro en contra de las serpientes dado el alto grado de urbanización, sin posibilidad de nuevos migrantes y eventualmente las especies son extirpadas por los mismos lugareños. En el caso de anfibios, el sapo de espuelas *Spea hammondii* el cual ha sufrido declive de sus poblaciones en California (Fisher & Shaffer, 1996; Morey, 2020) y posiblemente también en Baja California (Acosta-Sánchez, 2020), no fue detectada en el área de estudio y tampoco se ha registrado en años recientes. Sin embargo, existe la necesidad de realizar más muestreos enfocados a estas especies y determinar si persisten o no en el área de estudio.

En cuanto a diversidad, la herpetofauna del EPB fue baja (*DMg* = 1.9), y se asemeja a la diversidad observada en el Delta de Río Colorado para hábitats perturbados (*DMg* = 1.89 y 1.58; Valdez-Villavicencio et al., en prensa). En relación con la riqueza del EPB, también fue baja si se compara con los hábitats de poca perturbación en la región del Cabo, Baja California Sur, en la que se reportan entre 36 y 43 especies de herpetozoos (Blázquez-Moreno et al., 2013; Hollingsworth et al., 2019). En cuanto a hábitats costeros, en un ambiente muy similar al EPB, Fisher & Case (2000) reportaron 19 especies de anfibios y reptiles en el estuario de Tijuana en California, EE.UU., seis especies más comparando con nuestros resultados (sin incluir especies no nativas). La especie mas abundante en el EPB fue la lagartija de costados manchados (*Uta stansburiana*), a diferencia de huico de garganta naranja (*Aspidoscelis hyperythrus*) que fue la más común en el trabajo de Fisher & Case (2000), sin embargo, fue la segunda especie mas abundante en el EPB (Fig. 3).

A pesar de que el EPB es un sitio Ramsar, el desarrollo costero está imponiendo una gran presión en el sitio, y da pie a la proliferación de especies exóticas, causando afectaciones en la abundancia de aves, y posiblemente otros grupos de animales (Palacios et al., 1991; Jiménez-Pérez et al., 2009; Moreno-Higareda et al., 2019). La invasión del hielito (*Carpobrotus edulis*) pudiera representar otra amenaza a la sobrevivencia de los reptiles que aún persisten en la zona, ya que puede reducir significativamente la abundancia de reptiles, y de insectos que son el principal alimento de muchas especies de lagartijas (Schirmel et al., 2016). Por ejemplo, la lagartija sin patas *Anniella stebbinsi* puede verse afectada por la invasión de esta especie de planta no nativa (Jennings & Hayes, 1994; Rutherford & Rorabaugh, 1995). También se ha reportado la falta de vigilancia en el sitio, permitiendo la presencia de mascotas (perros y gatos) los cuales depredan sobre las aves anidantes y residentes (Jiménez-Pérez et al., 2009; J. Vargas com. pers., 2020) y posiblemente también sobre los reptiles. Por otra parte, solo dos especies de lagartijas (*U. stansburiana* y *S. zosteromus*), se registraron en todos los sitios de muestreo a pesar de los disturbios del hábitat, incluso se observaron cercanas a zonas suburbanas, entre matorrales y escombros.

De las 13 especies nativas que fueron registradas en este estudio, seis se encuentran enlistadas en la NOM-059-SEMARNAT-2010 bajo alguna categoría de protección (DOF, 2010), sin embargo, dicha lista omite otras especies de mediana vulnerabilidad (*S. occidentalis* y *M. lateralis*) consideradas por Wilson et al. (2013b), que también son de importancia en el ecosistema y deberían tomarse en cuenta en las estrategias de conservación y ayudar a mitigar su vulnerabilidad. Por su parte, aunque la IUCN considera a todas las especies registradas en este estudio en Preocupación menor, cinco de las especies se les considera en disminución de sus poblaciones.

Con base en los resultados, recomendamos realizar muestreos dirigidos a las especies ausentes para confirmar si han sido extirpadas. Además, realizar monitoreos continuos de las especies en el Estero de Punta Banda, con el fin de detectar cambios en las poblaciones derivados de alteraciones en el hábitat por el desarrollo turístico y urbano en la zona (Berriozabal-Islas et al., 2017), que también han afectado a otras especies de interés para la conservación (Jiménez-Pérez et al., 2009). De igual forma, es necesario llevar a cabo estudios enfocados a detectar las posibles afectaciones por parte de plantas exóticas hacia las especies nativas del lugar y de esta manera poder desarrollar mejores estrategias de conservación y evitar la perdida de especies en el Estero de Punta Banda..

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LISTA ACTUALIZADA DE LOS ANFIBIOS Y REPTILES DE ZAACHILA Y SANTIAGO CLAVELLINAS, OAXACA

UPDATED LIST OF THE AMPHIBIANS AND REPTILES OF ZAACHILA AND SANTIAGO CLAVELLINAS, OAXACA

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Abstract.— Oaxaca is Mexico's richest state in terms of herpetozoan species, but it is also one of the top ten states with the highest rates of deforestation in the country. Therefore, having update checklists of the herpetofauna that inhabit a region and the threats they face are the ground for establishing good conservation policies for these species. The herpetofauna of Santiago Clavellinas and Zaachila, Oaxaca, has been partially surveyed and there is no updated inventory of the species that are distributed in this region. This region is located between the physiographic subprovinces of the Central Valleys of Oaxaca and the Mountains and Valleys of Western Oaxaca. We integrated the herpetofauna checklist with records obtained during 15 years of field work, complemented with information retrieved from digital web pages. In total we recorded 70 species of herpetozoos, 14 amphibians and 56 reptiles. Sixteen species represent new distributional records for the Central Valleys and six are new distributional records for the Mountains and Valleys of Western Oaxaca. The percentage of endemic species to Mexico was 61.7% and species endemic to Oaxaca was 11.7%. The percentage of species classified under some risk category according to NOM-059-SEMARNAT-2010 and the IUCN Red List was 39.7%. The pine-oak forest with 46 species, the oak forest with 42 and the lowland grassland with 36, were the habitats with the highest specific richness. The main threats to herpetofauna are increased urbanization in the Central Valleys, and deforestation in the Western Mountains and Valleys of Oaxaca, due to the lack of sustainable forest management programs.

Keywords.— Central Valleys of Oaxaca, conservation, deforestation, endemic species, inventories, Mountains and Valleys of the West, species richness.

Resumen.— Oaxaca es el estado de México con mayor riqueza de especies de herpetozoarios, pero también es uno de los diez estados con mayor tasa de deforestación del país. Por lo tanto, contar con listas actualizadas de las especies de herpetozoarios que se distribuyen en una región y las amenazas que enfrentan, son la base para establecer buenas políticas de conservación para estas especies. La herpetofauna de Santiago Clavellinas y Zaachila, Oaxaca, ha sido estudiada parcialmente y no existe un inventario actualizado de las especies que se distribuyen en esta región, la cual está ubicada entre las subprovincias fisiográficas de los Valles Centrales de Oaxaca y las Montañas y Valles del Occidente de Oaxaca. El listado de la herpetofauna lo integramos con registros obtenidos durante 15 años de trabajo de campo, y fue complementado con información recuperada de plataformas digitales. En total registramos 70 especies de herpetozoarios, 14 de anfibios y 56 de reptiles. Dieciséis especies representan nuevos registros de distribución para los Valles Centrales y seis lo son para las Montañas y Valles del Occidente. El 61.7% de las especies nativas son endémicas de México, de las cuales el 11.7% son endémicas de Oaxaca. El 39.7% de las especies nativas están clasificadas bajo alguna categoría de riesgo de acuerdo con la NOM-059-SEMARNAT-2010 y la lista roja de la IUCN. El bosque de pino-encino con 46 especies, el bosque de encino con 42 y el pastizal de tierras bajas con 36, fueron los hábitat con mayor riqueza específica. Las

principales amenazas identificadas para la herpetofauna fue el incremento de la urbanización en los Valles Centrales, mientras que la deforestación y carencia de programas de gestión forestal sustentable lo fue para las Montañas y Valles del Occidente de Oaxaca.

Palabras clave.— Conservación, deforestación, especies endémicas, inventarios, Valles Centrales de Oaxaca, Montañas y Valles del Occidente de Oaxaca.

INTRODUCCIÓN

La pérdida de la biodiversidad como resultado de la crisis ambiental ocasionada por las actividades humanas, como el cambio de uso del suelo, contaminación, introducción de especies exóticas y cambio climático, es un problema a escala mundial (Doherty et al., 2020; Foster et al., 2012; Palmeirim et al., 2017; Whitfield et al., 2007). La situación es grave cuando se desconocen las especies que se distribuyen en un área en particular y el grado de vulnerabilidad en que se encuentran sus poblaciones (Gotelli, 2004). Por lo tanto, contar con inventarios actualizados y el reconocimiento de las posibles amenazas a las que se enfrentan las especies, es básico para establecer prioridades y políticas de conservación, sobre todo para los taxa más vulnerables (Böhm et al., 2013; Gotelli, 2004; Mace, 2004). En el estado de Oaxaca se han registrado hasta el momento 149 especies de anfibios y 293 de reptiles, siendo el estado con mayor diversidad de herpetozoos de México (Mata-Silva et al., 2012). Pero también es uno de los diez estados con mayor tasa de deforestación de la república mexicana (Céspedes-Flores & Moreno-Sánchez, 2010). La tasa de deforestación tasa varía entre las regiones que conforman el estado, y únicamente se ha estabilizado en la Sierra Norte, mientras que en las demás regiones aún existen pérdida importante de la cubierta forestal. En el caso de los Valles Centrales se debe principalmente a la agricultura, extracción de leña y tala clandestina (Ellis et al., 2016).

El centro de Oaxaca es una región parcialmente explorada desde el punto de vista herpetofaunístico (Aldape-López et al., 2009; Aldape-López y Santos-Moreno, 2016a y b; Casas-Andreu et al., 2004; Martín-Regalado et al., 2012, 2016), y el inventario de algunas áreas aún es incompleto, o no está actualizado, como es el caso de los municipios de Zaachila y la agencia de Santiago Clavellinas, municipio de Zimatlán de Álvarez. Algunos autores como Aldape-López et al. (2009), Myers y Campbell (1981), Goyenechea y Flores-Villela (2006), Hanken (1983), Rovito et al. (2013), López-Hernández et al. (2008) y Martín-Regalado et al. (2016) enlistan solo algunos elementos de la herpetofauna que se distribuye en Zaachila o en áreas cercanas. Debido a lo anterior, el objetivo del presente trabajo es presentar un listado actualizado de los anfibios y reptiles del distrito de Zaachila y de la agencia de Santiago Clavellinas, Municipio de Zimatlán de Álvarez, Oaxaca. Asimismo, damos a conocer el porcentaje de endemismo, estado de conservación, distribución por hábitat y nuevos registros de distribución.

ÁREA DE ESTUDIO

El área de estudio queda comprendida entre las coordenadas extremas 16.83 y 17.03 y -96.65 y -97.2333 (WGS84), que incluyen los seis municipios del distrito de Zaachila: San Antonio Huitepec, Santa Inés del Monte, San Miguel Peras, San Pablo Cuatro Venados, La Trinidad Zaachila y Villa de Zaachila, así como la Agencia de Santiago Clavellinas, Municipio de Zimatlán de Álvarez (Fig. 1), los que cubren una superficie aproximada de 590 km2 (INEGI, 2016).

La región está compuesta por valles y montañas con altitudes que van de los 1 500 a más de 2800 m s.n.m. Fisiográficamente la zona de estudio se ubica entre la subprovincia de Los Valles Centrales de Oaxaca (VCO) y la subprovincia de las Montañas y Valles del Occidente (MVO). La primera se caracteriza por ser una llanura escalonada y rampas de piedemonte que en la zona están por debajo de los 1800 m s.n.m., a la cual pertenecen los territorios de Villa de Zaachila y La Trinidad Zaachila y las partes bajas de los municipios de San Pablo Cuatro Venados y Santa Inés del Monte. La segunda subprovincia se caracteriza por su orografía montañosa y a la cual pertenecen los demás municipios (Ortiz-Pérez et al., 2004).

En el área de estudio existen cinco tipos de clima (INEGI, 2020), que se distribuyen de este a oeste de la siguiente manera: el primero es un clima seco cálido semiseco con lluvias en verano y está presente en las partes planas y bajas de Villa de Zaachila y la Trinidad Zaachila; el segundo es un clima templado semicálido húmedo con lluvias en verano y ocupa el piedemonte de Villa de Zaachila, la Trinidad Zaachila, Santa Inés del Monte y San Pablo Cuatro Venados; el siguiente es un clima templado subhúmedo con lluvias de verano y está presente en las partes altas de Santa Inés del Monte, San Pablo Cuatro Venados, Santiago Clavellinas, San Miguel Peras y San Antonio Huitepec; un clima cálido semicálido subhúmedo con lluvias en verano y está presente en las altitudes medias de San Miguel Peras y San Antonio Huitepec y el último tipo corresponde a un cálido subhúmedo con lluvias

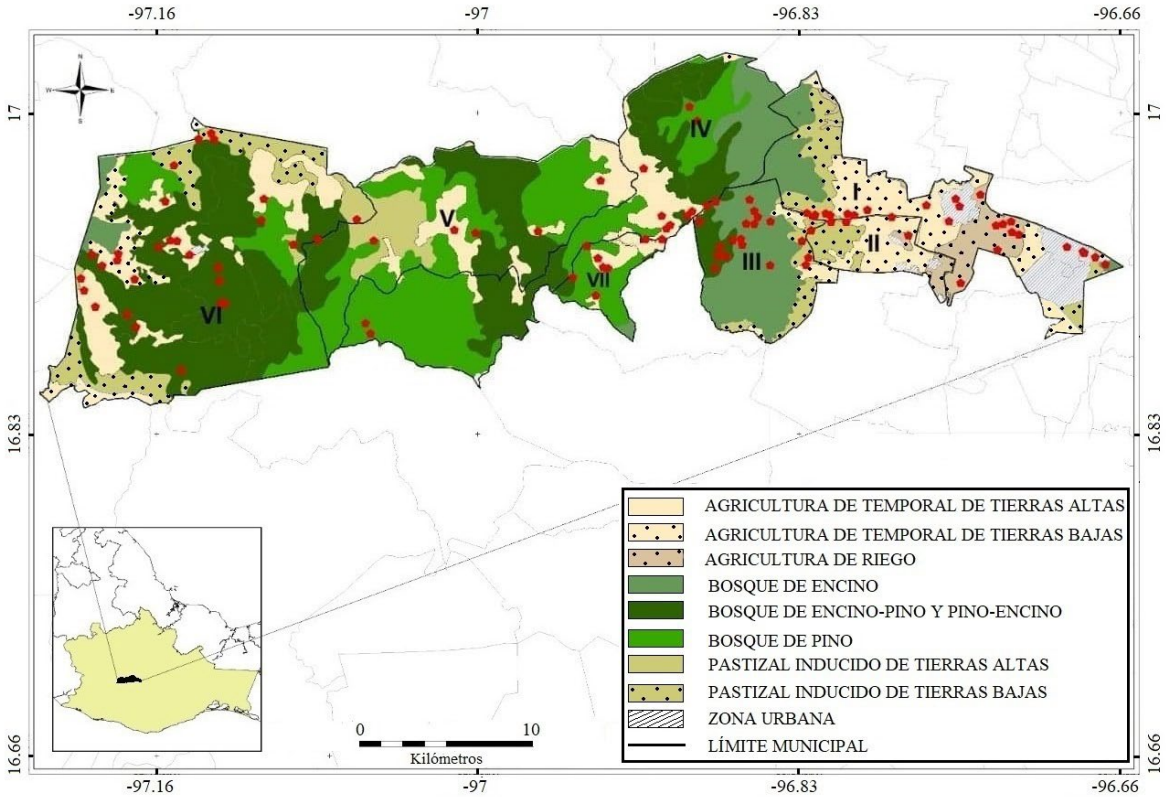

Figure 1. Geographical location and types of vegetation in the study area (INEGI, 2016). Roman numerals correspond to the six municipalities of the Zaachila District: I, Villa de Zaachila; II, La Trinidad Zaachila; III, Santa Inés del Monte; IV, San Pablo Cuatro Venados; V, San Miguel Peras; VI, San Antonio Huitepec, and VII belongs to the Santiago Clavellinas Agency, Municipality of Zimatlán de Álvarez, Oaxaca. The red dots indicate 112 sampling localities visited during fieldwork from 2004–2019.

Figura 1. Localización del área de estudio y tipos de vegetación (INEGI, 2016). Los números romanos corresponden a los municipios del Distrito de Zaachila: I, Villa de Zaachila; II, La Trinidad Zaachila; III, Santa Inés del Monte; IV, San Pablo Cuatro Venados; V, San Miguel Peras; VI, San Antonio Huitepec, y el VII pertenece a la Agencia de Santiago Clavellinas, Municipio de Zimatlán de Álvarez, Oaxaca. Los puntos rojos señalan la ubicación de los 112 sitios de muestreo visitados entre 2004-2019.

en verano, presente en las partes más bajas al oeste de San Antonio Huitepec. En la región corren arroyos y ríos de régimen perenne como el Atoyac, Cerezal, Contreras, Las Peras, Mangal, Minas y Plumas, además de otros de régimen intermitente.

En la zona de estudio el INEGI (2016) reconoce cinco tipos de vegetación: pastizal inducido, bosque de encino, bosque de pino, bosque de encino-pino y bosque de pino-encino, pero en el trabajo de campo nosotros determinamos la existencia de bosque de oyamel y bosque de táscate (Figs. 1 y 2). Los bosques de pino-encino y encino-pino, considerados como uno solo en este trabajo, cubren una superficie del 30.21% en el área de estudio y representan la comunidad vegetal dominante por su extensión. El bosque de pino representado por varias especies de *Pinus* sp., tiene una cobertura de 19.60%. El bosque de oyamel (*Abies hickelii*), ocupa una mínima parte del área de estudio y se presentan en forma de manchones aislados en las cañadas con elevada humedad ambiental. Estos tres tipos de bosques se desarrollan por arriba de los 2000 m s.n.m. en San Antonio Huitepec, Santa Inés del Monte, San Miguel Peras, San Pablo Cuatro Venados y Santiago Clavellinas. El bosque de encino cubre el 9.81% de la superficie del área estudiada y se encuentra en áreas donde la humedad es menor y en altitudes que van de los 1800 a 2500 m s.n.m., en los municipios de San Antonio Huitepec, Santa Inés del Monte, San Pablo Cuatro Venados, San Miguel Peras y Santiago Clavellinas. Asimismo, existen manchones de esta comunidad en los extremos oriental y occidental de Villa de Zaachila. El bosque de enebro o tascate (*Juniperus flaccida*) se desarrolla entre los 1650 y 2000 m s.n.m. al oeste de San Antonio Huitepec, siguiendo la trayectoria NW-SE del Arroyo Carrizal, y es más o menos continuo por 4 Km de largo (del Castillo et al., 2004 y Torres-Colín, 2004). Del pastizal inducido reconocimos

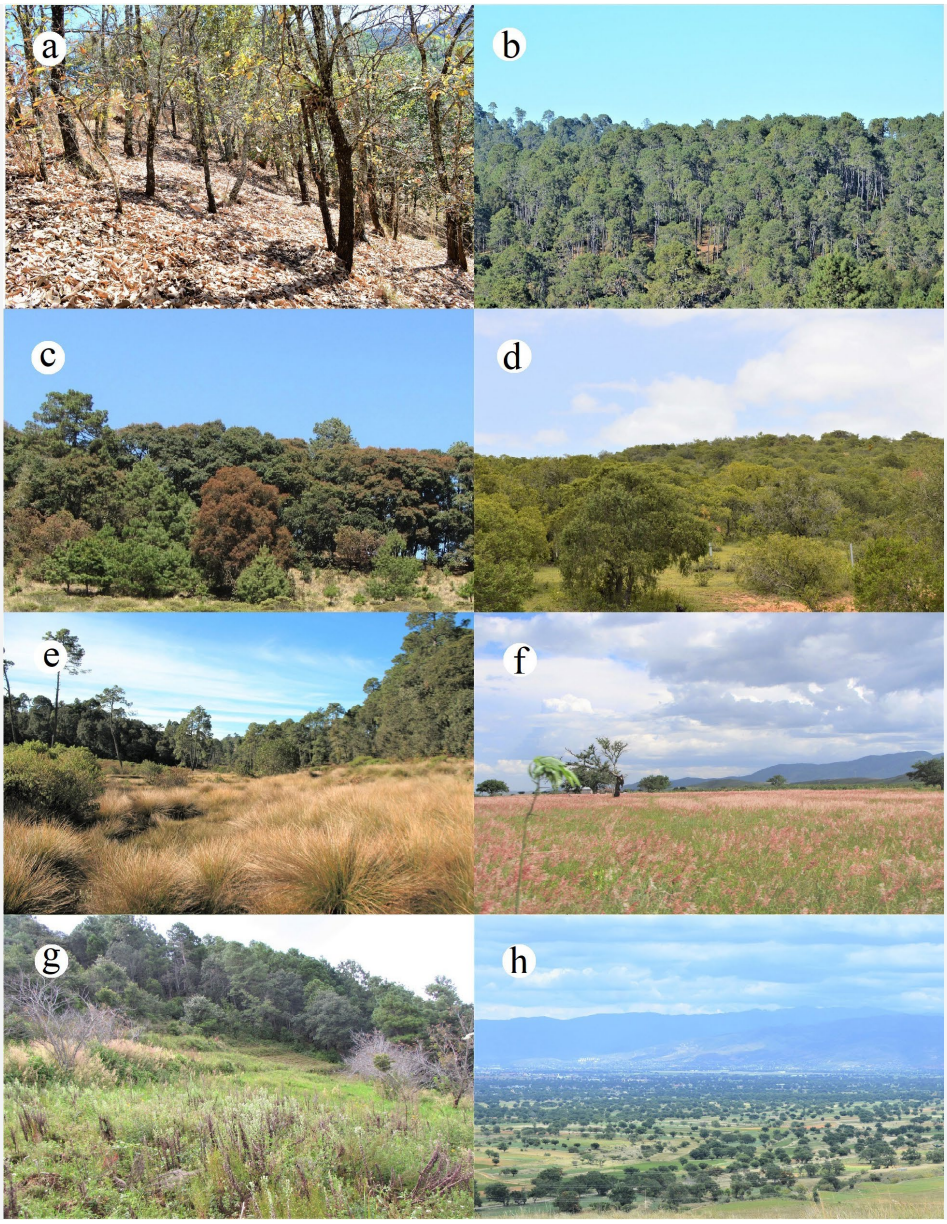

Figure 2. Representative habitats where we carried out the herpetozoan sampling in the Zaachila district and Santiago Clavellinas agency, Municipality of Zimatlán de Álvarez, Oaxaca, between 2004 and 2019. a) Oak forest, b) pine forest, c) pine-oak forest, d) juniper forest, e) upland grassland, f) lowland grassland; g) upland agriculture, h) lowland agriculture.

Figura 2. Hábitat representativos donde llevamos a cabo el muestreo de herpetozoos en el distrito de Zaachila y agencia Santiago Clavellinas, Municipio de Zimatlán de Álvarez, Oaxaca, entre 2004 y 2019. a) bosque de encino, b) bosque de pino, c) bosque de pino-encino, d) bosque de táscate, e) pastizal de tierras altas, f) pastizal de tierras bajas, g) agricultura de tierras altas, h) agricultura de tierras bajas.

en el trabajo de campo dos asociaciones dependiendo de su ubicación altitudinal, composición y estructura: un pastizal que crece en altitudes <1800 m s.n.m., que nombramos pastizal de tierras bajas, es dominado principalmente por el pasto *Rhynchelytrum roseum*, que en algunos sitios se asocia o es sustituido por otros como *Bouteloa* sp. y *Panicum* sp. Este pastizal se desarrolla principalmente en áreas planas, en campos de cultivos abandonados y en el piedemonte en San Antonio Huitepec, Santa Inés del Monte, San Pablo Cuatro Venados, La Trinidad Zaachila y Villa de Zaachila. Este tipo de vegetación cubre el 9.81% de la superficie del área de estudio. Mientras que el pastizal que crece en altitudes superiores a 1800 m s.n.m., que llamamos pastizal de tierras altas, puede presentarse como una comunidad de pastos amacollados dominado por *Muhlenbergia emersleyi* y *Stipa ichu*, o como un pastizal cespitoso que crece cerca de los arroyos y planicies inundables. Estas asociaciones cubren el 3.20% del área estudiada y crece en San Antonio Huitepec, Santa Inés del Monte, San Pablo Cuatro Venados, San Miguel Peras y Santiago Clavellinas. De la superficie cultivada diferenciamos los terrenos agrícolas de las tierras altas (>1800 m s.n.m.) de los terrenos agrícolas de tierras bajas (<1800 m s.n.m.). Los primeros abarcan el 12.30% del área de estudio y se encuentran en los municipios de San Antonio Huitepec, Santa Inés del Monte, San Pablo Cuatro Venados, San Miguel Peras

y Santiago Clavellinas. Los segundos ocupan una superficie de 8.91% de los municipios de la Trinidad Zaachila y Villa de Zaachila. En las tierras bajas también se practica una agricultura de riego, que cubre el 3.01% del territorio estudiado y se practica exclusivamente en la Trinidad Zaachila y Villa de Zaachila.

MATERIALES Y METODOS

De agosto de 2004 a noviembre de 2019 se llevaron a cabo 63 salidas a la zona de estudio, cuatro salidas por año, excepto 2009 que no hubo trabajo de campo y entre 2015 y 2017 el número de salidas al campo fueron cinco. Cada salida tuvo una duración de cinco días. En total se visitaron 112 localidades, en cada una de ellas las muestreamos cuatro veces a lo largo del estudio, con el objetivo de cubrir la época de lluvias y de secas, excepto tres de ellas que fueron visitadas en 12 ocasiones a lo largo de diferentes años. En cada localidad el número de hábitat muestreados varió de uno a tres.

La búsqueda de los anfibios y reptiles fue por el método de inspección visual por tiempo determinado (Guyer & Donelly, 2012; Heyer et al., 1994), que consistió en el desplazamiento aleatorio y con velocidad variable de dos personas a través de un tipo de hábitat, por un tiempo determinado. Durante la caminata el observador buscaba visualmente la presencia de los herpetozoarios en microhábitat potenciales (acuático, arborícola, fosoriales, saxícola y terrestre), asimismo, se revisaban bajo rocas, troncos, hojarasca y borde de cuerpos de agua. Cada que se avistaba un herpetozoario se determinó la especie, en algunos casos los ejemplares fueron capturados para corroborar la su determinación taxonómica, de estos ejemplares se registró el sexo, edad y condición reproductiva, la longitud hocico-cloaca, longitud de la cola y longitud del fémur. Las mediciones se obtuvieron con un calibrador digital. La mayoría de los ejemplares fueron liberados en el mismo sitio de captura, solo algunos representantes de cada especie fueron procesados como material de referencia, amparados en el permiso de colector FAUT-0125 otorgado por la Dirección General de Vida Silvestre de la SEMARNAT a nombre de Matías Martínez Coronel. El material obtenido está depositado en la Colección de Anfibios y Reptiles de la Universidad Autónoma Metropolitana-Iztapalapa (CAR-I).

El horario de trabajo para las especies diurnas fue entre las 09:00-12:00 h y 17:00-19:00 h, mientras que para las especies nocturnas fue entre las 20:00-24:00 h. El muestreo se condujo en los siguientes ambientes que fueron considerados hábitat distintos, debido a sus marcadas diferencias en condiciones físicas, composición y estructura florística: bosque de encino; bosque de pino; bosque de pino-encino; bosque de oyamel; bosque de táscate; pastizal de tierras altas; pastizal de tierras bajas; agricultura de tierras altas y agricultura de tierras bajas. También se obtuvo información ocasional de las especies que habitan en los núcleos poblacionales de tierras bajas (ubicados en altitudes < 1800 m s.n.m.) y en los núcleos poblacionales de tierras altas (ubicados en la sierra en altitudes >1800 m s.n.m.).

La lista de las especies sigue el arreglo taxonómico aceptado por las páginas electrónicas Amphibian Species of the World (Frost, 2021) y Reptile Database (Uetz et al., 2021) para los reptiles. En el trabajo no se usó la categoría de subespecie.

El listado de especies generado durante el trabajo de campo fue complementado con los registros obtenidos de las páginas electrónicas GBIF (2021a y 2021b), Naturalista (CONABIO, 2021) y VertNet (2021a y 201b). De estos registros fueron excluidas las siguientes especies: la rana *Leptodactylus melanonotus*, ya que su presencia en la zona de estudio es dudosa, debido a que el ambiente no es propicio para esta especie que necesita hábitat con agua abundante, condición que no se cumple en la zona de estudio (Heyer, 1969). Asimismo, fueron excluidas *Sceloporus cryptus* por ser una especie con distribución en la Sierra de Juárez (Köhler & Heimes, 2002), mientras que *Conopsis nasus* es una especie de la Mesa Central, por lo tanto, no se distribuye en Oaxaca (Goyenechea & Flores-Villela, 2006).

La categoría de riesgo y distribución de las especies se obtuvo de la NOM-059-SEMARNAT-2010 (SEMARNAT, 2019) y de la lista roja de la Unión Internacional para la Conservación de la Naturaleza (IUCN, 2021). Para el análisis de la distribución de las especies por hábitat, solo utilizamos la información obtenida en el campo por nosotros, la cual se presenta en una tabla.

RESULTADOS

La herpetofauna de Zaachila está integrada por 70 especies: 14 anfibios y 56 reptiles (Tabla 1). Sesenta y ocho de estas especies son nativas y dos (*Hemidactylus frenatus* y *Virgotyphlops braminus*) son exóticas. De los anfibios, las familias Hylidae y Plethodontidae fueron las de mayor riqueza específica con tres y cuatro especies respectivamente. Mientras que en los reptiles las familias con mayor riqueza fueron Phrynosomatidae y Colubridae con 11 especies cada una. Durante el trabajo de campo obtuvimos 5349 registros de 14 especies de anfibios y 53 reptiles (Figs. 3, 4, 5 y 6). Con excepción de *Boa imperator*, *Crotalus molossus*, *Tantalophis discolor* y *Micrurus browni*, que solo fueron observadas y fotografiadas, las demás especies están representadas por al menos un ejemplar de referencia en la colección de anfibios

Table 1. Taxonomic list of amphibians and reptiles registered in the Zaachila district and Santiago Clavellinas agency, Municipality of Zimatlán de Álvarez, Oaxaca, during 15 years of field work. For each species we give the catalog number of the voucher specimens of the amphibian and reptile collection of the Universidad Autónoma Metropolitana-Iztapalapa (CAR-I), u (Obs.) in case of having been registered by observation, degree of endemism and state of conservation in accordance with NOM-059-SEMARNAT-2010 (SEMARNAT 2019) and red list (IUCN 2021). An asterisk (*) next to the scientific name indicates the records that were retrieved from digital platforms, the information of which is given in Table 2.

Tabla 1. Lista taxonómica de anfibios y reptiles registradas en el distrito Zaachila y agencia de Santiago Clavellinas, Municipio de Zimatlán de Álvarez, Oaxaca. De cada especie damos el número de catálogo de los ejemplares depositados en la colección de anfibios y reptiles de la Universidad Autónoma Metropolitana-Iztapalapa (CAR-I) u (Obs.) en caso de observación, grado de endemismo y estado de conservación de acuerdo con la NOM-059 SEMARNAT-2010 (SEMARNAT 2019) y de la lista roja (IUCN 2021). El asterisco (*) junto al nombre científico indica los registros que fueron recuperados de plataformas digitales, cuya información se da en la Tabla 2.

Clase/Orden/ Familia/ Especie	CAR-I	Endemismo	NOM-059	IUCN
Amphibia, Anura				
Bufonidae				
Incilius occidentalis (Camerano, 1879)	287-305	MX		LC
Rhinella horribilis (Wiegmann, 1833)	306-324	NE		LC
Craugastoridae				
Craugastor mexicanus (Brocchi, 1877)	326-345	MX		LC
Craugastor pygmaeus (Taylor, 1937)	346-352	NE		LC
Eleutherodactylidae				
Eleutherodactylus nitidus (Peters,1870)	353-365	MX		LC
Hylidae				
Exerodonta sumichrasti Brocchi, 1879	454-462	MX		LC
Dryophytes euphorbiaceus Günther, 1859	438-454	MX		LC
Sarcohyla pentheter (Adler, 1965)	463-469	MX		VU
Ranidae				
Lithobates spectabilis (Hillis & Frost, 1985)	470-533	MX		LC
Scaphiopodidae				
Spea multiplicata (Cope, 1863)	534-583	NE		LC
Caudata				
Plethodontidae				
**Isthmura boneti* Alvarez y Martin, 1967	269-270	OX		EN
**Pseudoeurycea cochranae* (Taylor, 1943)	271-278	OX	A	VU
**Thorius narisovalis* Taylor, 1939	279-280	OX	Pr	EN
**Thorius* sp.	281			

Table 1 (cont.). Taxonomic list of amphibians and reptiles registered in the Zaachila district and Santiago Clavellinas agency, Municipality of Zimatlán de Álvarez, Oaxaca, during 15 years of field work. For each species we give the catalog number of the voucher specimens of the amphibian and reptile collection of the Universidad Autónoma Metropolitana-Iztapalapa (CAR-I), u (Obs.) in case of having been registered by observation, degree of endemism and state of conservation in accordance with NOM-059-SEMARNAT-2010 (SEMARNAT 2019) and red list (IUCN 2021). An asterisk (*) next to the scientific name indicates the records that were retrieved from digital platforms, the information of which is given in Table 2.

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Clase/Orden/ Familia/ Especie	CAR-I	Endemismo	NOM-059	IUCN
Reptilia, Squamata				
Anguidae				
**Abronia gadovii* (Boulenger, 1913)	639-664	MX	Pr	LC
Abronia oaxacae (Günther, 1885)	1473	OX	A	VU
Barisia imbricata (Wiegmann, 1828)	585-597	MX	Pr	LC
Gerrhonothus liocephalus Wiegmann, 1828	598	NE	Pr	LC
Dactyloidae				
Anolis quercorum Fitch, 1978	689-714	MX		LC
Gekkonidae				
Hemidactylus frenatus Schlegel, 1836	715-782	NE		LC
Mabuyidae				
**Marisora syntoma* McCranie, Mathew & Hedges, 2020	1214-1218	MX		
Phrynosomatidae				
**Phrynosoma braconnieri* Bocourt, 1870	783-784	MX	Pr	LC
Sceloporus aureolus Smith, 1942	786-807	MX		
Sceloporus bicanthalis Smith, 1937	808-828	MX		LC
**Sceloporus formosus* Wiegmann, 1834	829-851	MX		LC
**Sceloporus grammicus* Wiegmann, 1828	873-902	NE	Pr	LC
**Sceloporus horridus* Wiegmann, 1834	943-957	MX		LC
**Sceloporus jalapae* Günther, 1890		MX		LC
**Sceloporus siniferus* Cope, 1870	960-1028	NE		LC
Sceloporus spinosus Wiegmann, 1828	1131-1157	MX		LC
Sceloporus subpictus Lynch & Smith, 1965	1159-1200	OX	A	DD
**Urosaurus bicarinatus* (Duméril, 1856)	1202-1211	MX		LC
Scincidae				
**Plestiodon brevirostris* (Günther, 1860)	1220-1222	MX		LC

Table 1 (cont.). Taxonomic list of amphibians and reptiles registered in the Zaachila district and Santiago Clavellinas agency, Municipality of Zimatlán de Álvarez, Oaxaca, during 15 years of field work. For each species we give the catalog number of the voucher specimens of the amphibian and reptile collection of the Universidad Autónoma Metropolitana-Iztapalapa (CAR-I), u (Obs.) in case of having been registered by observation, degree of endemism and state of conservation in accordance with NOM-059-SEMARNAT-2010 (SEMARNAT 2019) and red list (IUCN 2021). An asterisk (*) next to the scientific name indicates the records that were retrieved from digital platforms, the information of which is given in Table 2.

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Clase/Orden/ Familia/ Especie	CAR-I	Endemismo	NOM-059	IUCN
Sphenomorphidae				
Scincella assata (Cope, 1864)	1223	NE		LC
Teiidae				
Aspidoscelis motaguae (Sackett, 1941)	1235-1239	NE		LC
Aspidoscelis sackii (Wiegmann, 1834)	1240-1299	MX		LC
Holcosus undulatus (Wiegmann, 1834)	1300-1302	NE		LC
Boidae				
Boa imperator Daudin, 1803	Obs.	NE		LC
Colubridae				
Conopsis amphisticha (Smith & Laufe, 1945)	1324	MX		NT
Conopsis megalodon (Taylor & Smith, 1942)	1326-1327	MX		LC
Drymarchon melanurus (Duméril, Bibron & Duméril, 1854)	1330-1331	NE		LC
Lampropeltis polyzona Cope, 1860	1332-1333	MX		LC
Masticophis mentovarius (Duméril, Bibron & Duméril, 1854)	1334-1335	NE		LC
Oxybelis microphthalmus Barbour & Amaral, 1926	1336-1337	NE		LC
Pituophis lineaticollis (Cope, 1861)	1338-1340	NE		LC
Salvadora intermedia Hartweg, 1940	1342	MX	Pr	LC
Senticolis triaspis (Cope, 1866)	1344-1345	NE		LC
Stenorrhina freminvillei Duméril, Bibron & Duméril, 1854	1346-1353	NE		LC
Tantilla rubra Cope, 1875	1354-1355	NE	Pr	LC
Dipsadidae				
Conophis vittatus Peters, 1860	1356	NE		LC
Enulius flavitorques (Cope, 1869)	1357	NE		LC
Geophis dubius (Peters, 1861)	1358	MX	Pr	LC
Leptodeira polysticta (Günther, 1895)	1359	NE		LC
Rhadinaea fulvivittis Cope, 1875	1366-1371	MX		VU

Table 1 (cont.). Taxonomic list of amphibians and reptiles registered in the Zaachila district and Santiago Clavellinas agency, Municipality of Zimatlán de Álvarez, Oaxaca, during 15 years of field work. For each species we give the catalog number of the voucher specimens of the amphibian and reptile collection of the Universidad Autónoma Metropolitana-Iztapalapa (CAR-I), u (Obs.) in case of having been registered by observation, degree of endemism and state of conservation in accordance with NOM-059-SEMARNAT-2010 (SEMARNAT 2019) and red list (IUCN 2021). An asterisk (*) next to the scientific name indicates the records that were retrieved from digital platforms, the information of which is given in Table 2.

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Clase/Orden/ Familia/ Especie	CAR-I	Endemismo	NOM-059	IUCN
Rhadinaea taeniata (Peters, 1863)	1372-1373	MX		LC
**Tantalophis discolor* (Günther, 1860)	Obs.	OX	A	VU
Elapidae				
Micrurus browni Schmidt & Smith, 1943	Obs.	NE	Pr	LC
Leptotyphlopidae				
**Epictia phenops* (Cope, 1875)	1305-1307	NE		
Natricidae				
Storeria storerioides (Cope, 1866)	1374	MX		LC
Thamnophis bogerti Rossman & Burbrink, 2005	1377-1388	OX		
**Thamnophis chrysocephalus* (Cope, 1885)	1389-1390	MX	A	LC
Thamnophis cyrtopsis (Kennicott, 1860)	1391-1396	NE	A	LC
**Thamnophis eques* (Reuss, 1834)		NE	A	LC
Virgotyphlops braminus (Daudin, 1803)	1308-1322	NE		
Viperidae				
Crotalus brunneus (Cope, 1865)	1402	OX	A	LC
Crotalus intermedius Troschel, 1865	1398-1401	MX	A	LC
Crotalus molossus Baird & Girard, 1853	Obs.	NE	Pr	LC
Mixcoatlus melanurus (Müller, 1824)	1403	MX	Pr	EN
**Ophryacus undulatus* (Jan, 1859)		MX	Pr	VU
Testudines				
Kinosternidae				
Kinosternon integrum Le Conte, 1854	1404-1408	MX	Pr	LC

* Endemism range: MX = Endemic to Mexico; OX = Endemic to Oaxaca; NE = Not endemic. ** Conservation status according to NOM-059-SEMARNAT-2010: A = Threatened; Pr = Special protection. *** Conservation status according to red list of IUCN: EN, endangered; LC, least concern; NT, near threatened and VU, vulnerable.

*Endemismo: MX= Endémica a México; OX= Endémica a Oaxaca; NE= No endémica. **Estatus de conservación de acuerdo con la NOM-059-SEMARNAT-2010: A= Amenazada; Pr= Protección especial. ***Estado de conservación de acuerdo con la IUCN: EN, en peligro de extinción; LC, preocupación menor; NT, casi amenazada y VU, vulnerable.

Figure 3. Amphibian species recorded in the municipalities of Zaachila district and Santiago Clavellinas agency, Municipality of Zimatlán de Álvarez, Oaxaca, between 2004 and 2019. a) *Incilius occidentalis*, b) *Craugastor mexicanus*, c) *Craugastor pygmaeus*, d) *Eleutherodactylus nitidus*, e) *Exerodonta sumichrasti*, f) *Dryophytes euphorbiaceus*, g) *Sarcohyla pentheter*, h) *Lithobates spectabilis*, i) *Isthmura boneti*, j) *Pseudoeurycea cochranae*, k) *Thorius narisovalis*, l) *Thorius* sp.

Figura 3. Especies de anfibios registrados en los municipios del distrito de Zaachila y agencia de Santiago Clavellinas, Municipio de Zimatlán de Álvarez, Oaxaca, entre los años 2004 y 2019. a) *Incilius occidentalis*, b) *Craugastor mexicanus*, c) *Craugastor pygmaeus*, d) *Eleutherodactylus nitidus*, e) *Exerodonta sumichrasti*, f) *Dryophytes euphorbiaceus*, g) *Sarcohyla pentheter*, h) *Lithobates spectabilis*, i) *Isthmura boneti*, j) *Pseudoeurycea cochranae*, k) *Thorius narisovalis*, l) *Thorius* sp.

Figure 4. Lizard species recorded in the municipalities of Zaachila district and Santiago Clavellinas agency, Municipality of Zimatlán de Álvarez, Oaxaca, between 2004 and 2019. a) *Abronia gadovii*, b) *Abronia oaxacae*, c) *Gerrhonotus liocephalus*, d) *Marisora syntoma*, e) *Phrynosoma bracconieri*, f) *Sceloporus aureolus*, g) *Sceloporus bicanthalis*, h) *Sceloporus siniferus*, i) *Sceloporus subpictus*, j) *Plestiodon brevirostris*, k) *Scincella assata*, l) *Aspidoscelis motaguae*.

Figura 4. Especies de lagartos registrados en los municipios del distrito de Zaachila y agencia de Santiago Clavellinas, Municipio de Zimatlán de Álvarez, Oaxaca, entre los años 2004 y 2019. a) *Abronia gadovii*, b) *Abronia oaxacae*, c) *Gerrhonotus liocephalus*, d) *Marisora syntoma*, e) *Phrynosoma bracconieri*, f) *Sceloporus aureolus*, g) *Sceloporus bicanthalis*, h) *Sceloporus siniferus*, i) *Sceloporus subpictus*, j) *Plestiodon brevirostris*, k) *Scincella assata*, l) *Aspidoscelis motaguae*.

Figure 5. Snake species recorded in the municipalities of Zaachila district and Santiago Clavellinas agency, Municipality of Zimatlán de Álvarez, Oaxaca, between 2004 and 2019. a) *Boa imperator*, b) *Conopsis amphistica*, c) *Conopsis megalodon*, d) *Drymarchon melanurus*, e) *Lampropeltis polyzona*, f) *Masticophis mentovarius*, g) *Oxybelis microphthalmus*, h) *Pituophis lineaticollis*, i) *Senticolis triaspis*, j) *Conophis vittatus*, k) *Enulius flavitorques*, l) *Leptodeira polysticta*.

Figura 5. Especies de serpientes registradas en los municipios del distrito de Zaachila y agencia de Santiago Clavellinas, Municipio de Zimatlán de Álvarez, Oaxaca, entre los años 2004 y 2019. a) *Boa imperator*, b) *Conopsis amphistica*, c) *Conopsis megalodon*, d) *Drymarchon melanurus*, e) *Lampropeltis polyzona*, f) *Masticophis mentovarius*, g) *Oxybelis microphthalmus*, h) *Pituophis lineaticollis*, i) *Senticolis triaspis*, j) *Conophis vittatus*, k) *Enulius flavitorques*, l) *Leptodeira polysticta*.

Figure 6. Snake and turtle species recorded in the municipalities of Zaachila district and Santiago Clavellinas agency, Municipality of Zimatlán de Álvarez, Oaxaca, between 2004 and 2019. a) *Tantalophis discolor*, b) *Micrurus browni*, c) *Epictia phenops*, d) *Storeria storerioides*, e) *Thamnophis bogerti*, f) *Thamnophis chrysocephalus*, g) *Thamnophis cyrtopsis*, h) *Crotalus brunneus*, i) *Crotalus intermedius*, j) *Crotalus molossus*, k) *Mixcoatlus melanurus*, l) *Kinosternon integrum*.

Figura 6. Especies de serpientes y tortuga registrados en los municipios del distrito de Zaachila y agencia de Santiago Clavellinas, Municipio de Zimatlán de Álvarez, Oaxaca, entre los años 2004 y 2019. a) *Tantalophis discolor*, b) *Micrurus browni*, c) *Epictia phenops*, d) *Storeria storerioides*, e) *Thamnophis bogerti*, f) *Thamnophis chrysocephalus*, g) *Thamnophis cyrtopsis*, h) *Crotalus brunneus*, i) *Crotalus intermedius*, j) *Crotalus molossus*, k) *Mixcoatlus melanurus*, l) *Kinosternon integrum*.

Table 2. Amphibian and reptile species species distributed in the municipalities of the Zaachila district and in the Santiago Clavellinas agency, Municipality of Zimatlán de Álvarez, Oaxaca, retrieved from the digital platforms GBIF (2021a and b), CONABIO (2021) and VertNet (2021a and 2021b). The acronym of the museum where the voucher specimens are deposited is given when it exists or the registration number in the case of observations.

Tabla 2. Especies de anfibios y reptiles con distribución en los municipios del distrito de Zaachila y en la agencia de Santiago Clavellinas, Municipio de Zimatlán de Álvarez, Oaxaca, recuperados de las plataformas digitales GBIF (2021a y b), CONABIO (2021) y VertNet (2021a y 2021b). Se da el acrónimo del museo donde se encuentran depositados los ejemplares de referencia cuando existe o bien el número de registro en el caso de observaciones.

Nombre científico	Museo y Número de Catálogo
Isthmura boneti	MVZ 137859-64, 137877-78, 162006-07
Pseudoeurycea cochranae	MVZ 138064-6;163753-54; 164692
Thorius narisovalis	MVZ 183012-27
Abronia gadovii	AMNH s/n,
	LACM 129611 y 129612
	Naturalista 62381467
Marisora syntoma	AMNH s/n.
Phrynosoma braconnieri	Naturalista 18650321
Sceloporus formosus	Naturalista 31950311
Sceloporus grammicus	MVZ 144132
	Naturalista 46029852 y 46030948
Sceloporus horridus	Naturalista 62647750
Sceloporus jalapae	IB-UNAM 7580
Sceloporus siniferus	MCNB 73
	Naturalista 38104393
Urosaurus bicarinatus	Naturalista 13926533
Plestiodon brevirostris	AMNH s/n.
Tantalophis discolor	MVZ 150313
Epictia phenops	Naturalista 13909108
Thamnophis chrysocephalus	ENCB-IPN 17021
Thamnophis eques	SDNHM 49367
Ophryacus undulatus	Naturalista 18796255

*AMNH, American Museum of Natural History; ENCB-IPN, Escuela Nacional de Ciencias Biológicas, I.P.N; FC-UNAM, Facultad de Ciencias UNAM; IB-UNAM, Instituto de Biología, UNAM; LACM, Natural History Museum of Los Angeles County; MCNB, Museu de Ciències Naturals de Barcelona; MVZ Museum of Vertebrate Zoology, University of California – Berkeley; SDNHM, San Diego Natural History Museum, San Diego, CA.

y reptiles de la Universidad Autónoma Metropolita Unidad Iztapalapa (CAR-I). De las plataformas electrónicas recuperamos 53 registros que corresponden a tres especies de anfibios y 15 de reptiles (Tabla 2). La mayoría de estos taxa fueron también registrados en el trabajo de campo, con excepción de *Sceloporus jalapae*, *Thamnophis eques* y *Ophryacus undulatus*.

Especies endémicas y estado de conservación. De las 68 especies nativas registradas, 10 anfibios y 32 reptiles son endémicos de México, las que representan el 61.7% del total registrado (Tabla 1). Las especies endémicas al estado de Oaxaca representan el 11.7%, y corresponden a tres salamandras (*Isthmura boneti*, *Pseudoeurycea cochranae* y *Thorius narisovalis*), dos lagartos (*Abronia oaxacae*, y *Sceloporus subpictus*) y tres serpientes (*Tantalophis discolor*, *Thamnophis bogerti* y *Crotalus brunneus*).

De las 68 especies nativas registradas, 27 de ellas (39.7%) se ubican en alguna categoría de riesgo de acuerdo con la NOM-059-2010 (SEMARNAT, 2019) y la lista roja de la IUCN (IUCN, 2021). De acuerdo con la primera clasificación, un anfibio y ocho reptiles están catalogados como amenazados, mientras que un anfibio y 13 reptiles bajo protección especial (Tabla 1). De acuerdo con la clasificación de la IUCN (2021), una lagartija tiene datos deficientes; una serpiente está cerca de la amenaza; dos anfibios y cuatro reptiles están clasificados como vulnerables, dos anfibios y un reptil como en peligro, el resto de las especies se ubica en la categoría de preocupación menor (Tabla 1). De las especies con alguna categoría de riesgo, sobresalen las clasificadas por ambos organismos y son: *Pseudoeurycea cochranae*, *Thorius narisovalis*, *Abronia oaxacae*, *Sceloporus subpictus*, *Tantalophis discolor*, *Mixcoatlus melanurus* y *Ophryacus undulatus*.

La herpetofauna tuvo una distribución desigual entre los once hábitat muestreados, el bosque de pino-encino fue el de mayor riqueza con 46 especies, seguido por el bosque de encino con 42 y el pastizal de tierras bajas con 36 (Tabla 3). Entre los hábitat restantes el número de especies varío entre 13 y 32, con excepción del bosque de oyamel donde solo fueron registradas cuatro especies.

DISCUSIÓN

Las 70 especies de herpetozoarios registrados en Zaachila y Santiago Clavellinas representan el 14.5% de las 480 registradas hasta el momento en Oaxaca (Mata-Silva et al., 2021). De estas especies sobresalen *Eleutherodactylus nitidus*, *Dryophytes euphobiaceus*, *Spea multiplicata*, *Sceloporus aureolus*, *Sceloporus horridus*, *Sceloporus siniferus*, *Urosaurus bicarinatus*, *Marisora syntoma*, *Holcosus undulatus*, *Drymarchon melanurus*, *Masticophis*

Table 3. Distribution of herpetozoa by habitat in the Zaachila district and Santiago Clavellinas agency, Zimatlán de Álvarez, Oaxaca. Only the species that were recorded during fieldwork between 2004 and 2019 are given. ATA, upland agriculture; ATB, lowland agriculture; BE, oak forest; BO, fir forest; BP, pine forest; BPE, pine-oak forest; BT, juniper forest; PTA, upland grassland; PTB, lowland grassland; NPA, highland population centers and NPB, lowland population centers.

Tabla 3. Distribución de los herpetozoarios por tipo de hábitat en el distrito de Zaachila y agencia de Santiago Clavellinas, Zimatlán de Álvarez, Oaxaca. Se presentan solamente las especies que fueron registradas durante el trabajo de campo entre 2004 y 2019. ATA, agricultura de tierras altas; ATB, agricultura de tierras bajas; BE, bosque de encino; BO, bosque de oyamel; BP, bosque de pino; BPE, bosque de pino-encino; BT, bosque de táscate; PTA, pastizal de tierras altas; PTB, pastizal de tierras bajas; NPA, núcleos de población de tierras altas y NPB, núcleos de población de tierras bajas.

Especie	ATA	ATB	BE	BEP	BO	BP	BT	PTA	PTB	NPA
Incilius occidentalis	X	X	X	X		X	X	X	X	X
Rhinella horribilis		X					X	X	X	
Craugastor mexicanus			X	X	X	X		X		
Craugastor pygmaeus			X	X		X		X	X	
Eleutherodactylus nitidus	X	X	X				X		X	X
Exerodonta sumichrasti		X	X						X	
Dryophytes euphorbiaceus	X	X	X	X			X	X	X	
Sarcohyla pentheter				X		X				X
Lithobates spectabilis		X	X	X		X	X	X	X	
Spea multiplicata		X							X	
Isthmura boneti				X		X		X		
Pseudoeurycea cochranae	X			X	X	X		X		
Thorius narisovalis				X	X	X				
Thorius sp.				X						
Abronia gadovii			X	X		X		X		
Abronia oaxacae				X		X				
Barisia imbricata				X				X		
Gerrhonothus liocephalus			X						X	
Anolis quecorum	X	X	X	X		X	X		X	X
Hemidactylus frenatus										
Phrynosoma braconnieri	X			X		X		X		
Sceloporus aureolus	X	X	X	X		X	X	X	X	X
Sceloporus bicanthalis	X			X				X		
Sceloporus formosus	X		X	X		X				X
Sceloporus grammicus	X	X	X	X	X	X	X	X	X	X
Sceloporus horridus		X	X				X		X	
Sceloporus siniferus		X	X	X			X		X	X

Table 3 (cont). Distribution of herpetozoa by habitat in the Zaachila district and Santiago Clavellinas agency, Zimatlán de Álvarez, Oaxaca. Only the species that were recorded during fieldwork between 2004 and 2019 are given. ATA, upland agriculture; ATB, lowland agriculture; BE, oak forest; BO, fir forest; BP, pine forest; BPE, pine-oak forest; BT, juniper forest; PTA, upland grassland; PTB, lowland grassland; NPA, highland population centers and NPB, lowland population centers.

Tabla 3 (cont).Distribución de los herpetozoarios por tipo de hábitat en el distrito de Zaachila y agencia de Santiago Clavellinas, Zimatlán de Álvarez, Oaxaca. Se presentan solamente las especies que fueron registradas durante el trabajo de campo entre 2004 y 2019. ATA, agricultura de tierras altas; ATB, agricultura de tierras bajas; BE, bosque de encino; BO, bosque de oyamel; BP, bosque de pino; BPE, bosque de pino-encino; BT, bosque de táscate; PTA, pastizal de tierras altas; PTB, pastizal de tierras bajas; NPA, núcleos de población de tierras altas y NPB, núcleos de población de tierras bajas.

Especie	ATA	ATB	BE	BEP	BO	BP	BT	PTA	PTB	NPA
Sceloporus spinosus		X	X	X			X		X	X
Sceloporus subpictus	X		X	X				X		
Urosaurus bicarinatus		X	X				X		X	
Marisora syntoma			X							
Plestiodon brevirostris	X		X	X		X		X		
Scincella assata			X							
Aspidoscelis motaguae		X	X	X					X	
Aspidoscelis sackii		X	X	X					X	X
Holcosus undulatus		X	X	X					X	
Boa imperator		X	X							
Conopsis amphistica				X		X		X		
Conopsis megalodon	X			X		X		X		X
Drymarchon melanurus		X	X						X	
Lampropeltis polyzona		X							X	
Masticophis mentovarius		X	X				X		X	
Oxybelis microphthalmus		X	X	X					X	
Pituophis lineaticollis		X	X	X		X			X	
Salvadora intermedia			X	X						
Senticolis triaspis		X	X	X					X	X
Stenorrhina freminvillei		X	X	X					X	
Tantilla rubra		X							X	
Conophis vittatus									X	
Enulius flavitorques			X						X	
Geophis dubius	X			X						
Leptodeira polysticta	X	X	X	X		X			X	
Rhadinaea fulvivittis				X		X		X		
Rhadinaea taeniata			X	X					X	

Table 3 (cont). Distribution of herpetozoa by habitat in the Zaachila district and Santiago Clavellinas agency, Zimatlán de Álvarez, Oaxaca. Only the species that were recorded during fieldwork between 2004 and 2019 are given. ATA, upland agriculture; ATB, lowland agriculture; BE, oak forest; BO, fir forest; BP, pine forest; BPE, pine-oak forest; BT, juniper forest; PTA, upland grassland; PTB, lowland grassland; NPA, highland population centers and NPB, lowland population centers.

Tabla 3 (cont). Distribución de los herpetozoarios por tipo de hábitat en el distrito de Zaachila y agencia de Santiago Clavellinas, Zimatlán de Álvarez, Oaxaca. Se presentan solamente las especies que fueron registradas durante el trabajo de campo entre 2004 y 2019. ATA, agricultura de tierras altas; ATB, agricultura de tierras bajas; BE, bosque de encino; BO, bosque de oyamel; BP, bosque de pino; BPE, bosque de pino-encino; BT, bosque de táscate; PTA, pastizal de tierras altas; PTB, pastizal de tierras bajas; NPA, núcleos de población de tierras altas y NPB, núcleos de población de tierras bajas.

Especie	ATA	ATB	BE	BEP	BO	BP	BT	PTA	PTB	NPA
Tantalophis discolor				X				X		
Micrurus browni		X							X	
Epictia phenops		X							X	
Storeria storerioides				X						
Thamnophis bogerti	X		X	X		X		X		X
Thamnophis chrysocephalus			X	X		X		X		
Thamnophis cyrtopsis	X	X	X	X		X		X	X	
Virgotyphlops braminus		X								
Crotalus brunneus			X	X						
Crotalus intermedius	X		X	X		X		X		
Crotalus molossus			X						X	
Mixcoatlus melanurus				X						
Kinosternon integrum	X	X	X	X				X	X	
Total de especies	**19**	**32**	**42**	**46**	**4**	**25**	**13**	**25**	**36**	**13**

mentovarius, *Oxybelis microphthalmus*, *Tantilla rubra*, *Leptodeira polysticata*, *Epictia phenops*, y *Kinosternon integrum* que representan nuevos registros para la subprovincia de VCO.

De manera que el número de especies con distribución para esta región asciende de 58 a 74 (Mata-Silva et al., 2021). Mientras que *Rhinella horribilis*, *Sceloporus bicanthalis*, *Aspidoscelis motaguae*, *Boa imperator*, *Conopsis amphistica* y *Masticophis mentovarius* representan nuevos registros para las MVO, aumentando la riqueza de esta subprovincia de 127 a 138 especies (Aldape-López & Santos-Moreno, 2016a,b; Martín-Regalado et al., 2016; Mata-Silva et al., 2021).

Tres herpetozoarios no nativos fueron registrados en los municipios ubicados en los VCO, dos de ellos se han establecido exitosamente, mientras que el tercero lo consideramos como observación ocasional. La Cuija, *Hemidactylus frenatus*, la detectamos desde agosto de 2004 en la de Villa de Zaachila y a partir mayo de 2016 en La Trinidad Zaachila y en El Carmen, Municipio de Santa Inés del Monte. La Agujilla, *Virgotyphlops braminus*, la registramos a partir septiembre de 2005 en los jardines de las casas de la Villa de Zaachila. Esta especie también la encontramos bajo desechos domésticos en áreas agrícolas en septiembre de 2007 en la Trinidad Zaachila y en marzo de 2016 en Villa de Zaachila. Ambas especies se han establecido exitosamente en los núcleos poblacionales de Villa de Zaachila y la Trinidad Zaachila, así como en Xoxocotlán y la Ciudad de Oaxaca, poblaciones cercanas al área de estudio (Mata-Silva et al., 2013). Tanto la Cuija como la Agujilla son originarias del sureste asiático y su presencia en los Valles Centrales, consideramos es consecuencia del deterioro ambiental causado por el incremento de los asentamientos humanos y del intercambio comercial (Kraus, 2009). Hasta el momento desconocemos si la presencia de estos organismos en la región puede afectar a otras especies

de la herpetofauna nativa, pues las especies exóticas, además de ser competidoras, pueden transmitir parásitos y enfermedades a la fauna nativa (Barton, 2007, 2015; Chinchio et al., 2020; Díaz et al., 2020). Una tercera especie exótica registrada en Zaachila fue la iguana negra, *Ctenosaura pectinata*, de la cual observamos un macho adulto en abril y mayo de 2018, a orillas del arroyo "La Lobera" al oeste de Zaachila. Debido a que fue el único ejemplar observado, no se tomó en cuenta en el listado de este trabajo. Asimismo, un habitante de la zona encontró recién muerto al animal en julio de 2018, y por el estado del cuerpo supone que fue de inanición. Este registro lo consideramos ocasional, y creemos se trató de un animal liberado por algún poseedor de mascotas.

El 61.7% de las especies nativas registradas en Zaachila y Santiago Clavellinas son endémicas a México, este porcentaje es menor en comparación con el 72.05% de la Sierra Madre del Sur (Flores-Villela et al., 2010), pero similar al 60.4% reportado para todo el estado de Oaxaca (Mata-Silva et al., 2021). El 11.7% de las especies encontradas en el área de estudio son endémicas al estado de Oaxaca, valor menor en comparación con el 21.8% a escala estatal (Mata-Silva et al., 2021). Es interesante anotar que todas las especies endémicas de Oaxaca registradas en la zona de estudio también son compartidas con la subprovincia de la Sierra Madre de Oaxaca, donde se ubica la Sierra de Juárez (Mata-Silva et al., 2015, 2021). De acuerdo con Flores-Villela et al. (2010) y Ochoa-Ochoa et al. (2014) la elevada endemicidad de la herpetofauna de Oaxaca es resultado de la compleja historia biogeográfica del estado Oaxaca, que se refleja en una mayor heterogeneidad ambiental dada por la orografía, temperatura, precipitación y altitud, así como con variables propias de la biología de cada grupo animal. La zona de Zaachila y Santiago Clavellinas se caracteriza por su heterogeneidad ambiental, con una orografía que varía desde zonas semiplanas a montañosas, con altitudes que van de los 1500 m s.n.m. en las partes más bajas hasta puntos que superan los 2800 m s.n.m. en la sierra. En esta área existen cinco tipos de clima y siete tipos de vegetación. Todas estas variables integran un mosaico de condiciones para los herpetozoarios, sobre todo para las especies con distribución en los bosques templados (Flores-Villela et al., 2010; Martin-Regalado et al., 2016; Ochoa-Ochoa et al., 2014).

El 39.7% de las especies nativas de herpetozoarios registrados en la zona de estudio están bajo alguna categoría de riesgo de acuerdo con la NOM-059-2010 (SEMARNAT, 2019) y lista roja (IUCN, 2021), valor similar al 41.7% reportado por Martín-Regalado et al. (2016) para toda la Sierra de Cuatro Venados. No obstante, la enorme riqueza de la región, la conservación de los herpetozoarios en la zona de estudio enfrenta diferentes problemas. En los municipios de los VCO los ecosistemas originales han sido sustituidos o alterados casi en su totalidad, por ejemplo, en Villa de Zaachila en 2015 quedaba un 16.76% de área boscosa, el 40% eran áreas agrícolas, el 30.45% pastizal inducido y 12.79% zona urbana. Mientras que en la Trinidad Zaachila el 45.18% de la superficie municipal eran terrenos agrícolas, el 51.03% pastizal inducido y el 3.79% área urbana (DIGEPO, 2016; INEGI, 2016). Además, en Villa de Zaachila nuevos asentamientos humanos se crearon durante el último quinquenio, afectando sobre todo la porción este del municipio. El incremento poblacional representa una mayor presión y deterioro de los ecosistemas, debido a todos los efectos que implica la urbanización y la dotación de servicios básicos a la nueva población (Elmqvist et al., 2015). En los municipios de las MVO el crecimiento poblacional es menor (DIGEPO, 2016), y la actividad agrícola es de subsistencia, además que está limitada por la pendiente del terreno, de manera que las actividades productivas recaen en la explotación de los bosques, de donde extraen principalmente leña, carbón y madera. Los recursos son de propiedad comunal y la gestión de estos se decide por asambleas comunitarias (Gómez-Sosa & Arellanes-Cancino, 2018; Rivera-Peña et al., 2017). No obstante, en todos los municipios existe tala clandestina y en la mayoría de ellos no existen programas de gestión forestal sustentable.

La problemática ambiental se agrava por la existencia de conflictos comunitarios por límites territoriales y por el manejo inadecuado de los recursos forestales (Garibay, 2002). No obstante, esta problemática puede resolverse, si se sigue el ejemplo de otros municipios de Oaxaca, como Zimatlán de Álvarez (Rosas-Baños & Lara-Rodríguez, 2013) o Ixtlán de Juárez (Vázquez-Cortez et al., 2018), donde las comunidades han sabido resolver sus conflictos. Por lo tanto, se considera primordial para la zona de estudio promover políticas de gestión sustentable de los bosques, ya que de esta manera se podrá asegurar la continuidad de la fauna asociada a ellos, como los anfibios y reptiles (Böhm et al., 2013; Ellis et al., 2016; Mace, 2004).

Cada especie de herpetozoario tiene requerimientos de hábitat propios, dependiendo de sus adaptaciones e historia filogenética (Vitt & Caldwell, 2014), de manera que su distribución entre hábitat también resulta desigual. Por lo tanto, era de esperar que la riqueza de especies entre hábitat resultara desigual en Zaachila y Santiago Clavellinas. Resultados similares registraron Martín-Regalado et al. (2016) para toda la Sierra de Cuatro Venados, quienes reportan que el bosque de pino encino, con 22 especies, fue el hábitat con mayor riqueza específica, seguido por el bosque de pino con 15, bosque de encino con 14 y bosque tropical caducifolio con solo tres taxa. En Zaachila y Santiago Clavellinas también el bosque de pino-

encino con 46 especies, fue el de mayor riqueza específica, seguido por el bosque de encino con 42 y el bosque de pino con 25. En comparación con otros estudios llevados a cabo en comunidades de bosques templados del centro de México, los bosques de Oaxaca albergan una mayor riqueza de especies de herpetozoarios (Martín-Regalado et al., 2016). Por ejemplo, Díaz de la Vega-Pérez et al. (2019) registraron 28 especies en el Volcán La Malinche, Tlaxcala, donde las áreas agrícolas y bosque de pino con 19 y 17 especies respectivamente fueron las más ricas en comparación con el bosque de pino-encino, bosque de pino-aile, pastizal alpino, bosque de oyamel y bosque de encino. Mientras que, Vega-López & Álvarez (1992) encontraron 22 especies en los volcanes Popocatépetl-Iztaccíhuatl, de las cuales el bosque de pino albergo 15, seguido por el bosque de oyamel, pastizal inducido, áreas agrícolas, pastizal alpino, bosque de pino-encino, bosque de encino y bosque de encino-pino. En el Parque Nacional "El Chico", Hidalgo, Ramírez-Pérez (2008) encontró 22 especies, siendo los bosques de oyamel y de encino con 10 especies cada uno, los más ricos, seguidos por los bosques de oyamel-encino, de pino-encino bosque de pino. La mayor diversidad de herpetozoarios en los bosques de Oaxaca se considera es resultado de la compleja historia biogeográfica del estado, que se refleja en su heterogeneidad ambiental, que ha favorecido una mayor riqueza de anfibios y reptiles en comparación con el centro de México (Flores-Villela et al., 2010; Martín-Regalado et al., 2016; Ochoa-Ochoa et al., 2014).

El incremento en el cambio de uso de la tierra debido a la apertura de campos agrícolas y asentamientos humanos ha generado cambios en las comunidades de la fauna, en general el efecto es negativo sobre la riqueza, diversidad y abundancia de los herpetozoarios. Sin embargo, la respuesta no es la misma en todos los grupos ni en todos los ambientes, ya que existen especies que son favorecidas por estos cambios (Biaggini & Corti, 2015; Doherty et al., 2020; Elmqvist et al., 2015; French et al., 2018; Leyte-Manrique et al., 2019; Scheffers et al., 2011; Suazo-Ortuño et al., 2008). En el presente estudio la riqueza de especies en las áreas agrícolas fue de intermedia a baja, de 70 especies registradas, 32 fueron observadas en los terrenos agrícolas de tierras bajas y 19 en los de altitud mayor. En cambio, Illescas-Aparicio et al. (2016) encontraron que, de 37 especies registradas en la Sierra Norte de Oaxaca, la mayor riqueza de especies ocurrió en los terrenos agrícolas (31) en comparación con los bosques bajo manejo (9) o los bosques conservados (8).

Resultados similares encontraron Leyte-Manrique et al. (2019) en Guanajuato, quienes registraron 10 especies en San Nicolás de los Agustinos y 16 en Urireo, de las cuales ocho fueron registradas en áreas agrícolas y seis en el bosque tropical caducifolio en la primera localidad, mientras que 12 y 9 respectivamente en el segundo sitio. Asimismo, Díaz de la Vega-Pérez et al. (2019) reportaron en el volcán La Malinche, Tlaxcala, que la mayor riqueza de especies de herpetozoarios ocurrió en las áreas agrícolas, donde encontraron 19 de 28 taxa registrados, en comparación con la vegetación de bosques templados. Hasta el momento no existe un consenso sobre que variables intrínsecas o del hábitat son responsables de la variación en la respuesta de cada especie a estos cambios (Hernández-Ordoñez & Suazo-Ortuño, 2016).

Un factor que identificamos en el área de estudio y que posiblemente favorece la presencia de herpetozarios en las áreas agrícolas es el tipo de agricultura no intensiva que se practica en la mayoría de los predios de los valles centrales, mientras que, en la sierra, debido al tipo de terrenos con pendiente, aun se practica una agricultura de roza-tumba-quema (Rivera-Peña et al., 2017). Otras variables identificadas por otros autores y observadas en la zona de estudio fueron: la presencia de cuerpos de agua naturales (arroyos y pozas) y artificiales (represas y canales) en las áreas agrícolas, recurso que atrae a una variedad de herpetozoarios. También los cultivos agrícolas favorecen la abundancia de alimento potencial para los herpetozoarios, principalmente de insectos y roedores. Por ejemplo, en Villa de Zaachila existen predios agrícolas activos mezclados con predios abandonados y donde crece un pastizal o manchones de matorral espinoso (*Acacia farnesiana*), de manera que estos integran una matriz de condiciones que favorecen la presencia de la herpetofauna. También, en el interior como entre límites de predios hay árboles, que, junto con las herbáceas de las orillas de los caminos, sirven de refugio y de corredores a las especies que usan estos sitios (Biaggini & Corti, 2015; Fernández-Badillo & Goyenechea-Mayer Goyenechea, 2010; Leyte-Manrique et al., 2019).

La presencia de especies de herpetozoarios en núcleos poblacionales humanos es un fenómeno común en todo el mundo, y se estima que representan el 5% de los reptiles y 4% de los anfibios a escala mundial (Mollov, 2011 y 2019; Ducatez et al., 2018). Como mencionamos anteriormente, la respuesta de cada especie a los cambios ambientales es variable, pero en el caso particular de las especies que habitan ambientes urbanos, se considera que la mayoría de estas son generalistas en sus requerimientos de hábitat (Ducatez et al., 2018; French et al., 2018; García-Grajales et al., 2018). En este estudio encontramos que el 27.1% de todas las especies registradas fueron observadas en núcleos poblacionales, 13 en poblaciones situadas a más de 1800 m s.n.m. y 15 en poblaciones de menor altitud. De estas especies, *Eleutherodactylus nitidus*, *Anolis quercorum*, *Sceloporus*

aureolus, *Sceloporus formosus*, *Sceloporus grammicus* y *Sceloporus siniferus* se observaron frecuentemente en núcleos poblaciones ubicados >1800 m s.n.m., mientras que *E. nitidus*, *A. quercorum*, *Hemidactylus frenatus*, *Sceloporus grammicus*, *Sceloporus spinosus*, *Aspidoscelis sackii* y *Virgotyphlops braminus* en poblados ubicados a menor altitud.

El resto de las especies que penetran a núcleos poblacionales las consideramos visitantes ocasionales, ya que fueron observadas tres o menos ejemplares durante el estudio. La presencia de especies de anfibios y reptiles en los núcleos poblacionales obedece en parte a que la mayoría de las casas mantienen áreas sin construcción, huertos familiares y jardines, donde los organismos obtienen alimento, refugio y sitios de reproducción (Ducatez et al., 2018; French et al., 2018; Gómez-Sosa & Arellanes-Cancino, 2018).

CONCLUSIONES

La herpetofauna del distrito de Zaachila y de la agencia de Santiago Clavellinas, Zimatlán de Álvarez, Oaxaca, está compuesta por 14 especies de anfibios y 56 de reptiles. Registramos seis nuevas especies para la subprovincia fisiográfica de la MVO y 16 para los VCO, aumentando la riqueza específica de estas subprovincias a 138 y 74 taxa respectivamente. Documentamos la presencia de *Hemidactylus frenatus* y *Virgotyphlops braminus*, especies exóticas que se han establecido en algunos poblados de los VCO. El 61.7% de la herpetofauna de la zona de estudio es endémica a México, mientras que 39.7% se encuentra bajo alguna categoría de riesgo. La elevada riqueza y endemicidad de la herpetofauna de la zona de estudio se considera resultado de la heterogeneidad ambiental y factores históricos. Los anfibios y reptiles de la región enfrentan serios problemas de conservación debido a nuevos asentamientos humanos en Villa de Zaachila, y a la falta de programas de manejo sustentable de los recursos en los demás municipios.

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EL CANTO DE ANUNCIO DEL ANURO MÁS PEQUEÑO DE MÉXICO, LA RANA PIGMEA *CRAUGASTOR PYGMAEUS* (ANURA: CRAUGASTORIDAE)

THE ADVERTISEMENT CALL OF MEXICO'S SMALLEST ANURAN, THE PYGMY FROG *CRAUGASTOR PYGMAEUS* (ANURA: CRAUGASTORIDAE)

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Abstract.— *Craugastor pygmaeus* is the smallest anuran within its genus and probably the smallest known anuran from Mexico. In this study, it is described the advertisement call of the *C. pygmaeus* from the population of La Cienega in Flora and Fauna Protection Area Sierra de Quila, Jalisco, Mexico. The call consists of the repetition of a short whistle without modulated frequency and irregular call repetition. It was distinguished that advertisement calls show individual variation in the dominant frequency, which suggests that *C. pygmaeus* has an individual spectral signature.

Keywords.— amphibians, bioacoustics, endangered species, call variation, smallest vertebrates.

Resumen.— *Craugastor pygmaeus* es el anuro más pequeño dentro de su género y probablemente el anuro más pequeño conocido en México. En el presente estudio se describe el canto de anuncio de la rana *C. pygmaeus* de una población localizada en una localidad de La Ciénega dentro del Área de Protección de Flora y Fauna Sierra de Quila, Jalisco, México. El canto consiste en un silbido corto sin frecuencia modulada con una repetición sumamente irregular en el tiempo. Se distinguió que los cantos de anuncio presentan variación restringida en la frecuencia dominante, lo cual sugiere que *C. pygmaeus* cuenta con una firma espectral distintiva a nivel individual.

Palabras clave.— anfibios, bioacústica, especies en peligro, variación del canto, vertebrados más pequeños.

INTRODUCCIÓN

Las señales acústicas son el principal tipo de señales que componen los sistemas de comunicación de los anuros. La diversidad de señales acústicas y el contexto social en que se expresan difiere entre especies y poblaciones (Wells & Schwartz, 2007). Entre la diversidad de tipos de señales acústicas, el canto de anuncio es el más estudiado debido a que se le atribuye la doble función de atraer parejas reproductivas y delimitar los espacios frente a otros conespecíficos (Gerhardt & Huber, 2002). En comunidades donde se mezclan las señales acústicas de distintas especies de anuros resulta relevante que las diferencias espectrales y temporales de los cantos de anuncio permiten el aislamiento reproductivo y potencian el reconocimiento entre especies (p. ej. Batallas & Brito, 2016), particularmente cuando estas pertenecen al mismo género (p. ej. Bignotte-Giró et al., 2019). Aunque esta repartición del nicho acústico puede no ocurrir cuando la composición de la comunidad acústica es más diversa en su composición de géneros y familias (p. ej. Ochoa-Ochoa et al., 2021).

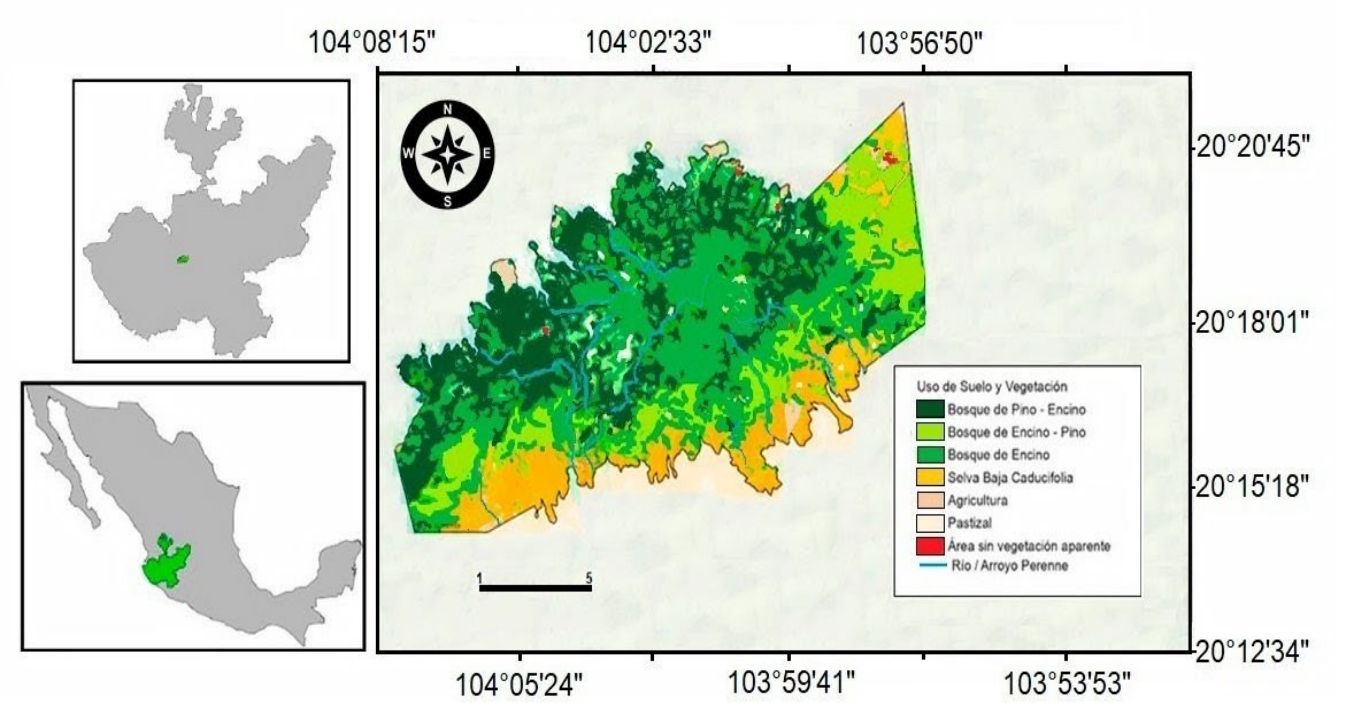

Figure 1. Geographic location and vegetation types of Sierra de Quila, Flora and Fauna Protection Area (APFF, by its acronym in Spanish), within the state of Jalisco, Mexico. The APFF has an area of approximately 152 km^2.

Figura 1. Ubicación geográfica y tipos de vegetación dentro del Área de Protección de Flora y Fauna (APFF) Sierra de Quila, en el estado de Jalisco, México. El APFF tiene una superficie aproximada de 152 km^2.

En particular las características acústicas de los cantos de anuncio pueden arrastrar una señal filogenética, por lo que se han incorporado como caracteres que permiten reconstruir las relaciones ancestrales entre especies cercanas (Wang et al., 2014; Mendoza-Henao et al., 2020). Así, las señales acústicas de los anuros constituyen un rasgo importante para distinguir taxonómicamente a las especies y conocer aspectos de sus interacciones intraespecíficas (Köhler et al., 2017). Por lo que identificar y distinguir las señales acústicas además de reconocer a las especies, permite eventualmente contar con herramientas con las que se pueden implementar monitoreos o medidas de manejo, particularmente en especies de anfibios amenazados, mediante el uso de grabadoras automáticas en campo (Dorcas et al., 2010; Buxton et al., 2018).

El género *Craugastor* está integrado por 120 especies que se distribuyen desde el sur de Estados Unidos hasta el norte de Sudamérica, y forma parte de la superfamilia Brachycephaloidea (Frost, 2021). Las ranas del género *Craugastor* suelen ocupar microhábitats con abundante hojarasca de bosques y selvas prístinas y secundarias (Urbina-Cardona et al., 2006; Pineda & Rodríguez-Mendoza, 2010). Estos microambientes proveen de condiciones favorables para la ovoposición de nidos terrestres, alimentación y refugio (Cooper et al., 2008; Urbina-Cardona & Reynoso, 2009; Luría-Manzano et al., 2019), así como un escenario con el que las especies se mimetizan (Carbajal-Márquez et al., 2019). Los cantos de anuncio de las ranas *Craugastor* son típicamente silbidos cortos de una sola nota, aunque algunas especies pueden emitir cantos de anuncio con múltiples notas (Cossel et al., 2019).

Entre los *Craugastor* hay especies de diverso tamaño que van de los 18 hasta los 110 mm de tamaño corporal longitud hocico cloaca (LHC), siendo *C. pygmaeus* la más pequeña dentro del género (Hedges et al., 2008) y posiblemente la especie más pequeña de los anuros registrados hasta ahora para México. En la descripción original de *C. pygmaeus*, Taylor (1936) indicó que, aunque "se escucharon varias llamadas en la maleza, ningún macho fue descubierto", lo que indica, en primer lugar, la dificultad de detectar estos anuros en el campo y, en segundo lugar, lo poco que se sabe sobre las peculiaridades entorno a su conducta. En el género *Craugastor*, existen numerosos casos en los que no se cuenta con la descripción específica de los machos y se asume que a quiénes se escucha vocalizar es a los

Figure 2. Individual of *Craugastor pygmaeus* of 12.9 mm (LHC) and weight of 0.135 g, was located among pine litter. Captured on July 17, 2013.
Figura 2. Individuo de *Craugastor pygmaeus* de 12.9 mm (LHC) y peso de 0.135 g, se localizó entre hojarasca de pino. Capturado el 17 de julio del 2013.

machos (Carbajal-Márquez et al., 2019). En el presente trabajo se describe por primera vez las características acústicas del canto de anuncio de *C. pygmaeus* en una población ubicada en la Sierra de Quila, Jalisco, México.

MATERIALES Y MÉTODOS

Durante los periodos de lluvias (julio-septiembre) de 2012 y 2013 efectuamos dos vistas por mes al área de estudio (doce visitas) a una planicie denominada La Ciénaga, situada en el bosque de pino-encino (20.30325° N, 104.03582° O), a 2145 m s.n.m. dentro del Área de Protección de Flora y Fauna Sierra de Quila. En este sitio se establecieron tres senderos de 200 m de largo por seis de ancho, tres personas registramos la presencia y cantos de *C. pygmaeus*. Cada visita fue de dos días, con recorridos nocturnos (de 19:00 a 24:00 h) y diurnos (de 6:00 a 9:00 h) por las márgenes de un manantial y un arroyo ubicados en La Ciénaga para localizar y grabar las vocalizaciones de individuos de *C. pygmaeus*. En cada captura de los individuos se registraban observaciones sobre el microhábitat desde el cual vocalizaban.

Los individuos que se encontraban vocalizando fueron grabados durante 3 a 9 min a una tasa de muestreo de 44.1 kHz y resolución de 16 bits en formato WAV con una grabadora digital Tascam DR 100 y conectada a ella un micrófono Sennheiser modelo e822S, el cual se ubicó por encima del ejemplar que cantaba a los 40 y 60 cm y en ángulos de los 90 y 45° respecto al hocico del espécimen. Aquellos individuos grabados fueron capturados y medidos del hocico-cloaca (LHC) con un calibrador digitar marca Mitutoyo modelo ABSOLUTE Digimatic con una precisión de 0.1 mm. Para el registro del peso se utilizó una balanza digital marca GemOro modelo Platinum 0800 con una precisión de 0.01 g. Con las mediciones de peso, LHC y las características acústicas se efectuó un análisis de correlación de Pearson $P<0.05$ con el objeto de determinar si existe una relación entre los aspectos morfológicos de la especie y su canto.

La caracterización acústica de los cantos de anuncio se realizó con el software Raven Pro. 1.6.1. Los análisis acústicos se obtuvieron mediante una trasformación rápida de Fourier (FFT) de un ancho de banda de 256 puntos y una ventana de análisis tipo Hanning. Las mediciones registradas fueron: el número de cantos por minuto (el número de cantos desde el primer canto hasta el último registrado para cada individuo en la grabación), la duración del canto (tiempo del inicio al final de la nota) y la frecuencia dominante (la frecuencia que ocurre a la mayor intensidad en la nota). Para cada variable acústica se calculó el coeficiente de variación individual e intrapoblacional de acuerdo con Gerhardt (1991). Finalmente, para investigar la asociación entre las características del canto y el tamaño corporal de los

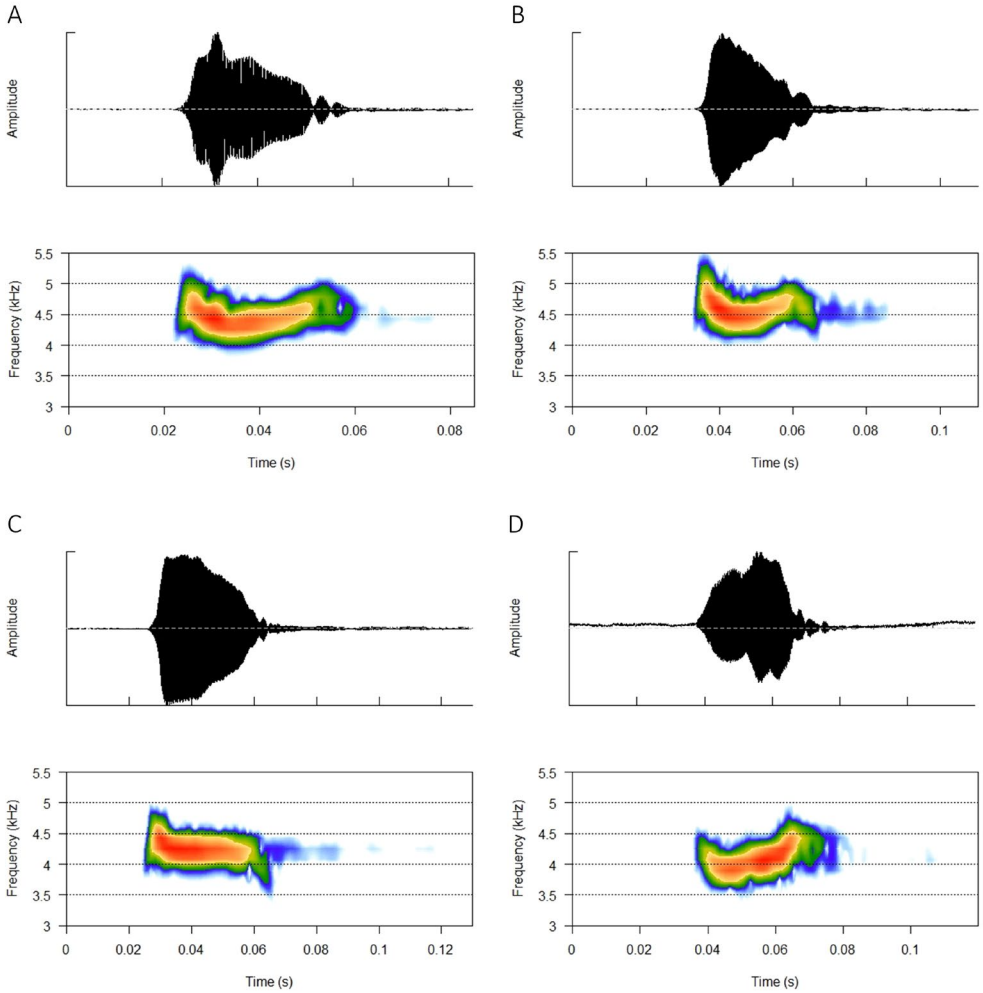

Figure 3. Oscillograms and spectrograms of the advertisement call from four individuals of *Craugastor pygmaeus* measuring 11.58 mm (A), 12.7 mm (B), 12.0 mm (C) and 11 mm (D) in body size. Sampling rate: 22 kHz and 256 FFT points.

Figura 3. Oscilogramas y espectrogramas del canto de anuncio de cuatro individuos de *Craugastor pygmaeus* de 11.58 mm (A), 12.7 mm (B), 12.0 mm (C) y 11 mm (D) de tamaño corporal. Tasa de muestreo: 44 kHz y 256 puntos de FFT.

individuos, se estimó la correlación entre los valores promedio de las variables acústicas y el tamaño corporal y peso de los individuos. Los espectrogramas y oscilogramas se elaboraron utilizando con el paquete seewave del software R versión 3.6.3 (R Development Core Team, 2020) debido a que ofrecen un ambiente gráfico más didáctico que el de Raven Pro.

RESULTADOS

Craugastor pygmaeus vocalizaba cerca del arroyo del sitio de estudio, principalmente sobre la hojarasca de pino depositada en el suelo con más de 60 cm de espesor y sobre troncos en descomposición. La vocalización de los individuos se escuchó de manera indistinta tanto en el día como durante la noche, pero con mayor frecuencia por las noches. En este escenario y debido a su diminuto tamaño corporal (Fig. 2), fue complicado localizar, grabar y capturar a todos los individuos. En total se escucharon y observaron 73 individuos, de estos 36 individuos en el año 2012 y 37 en 2013, el esfuerzo de muestreo fue de 288 horas-hombre (Tabla 1). Fueron grabados 18 individuos de *C. pygmaeus*, esto representa el 29 % del total de individuos. De los individuos grabados, el 83% fueron registrados en los muestreos nocturnos y el 17% durante los muestreos diurnos. Cabe aclarar que los cantos de cuatro de los individuos no fueron incluidos

Table 1. Number of *Craugastor pygmaeus* individuals captured during day and night samplings in Sierra de Quila Flora and Fauna Protection Area in the summers of 2012 and 2013.
Tabla 1. Número de individuos de *Craugastor pygmaeus* capturados durante muestreos diurnos y nocturnos en el Área de Protección de Flora y Fauna Sierra de Quila en los veranos de 2012 y 2013.

Año 2012						
Horario	**Julio**		**Agosto**		**Septiembre**	
	visita 1	visita 2	visita 1	visita 2	visita 1	visita 2
Nocturno	3	4	5	5	3	4
Diurno	2	2	2	2	2	2
Año 2013						
Horario	**Julio**		**Agosto**		**Septiembre**	
	visita 1	visita 2	visita 1	visita 2	visita 1	visita 2
Nocturno	5	5	4	3	4	4
Diurno	2	2	2	2	2	2

en el análisis por la baja proporción señal/ruido de la grabación o porque se contaba con menos de tres cantos por organismo. Los 14 individuos restantes emitieron un total de 123 cantos, los cuales se emplearon para el análisis considerando a su vez que todos ellos fueron emitidos por los machos, hacemos esta aclaración ya que no fue posible determinar el sexo de los individuos en el muestreo.

El canto de anuncio de *C. pygmaeus* consiste en un silbido agudo corto (Fig. 3), con repetición intermitente en el tiempo, es decir, sin una periodicidad específica entre el lapso de emisión de cantos consecutivos. Las características acústicas, y tamaño corporal (LHC) y peso de los organismos grabados se presentan en la Tabla 2. En promedio, el canto presenta una tasa de 0.64 cantos por minuto, una duración del canto de 0.054 s y frecuencia dominante de 4 444 Hz. La variabilidad individual e intrapoblacional fue mayor en la duración del canto, con un rango de la variación individual de 18.29 a 64.11, y presentó menor variabilidad individual en la frecuencia dominante con un rango de 2.15 a 10.61 (Tabla 2). No se encontró alguna relación significativa entre las características acústicas de tasa de repetición de cantos, duración del canto y la frecuencia dominante con el tamaño corporal ($r = 0.50$, $p = 0.066$; $r = 0.38$, $p = 0.182$; $r = -0.05$, $p = 0.851$, respectivamente) o el peso de los individuos ($r = -0.25$, $p = 0.379$; $r = -0.31$, $p = 0.282$; $r = -0.31$, $p = 0.280$; respectivamente). Las grabaciones con las que obtuvimos los datos para esta descripción fueron depositadas en la Biblioteca Digital de Sonidos de Anfibios de México del Museo de Zoología Alfonso L. Herrera (MZFC-HEC) de la Facultad de Ciencias de la UNAM con el folio MZFC-HEC4349.

DISCUSIÓN

Las características acústicas del canto de anuncio de *C. pygmaeus* son similares al de otras especies del mismo género, siendo el canto de *C. pygmaeus* un sonido corto de mediana frecuencia con una tasa de repetición irregular. El sonido es débil probablemente debido a que carece de saco vocal (Hedges et al., 2008) y a su pequeño tamaño corporal, por lo que su canto a una distancia mayor a cinco metros es inaudible. Aunque no pudimos registrar las características de amplitud del canto de *C. pygmaeus*, es probable que tengan una de las amplitudes más bajas registradas para el género *Craugastor* (Cossel et al., 2019). Los datos obtenidos sugieren que la vocalización de *C. pygmaeus* es principalmente nocturna.

Ninguna de las variables acústicas examinadas en *C. pygmaeus* tuvo relación con el tamaño corporal y el peso. En el continuo de variación de los cantos propuesta por Gerhardt (1991), la variabilidad del canto de *C. pygmaeus* fue mayor en la duración del canto con un CV intrapoblacional de 33.75, por lo que se considera una variable dinámica, y con un CV intrapoblacional de 5.62 en la frecuencia dominante, por lo que se considera una variable estática. Esta propiedad estática de la frecuencia dominante es común entre los anuros y está relacionado con su relevancia para reconocimiento específica de los cantos de anuncio (Gerhardt, 1991).

A diferencia de otros anuros, la identidad del sexo en *C. pygmaeus* no es evidente a través de la presencia de huevos en el vientre o alguna otra característica morfológica externa.

Table 1. Average values (x) and coefficient of variation (CV) of the acoustic variables of the call of *C. pygmaeus* registered in 14 individuals. Abbreviations: CM: number of songs per minute; DC: song duration; FD: dominant frequency; LHC: snout-vent length size.

Tabla 1. Valores promedio (X) y coeficiente de variación (CV) de las variables acústicas del canto de *C. pygmaeus* registrada en 14 individuos. Abreviaciones: CM: número de cantos por minuto; DC: duración del canto; FD: frecuencia dominante; LHC: tamaño corporal longitud hocico-cloaca.

Individuo	No. de cantos	CM	dc (s) X(rango)	CV	FD (Hz) X(rango)	CV	Peso (gr)	LHC (mm)
1	10	0.53	0.038	49.24	4760.79	4.36	0.14	12.9
2	11	0.52	(0.0045 – 0.0718)	27.77	(4478.91 – 5167.0)	8.62	1	11.58
3	8	0.52	0.042	18.29	4435.84	7.54	0.9	12.0
4	10	0.68	(0.0247 – 0.0628)	57.35	(3962.11 – 5512.5)	7.01	0.35	12.7
5	10	0.68	0.038	19.39	4048.24	6.09	0.3	16.4
6	26	0.52	(0.0292 – 0.051)	26.24	(3617.57 – 4478.9)	2.15	0.5	11.7
7	8	0.58	0.12	47.86	4203.28	2.22	0.7	11.0
8	5	0.52	(0.0583 – 0.2708)	31.06	(3789.84 – 4651.17)	10.61	0.5	12.0
9	3	0.98	0.058	37.71	4168.82	7.44	0.45	11.5
10	3	0.94	(0.0451 – 0.0752)	0	(3789.84 – 4478.91)	4.17	0.5	11.0
11	4	0.28	0.039	25.28	3847.26	6.71	0.3	14.3
12	7	0.48	(0.0291 – 0.0822)	18.39	(3789.84 – 3962.11)	4.08	0.45	12.0
13	6	0.45	0.043	49.85	4134.38	3.9	0.4	11.5
14	12	1.9	(0.0222 – 0.0654)	64.11	(3962.11 – 4306.64)	3.82	0.25	17.0
Promedio poblacional	**8.8**	**0.68**	**0.028**	**33.75**	**4788.98**	**5.62**	**0.48**	**12.7**

En la caracterización del canto de *Craugastor yucatanensis*, Carbajal-Márquez et al. (2019) establecieron que los machos fueron identificados por la conducta de canto, a su vez por las excresencias nupciales que presentan solo ellos no así las hembras. En otras especies del mismo género, las hembras suelen tener un rango de tamaño corporal mayor al de los machos (Schlaepfer & Figueroa-Sandi, 1998; Carbajal-Márquez et al., 2019). En la descripción original de la especie, Taylor (1936) describió sólo a una hembra con 18 mm de LHC. En el caso de nuestros registros de *C. pygmaeus*, se incluyen a 14 individuos cuyo tamaño corporal ronda entre 11 y 17 mm, de entre ellos, es destacable que once individuos tienen un tamaño corporal menor a los 13 mm y tres de ellos tienen un tamaño corporal entre 14.3 y 17 mm, por lo que es posible que estos últimos sean hembras. Un estudio detallado sobre la diferenciación entre hembras y machos de *C. pygmaeus* debería incluir las diferencias morfológicas y corroborar si las hembras de esta especie efectivamente vocalizan como en otras especies del género (Schlaepfer & Figueroa-Sandi, 1998; Carbajal-Márquez et al., 2019).

En los últimos años, el conocimiento sobre la distribución de *C. pygmaeus* se ha incrementado después de ampliar sus registros en el occidente de México, que ahora incluyen el sur de Sinaloa, Jalisco y diversas localidades en Guerrero, México, lo que complementó a la distribución histórica conocida en el sureste de México y Guatemala (Ahumada-Carrillo et al., 2013; García-Padilla & Mata-Silva, 2014; Loc-Barragán & Carbajal-Márquez, 2016; Frost, 2020). *Crugastor pygmaeus* está presente en una gran diversidad de hábitats, incluyendo bosques húmedos tropicales, bosques deciduos, bosques encinos, pino-encino e incluso bosque mesófilo (Ahumada-Carrillo et al., 2013; García-Padilla & Mata-Silva, 2014; IUCN SSC Amphibian Specialist Group, 2020). La alopatría en su distribución geográfica, así como el rango altitudinal y de ecosistema en que ocurre esta especie, brinda la oportunidad de realizar estudios más profundos sobre la variación geográfica de sus características bioacústicas, morfológicas y genéticas para poner a prueba distintas hipótesis ecológicas acerca del anuro más pequeño presente en México

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HERPETOFAUNISTIC DIVERSITY IN THE ECOLOGICAL PARK "LA JOYA–LA BARRETA", QUERÉTARO, MÉXICO: A COMPARISON BETWEEN TWO SAMPLING METHODS AND THREE VEGETATION TYPES

DIVERSIDAD HERPETOFAUNISTA EN EL PARQUE ECOLÓGICO "LA JOYA – LA BARRETA", QUERÉTARO, MÉXICO: COMPARACIÓN ENTRE DOS MÉTODOS DE MUESTREO Y TRES TIPOS DE VEGETACIÓN

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Resumen.— Por su diversidad topográfica y climática, el estado de Querétaro posee altos niveles de riqueza, abundancia y endemismo de anfibios y reptiles. Esta información debe actualizarse constantemente a medida que se exploran más las regiones con poca o ninguna información, utilizando métodos de muestreo que permiten un registro eficiente de la diversidad biológica. El objetivo de este estudio fue comparar la diversidad herpetofaunística entre tres tipos de vegetación (bosque de robles, pastizales y vegetación secundaria asociada) utilizando dos métodos de muestreo (trampas de caída y transectos). Registramos trece especies: cinco anfibios y ocho reptiles. Encontramos diferencias en la dominancia de especies con anfibios que muestran valores más altos de abundancia relativa en bosques de encino y pastizales para ambos métodos de muestreo. Los transectos mostraron un mayor número efectivo de especies para q^0, q^1 y q^2, para ambos, anfibios y reptiles. El encinar y la vegetación secundaria poseen porcentajes de similitud comparables y no mostraron diferencias significativas. Observamos diferencias significativas entre el pastizal y la vegetación secundaria. Encontramos altos niveles de distinción (> 70%) entre las técnicas de muestreo. El presente estudio resalta la importancia de las áreas naturales protegidas como refugio para grupos amenazados como anfibios y reptiles, y destaca la importancia de utilizar métodos de muestreo complementarios.

Palabras clave.— Anfibios; áreas perturbadas; conservación; Áreas Naturales Protegidas; reptiles

Abstract.— Due to its topographic and climatic diversity, the state of Querétaro presents high levels of amphibian and reptile richness, abundance, and endemism. However, this information must be updated constantly as regions with previously little to no information are further explored, using sampling methods that allow efficient recording of biological diversity. The objective of this study was to compare herpetofaunistic diversity among three different vegetation types (oak-forest, grassland, and secondary vegetation) using two sampling methods (pitfall traps and transects). We recorded thirteen species: five amphibians, and eight reptiles. We found differences in dominance between herpetofaunal groups, with amphibians showing higher values of relative abundance in oak forest and grassland for both sampling methods. Transects showed a higher effective number of species for q0, q1, and q2, for both, amphibians and reptiles. The oak forest and secondary vegetation possess comparable similarity percentages and did not show significant differences. We observed significant differences between the grassland and secondary vegetation. We

found high distinctness levels (> 70%) between sampling techniques. The present study shows the importance of protected natural areas as shelters for threatened groups such as amphibians and reptiles, and highlights the importance of using complementary sampling methods.

Keywords.– Amphibians; disturbed areas; conservation; Protected Areas; reptiles.

INTRODUCTION

Biological diversity is currently facing an unprecedented decline caused by global change that threatens richness and functioning of ecosystems (Dirzo et al., 2014). Loss of diversity is caused by alterations to primary ecological factors such as temperature and humidity that ultimately limit diversity patterns at different scales (Ochoa-Ochoa & Flores-Villela, 2009; McCain 2010; Ochoa-Ochoa et al., 2014), as well as anthropogenic factors such as pollution and habitat loss or degradation (Gibbons et al., 2000; Fischer & Lindermayer, 2007).

Amphibians and reptiles are among the most threatened groups of vertebrates and are especially susceptible to environmental disruptions, specifically to habitat modifications caused by humans that can have serious effects on the ecological, reproductive, and physiological attributes of these organisms (Berriozabal-Islas et al., 2017; Leyte-Manríquez et al., 2019). Therefore, studying them in areas with high levels of anthropogenic pressures may be useful to gauge the status of the ecosystems they inhabit (Andrews et al., 2008; Valencia-Aguilar et al., 2013).

Querétaro is the sixth smallest state in Mexico, with an area of 11,762 km2 (Gobierno del Estado de Querétaro, 2002). Regardless its small size, Querétaro harbors high levels of floral and faunal diversity (Dixon & Lemos, 2010; Jones & Serrano 2016; Zamudio, 1992). Despite the numerous studies of herpetofauna performed in Querétaro (e.g. Dixon & Lemos, 1972, 2010; Padilla, 1996; Padilla & Pineda, 1997; Cruz-Elizalde et al., 2016, 2019), basic information such as species inventories are still incomplete, especially in areas bordering urban developments that could potentially function as biodiversity reservoirs. This information is central to addressing research of current relevance, such as ecosystem degradation, habitat loss, and their effects on amphibian and reptile populations.

Due to the difficulty of performing herpetofaunistic surveys, numerous sampling techniques have been developed (e.g. time-constrained searches, quadrant searches, visual encounter surveys, pitfall and funnel traps, etc.), and these have allowed consistent improvements of species inventories (Heyer et al., 1994, McDiarmid et al., 2012). However, their use and analysis have focused on specific regions with high herpetofaunistic richness and abundance because sampling techniques respond to both, species intrinsic features (e.g. microhabitat use, activity hours, and type of foraging), and study area features (vegetation structure and composition). In this study, we analyzed the community structure of amphibians and reptiles in the ecological park "La Joya – La Barreta", comparing two sampling techniques (transects and pitfall traps) in three vegetation types (oak forest, grassland, and secondary vegetation).

MATERIALS AND METHODS

The ecological park "La Joya – La Barreta" (EPJB) is located in the northwest region of Querétaro municipality within the Protected Natural Area "Zona Occidental de Microcuencas" (Western Microbasin Zone; Fig. 1), and has an extension of 242.87 ha. It was designated as a site for Ecological Preservation under Special Protection since 1970. However, despite its designation, the park receives visitors throughout the year for ecotourism activities such as camping, hiking, and mountain biking, among others (Gobierno del Estado de Querétaro, 2012).

The EPJB covers 242.87 ha in the geographic coordinates 20.80898°N, 100.52866 ° W, and is located in the municipality of Querétaro, Santa Rosa Jauregui delegation (Gobierno del Estado de Querétaro, 2012). Over the last decades, this region was under strong anthropogenic pressures such as soil and wood extraction, as well as overgrazing. However, actions have been taken to maintain and preserve the area (UAQ, 2002). According to Köppen's classification, modified by García (2004), the climate of the region is BS1kw (w), and corresponds to general dry climates (B), specifically semidry (S1), and semidry temperate subtype (kw).

We analyzed three predominant vegetative associations described previously for the study area by Zamudio and Rzedowski (1992) and Hernández et al. (2000): grassland, oak forest, and secondary vegetation, in an elevational range of 2300 to 25000 masl. The oak forest habitat is restricted to the highest parts, and is dominated by a single species, *Quercus* aff. *castanea*, with other species scattered such as *Buddleja cordata* and *Condalia*

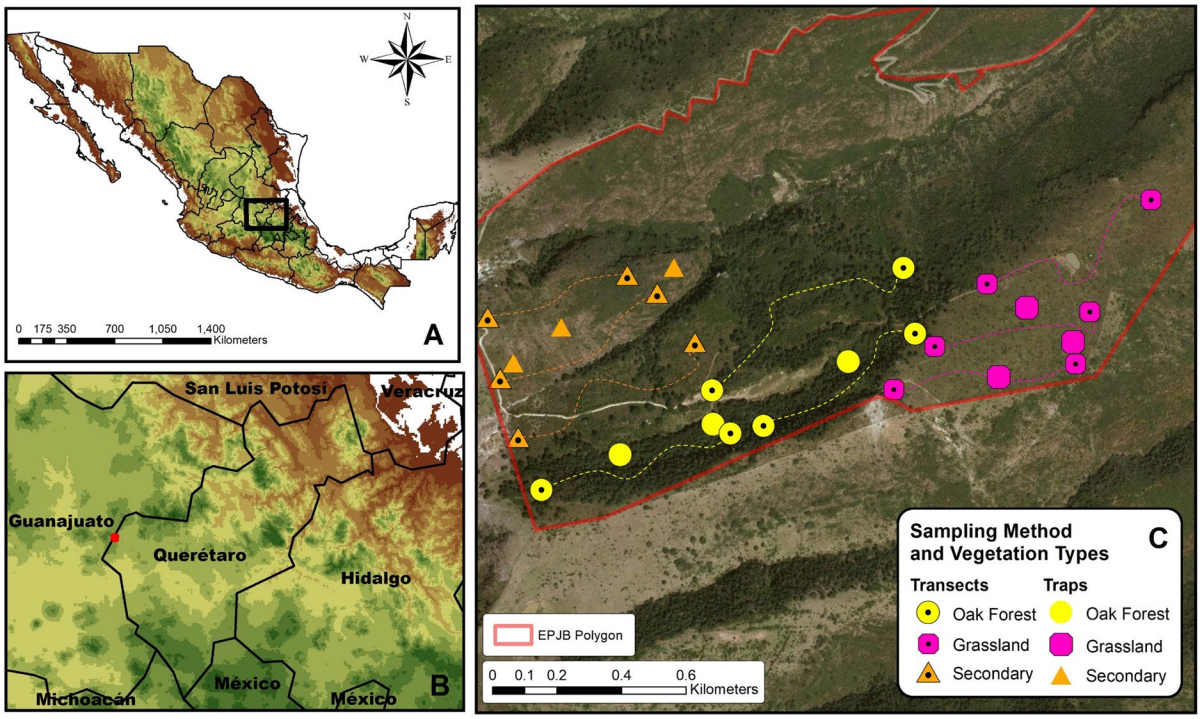

Figura 1. (A) Mapa de México mostrando la ubicación del estado de Querétaro. (B) Mapa de Querétaro y estados adyacentes mostrando en rojo la ubicación del PEJB al suroeste del estado. (C) Polígono del PEJB y disposición de los transectos y las trampas dentro del parque.

Figure 1. (A) Map of Mexico showing the location of Querétaro state. (B) Map of Queretaro and adjacent states showing in red the location of EPJB in the southwest part the state. (C) Polygon of EPJB, and placement of transects and traps within the park.

mexicana, and correspond to 59% of the total extension of the EPJB. The secondary vegetation is composed of species such as *Acacia schaffneri*, *A. farnesiana*, *Condalia mexicana*, *Prosopis laevigata*, *Ipomea murucoides*, *Myrtyllocactus geometrizans*, and some *Opuntia* spp and correspond to 24% of the total extension of the EPJB. Species registered in the grassland includes *Andropogon* sp., *Bouteloua* sp., *Eragrostis* sp., and *Aristida* sp and correspond to 17% of the total extension of the EPJB.

We performed two sampling methods: transects (500 x 30 m) and pitfall traps (a cross design with central bucket and four perimetral) associated with drift fences (metal sheets 0.5 x 5 m). We set up a total of nine transects and nine trapping stations, three for each vegetation type. We performed o total of six field trips composed of two sampling days each, with day (7:00-11:00 h) and night (19:00-23:00 h) surveys between June and October 2013. Two persons checked both, transects and traps, three times a day, accumulating a sampling effort of 192 person-hours for transects and 2754 trap-hours for pitfall traps. We performed intensive visual encounter surveys along transects in the most frequent microhabitats for herpetofauna (under logs and tree stumps, rocks, ponds, and pools; Jiménez-Velázquez & Sandoval 2010; Foster 2011). Traps remained open during the night and until noon of the next day, paying special attention to provide shelter from weather and potential predators in each trap. During the inactive period (noon to night), the traps were sealed to avoid accidental captures. Specimens were photographed and identified to species level using taxonomic keys for amphibians and reptiles of the State of Querétaro (Dixon & Lemos-Espinal, 2010). Species names were updated according to Amphibians of the World Data Base (Frost, 2020) and the Reptile Database (Uetz et al., 2020). Captured animals were released after observations were made. This study was conducted under the collection permit SGPA/DGVS/09960/12 issued by Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT).

To assess the overall inventory completeness for each sampling method, we used the non-parametric estimator Chao2 (Chao, 1987) using the software EstimateS 9.1 (Colwell, 2013). Non-parametric estimators are reliable methods for evaluating sampling completeness since they are the most rigorous and present less bias for small sample sizes than other estimators (Walther & Moore, 2005).

To compare species richness, we calculated the effective numbers of species or Hill numbers (Jost, 2006), at a sampling coverage level of 80% and using 95% confidence intervals obtained through resampling with 1000 randomizations in the iNext software (Chao & Jost, 2012; Hsieh et al., 2015). These numbers are useful because they are a simple measure that allows direct comparison of the obtained results (Jost, 2006; Moreno et al., 2011). For this analysis, we considered three diversity orders that estimate the effective numbers of species: 1) according to the net species richness (q^0), 2) according to the number of common species (q^1), and 3) according to abundant species (q^2; Jost, 2006).

To compare community composition, we created range-abundance curves (Magurran, 1998), and dendrograms employing the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) algorithm using the Jaccard similarity index, which considers species incidence (Rohlf & Fisher, 1968; Birks, 1987, Real & Vargas, 1996). Additionally, to establish whether there are differences between the species registered with both sampling methods and between vegetation types, we performed a non–parametric analysis of similarities (ANOSIM; Clarke, 1993) using the software PAST (Hammer et al., 2001).

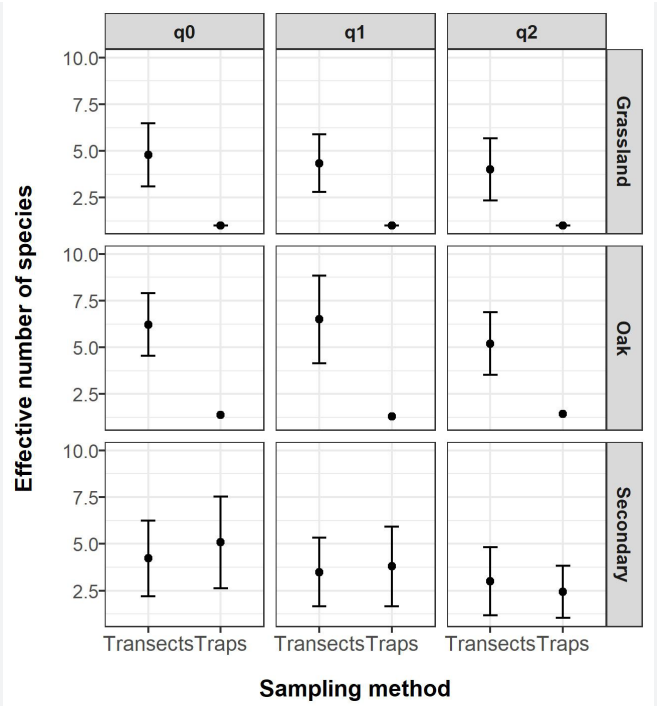

Figura 2. Número efectivo de especies estimado de acuerdo con diferentes órdenes de diversidad, método de muestreo y tipo de vegetación. Se muestran intervalos de confianza del 95%.

Figure 2. Estimated effective number of species according to diversity orders, sampling method, and vegetation type. 95% CI are shown.

To calculate complementarity between sampling methods we used the formula proposed by Colwell and Coddington (1994), which weighs the presence and absence of every species in each site in the following manner:

$$C= [(S_j + S_k) - 2V_{jk} / (S_j + S_k) - V_{jk}] * 100$$

where Sj and Sk are the numbers of species in sites j and k, respectively, and Vjk is the number of species in common between both sites. To visualize the differences between the methods and vegetation type, we used range-abundance curves that show in a simple way the species richness, abundance, and relative equitability (Magurran 2004; Stoner 2005). Dominant species were determined by their relative abundance regarding to the total number of organisms observed in this study.

RESULTS

We recorded thirteen species for the EPJB: five amphibians and eight reptiles. Pitfall traps were slightly more effective than transects for amphibian detection (four vs three species,), transects were more effective for reptile detection (seven vs three species), while pooling amphibians and reptiles, transects were more effective (six vs ten species). However, homogeneity test did not show significant differences assessing for abundance between traps (N=27) and transects (N=42; X^2 = 3.26; df=1; p = 0.07).

Amphibian and reptile diversity is represented by four families each. Four species (31%), two amphibians and two reptiles, are listed in some category of protection under Mexican Government (SEMARNAT, 2010). Eight species (61%), two amphibians, and five reptiles, are endemic to Mexico (Table 1). Transects registered 10 species while traps registered six species. Overall sampling completeness observed was about 79% for transects and 59% for traps.

For the three diversity orders (^0Q, ^1Q and ^2Q), at a sample coverage of 80%, we observed significantly lower values for traps than those reported for transects, in grassland and oak forest. We did not observe differences in secondary vegetation (Fig. 2). The oak forest vegetation type showed the highest richness value (nine species), followed by secondary vegetation (six species), and finally grassland (five species). Richness in oak forest is fully represented in transects, while secondary vegetation richness was best represented using pitfall traps. Higher abundance values were registered in the grassland, followed by oak forest and secondary vegetation. Pitfall traps registered more species in the grassland and secondary vegetation.

Tabla 1. Especies de anfibios y reptiles del Parque Ecológico Joya - La Barreta. Las especies endémicas de México están marcadas con un asterisco (*). Estado de conservación (entre paréntesis) según SEMARNAT (2010): Pr = sujeto a protección especial.
Table 1. Amphibian and reptile species in the Ecologic Park Joya–La Barreta. Endemic species to Mexico are marked with an asterisk (*). Conservation status (in parentheses) according to SEMARNAT (2010): Pr = subject to special protection.

Amphibia
Order Caudata
Ambystomatidae
*Ambystoma velasci** (Pr)
Order Anura
Eleutherodactylidae
*Eleutherodactylus verrucipes** (Pr)
Hylidae
Dryophytes arenicolor
Dryophytes eximius
Scaphiopodidae
Spea multiplicata
Reptilia
Order Squamata
Anguidae
Gerrhonotus ophiurus
Phrynosomatidae
*Sceloporus dugesii**
*Sceloporus torquatus**
*Sceloporus spinosus**
Colubridae
*Conopsis nasus**
Tantilla rubra
Viperidae
*Crotalus aquilus** (Pr)
Crotalus molossus (Pr)

Dendrograms were very similar across both methods (Fig. 3). The oak forest and secondary vegetation showed medium values of similarity (0.4-0.5). The grassland showed a low similarity (0.2) with respect to oak forest and secondary vegetation. However, significant differences were only found between grassland and secondary vegetation (p = 0.02) in each method. Although differences in species presence were observed between both sampling methods, these differences were not significant (R = 0.51; p = 0.09) according to the ANOSIM.

The pitfall traps registered 42 captures representing six species. *Spea multiplicata* was the most abundant species, followed by *Sceloporus spinosus*. Two species, *Ambystoma velasci* and *Eleutherodactylus verrucipes*, were detected exclusively with this methodology and represent 16% of the total species encountered in this study.

The transect surveys resulted in 26 specimens representing 10 species recorded. *Dryophytes eximius, S. multiplicata* and *Sceloporus torquatus* were the most abundant species. Of all the species registered by this methodology, *Dryophytes arenicolor, Crotalus aquilus, C. molossus, Gerrhonotus ophiurus, Sceloporus dugesii*, and *Tantilla rubra* appeared only once, and combined represent 46% of the total species registered. The dominant species using traps was *Spea multiplicata* in the oak forest and grassland, and *Ambystoma velasci* in secondary vegetation.

The dominant species using transects were *Dryophytes arenicolor* and *Crotalus aquilus* in the oak forest, *Dryophytes eximius* and *S. multiplicata* in the grasslands, and *Sceloporus torquatus* in secondary vegetation (Fig. 4). Species registered with both methods obtained a 77% complementarity percentage, indicating important differences in the species composition registered with each sampling method.

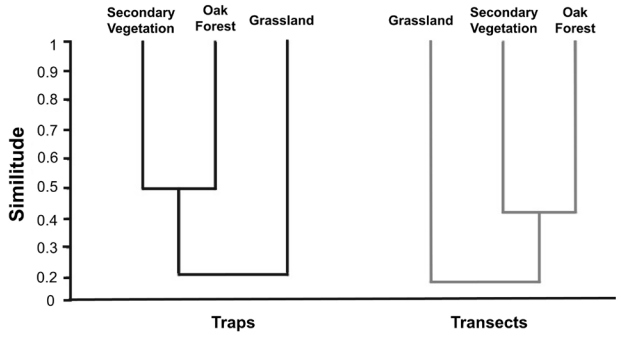

Figura 3. Dendrogramas recuperados utilizando el método UPGMA. Se muestra relaciones de similitud en riqueza de especies utilizando dos métodos de muestreo (estaciones de trampeo y transectos).
Figure 3. Dendrograms recovered using the UPGMA method showing similarity relationships of species richness among vegetation communities using two sampling methods (trapping stations and transects).

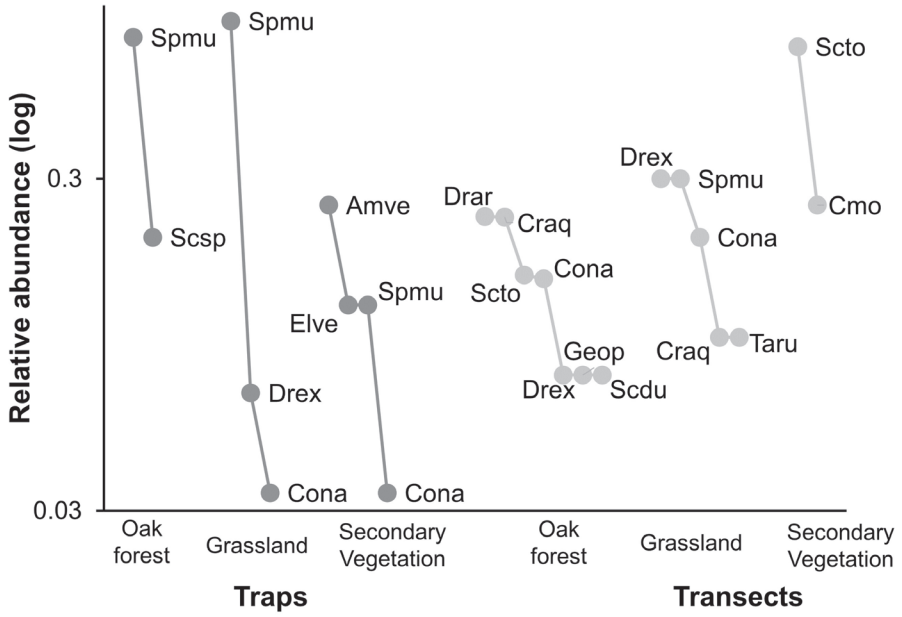

Figura 4. Curvas de rango abundancia basadas en el logaritmo de la abundancia relativa de las especies para cada tipo de vegetación y método de muestreo. Las abreviaciones de las especies representan las dos primeras letras del género y la especies para cada taxón.

Figure 4. Rank abundance curves showing species composition based on the logarithm of relative abundance for every species grouped for vegetation type and sampling method. Species abbreviations are coded following first two letters of genus and species for each taxon.

DISCUSSION

Species encountered in this study represent 9.4% of the species registered for the state of Querétaro (Cruz-Elizalde et al., 2016). The highest richness values were found in oak forest habitats, despite its restriction to the highlands within the study area, and the considerable degree of anthropogenic alterations in the surrounding areas. Several studies have shown that Protected Natural Areas (PNA's) harbor important levels of species richness on a global scale, and therefore constitute the main tool for conservation, in addition to offering diverse environmental and sociocultural services (Böhm et al., 2013; Stolton & Dudley, 2010; Wilson et al., 2013a, 2013b). Protected Areas are particularly important in environments closely associated with human activities; for example, they have been shown to provide vital habitat to protect native amphibian and reptile populations persisting in urban areas (Domínguez-Vega et al., 2017; Mitchell et al., 2008). Going forward, it will be necessary to integrate conservation strategies within these protected areas (e.g. besides richness and abundance, take into account aspects such as ecosystem functionality and services; Stolton & Dudley, 2010). To reach these goals, we must acknowledge that PNA's cannot function as isolated elements in the landscape. To maximize their importance as biodiversity shelters, it is imperative to create plans for their integration into the anthropized landscapes that surround them.

We observed differences in effective numbers of species estimated between sampling methods at the same sample coverage. These differences are the product of high net richness (q^0), high proportion of rare species (q^1), and differences in relative abundance (q^2). Active searching via transects proved to be more effective than pitfall traps in registering species richness, suggesting lower probabilities to record some species using traps due to their ability to escape or avoid trapping stations. Our results are congruent with Carpio et al. (2015), who report that transects are more effective in determining reptile diversity in olive groves in Spain; but contrast those reported by Hutchens & dePerno (2009), who reported more species registered by pitfall traps in wetlands of Washington County, North Carolina. Despite these differences, other authors report transects and pitfall traps to be equally effective in detecting reptile species (Sung et al., 2011).

Sampling techniques are designed to collect information from wild populations (e.g. richness and abundance) based

on intrinsic characteristics of the species and habitat types they occupy (Heyer et al., 1994; McDiarmid et al., 2012). Therefore, no single technique can provide all the information concerning a study site's diversity. Both sampling techniques used in this study gave complementary information regarding herpetofaunistic diversity in EPJB. This is highlighted by the high complementarity of sampling methods, and the fact that total species richness could not have been registered with just one of the techniques employed. Our results strongly highlight the necessity to carefully consider different sampling methods, and we suggest that future studies aimed at the management and conservation of amphibians and reptiles utilize different techniques in line with the goals of investigation.

EPJB species richness deferred significantly among vegetation types. Despite numerous authors reporting that oak forests contain some of the highest levels of diversity and endemism in Mexico (Ochoa-Ochoa & Flores-Villela, 2006; Wilson 2013a, 2013b; Flores-Villela & García-Vázquez, 2014), we did not find high richness values in this vegetation type, although being the most extensive vegetation type in the study area, and unlike results from similar studies (Cruz-Elizalde & Ramírez-Bautista, 2012). However, most of these studies surveyed pine-oak forest and not oak exclusively. Therefore, it is likely that differences in richness and abundance values are determined by this factor, in addition to the isolation and the extension of the oak forest in the EPJB.

Other authors have suggested that high diversity values in temperate montane ecosystems can be explained by disturbance degree (makes available more microhabitat types) and tolerances of certain groups, like some species of *Sceloporus* lizards, to abiotic variations (Mitchell et al. 2008; Cruz-Elizalde & Ramírez-Bautista 2012). Even though we did not assess the relationship between disturbance degree and richness in the EPJB, we did not observe high diversity values associated with recurrent anthropic impact areas such as camping sites or mountain bike trails, which may be related to the fact that these types of disturbance do not necessarily produce a greater number of suitable microhabitats for amphibians or reptiles. More research is needed related to the anthropic impact on amphibian and reptile populations in peri-urban and rural areas of Mexico.

Both methods showed similar results in terms of comparing species composition between vegetation, with high levels of complementarity, with the oak forest grouping with secondary vegetation, both distinct from grassland. These results are concordant with those reported by Nieto-Montes de Oca and Pérez-Ramos (1999), where species composition reported for the grassland differed drastically from that of other vegetation types. However, many studies consider grasslands to be an induced vegetation type, which is not the case in EPJB and share some elements with oak forests.

Community structure observed in this study is similar to the results reported by Cruz-Elizalde and Ramírez-Bautista (2012), and Vite-Silva et al. (2010) for oak forest in the state of Hidalgo, showing dominant species with temperate affinities that include genera such as *Dryophytes* for amphibians, and *Sceloporus* for reptiles. We did not find previous records of community structure for grassland and secondary vegetation in adjacent areas, but dominant species observed for these vegetation types correspond to those with arid semi-arid affinities, such as *Spea multiplicata* (the most abundant species in this study). This species is associated with semiarid ecosystems and exhibits biological traits such as estivation, limited annual activity time, and local migrations that likely contribute to making it a dominant species in EPJB (Dixon & Lemos, 2010). Overall, most species abundances were low, which may be a consequence of environmental degradation within EPJB and adjacent areas.

Herpetofaunistic distribution in EPJB is heterogeneous in terms of abundance, with the grassland habitats showing remarkably high values in comparison to the other vegetation types. However, this abundance is mainly explained by two species (*S. multiplicata* and *D. eximus*). Both species are commonly found in abundant populations that are spatially restricted to a specific habitat, such as water reservoirs (Dixon & Lemos-Espinal, 2010; Lemos-Espinal & Smith, 2016), which, in the EPJB, are restricted to grassland habitats.

Despite the low richness values in the EPJB, it should be considered an important regional spot for herpetological conservation due to the number of species listed under protection or endemic to Mexico. However, a greater number of studies are needed in surrounding areas to allow comparison of the levels of herpetological diversity in areas with similar characteristics. Sampling techniques employed provided complementary information about local herpetofauna.

Future studies aimed at the management and conservation of these vertebrates should incorporate a sampling scheme that includes multiple techniques, due to the environmental heterogeneity of the study site and the low similarity of species among vegetation types. Studies like this provide insights that may enhance biological conservation in anthropized environments, especially considering the species decline to degradation and habitat loss.

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ATTEMPTED PREDATION OF *PHYSALAEMUS ERIKAE* (ANURA, LEPTODACTYLIDAE) BY *XENOPHOLIS SCALARIS* (WUCHERER, 1861; COLUBRIDAE) IN SOUTHERN BAHIA, BRAZIL

INTENTO DE DEPREDACIÓN DE *PHYSALAEMUS ERIKAE* (ANURA, LEPTODACTYLIDAE) POR *XENOPHOLIS SCALARIS* (WUCHERER, 1861; COLUBRIDAE) EN EL SUR DE BAHIA, BRASIL

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Resumen.— Las interacciones entre depredadores y presas son componentes importantes para la estructuración de las comunidades terrestres. Los anuros se consideran el principal alimento de las serpientes. *Xenopholis scalaris* tiene una amplia distribución geográfica, ocupando la selva amazónica y la selva atlántica, viviendo en bosques primarios y secundarios en ambientes húmedos. Los anuros son uno de los principales alimentos que componen su dieta. Otros estudios han reportado intentos infructuosos de depredación de esta especie en ranas de la familia Leptodactylidae. La rana *Physalaemus erikae* es una especie endémica de la región sur del estado de Bahía, Brasil oriental, ocupando hábitats en el borde del bosque atlántico, claros y plantaciones de cacao (cabrucas). El caso del intento fallido de depredación de la especie involucrada en el evento aquí reportado puede deberse al tamaño del cuerpo de la presa y a la capacidad de ésta de presentar una alta resistencia durante la captura del depredador.

Palabras clave .— Anfibios, serpientes, depredación, selva atlántica.

Abstract.— Interactions between predator and prey are important components for the structuring of terrestrial communities. Anurans are considered the main food item for snakes. *Xenopholis scalaris* has a wide geographic distribution, occupying the Amazon Forest and Atlantic Forest, inhabiting primary and secondary forests in humid environments. Anurans are one of the main food items that make up its diet. Other studies have reported unsuccessful predation attempts of this species on frogs of the family Leptodactylidae. The frog *Physalaemus erikae* is an endemic species from the southern region of Bahia state, eastern Brazil, occupying habitats on the edge of the Atlantic Forest, clearings, and cocoa plantations (Cabrucas). The case of the unsuccessful attempt at predation on the species involved in the event described here may be due to the size of the prey and the prey's ability to strongly resist the predator's capture.

Keywords.— Amphibians, snakes, predation, atlantic rainforest.

Snakes and anurans are important in the trophic levels they occupy and are important components of terrestrials communities (Costa & Trevelin, 2020). Snakes are carnivorous animals that feed on a variety of prey, however, studies suggest that frogs are among the main food items of Atlantic Forest snakes (Ringler et al., 2010; Solé et al., 2010; Lenger et al., 2014;

Figura 1. Un individuo de *Xenopholis scalaris* que intenta cazar a un individuo de *Physalaemus erikae* en un bosque en el municipio de Ilhéus, estado de Bahía, Brasil.

Figure 1. An individual of *Xenopholis scalaris* trying to prey on an individual of *Physalaemus erikae* in a forest in the municipality of Ilhéus, state of Bahia, Brazil.

Paulo et al., 2018; Teles et al., 2018; Pasukonis & Loretto 2020; Costa & Trevelin, 2020). On the other hand, although frogs seem to be an easy prey to catch, they have a variety of defensive mechanisms (for example, swelling of the body, tanathosis, spine agression) and also chemical defense (secretion emission) (Wells, 2007; Paulo et al., 2018).

Consisting of three species, *Xenopholis scalaris* (Wucherer, 1861), *X. undulatus* (Jensen, 1900) and *X. werdingorum* (Jansen et al., 2009), the genus Xenopholis includes small snakes with cryptic habits (Powell et al., 2016). *Xenopholis scalaris* (Wucherer, 1861) has a wide distribution in the Amazon Forest, in Bolivia, Peru, Ecuador, Colombia and Brazil, in the states of Amazonas, Pará, Mato Grosso, Rondônia, with occurrences in the Atlantic Forest in the southern region of the state of Bahia, and in the states of Pernambuco, Alagoas, Rio de Janeiro and São Paulo. It inhabits primary and secondary forests in humid environments (Ringler et al., 2010, Vieira et al., 2012, Powell et al., 2016, França et al., 2019, Gomes et al., 2020) and shows an opisthoglyph dentition. This species is found mainly in the leaf litter on the ground (Ringler et al., 2010; Mendes et al., 2013) where it forages mainly during the night (Ringler et al., 2010). Anurans are the main food item of *X. scalaris* and predation events have been reported for anurans of the family Leptodactylidae (Vieira et al., 2012; Costa & Trevelin, 2020). Additionally, our observation is the first record of an attempted predation of a snake on the frog *Physalaemus erikae*.

Physalaemus erikae (Cruz & Pimenta, 2004) is an endemic species in the Southern region of Bahia, occupying habitats such as the edges of fragments of Atlantic Forest, clearings and cocoa plantations (cabrucas; Dias & Solé, 2012). This species has terrestrial habits with peak activity at night and is characterized by a moderate size and a robust body (Cruz & Pimenta, 2004; Dias & Solé, 2012).

On July 20, 2020, at 6:53 pm, at Fazenda Provisão located at Km 27 of the Ilhéus-Uruçuca Highway, in the municipality of Ilhéus, state of Bahia, Brazil, an individual of *X. scalaris* was registered in an area of cabruca (agroforest of cocoa) in an attempt to prey upon a *P. erikae* individual. The snake was already with the amphibian captured by the lateral region of the body. The amphibian was immobile and with its venter turned upwards (Fig. 1). However, after a few minutes (approximately 5 min), the amphibian managed to get loose, possibly influenced by our presence, which caused the snake to give up its capture.

Neither the amphibian nor the snake was collected, but the photographic record is evident and can contribute to a better understanding of *X. scalaris* capture strategies, as well as *P. erikae* defense strategies, as well as the food items that make up the diet of *X. scalaris*.

Teles et al. (2018) and Costa & Trevelin (2020) also reported unsuccessful predation attempts by *Xenopholis undulatus* on anuran species of the family Leptodactylidae. On the other hand, Ringler et al. (2010), reported a case of death of an individual of *X. scalaris* that preyed upon an individual of the venomous frog, *Allobates femoralis* (Dendrobatidae), that had a radio transmitter attached to its inguinal region.

Unsuccessful predation events between snakes and anurans can be related to the relative sizes of predator and prey, secretions on the skin of the frogs, and physical resistance by the prey (Costa & Trevelin, 2020). The unsuccessful predation reported herein of *X. scalaris* on *P. erikae* may be due to a combination of a large prey size in relation to the snake size and the ability of the frog to resist the predation attempt, resulting in it being difficult to ingest. In addition to being a rare field observation, this observation is an evidence of a failed predation attempt.

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DEPREDACIÓN DE LA LAGARTIJA *SCELOPORUS PYROCEPHALUS* (PHYNOSOMATIDAE) POR LA TARÁNTULA RODILLAS ROJAS *BRACHYPELMA SMITHI* (THERAPHOSIDAE) EN MICHOACÁN, MÉXICO

PREDATION OF THE LIZARD *SCELOPORUS PYROCEPHALUS* (PHYNOSOMATIDAE) BY THE RED-KNEED TARANTULA *BRACHYPELMA SMITHI* (THERAPHOSIDAE) IN MICHOACÁN, MÉXICO

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Abstract.— I report observing a red knee tarantula *Brachypelma smithi* by preying a *Sceloporus pyrocephalus* lizard. Although it is known that among the prey of *B. smithi* are some species of lizards, this is the first record of an act of predation of a lizard *S. pyrocephalus*.

Keywords.— Phrynosomatidae, Theraphosidae, diet, prey.

Resumen.— Reporto la observación de una tarántula rodillas rojas *Brachypelma smithi* depredando una lagartija *Sceloporus pyrocephalus*. Si bien se conoce que entre las presas de *B. smithi* se encuentran algunas especies de lagartijas, este es el primer registro de un acto de depredación de una lagartija *S. pyrocephalus*.

Palabras clave.— Phrynosomatidae, Theraphosidae, dieta, presa.

La lagartija espinosa de cabeza roja (*Sceloporus pyrocephalus*) es una lagartija mediana (longitud hocico cloaca 72 mm), con coloración general del dorso café con dos líneas longitudinales blancas tenues y manchas transversales oscuras en el cuerpo, con una mancha oscura de centro blanco sobre la cabeza, barras oscuras y clara en los labios y garganta, y un collar incompleto de color negro y blanco en la nuca. Ventralmente son de color claro con barras transversales azules en el cuerpo, sobre todo en los machos. Son diurnas, terrestres, insectívoras y ovíparas. Es una especie endémica de México que se distribuye a lo largo de la costa del Pacífico, desde Jalisco hasta Guerrero y la cuenca balsas. Habita en bosques medianos de hoja perenne, cultivos y pastizales. Se encuentra en el suelo, entre las rocas y la hojarasca (García & Ceballos, 1994).

Brachypelma smithi, la tarántula de rodillas rojas se distribuye a lo largo de la costa del pacífico mexicano, en ambos lados de la cuenca del río Balsas. Habita principalmente en el suelo, en madrigueras de tierra, en zonas rocosas con vegetación espinosa generalmente en matorrales, y en bosque espinoso seco o bosque tropical caducifolio. Es una araña grande, las hembras alcanzan en promedio una longitud de 52-59 mm, mientras que los machos se encuentran entre 44-49 mm (Locht et al., 1999).

El 20 de enero de 2020, a las 11:45 h, mientras realizábamos recorridos en campo buscando reptiles en el ejido de Playa Azul, en el municipio de Lázaro Cárdenas, Michoacán, México (18.069953° N, 102.347981° W, WGS 84, 62 m s.n.m.), observamos un individuo adulto de *B. smithi* sobre el suelo, sujetando a un adulto de *S. pyrocephalus* (Figs. 1 y 2), se observaron por un tiempo aproximado de tres minutos y se tomaron fotografías, posteriormente nos alejamos del lugar. Si bien se conoce que entre las presas de *B. smithi* se encuentran algunas especies de lagartijas, este es el primer registro de un acto de depredación de una lagartija *S. pyrocephalus*.

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Figure 1. *Tarántula Brachypelma smithi* capturando un *Sceloporus pyrocephalus.* Foto: Luis Eduardo Bucio Jiménez.

Figura 1. *Brachypelma smithi* capturing a *Sceloporus pyrocephalus.* Photo: Luis Eduardo Bucio Jiménez.

Figure 2. *Brachypelma smithi* eating a *Sceloporus pyrocephalus.* Photo: Luis Eduardo Bucio Jiménez.

Figura 2. Tarántula *Brachypelma smithi* comiendo un *Sceloporus pyrocephalus.* Foto: Luis Eduardo Bucio Jiménez.

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DEPREDACIÓN DE LA LAGARTIJA *ASPIDOSCELIS COMMUNIS* (TEIIDAE) POR LA SERPIENTE *OXYBELIS MICROPHTALMUS* (COLUBRIDAE) EN MICHOACÁN, MÉXICO

PREDATION OF THE LIZARD *ASPIDOSCELIS COMMUNIS* (TEIIDAE) BY THE SNAKE *OXYBELIS MICROPHTALMUS* (COLUBRIDAE) IN MICHOACAN, MÉXICO

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Abstract.— We reported observing an *Oxybelis microphtalmus* snake by preying on an *Aspidoscelis communis* lizard. Although there is a lot of information about the *O. microphtalmus* diet, this is the first predation record of *A. communis*. This information is important to learn more about the diet of the genus *Oxybelis*.

Keywords.— Colubridae, Teiidae, diet, prey.

Resumen.— Reportamos la observación de una serpiente bejuquillo *Oxybelis microphtalmus* depredando una lagartija *Aspidoscelis communis*. A pesar de que existe información abundante acerca de la dieta de *O. microphtalmus*, este es el primer registro de depredación de *A. communis*. Esta información es importante para conocer más sobre la dieta y hábitos del género *Oxybelis*.

Palabras clave.— Colubridae, Teiidae, dieta, presa.

Oxybelis microphtalmus es una serpiente de cuerpo extremadamente delgado y alargado, cabeza elongada y hocico en forma de flecha. Alcanzan longitudes de hasta 1,000 mm de hocico a cloaca. La cola al igual que el resto del cuerpo es delgada y abarca aproximadamente el 65% de la longitud del cuerpo. Presenta ojos grandes con pupila redonda. La coloración del dorso es café cenizo con pequeñas manchas negras esparcidas y el vientre es de color gris. La zona infralabial y supralabial es amarillenta.

Es de hábitos diurnos y arborícolas, habitante común de bosques tropicales húmedos y secos, así como ecosistemas modificados (Köhler, 2008). Las serpientes del género *Oxybelis* tienen una estrategia de caza al acecho, su dieta está compuesta principalmente por insectos, pequeños mamíferos, aves, ranas (*Oophaga*) (Sellmeijer & P. van den Burg, 2020), peces (*Rivulus*) (Hetherington, 2006) y principalmente lagartijas de los géneros *Ameivula, Lygodactylus, Basiliscus, Gymnophtalmus, Iguana, Brasiliscincus, Hemidactylus, Sceloporus, Anolis, Aspidoscelis, Gonatodes, Tropidurus y Urosaurus* (Mesquita et al., 2012; Ferreira Da Silva et al., 2015; López-De La Cruz, et al., 2016; Ramirez-Ramirez et al., 2020; Cid Mora & Vásquez-Cruz, 2020; Oliveira-Souza et al., 2021). Esta especie se distribuye desde el sur de Arizona en los Estados Unidos de América hasta el sur de México. Su intervalo de elevación va desde el nivel del mar hasta los 2500 m snm (Quintero-Díaz et al., 2017).

El 12 de febrero de 2020 a las 12:40 horas, a orillas del río Acalpican, en una zona de vegetación secundaria y potreros, en el municipio de Lázaro Cárdenas, Michoacán, México (18.033873° N, 102.359799° W, WGS 84, 32 m s.n.m.), observamos a un individuo adulto de *O. microphtalmus* en el suelo sosteniendo en el hocico, a un adulto muerto de *Aspidoscelis communis* (Fig. 1). Posteriormente observamos a la serpiente durante tres minutos más antes de que tragara totalmente a su presa y entrara en la vegetación.

Aunque hay evidencia de la amplia variedad de presas de *O. microphtalmus*, incluyendo lagartijas del género *Aspidoscelis*, no encontramos información relacionada a la depredación de lagartijas de la especie a la que este trabajo hace referencia (*A.*

Figure 1. *Oxybelis microphtalmus* eating an *Aspidoscelis communis*. Photo: Luis Eduardo Bucio Jiménez.
Figura 1. *Oxybelis microphtalmus* comiendo un *Aspidoscelis communis*. Foto: Luis Eduardo Bucio Jiménez.

communis), es por esto que consideramos que este es el primer registro de depredación de *O. microphtalmus* en *A. communis*.

A pesar de que *O. microphtalmus* es una serpiente arbórea, hay registros de comportamiento similar en *O. fulgidus* en los que descienden al suelo para capturar lagartijas terrestres como *Ameiva undulata* (Smith et al., 2018), esto podría deberse a la disponibilidad de presas, ya que como se mencionó anteriormente, *O. microphtalmus* es una serpiente de dieta generalista.

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NOTAS DE DISTRIBUCIÓN E HISTORIA NATURAL DE *CROTALUS TRISERIATUS* (VIPERIDAE) EN EL CENTRO-OESTE DEL ESTADO DE VERACRUZ Y EN EL ESTE DEL ESTADO DE PUEBLA

DISTRIBUTIONAL AND NATURAL HISTORY NOTES OF *CROTALUS TRISERIATUS* (VIPERIDAE) IN THE CENTRAL-WEST OF THE STATE OF VERACRUZ AND IN THE EAST OF THE STATE OF PUEBLA

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Abstract.— In this note we record the presence of *Crotalus triseriatus* in five municipalities in the Central-West portion of the state of Veracruz and a new locality of the state of Puebla. We also record a new vegetation type occupied by the species, and a new lower boundary in their altitudinal range.

Keywords.— Altas montañas, Pico de Orizaba, Sierra de Zongolica, Central Plateau Dusky Rattlesnake, cloud forest, distribution.

Resumen.— En esta nota se registra la presencia de *Crotalus triseriatus* en cinco municipios en el centro-oeste del estado de Veracruz y una localidad nueva en el estado de Puebla. Así mismo, se reporta un nuevo registro de tipo de vegetación ocupado por la especie y un nuevo límite inferior en su intervalo de distribución altitudinal.

Palabras clave.— Altas montañas, Pico de Orizaba, Sierra de Zongolica, bosque mesófilo de montaña, distribución, Víbora de Cascabel Transvolcánica.

Crotalus triseriatus (Wagler, 1830) es una serpiente de cascabel pequeña, se distingue por presentar una franja oscura que parte desde las escamas postoculares extendiéndose hasta las últimas escamas supralabiales, la sexta o séptima escama supralabial está en contacto con el borde inferior de la órbita, presenta parches dorsales redondeados color negro con un borde color blanco, en la cola presenta franjas blancas distribuidas en forma de anillos (Ramírez-Bautista et al., 2009; Heimes, 2016). *C. triseriatus* no está considerada bajo alguna categoría de riesgo en la Norma Oficial Mexicana NOM-59-SEMARNAT-2010 (SEMARNAT, 2010), aunque, de acuerdo a la UICN, está catalogada como en preocupación menor (Canseco-Márquez & Mendoza-Quijano, 2007). Es endémica de México, se distribuye en tierras altas de la provincia biogeográfica denominada Faja Volcánica Transmexicana en los estados de Michoacán, Estado de México, Ciudad de México, Morelos, Hidalgo, Tlaxcala, Puebla y Veracruz (Campbell & Lamar, 2004; Bryson et al., 2014; Heimes, 2016; SEMARNAT, 2018). Esta especie tiene afinidad por habitar en los bosques de oyamel, encontrándose también en bosques de pino, pino-encino, praderas de alta montaña y en zonas de actividad agrícola, en un intervalo de distribución altitudinal que va de 2200 a 4600 m s.n.m. (Campbell & Lamar, 2004; Canseco-Márquez & Mendoza-Quijano, 2007; Wilson & Johnson, 2010; Sunny et al., 2019). Particularmente, en el centro oeste del estado de Veracruz, existe inconsistencia en el límite este de la distribución de la especie (p. ej. Canseco-Márquez & Mendoza-Quijano, 2007; Paredes-García et al., 2011; Heimes, 2016; Almaraz-Vidal & Cerón, 2016). En este trabajo damos cuenta de nuevos registros para la especie en 13 localidades de la región de las Altas Montañas en el centro-oeste del estado de Veracruz y una en el estado de Puebla, México. Para cada nuevo registro se documentó tipo de vegetación, altitud, coordenadas y se tomaron fotografías, los individuos encontrados no fueron colectados, sin embargo, las fotografías obtenidas fueron

depositadas en la Colección Digital de Vertebrados de la Facultad de Estudios Superiores de Zaragoza, UNAM (MZFZ-IMG) y en la colección digital del Natural History Museum of Los Angeles (LACM PC). Adicionalmente, examinamos material conservado del PIMVS Herpetario Palancoatl (HPCT).

El 08 de mayo del 2011, ca. 18:00 h, se observó un individuo adulto (Fig. 1A; LACM PC 2628) en la localidad de Tequila, municipio de Tequila (18.729306° N, 97.070876° O, WGS 84; elev. 1925 m s.n.m.). El individuo se localizaba activo en un traspatio.

El 11 de agosto del 2016, ca. 09:00 h, se observó un individuo adulto (Fig. 1B; LACM PC 2629) en la localidad de Alpatlahuac cerca de la capilla, en el municipio de Alpatlahuac (19.119838° N, 97.093674° O), WGS 84; elev. 1905 m s.n.m.). El individuo se encontraba termorregulando en un área abierta cerca de un remanente de bosque de pino.

El 06 de noviembre de 2016, se observó un individuo adulto muerto bajo una roca (Fig. 1D; LAMC PC 2636) en la localidad de Atzizintla, Puebla (18.896838° N, 97.323994° O); elev. 4190 m s.n.m.). El individuo se localizó en relictos de bosque de *Pinus hartwegi* rodeados por pastizal alpino.

El 03 de febrero del 2017, ca. 11:00 h, se observó un individuo neonato muerto (LACM PC 2591) en la localidad de Necoxtla, municipio de Camerino Z. Mendoza (18.803973° N, 97.181077° O); WGS 84; elev. 2300 m s.n.m.). La vegetación dominante es bosque de pino con parches destinados a actividades agrícolas.

El 13 de octubre del 2018, ca. 14:00 h, se observó un individuo juvenil (Fig. 1C; LAMC PC 2637) en el municipio de Mariano Escobedo Mariano Escobedo (18.912286° N, 97.130780° O); elev. 2540 m s.n.m.). Dentro de una zona de vegetación dominada por coníferas de reforestación (*Pinus* y *Cupressus*), en los alrededores es posible observar bosque de pino-encino.

Figure 1. Specimens of *Crotalus triseriatus* del municipio de Coscomatepec, Veracruz.
Figura 1. Ejemplares de *Crotalus triseriatus* del municipio de Coscomatepec, Veracruz.

Durante un muestreo de herpetofauna con duración de un año de noviembre del 2018 a noviembre del 2019, se observaron siete individuos, tres en el municipio de Coscomatepec (19.073065° N, 97.047615° O) el 30 de marzo, 12 de Julio y el 07 de septiembre del 2019 (Fig. 1) y cuatro en el municipio de Calcahualco (19.122359° N, 97.085429° O), Veracruz el 09 de febrero, 15 de Junio, 10 y 30 de agosto del 2019 (Fig. 3; Tabla 1). Entre estas siete observaciones, se resalta una en la localidad de Atotonilco, Calcahualco (19.140° N, 97.203° O; WGS84; elev. 2280 m s.n.m. Fig 3C; MZFZ-IMG 266), un individuo neonato fue encontrado cerca del río Jamapa donde la vegetación original del sitio es un remanente de bosque mesófilo de montaña, tipo de vegetación no documentado previamente para *C. trisetiatus*. Todas estas observaciones, con excepción de Atzizintla, tienen lugar la región de Las Altas Montañas en el centro-occidente del estado de Veracruz.

Finalmente, examinamos una fotografía y la piel preservada de un individuo adulto en el PIMVS Herpetario Palancoatl (HPCT-08) verificado como *Crotalus triseriatus*, este individuo fue colectado el 21 de agosto del 2011 en la localidad de Mazituaya, municipio de Xoxocotla (18.647823° N, 97.151708° O), en la Sierra de Zongolica.

Estos registros aportan nuevos datos de distribución en el estado de Veracruz en 13 localidades pertenecientes a ocho municipios: Alpatlahuac, Calcahualco, Camerino Z. Mendoza, Coscomatepec, Mariano Escobedo, Tequila y Xoxocotla ubicados en la denominada región de las altas montañas, ubicada en el centro-oeste del estado de Veracruz. Además de un registro dentro del municipio de Atzitzintla en el estado de Puebla. Paredes-García et al. (2011) mediante el uso de modelos de nicho ecológico no mencionan la presencia de *C. triseriatus* en el Parque Nacional Pico de Orizaba, no obstante, existen registros

Figure 2. Specimens of *Crotalus triseriatus* of the municipality of Calcahualco, Veracruz.

Figura 2. Ejemplares de *Crotalus triseriatus* del municipio de Calcahualco, Veracruz.

históricos disponibles en la base de datos de VertNet y GBIF, para el municipio de La Perla, Mariano Escobedo y "cerca de Orizaba". Varios aspectos sobre la ecología e historia natural de *C. triseriatus* han sido recientemente estudiados (Bryson et al., 2014; Mociño-Deloya et al., 2014; Sunny et al., 2015; Pérez-Mendoza et al., 2018; Sunny et al., 2018; Savarino-Drago & Ruvalcaba-Ortega, 2019; Sunny et al., 2019; Soria-Díaz et al., 2019; Zaragoza-Bastida et al., 2020; Jaramillo-Alba et al., 2020), en su mayoría realizados en el centro de México. Particularmente, en algunos de éstos existe inexactitud en los límites de su distribución altitudinal, Armstrong & Murphy (1979) mencionan los 2743 a 3353 m s.n.m. como los de mayor incidencia para la especie y el registro a 4 572 m como el más alto de ocurrencia de *C. triseriatus* (en el Pico de Orizaba). Por su parte, Wilson y Johnson (2010) consideran los 2300 a 4600 m s.n.m. como el rango altitudinal. Los resultados de nuestro estudio, revelan nueva información en el límite altitudinal más bajo a los 1905 m s.n.m., 295 m por debajo a lo considerado previamente por Heimes (2016; 2200 m s.n.m.). Estos datos indican que en nuestra área de estudio *C. triseriatus* ocurre con mayor frecuencia en elevaciones que van desde los 1905 a 4190 m s.n.m.

Así mismo, Sunny et al. (2019) mencionan la baja probabilidad de encontrar *C. triseriatus* en bosque mesófilo de montaña, pero los modelos realizados en dicho estudio se restringieron a una porción en el centro de México, también, señala que esta especie prefiere habitar en bosques de oyamel, pero es posible encontrarlas en bosque de pino y zonas agrícolas (Sunny et al., 2015). Sin embargo, aquí reportamos de manera formal la presencia de la especie en el bosque mesófilo de montaña, incluyendo varios municipios en el interior del Área Natural Protegida (ANP): Parque Nacional Pico de Orizaba, lo que representa un refugio natural para *C. triseriatus*. Cabe señalar, que esta ANP no figuró para *C. triseriatus* en el trabajo de Paredes-García et al. (2011).

Desafortunadamente, la tasa de deforestación en el centro de Veracruz, así como en el resto del estado, es una de las más altas del país (Muñiz-Castro et al., 2015; Gómez-Díaz et al., 2018), siendo el bosque mesófilo de montaña uno de los más amenazados (Ochoa-Ochoa et al., 2017). Por tal motivo, recomendamos la mejora e implementación de planes de manejo forestal, fomentar la educación ambiental para mitigar el sacrificio de individuos de *Crotalus triseriatus* por temor irracional, estas iniciativas pueden contribuir con la preservación de las poblaciones de la especie y su hábitat.

La distribución de *Crotalus triseriatus* en la región de las altas montañas y particularmente en el estado de Veracruz es discontinua, puesto que prefiere habitar ecosistemas montañosos donde algunas poblaciones de esta especie se restringen en sitios con difícil acceso como laderas, grandes montañas, cañadas, barrancos y zonas rocosas. En los sitios donde se observó esta especie han sido altamente modificados, los sitios conservados son solo relictos de vegetación original, por lo que consideramos como principal amenaza la perdida

Figure 3. *Crotalus triseriatus* of the municipality of Tequila situated in the sierra of Zongolica (A), *C. triseriatus* of the municipality of Alpatlahuac (B), *C. triseriatus* of the municipality of Mariano Escobedo (C), and *C. triseriatus* of Atzitzintla estate of Puebla (D).

Figura 3. *Crotalus triseriatus* del municipio de Tequila ubicado en la sierra de Zongolica (A), *C. triseriatus* del municipio de Alpatlahuac (B), *C. triseriatus* del municipio de Mariano Escobedo (C), *C. triseriatus* del municipio de Atzitzintla estado de Puebla (D).

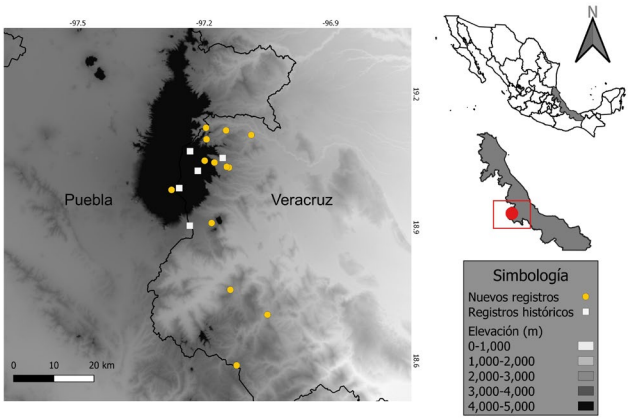

Figure 4. Map of historical records and new records of *Crotalus triseriatus* in the High Mountain Region.

Figura 4. Mapa de los registros históricos y nuevos registros de *Crotalus triseriatus* en la región de las Altas Montañas.

de hábitat, destinadas para áreas agrícolas, sitios de pastoreo y de cultivo de pino para el consumo humano, ocasionando que las poblaciones de *C. triseriatus* se vean sometidas a desplazarse a sitios perturbados, áreas agrícolas y cerca de poblaciones humanas, a lo que sumamos la muerte indiscriminada por la falta de conocimiento. A pesar de esto, los hallazgos en este estudio indican que *C. triseriatus* aún se encuentra en el Área Natural Protegida (ANP): Parque Nacional Pico de Orizaba después de sus últimas observaciones realizadas hace 55 años, además del primer registro de la presencia de *C. triseriatus* en la Sierra de Zongolica, pese a que la mayoría de las áreas circundantes han sido objeto de un estudio de anfibios y reptiles sin observaciones (p. ej. De La Torre-Loranca et al., 2020). Es por eso que alentamos a realizar investigaciones de rasgos ecológicos, poblacionales y evaluaciones para predecir el riesgo de extinción de la especie en la región y como lo indica Bryson et al. (2014) es necesario una revaluación del estatus de conservación de *C. triseriatus*, adicionalmente, Serna-Lagunes et al. (2020) reportó la presencia

Table 1. Records of Crotalus triseriatus in municipalities in the region of Altas Montañas in Veracruz and estate of Puebla.

Tabla 1. Registros de Crotalus triseriatus en municipios de la Región de las Altas Montañas in Veracruz y del estado de Puebla. .

Registro	Municipio	Localidad	Fecha	Elev. (m)	Latitud (N)	Longitud (O)	Hábitad	Foto - voucher
1	Calcahualco	Vaqueria	10/08/19	3,534	19.066	97.209	Bosque de coníferas	MZFZ-IMG 265
2	Calcahualco	Atotonilco	30/08/19	2,280	19.140	97.203	Bosque mesófilo de montaña	MZFZ-IMG 266
3	Calcahualco	Totozinapa	09/02/19	3,318	19.133	97.156	Bosque de pino-encino	MZFZ-IMG 267
4	Calcahualco	Tlacotiopa	15/06/19	2,740	19.114	97.203	Bosque de pino-encino	MZFZ-IMG 268
5	Coscomatepec	Aserradero	12/07/19	2,860	19.061	97.186	Bosque de coníferas	MZFZ-IMG 269
6	Coscomatepec	Cuiyachapa	07/09/19	2,550	19.051	97.157	Bosque de pino- encino	LACM PC 2627
7	Coscomatepec	Tetelcingo	30/03/19	2,404	19.049	97.152	Bosque de pino- encino	MZFZ-IMG 270
8	Camerino Z. Mendoza	Necoxtla	03/02/17	2,300	18.774	97.159	Bosque de pino	LACM PC 2592
9	Xoxocotla	Mazituaya	21/09/11	2,550	18.603	97.150	Bosque de pino- encino	HPCT-08
10	Tequila	Tequila	08/05/11	1,935	18.715	97.073	Remanentes de bosque de encino	LACM PC 2628
11	Alpatlahuac	Cabecera municipal	11/08/16	1,905	19.120	97.097	Bosque de pino	LACM PC 2629
12	Mariano Escobedo	San isidro el Berro	13/10/18	2,540	18.925	97.197	Remanentes de bosque de encino	LACM PC 26237
13	Atzitzintla	Puebla	06/11/16	4,190	19.003	97.290	Pastizal alpino	LACM PC 2636

de *Crotalus intermedius* en el Parque Nacional Pico de Orizaba. Sin embargo, basandonos en una revision detenida en su contenido fotografico, consideramos que posiblemente corresponden a *C. triseriatus* por lo que es necesario una revision de los ejemplares en trabajos futuros.

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NEW DATA OF SAUROPHAGY IN *SCELOPORUS VARIABILIS* (SQUAMATA: PHRYNOSOMATIDAE) AND CONFIRMATION OF CANNIBALISM

NUEVOS DATOS DE SAUROFAGIA EN *SCELOPORUS VARIABILIS* (SQUAMATA: PHRYNOSOMATIDAE) Y CONFIRMACIÓN DEL CANIBALISMO

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Resumen.— *Sceloporus variabilis* es una especie de amplia distribución y ocupa distintos tipos de hábitats. En este trabajo se reportan nuevos datos sobre el consumo de lagartijas, tanto de bosque tropical como de bosque mesófilo, y confirma la ocurrencia del canibalismo.

Palabras clave.— Dieta, presas, Scincidae, contenido estomacal.

Abstract.— *Sceloporus variabilis* is a species of wide distribution and occupies different types of habitat. This paper reports new data on the consumption of lizards, both in tropical and cloud forests, and confirms the occurrence of cannibalism.

Keywords.— Diet, prey, Scincidae, stomach content.

Sceloporus variabilis is a species with wide distribution from southern Texas, in United States of America, Mexico, and Middle America up to Costa Rica (Smith et al., 1993). The species occurs in different environments (tropical, temperate, and arid), vegetation types (e.g., tropical dry forest, cloud forest, pine forest) and elevations, from about sea level to 2,000 m a.s.l. and it has terrestrial and arboreal habits (Smith et al., 1993). Some of its predators are snakes, such as *Leptodrymus pulcherrimus* (Sunyer & Leonardi, 2015), and lizards, such as *Aspidoscelis deppii* (Martínez-Fonseca et al., 2016). The diet of *S. variabilis* is generally insectivorous (Fitch, 1973; Savage, 2002); however, it has been reported that it feeds on juvenile lizards of *A. deppii* (Köhler & Fried, 2012), in addition to reports of cannibalism (Mendoza-Quijano et al., 1991). To our knowledge *S. variabilis* has

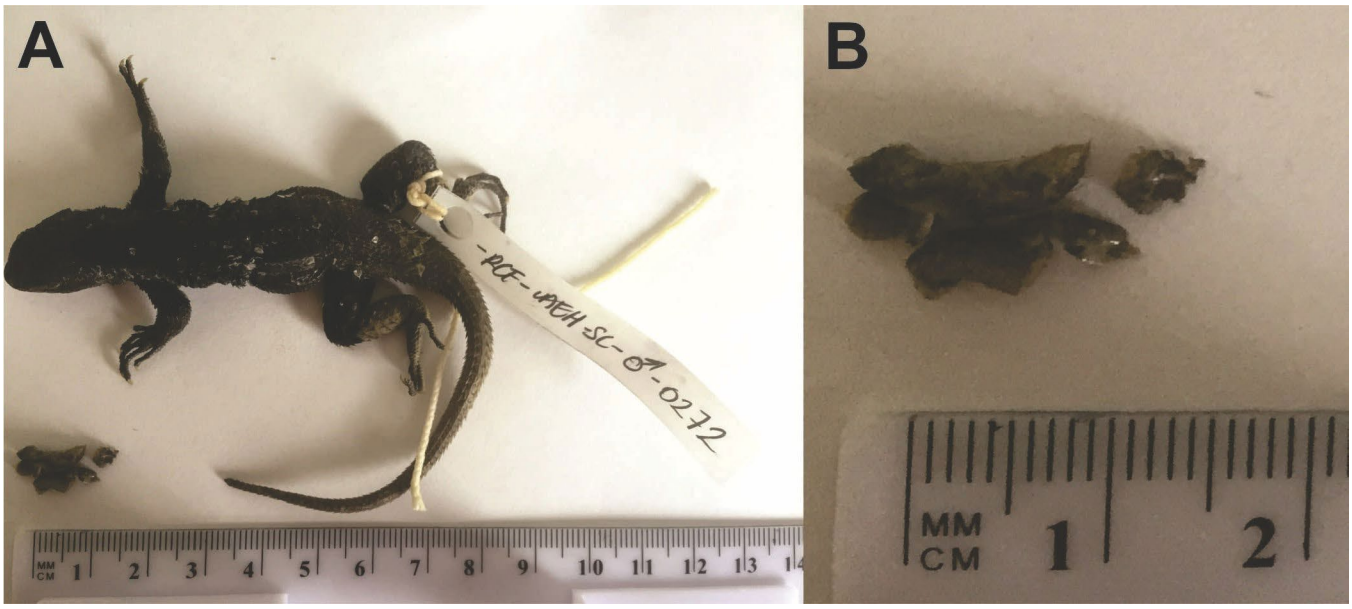

Figura 1. Vista dorsal del macho adulto de *Sceloporus variabilis* (depredador) (A) y restos de ***Scincella gemmingeri*** (presa) (B) que se encontraron en el contenido estomacal. Foto: Raciel Cruz-Elizalde.

Figure 1. Dorsal view of the adult male of *Sceloporus variabilis* (predator) (A) and the remains of a ***Scincella gemmingeri*** (prey) (B) found in its stomach contents. Photo: Raciel Cruz-Elizalde.

not been shown to feed on other species of lizards in vegetation types other than tropical. In this note we report two events of saurophagy by *S. variabilis.*

On 2 July 2014, an adult male (CIB–6103) of *S. variabilis* (SVL = 71.35 mm) was collected under rock in the locality of Santa Catarina, Municipality of Acaxochitlán, Hidalgo, Mexico (20.257531°N, 98.183400°W; WGS 84; elev. 1,845 m) in a cloud forest. The analysis of the stomach contents revealed insects (coleopterans, orthopterans, hymenopterans, and lepidopteran larvae) and the remains of a lizard, *Scincella gemmingeri* (Fig. 1). Using the formula of an ellipsoid (Selby, 1965), we calculate the volume of *S. gemmingeri's* remnants was 234.5 mm^3 (28 mm length; 4 mm width) and weighed 0.1197 g (using an analytical balance, ± 0.0001 g).

Another adult male of *S. variabilis* (CIB–6104; SVL = 59.44 mm) was collected on 30 August 2014 in the locality of Atlapexco, Municipality of Atlapexco, Hidalgo, Mexico (21.016176°N, 98.338403°W; WGS 84; elev. 140 m) in a tropical dry forest. The analysis of its stomach content revealed arthropods (coleopterans, hymenopterans, hemipterans, lepidopteran larvae, and spiders), plant matter (leaves) and a juvenile lizard, *S. variabilis* (Fig. 2). The prey had a volume of 1436.76 mm^3 (14 mm length; 14 mm width), and a weight of 0.1673 g.

For the determination of the remains of lizards, we used the identification keys for the herpetofauna of Hidalgo, Mexico (Ramírez-Bautista et al., 2014), and it was corroborated with the list of reptile species for the region (Cruz-Elizalde & Ramírez-Bautista, 2012). In the locality of Santa Catarina, the species *S. gemmingeri* and *Plestiodon lynxe* can be found, so the determination of the species could be carried out considering distinctively a coppery and light coloration in *S. gemmingeri* (by the dark and blue in *P. lynxe*) and arrangement of scales in the tail fragments found (with more overlapping scales in *S. gemmingeri*) (Ramírez-Bautista et al., 2014). In the case of the prey corresponding to *S. variabilis*, the organism was complete, and it was identified through the arrangement and pattern of dorsal scales, in addition to the postfemoral pocket, characteristic of the *Sceloporus variabilis* group (Ramírez-Bautista et al., 2014).

The consumption of *S. gemmingeri* by *S. variabilis* had not been recorded, and thus herein, we present the first record. Also, our data suggest that this species as integrant of the *Sceloporus* genus, is mainly insectivorous (Serrano-Cardozo et al., 2008), and this species maybe an opportunistic carnivorous, showing cannibalism, which is also known to occur in some *Sceloporus* species (Mendoza-Quijano et al., 1991; Robbins et al., 2013; Ramírez-Bautista et al., 2014). It is important to point out that despite being a species with a wide distribution, and that its

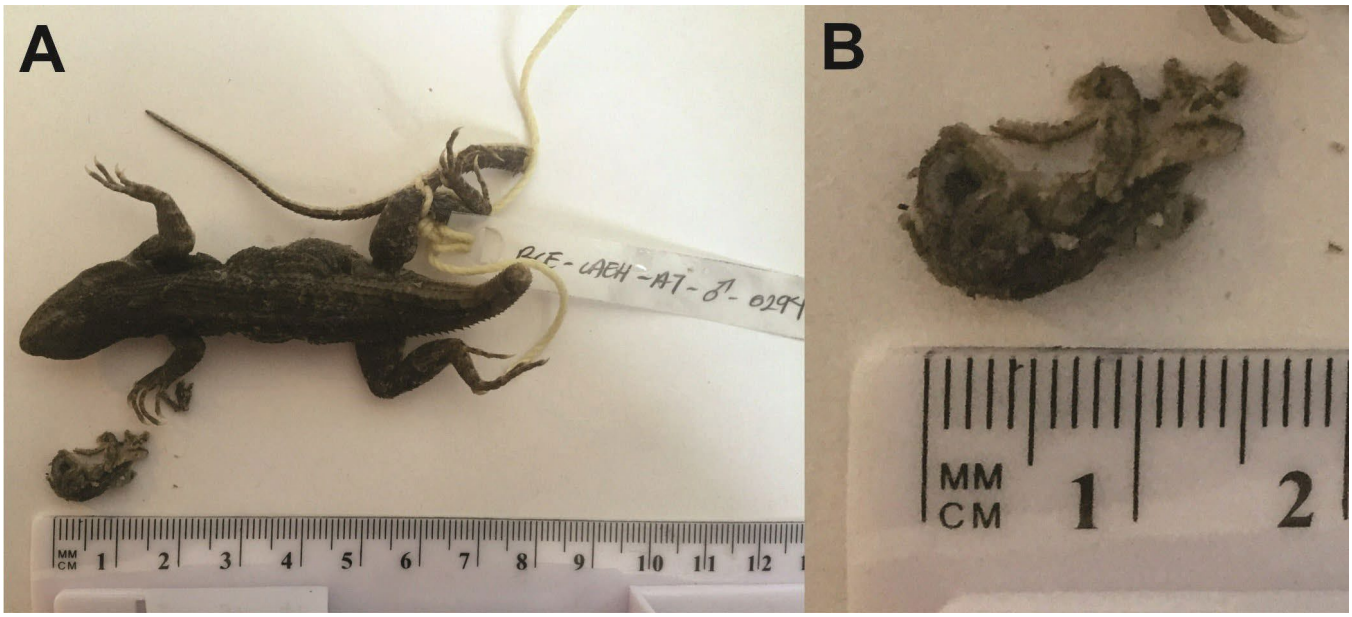

Figura 2. Vista dorsal del macho adulto de *Sceloporus variabilis* (depredador) (A) y juvenil (B) de la misma especie que se encontró en el contenido estomacal. Foto: Raciel Cruz-Elizalde.
Figure 2. Dorsal view of the adult male of *Sceloporus variabilis* (predator) (A) and juvenile (B) of the same species found in its stomach contents. Photo: Raciel Cruz-Elizalde.

reproductive cycle (Benabib, 1994; Cruz-Elizalde & Ramírez-Bautista, 2016) or morphology (Cruz-Elizalde et al., 2017) are known, there is not a complete study on the feeding habits of the species to date. In this sense, we can suggest that the consumption of plant matter may be accidental, as they capture their prey (Mendoza-Quijano et al., 1991; Ramírez-Bautista et al., 2014) as occur in *S. grammicus* (Leyte-Manrique & Ramírez-Bautista, 2010) or *Xenosaurus mendozai* (Zamora-Abrego & Ortega-León, 2016). Diverse events as i) an increase of juvenile density, ii) overlap of microhabitats and dietary niche between juveniles and adults, and iii) a decrease of food availability could result in cannibalistic behavior (Robbins et al., 2013), especially with high densities of individuals. *Sceloporus variabilis* shows high densities in its populations (Smith et al., 1993), principally in tropical environments (Ramírez-Bautista et al., 2006), where the phenomenon of cannibalism has been recorded. Our records of saurophagy in the locality of Santa Catarina, with cloud forest suggests the possibility of cannibalism in environments other than tropical dry forests if populations experience environmental factors that promote cannibalistic behavior (Robbins et al., 2013).

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FIRST RECORD OF A DEFENSIVE BEHAVIOR IN *MICROCAECILIA NICEFORI* (GYMNOPHIONA: SIPHONOPIDAE) PROVOKED BY THE SNAKEBITE OF *MICRURUS DUMERILII* (SERPENTES: ELAPIDAE)

PRIMER REGISTRO DE UN COMPORTAMIENTO DEFENSIVO EN *MICROCAECILIA NICEFORI* (GYMNOPHIONA: SIPHONOPIDAE) PROVOCADO POR LA MORDEDURA DE *MICRURUS DUMERILII* (SERPENTES: ELAPIDAE)

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Resumen.— Reportamos por primera vez un evento dinámico de depredación y comportamiento defensivo de *Microcaecilia nicefori* provocado por *Micrurus dumerilii* en Armero, Tolima, Colombia y presentamos un compendio de todos los registros de cecilias depredadas por serpientes en el Neotrópico.

Palabras clave.— Cecilias, Colombia, comportamiento, serpientes de coral, defensa, dieta.

Abstract.— We here report the first dynamic event of predation and defensive behavior in *Microcaecilia nicefori* provoked by *Micrurus dumerilii* in Armero, Tolima, Colombia, and we also provide a compendium of all the available literature records of caecilians being preyed upon by snakes in the Neotropic.

Keywords.— Behavior, caecilians, Colombia, coral snakes, defense, diet.

Microcaecilia nicefori (Barbour, 1924) is a small, pink-headed, dark gray-bodied caecilian (Fig. 1D), with a maximum total length of 256 mm (Taylor, 1968). It is endemic to a portion of the Middle Magdalena Valley lowlands between 225-400 m.a.s.l. in Colombia (Lynch, 2000) (Fig. 2). This species is easily distinguished from all its sympatric congeners by having 145-157 primary grooves and 94-155 secondary grooves, and its length/width ratio, between 43-63 times (Lynch, 2000). *Micrurus dumerilii* (Jan, 1858) is a venomous snake with a maximum total length of 954 mm (Meneses-Pelayo & Caicedo-Portilla, 2015) distributed in northern South America; Panama lowlands, Andean slopes, Pacific and Caribbean continental coasts of Colombia, the Pacific region of Ecuador and northwestern Venezuela, between 0-1500 m.a.s.l. (Campell & Lamar, 1989; Roze, 1996; Campbell & Lamar, 2004).

This species is easily distinguished from all sympatric congeners by the presence of a tricolored monadal pattern composed of 10-27 single black rings (in monadal populations) or 14 false triads (in "triads" populations); 177-206 ventrals and 44-58 subcaudals in males, and 198-220, 31-42 in females, respectively; and the supracloacal keels that are well developed in males and in some females (Campell & Lamar, 1989; Roze, 1996; Campbell & Lamar, 2004).

Coral snakes have been long regarded as predators who have become specialized eaters of other vermiform vertebrates, particularly of caecilian Amphibians (Roze, 1996). Currently, several coral snake species i.e., *M. dumerilii*, *M. lemniscatus* (Linnaeus, 1758), and *M. mipartitus* (Duméril, Bibron & Duméril, 1854) (among others) are known predators of different species of caecilians i.e., *Caecilia thompsoni* Boulenger, 1902, *Oscaecilia bassleri* (Dunn, 1942), *O. polyzona* (Fischer, 1880), and *Rhinatrema bivittatum* (Guérin & Méneville, 1838) (among others) (See Table 1 for a compendium of literature records).

Most of these studies are based on the examination of stomach content obtained from dissected snakes in natural history museums (Greene, 1983; Roze, 1996; Martins & Oliveira, 1998; Maschio et al., 2010), but reports carried on in the field are rare. Some of these are the result of snake regurgitation (either induced or natural) (Villacampa & withworth, 2016; Gonzalez et

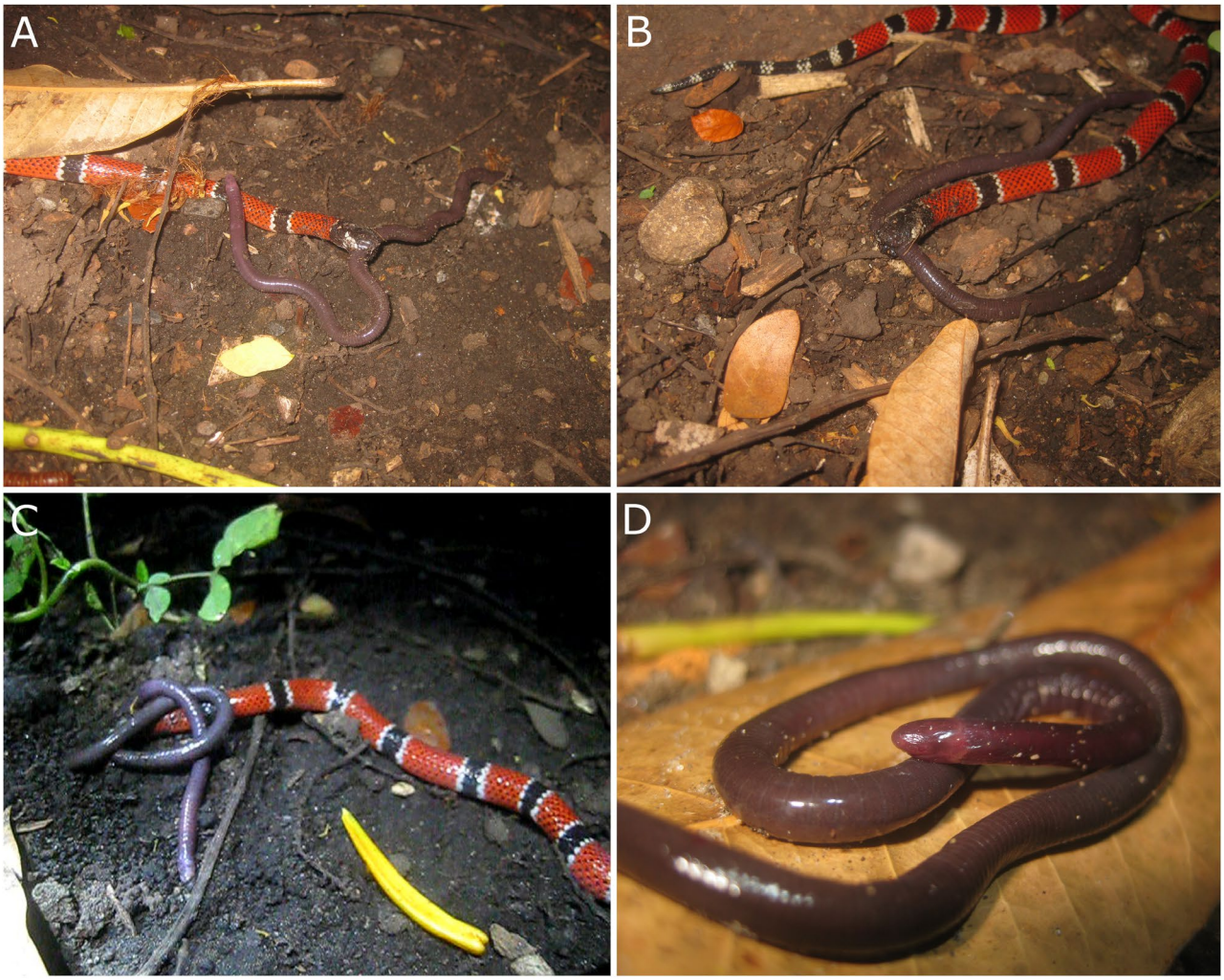

Figura 1. *M. dumerilii* depredando a *M. nicefori*. A-B) los primeros momentos del ataque, cuando la serpiente sacó a la cecilia del suelo; C) *M. nicefori* haciendo un nudo alrededor de la cabeza de la serpiente; D) vista general de *M. nicefori* tras haber sido envenenada.

Figure 1. *M. dumerilii* preying upon *M. nicefori*. A-B) the first moments of the attack, when the snake pulled the caecilian out of the ground; C) *M. nicefori* knotting itself around the head of the snake; D) overview of *M. nicefori* after envenoming.

al., 2018), and few cases have occurred in situ (Viana & Mello-Mendes, 2015; Ramos, 2017; Fernández-Roldán et al., 2021; this study).

The event that will be here discussed (Fig. 1) took place on April 24 2015 at 23:58h, in the Tolima University Farm (5.0032778, -74.9076666, 286 m.a.s.l.; Fig. 2). The exact locality is a nursery garden placed among several farming installations near a secondary forest used for wood supply in Guayabal, Armero, in the north zone of upper Magdalena Valley, Tolima department, Colombia. Initially, a *M. dumerilii* (snout-vent length 465 mm) was pulling out a *M. nicefori* (total body length 200 mm) from the ground. The caecilian had been bitten and strongly grabbed at mid-body by the coral snake (Figs. 1 A-B). Additionally, the snake's head was completely covered by a mucus substance (a glandular secretion by the caecilian). Subsequently, *M. nicefori* curled up and around itself forming a knot, and tried to move it towards the snake's head several times in an attempt to escape without success (Fig. 1C). *M. dumerilii* responded by spinning its body on its own axis repeatedly and did not release the caecilian. This event occurred for approximately two minutes before both animals were interrupted and separated by the researchers and brought to the field station. The caecilian died almost an hour later at 1:07h on April 25 of 2015 in the field station (Fig. 1D), afterwards the snake was euthanized and both animals were preserved. Lastly, the specimens were deposited at the Museum

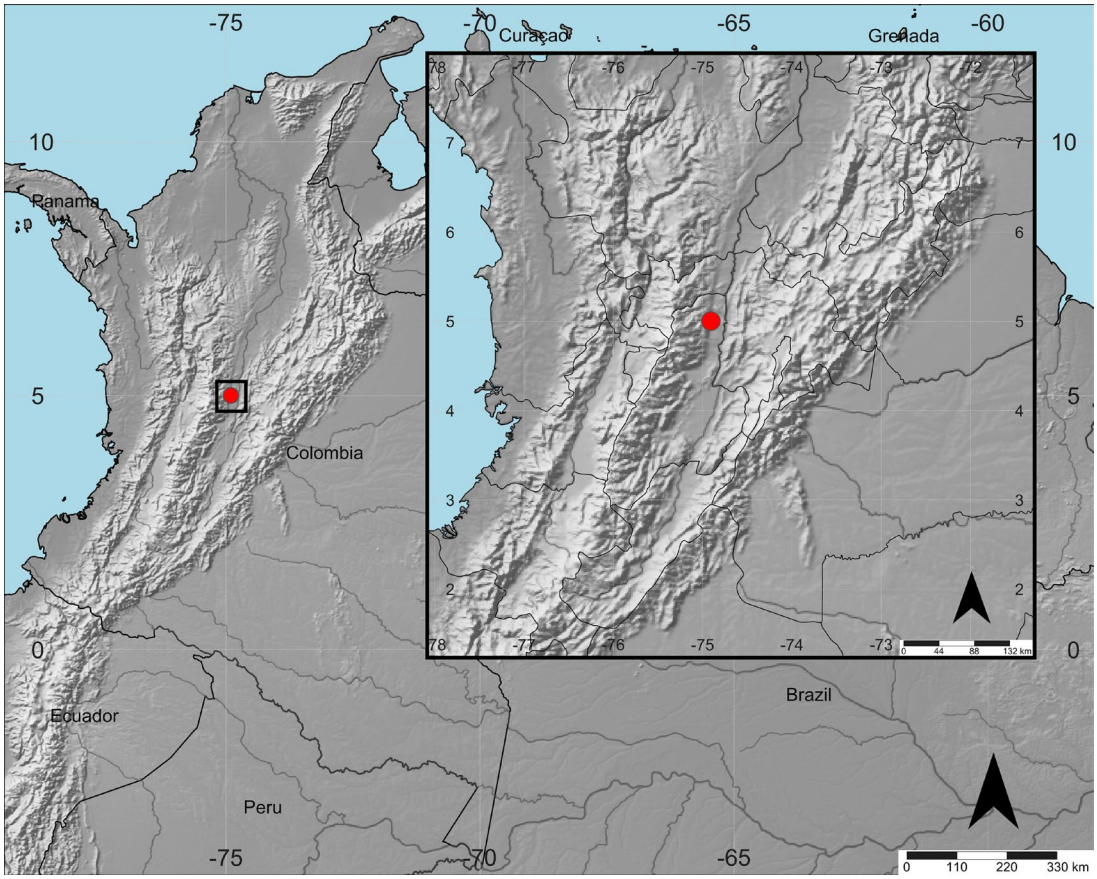

Figura 1. Mapa del noroccidente de Sur América mostrando el lugar donde ocurrió el evento de depredación (punto rojo); Guayabal, Armero, Tolima, Colombia.

Figure 1. Map of northwestern South America indicating the locality (red dot) where the event of predation took place; Guayabal, Armero, Tolima, Colombia.

of Natural History C.J. Marinkelle, Universidad de Los Andes, Bogotá, and cataloged as *M. nicefori* ANDES-A-3615 and *M. dumerilii* ANDES-R-959.

Usually, this kind of natural history observations focus on the behavior of the predator rather than on that of the prey (Ramos, 2017). However, a report by Viana & Mello-Mendes (2015) describes a predatory event of *M. lemniscatus* on *R. bivittatum*, which exhibited a defensive behavior similar to the one described here. In both cases the caecilians were bitten at mid-body by the coral snakes, and these responded to the attack by curling their bodies around that of their predators in an attempt to escape from their bite. It is important to highlight that 'caecilian body curling' has been reported to occur in two different ways: a spiral knot (i.e. *R. bivittatum*; Viana & Mello-Mendes, 2015), or a simple knot (i.e. *M. nicefori*) (Fig. 1C), similar to the defensive behavior reported in the snake *Trilepida jani* (Martins et al., 2018). We can confirm that the caecilian did not attempt to bite the coral snake, which could be an important defensive mechanism, given that caecilians have a powerful bite due to their well-developed dual jaw-closing mechanism and their many rows of long sharp teeth (Wake & Wurst, 1979; Greene, 1983; Nussbaum, 1983).

Recently, Jared et al. (2018a) and Mailho-Fontana et al., (2020) provided anatomical and chemical evidence that *Siphonops annulatus* (Mikan, 1822) - a member of the same family as *M. nicefori* (Siphonopidae) - has dental glands that secrete proteins associated with toxicity (Gelatinolyc, Caseinolyc, Fibrinogenolytic, Hyluronidase, Phospolipase A2). Additional poisonous glands have also been found on the terminus of *S. annulatus* by Jared et al. (2018b). Still, the presence of these glands in *M. nicefori* needs to be determined. Furthermore, the only other report of defensive behavior by a caecilian in the Neotropic (Viana & Mello-Mendes, 2015) did not show evidence of any defensive bite by the caecilian. We consider this strategy of secreting mucous substances as an anti-predatory behavior because these secretions were generated as a direct response to the bite of *M. dumerilii*; perhaps attempting to make itself slippery and escape from the grasp of its predator.

Tabla 1. Compendio de registros publicados de depredación de cecilias por serpientes en la región Neotropical.
Table 1. A compendium of published records of predation of caecilians by snakes in the Neotropic region.

Predator	Prey	Source
Anilius scytale	*Siphonops annulatus*	Greene, 1983
Anilius scytale	*Typhlonectes* sp.	Greene, 1983
Anilius scytale	*Caecilia gracilis*	Greene, 1983; Maschio et al., 2010
Anilius scytale	*Oscaecilia bassleri*	Villacampa & Witworth, 2016
Anilius scytale	*Microcaecilia unicolor*	Bittencourt-Silva & Wilkinson, 2018
Bothrops asper	*Dermophis parviceps*	Jones et al., 2014
Clelia clelia	*Siphonops* sp.	Jared et al., 2018b
Micrurus bocourti	*Unidentified caecilian*	Roze, 1996
Micrurus corallinus	*Chthonerpeton* aff. *braestrupi*	Gonzalez et al., 2018
Micrurus corallinus	*Siphonops* sp.	Marques & Sazima, 1997; Roze, 1996
Micrurus decoratus	*Siphonops* sp.	Marques, 2002
Micrurus diastema	*Gymnopis syntrema*	West et al., 2019
Micrurus dumerilii	*Caecilia thompsoni*	Herrera-Lopera et al., 2018
Micrurus dumerilii	*Microcaecilia nicefori*	This study
Micrurus ibiboboca	*Siphonops annulatus*	Roze, 1996
Micrurus latifasciatus	*Dermophis mexicanus*	Roze, 1996
Micrurus lemniscatus	*Rhinatrema bivittatum*	Viana & Mello-Mendes, 2015
Micrurus lemniscatus	*Microcaecilia* sp.	Martins & Oliveira, 1998
Micrurus lemniscatus	*Oscaecilia* sp.	Martins & Oliveira, 1998
Micrurus mipartitus	*Unidentified caecilian*	Roze, 1996
Micrurus mipartitus	*Caecilia occidentalis*	Vera-Pérez et al., 2019
Micrurus mipartitus	*Caecilia thompsoni*	Bernal & Palma, 2011
Micrurus mipartitus	*Oscaecilia polyzona*	Fernández-Roldán et al., 2021
Micrurus narduccii	*Oscaecilia* cf. *bassleri*	Ramos, 2017
Micrurus nigrocinctus	*Gymmopis multiplicata*	Campbell, 1998
Ninia sebae	Unidentified caecilian	Landy et al., 1966

Although *M. dumerilii* is a medically important species because of the compounds in its venom (Rey-Suárez et al., 2016), not much of its natural history is known aside from the fact that this species preys on caecilians (*C. thompsoni* and *M. nicefori*), fishes (*Synbranchus marmoratus* Bloch, 1795) and lizards (*Bachia* spp.) (Roze, 1996; Herrera-Lopera et al., 2018; this study). Our report provides a small contribution to the ecology and natural history of *M. dumerilii* by adding a new prey item to its diet, but perhaps even more importantly this record represents the first documented case of a defensive behavior ever made upon *M. nicefori*, given that no other natural history aspects or events had ever been documented for this endemic caecilian.

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MORPHOLOGICAL MALFORMATIONS IN ADULTS OF *RHINOCLEMMYS ANNULATA* (REPTILIA, TESTUDINES), IN PANAMA

MALFORMACIONES A NIVEL MORFOLÓGICO EN ADULTOS DE *RHINOCLEMMYS ANNULATA* (REPTILIA, TESTUDINES), EN PANAMÁ

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Resumen.— Se reportan dos casos de malformaciones en *Rhinoclemmys annulata* adultas, en las provincias de Colón y Panamá Oeste.

Palabras clave.— Desarrollo embrionario, genética, malformaciones, tortuga.

Abstract.— Two cases of malformations are reported in adult *Rhinoclemmys annulata*, in the provinces of Colón and Panamá Oeste.

Keywords.— Embryonic development, genetics, malformations, turtle.

Malformations are abnormalities that are generally related to abnormal development, particularly congenital, of some limb or in some part of the body (Cruz-Pérez et al., 2009; Moreno, 2017). The causes where malformations can occur in turtles are generally in animals that are deep in the nest (Otto & Hernández, 2004), as well as embryonic anoxia at a certain moment of development (Frye, 1991), or be related to processes of agenesis of the limbs (Martínez et al., 1997).

It has been estimated that the malformations found may be due 10% to environmental factors, 25% to genetic factors and 65% to unpublished factors (Rojas & Walker, 2012). In this work we present two cases of malformations in *Rhinoclemmys annulata* (semiaquatic turtles) found in Panama. In both cases we used the generalized search method, for the observation of the individuals, a Canon SX60 SH camera to obtain the photographic evidence, a Garmin MAP 62 GPS for the georeferencing of the events.

Case 1. On March 25, 2018, during a tour in the Altos de Campana National Park, Panama Oeste Province at 745 meters above sea level, which aimed to place camera traps to show the presence of a jaguar (*Panthera onca*), we took an exploratory tour of a body of water near the provisional camp, when we observed an adult individual of *R. annulata* (female) that presented normal behavior for this species. It was at the edge of the stream, when it noticed our presence and it immediately hid inside its shell, it was not until we captured the individual, for its determination, that we noticed the absence of part of both forelimbs; It did not present visible wounds from attack or combat with a possible predator, nor scars that show that these limbs had been amputated, so we consider them to be genetic malformations that are appreciable at a morphological level (Fig. 1B and C).

Case 2. On March 15, 2020, during a tour to place camera traps in the Portobelo National Park, Colón Province at 834 meters above sea level, away from bodies of water (approximately 400 m), among the vegetation on the slope, we were able to observe an individual (Female) *R. annulata* adult with absence of the right hind limb (Fig. 1D and E).

Once photographed and the species determined, both turtles were released in the same place where they were found. The appearance of malformations may be due to intrinsic (genetic

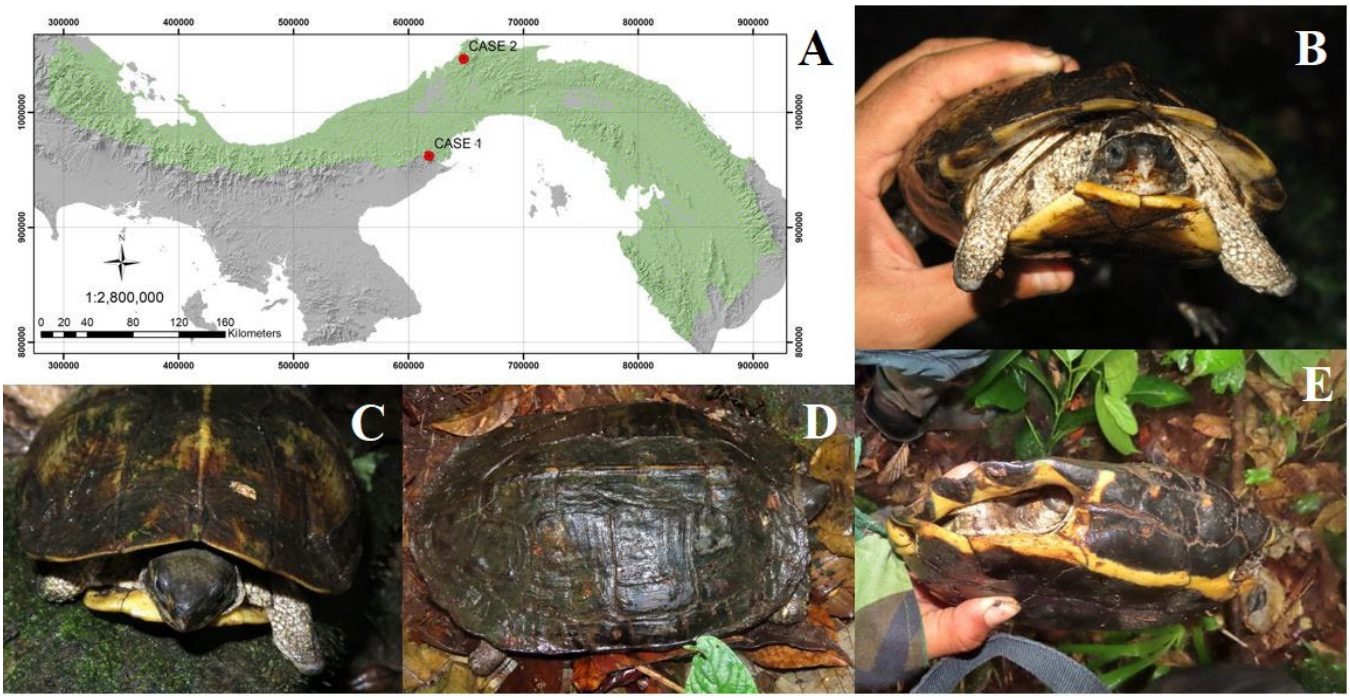

Figura 1. A) Mapa de distribución de *R. annulata* y casos reportados (1 y 2), en Panamá. Vistas de los individuos de *R. annulata*; B) y C) Caso 1 en la imagen frontal se aprecia la extensión de las extremidades; Caso 2, D) Dorsal, apreciamos el miembro incompleto, E) vista lateral.

Figure 1. A) Distribution map of *R. annulata* and reported cases (1 and 2), in Panama. Views of individuals of *R. annulata*; B) and C) Case 1 Frontal, the extension of the extremities is appreciated; Case 2, D) Dorsal, we appreciate the incomplete limb, E) lateral view.

and physiological) and extrinsic factors (chemical, physical, edaphological, among others.) which seriously affect embryonic development (Bárcenas-Ibarra & Maldonado, 2009). It should be noted that, due to anthropic pressure, pollutants and industrial activities introduced into the environment can also cause deformities in turtles (Van Meter et al., 2006).

Some intrinsic factors include intracellular anomalies such as in the *Kinosternon leucostomum* species (Hernández-Guzmán et al., 2015), causing repercussions on their progeny due to modifications of the genetic material. Similarly, the presence of malformations and deformities in the embryonic state, in some cases may be due to their homozygosity, as is the case of parthenogenic species that have low genetic variability (Booth et al., 2012). The little genetic variability in reproductive individuals can increase the appearance of anomalies in embryonic development, as is the case of parthenogenic species (Bellairs, 1981; Martínez et al., 1997).

Unlike their skin, the membrane of the eggs in reptiles is permeable and a little more susceptible to changes in the exterior (Ortíz-Santalisterra & Egea-Serrano, 2013). In amphibians, for example, malformations and inability to complete the metamorphosis in larvae of *Lithobates vaillanti* have been reported due to the presence of sulphurous waters (Hernández-Guzmán et al., 2014) highlighting the disruptive role of extrinsic factors in the development of animals. The factors that could have induced the malformations in these chelonians are not known, therefore, we recommend more sampling and monitoring to know the possible causes of the appearance of these malformations. This is the first report, in Panama, of malformations in this species of turtle.

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NEW RECORDS OF HUMAN-CROCODILE INTERACTIONS IN MEXICO FROM 2018 THROUGH THE FIRST HALF OF 2021

NUEVOS REGISTROS DE INTERACCIONES HUMANO-COCODRILO EN MÉXICO DESDE 2018 HASTA EL PRIMER SEMESTRE DE 2021

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Resumen.— El crecimiento poblacional humano y sus actividades económicas asociadas han incrementado las interacciones humano-vida silvestre. Aquí, proporcionamos nuevos registros de las interacciones humano-cocodrilo (HC) de 2018 a la primera mitad del 2021 en México. Cincuenta y un casos fueron registrados en este estudio, 2018 fue el año con el número más alto de casos (n= 19) y 2021 (en su primer semestre) es el año con el número más bajo de casos. Tamaulipas y Quintana Roo en el Golfo de México representan el 40% de los casos, mientras que Oaxaca y Nayarit en la costa del Pacífico Mexicano representaron el 22%. Las victimas masculinas (n= 32) fueron las más comunmente asociadas a los incidentes entre humanos y cocodrilos que las víctimas femeninas (n= 10). Sin embargo, 44 casos fueron no fatales y solamente siete fueron fatales. Por lo que sabemos, nuestros registros de interacciones HC incrementan el número de conflictos en México a 250 casos entre el año 2000 y la primera mitad del año 2021.

Palabras clave.— Ataques de cocodrilos, conflictos, lesiones inhabilitantes, lesiones no inhabilitantes, secuelas.

Abstract.— The growing human population and its associated economic activities have increased human-wildlife interactions. Herein, we provide new records of human-crocodile (HC) interactions in Mexico from 2018 through the first half of 2021. Fifty-one cases were recorded in this study; 2018 had the highest number of cases (n = 19), and 2021 (the first half) had the lowest number of cases. The states of Tamaulipas and Quintana Roo on the Gulf of Mexico represented 40% of the cases, while Oaxaca and Nayarit on the Mexican Pacific coast represented 22% of the cases. Male victims (n = 32) were more commonly associated with human-crocodile interactions than females (n = 10). Forty-four cases were non-fatal and only seven were fatal. As far as we know, our records of HC interactions increase the number of conflicts in Mexico to 250 cases.

Keywords.— Crocodile attacks, conflicts, disabling injuries, non-disabling injuries, sequels.

The growing human population and its associated economic activities have increased human-wildlife interactions (Weladji & Tchamba, 2003). Wildlife conflicts likely increase when an ever-increasing number of human populations gather in a limited area close to natural habitats (Inskip & Zimmermann, 2009), especially with large predators (Lamarque et al., 2009). From a human perspective, some interactions are positive, and others are negative (Flores-Armilla et al., 2020). The interactions that are perceived negatively are referred to as human-wildlife conflicts (Inskyp & Zimmerman, 2009), when these interactions have negative effects –either real or perceived– trigger human reaction that can result in harmful impacts on wildlife individuals and populations (García-Grajales, 2013; Morzillo et al., 2014).

Some of the causes that contribute to the increase in this type of conflict are human population growth (Fukuda et al., 2014); the transformation of undeveloped lands, coastal rivers, swamps and shorelines for urbanization (Pooley, 2015; Redpath et al., 2015); and human encroachment into crocodile habitats

for tourism, recreation, agriculture, fishing or other purposes (Wallace et al., 2011; Fukuda et al., 2014). Unfortunately, human expansion has put pressure on crocodilian habitats, reducing the natural physical space available. Despite this pressure, crocodile populations have recovered during the last two decades thanks to law enforcement and conservation efforts, such as permanently banning crocodile hunting in the 1970s.

As a result of this recovery of crocodilian populations, along with a growing human population and its associated economic activities, negative interactions between people and crocodiles have escalated (González-Desales et al., 2021). These conflicts should receive attention from the federal government to improve public safety and prevent the extermination of crocodiles by local communities (García-Grajales, 2013), who often react emotionally to the incidents (Lamarque et al., 2019).

It is not possible to track the number or severity of interactions between crocodiles and humans if there is no concerted effort to monitor new reports and log the data (Porras-Murillo and Mata, 2020). Countries such as Australia, as well as several nations in Asia, Africa and Latin America are also facing crocodile species attacks, but incidence rates are unknown due to a lack of reporting (Caldicott et al., 2015; Porras-Murillo and Mata, 2020). In Mexico, between 2000 and 2018, 149 unprovoked crocodile attacks on humans were registered, with 102 cases corresponding to the Pacific coast and 47 to the Gulf of Mexico coast (García-Grajales and Buenrostro-Silva, 2019). Although Pooley et al. (2020) provide an update of human-crocodilian interaction in Latin America, their records for Mexico are questionable, mostly because of their numerical inconsistencies. Therefore, we provide new records of human-crocodile (HC) interactions in Mexico from 2018 through the first half of 2021 and an update on incidents for the country.

We compiled the publicly available data on incidents of HC interactions from 2018 through the first half of 2021 (Table 1). Our data compilation was obtained through various methods: 1) interviewing victims, witnesses, police officers or rangers involved in the incidents by telephone or email; 2) searching media sources, such as newspapers, magazines and websites (Croc-Bite database, CrocBite 2021); 3) communicating in person with some researchers; and 4) personally experiencing attacks in our respective states (Jalisco, Guerrero and Oaxaca). All incidents were grouped and classified by date; location; sex, age, activity and origin of the affected person; time (daylight or nocturnal); presence of witnesses; type of crocodile habitat; region; political unit (municipality); and type of attack (fatal or non-fatal). We grouped the victims into six age categories (1–10, 11–17, 18–40, 41–60, >60), based on the economically active ages in Mexico. Furthermore, when it was possible with non-fatal attacks, we classified the type of outcome as disabling (the extent of the loss of tissue continuity resulted in amputation or the impairment of motor functionality, limiting or impeding daily physical activities) or non-disabling (no amputation or lack of motor function, which allowed the victims to continue with daily physical activities). In all cases it was possible to determine the species and total length of crocodile involved.

Fifty-one HC interactions were recorded from 2018 through the first half 2021; 2018 had the highest number of cases (n = 19) and 2021 (in its first semester) had the lowest number of cases (n= 7). The Gulf of Mexico had the highest number of cases (n = 29), and the Mexican Pacific coast had the lowest number (n = 20), highlighting two additional cases that occurred inside the continent (Coahuila and San Luis Potosí). Tamaulipas and Quintana Roo on the Gulf of Mexico represented 40% of the cases, while Oaxaca and Nayarit on the Mexican Pacific coast represented 22% of the cases. Regarding the municipalities, Tampico had the greatest number of cases (n = 7).

Male victims (n = 32) were more commonly involved in incidents of HC interactions than females (9), however, a small percentage (18%), it was not possible to identify the human sex involved because of the features of the report. Forty-four cases were non-fatal, and only seven were fatal (5 males and 2 females). The most common activities at the time of non-fatal incidents were fishing (22%), swimming (14%) and walking near the water's edge (10%). The ages of the victims involved in the majority of the attacks ranged from 18 to 40 years old (32%), followed by those from 41 to 60 years old (20%). With a significant percentage of victims, it was not possible to determine their age (32%).

With respect to the injuries caused by non-fatal attacks, the highest proportion of victims (80%) showed non-disabling injuries, with only two cases resulting in the amputation of a limb (disabling sequelae). Regarding the months in which the attacks occurred, June and July presented the highest number of crocodile attacks (11 cases, respectively), and in February, no attacks occurred over the years evaluated. Both, fatal and non-fatal attacks took place more commonly in the daytime (88%). Of the crocodile species involved, *Crocodylus acutus* and *C. moreletii* had the same number of cases (n = 25), respectively. Only, in one case, it was not possible to identify the species involved in the incident. In recent years, the number of HC incidents have been increasing in many parts of the world (Langley, 2005; Pooley, 2015; Das & Jana, 2018); however, the statistics are skewed because numerous episodes involving crocodilians go unreported or

Tabla 1. Registros de incidentes entre humanos y cocodrilos en México desde 2018 hasta la primera mitad de 2021. M = Masculino, F = Femenino; UK = Desconocido, www = World wide web; - = No disponible. NF = no fatal, F = fatal, ND = no determinado, LT = longitud total; DIS = Discapacitante, ND = No discapacitante. * Nuevos registros de agosto a octubre de 2021. / **Table 1.** Records of human-crocodile incidents in Mexico from 2018 through the first half of 2021. M= Male, F= Female; UK= Unknown, www = World wide web; - = Not available. NF = Non-fatal, F = Fatal, ND= Non-determined, LT = Total length; DIS = Disabling, ND = Non-disabling. * New records from August to October 2021.

Year	Source	Date	StATE	Municipality	LOCATION	Sex of victim	Age of victim	Origin of the victim	Activity	Type of habitat	Presence of witnesses	Time of incident	Type of incident	Type of sequel	Species	Crocodile LT
2021 (10)	www	October 6 *	Nayarit	Nuevo Vallarta	Hotel RIU	M	24	Foreign	Swimmin in ocean	Beach	Yes	Night	NF	-	C. acutus	3 m
	www	September 11 *	Tabasco	Villahermosa	Avenida	M	45	Local	Bathing	Lagoon	Yes	Daylight	NF	DIS	C. moreletti	3 m
	www	July 26 *	Jalisco	Puerto Vallarta	Hotel Marriot	F	24	Foreign	Swimming in shore	Beach	Yes	Night	NF	-	C. acutus	2-3 m
	www	July 20	Quintana Roo	Cancún	Restaurant Ilios, Boulevard Kukulcan	F	23	Foreign	Dinner	Lagoon	Yes	Night	NF	ND	C. moreletti	UK
	www	June 25	Veracruz	Catemaco	Anayaga	M	56	Local	Fishing	Lagoon	Yes	Daylight	NF	ND	C. moreletti	2-3 m
	www	June 23	Coahuila	Piedras Negras	Río Bravo	F	3	UK	Crossing body water	River	No	UI	F	-	UI	UK
	www	June 21	Tamaulipas	Tampico	Laguna El Carpintero	F	46	Local	Washing clothes	Lagoon	Yes	Daylight	F	-	C. moreletti	2-3.5 m
	www	June 18	Quintana Roo	Cancún	Hotel Club Med	M	12	Foreign	Playing near water	Lagoon	Yes	Daylight	NF	ND	C. acutus	2-3.5 m
	www	June 6	Oaxaca	Villa de Tututepec	Puerto Suelo	F	27	Foreign	Swimming in lagoon	Lagoon	Yes	Daylight	NF	ND	C. acutus	2-3.5 m
2020 (12)	Interview	may-16	Guerrero	Copala	Barra de Copala	F	24	Local	Swimming in shore estuary	Estuary	Yes	Daylight	NF	ND	C. acutus	2-3 m
	Interview	December 14	Oaxaca	Santa María Tonameca	Barra del Potrero	M	48	Local	Washing hands	River	No	Daylight	NF	DIS	C. acutus	UK
	www	Octuber 16	Tamaulipas	Tampico	Laguna El Carpintero	M	56	Homeless	Swimming in lagoon	Lagoon	Yes	Daylight	F	-	C. acutus	3 m
	www	September 29	Tabasco	Tenosique	Río Tenosique	UI	UI	UK	UK	River	UI	UI	NF	ND	C. moreletti	UK
	www	September 24	Sinaloa	Navolato	Sataya Lagoon	M	UI	Local	Fishing	Lagoon	Yes	Daylight	NF	ND	C. acutus	UK

Tabla 1 (cont.). Registros de incidentes entre humanos y cocodrilos en México desde 2018 hasta la primera mitad de 2021. M = Masculino, F = Femenino; UK = Desconocido, www = World wide web; - = No disponible. NF = no fatal, F = fatal, ND = no determinado, LT = longitud total; DIS = Discapacitante, ND = No discapacitante. * Nuevos registros de agosto a octubre de 2021. / **Table 1 (cont.).** Records of human-crocodile incidents in Mexico from 2018 through the first half of 2021. M= Male, F= Female; UK= Unknown, www = World wide web; - = Not available. NF = Non-fatal, F = Fatal, ND= Non-determined, LT = Total length; DIS = Disabling, ND = Non-disabling. * New records from August to October 2021.

Year	Source	Date	StATE	Municipality	LOCATION	Sex of victim	Age of victim	Origin of the victim	Activity	Type of habitat	Presence of witnesses	Time of incident	Type of incident	Type of sequel	Species	Crocodile LT
2020 (12)	www	September 5	Veracruz	Tuxpan	Barra Norte	UI	UI	UK	UK	River	Yes	Daylight	NF	ND	*C. moreletti*	UK
	www	August 25	Tamaulipas	Tampico	Laguna El Carpintero	UI	UI	UK	UK	Lagoon	Yes	Daylight	NF	ND	*C. moreletti*	UK
	www	August 24	Guerrero	Zihuatanejo	Ixtapa	UI	UI	UK	UK	River	Yes	Daylight	NF	ND	*C. acutus*	UK
	Interview	July 28	Yucatan	Dzonot Carretero	Dzonot	UI	UI	UK	UK	River	Yes	Daylight	NF	ND	*C. moreletti*	UK
	www	July 14	Guerrero	Zihuatanejo	Ixtapa	UI	UI	UK	UK	River	Yes	Daylight	NF	ND	*C. acutus*	UK
	Interview	June 30	Jalisco	Tomatlan	Chalacatepec	M	61	Local	Fishing	Lagoon	Yes	Daylight	NF	ND	*C. acutus*	UK
	www	June 7	Tamaulipas	Tampico	El Carpintero	UI	UI	UK	UK	Lagoon	Yes	Daylight	NF	ND	*C. moreletti*	UK
	Interview	may-25	Chiapas	Flores Magon	Rio Lacantun	M	22	Local	Fishing, bathing horse	River	Yes	Daylight	F	ND	*C. moreletti*	UK
2019 (13)	www	November 10	Quintana Roo	Playa del Carmen	Cozumel	UI	UI	UK	UK	Island	Yes	Daylight	NF	ND	*C. acutus*	UK
	www	November 8	Oaxaca	Santa María Colotepec	Barra de Navidad	UI	UI	UK	UK	River	Yes	UI	NF	ND	*C. acutus*	UK
	www	September 13	Quintana Roo	Cancún	Banco Chinchorro	M	UI	UK	Washing	Island	Yes	Daylight	NF	ND	*C. acutus*	UK
	Interview	August 29	Nayarit	El Monteon	Laguna Canalan	M	54	Local	Fishing	Lagoon	Yes	Daylight	NF	ND	*C. acutus*	UK
	www	August 23	Campeche	Ciudad del Carmen	Bugambilias	M	37	Local	Cleaning mangrove	Estuary	Yes	Daylight	NF	ND	*C. moreletti*	UK
	Interview	August 10	Jalisco	Puerto Vallarta	El Salado	M	35	Local	Try touch	Estuary	Yes	Daylight	NF	ND	*C. acutus*	UK
	Interview	July 22	Quintana Roo	Chetumal	Chichankanaab	M	UI	Local	Fishing	Lagoon	Yes	Daylight	NF	ND	*C. moreletti*	UK

Tabla 1 (cont.). Registros de incidentes entre humanos y cocodrilos en México desde 2018 hasta la primera mitad de 2021. M = Masculino, F = Femenino; UK = Desconocido, www = World wide web; - = No disponible. NF = no fatal, F = fatal, ND = no determinado, LT = longitud total; DIS = Discapacitante, ND = No discapacitante. * Nuevos registros de agosto a octubre de 2021. / **Table 1 (cont.).** Records of human-crocodile incidents in Mexico from 2018 through the first half of 2021. M= Male, F= Female; UK= Unknown, www = World wide web; - = Not available. NF = Non-fatal, F = Fatal, ND= Non-determined, LT = Total length; DIS = Disabling, ND = Non-disabling. * New records from August to October 2021.

Year	Source	Date	StATE	Municipality	LOCATION	Sex of victim	Age of victim	Origin of the victim	Activity	Type of habitat	Presence of witnesses	Time of incident	Type of incident	Type of sequel	Species	Crocodile LT
2019 (13)	Interview	July 8	Tamaulipas	Tampico	El Carpintero	M	59	Local	Walking	Lagoon	Yes	Daylight	NF	ND	*C. moreletti*	UK
	Interview	July 2	Quintana Roo	Cancún	Punta Cancun LeBlanc	M	40	Local	Swimming	Lagoon	Yes	Daylight	NF	ND	*C. acutus*	UK
	www	June 05	Tamaulipas	Altamira	Río Barberena	M	-	Homeless	-	-	-	-	F	-	*C. moreletti*	?
	Interview	May, 25	Campeche	Palizada	Boca Chica	M	UI	Local	Fishing	Lagoon	Yes	Daylight	NF	ND	*C. moreletti*	UK
	www	March 12	San Luis Potosi	Tamuin	Centro	M	18	Local	Bathing	River	Yes	Daylight	NF	ND	*C. moreletti*	3 m
	Interview	March 3	Quintana Roo	Chetumal	Petcacab	M	12	Local	Bathing	Lagoon	Yes	Daylight	NF	ND	*C. moreletti*	UK
2018 (19)	Interview	September 25	Jalisco	Puerto Vallarta	Marina	F	30	No local	Swimming	Beach	Yes	Night	NF	Dis	*C. acutus*	3.5 m
	Interview	September 9	Nayarit	San Blas	Mirador de aves	M	38	Local	Fishing	Lagoon	Yes	Night	NF	ND	*C. acutus*	3 m
	Interview	September 9	Nayarit	San Blas	Mirador de aves	M	19	Local	Fishing	Lagoon	Yes	Night	NF	ND	*C. acutus*	3 m
	Interview	September 3	Nayarit	Bahia de Banderas	Rio Ameca	M	35-40	UK	Wading in waist-deep wáter	River	Yes	Daylight	F	Dis	*C. acutus*	3.5 m
	www	August 21	Tamaulipas	Cd. Madero	Laguna Candelario Garza	M	52	Local	Fishing	Lagoon	Yes	Daylight	NF	ND	*C. moreletti*	2 m
	www	July 22	Quintana Roo	Dziuche	Laguna Chichankanaab	M	UK	UK	UK	Lagoon	Yes	Daylight	NF	ND	*C. moreletti*	UK
	www	July 14	Tamaulipas	Ejido Vicente Canek	Presa Vicente Guerrero	M	UK	Local	Walking along edge of dam	Lagoon	Yes	Daylight	NF	ND	*C. moreletti*	2 m
	Interview	July 13	Chiapas	Pijijiapan	Zapotal	M	30	Local	Swimming	River	Yes	Daylight	NF	ND	*C. acutus*	UI

Tabla 1 (cont.). Registros de incidentes entre humanos y cocodrilos en México desde 2018 hasta la primera mitad de 2021. M = Masculino, F = Femenino; UK = Desconocido, www = World wide web; - = No disponible. NF = no fatal, F = fatal, ND = no determinado, LT = longitud total; DIS = Deshabilita, ND = No discapacitante. * Nuevos registros de agosto a octubre de 2021. / **Table 1 (cont.).** Records of human-crocodile incidents in Mexico from 2018 through the first half of 2021. M= Male, F= Female; UK= Unknown, www = World wide web; - = Not available. NF = Non-fatal, F = Fatal, ND= Non-determined, LT = Total length; DIS = Disabling, ND = Non-disabling. * New records from August to October 2021.

Year	Source	Date	StATE	Municipality	LOCATION	Sex of victim	Age of victim	Origin of the victim	Activity	Type of habitat	Presence of witnesses	Time of incident	Type of incident	Type of sequel	Species	Crocodile LT
2018 (19)	Interview	July 7	Tamaulipas	Tampico	El Carpintero	M	15-18	Local	Swimming	Lagoon	Yes	Daylight	NF	ND	*C. moreletti*	UI
	www	July 2	Yucatan	Celestun	Ojo de Agua Baldiosera	F	46	UK	Swimming	Water hole	Yes	Daylight	NF	ND	*C. moreletti*	2 m
	www	June 22	Tamaulipas	Cd. Mante	Rio Mante	M	67	Local	Try to catch	Road near to river	No	Daylight	NF	ND	*C. moreletti*	1- 1.5 m
	www	June 17	Tamaulipas	Villa de Casas	Presa Vicente Guerrero	M	13	Local	Fishing	Dam	Yes	Daylight	NF	ND	*C. moreletti*	2 m
	Interview	June 15	Oaxaca	Tierra Blanca	Tierra Blanca	M	40	Local	Walking dog near to river	River	No	Daylight	NF	ND	*C. acutus*	UK
	Interview	June 4	Nayarit	Bahia de Banderas	San Vicente	M	37	Local	Jumped into pond	Pond	Yes	Daylight	NF	ND	*C. acutus*	2.5 m
	Interview	May, 16	Tabasco	Villahermosa	Yumka	F	20	UK	Feeding wild crocodile	Lagoon	Yes	Daylight	NF	ND	*C. moreletti*	UI
	www	May, 10	Tamaulipas	Tampico	El Carpintero	M	36	Local	Fishing	Lagoon	Yes	Daylight	NF	ND	*C. moreletti*	2 m
	Interview	April 15	Oaxaca	Santa María Colotepec	Barra de Colotepec	F	50	UK	Lying alongside estuary	Estuary	Yes	Daylight	NF	ND	*C. acutus*	UK
	www	April 12	Quintana Roo	Cozumel	Laguna de la Plata	M	UK	UK	Wading in waist-deep wáter	Lagoon	Yes	Daylight	NF	ND	*C. acutus*	2 m
	www	January 1	Oaxaca	Pinotepa Nacional	Playa la Peña	M	4	No local	Walking in or near lagoon shore	Lagoon	Yes	Daylight	F	ND	*C. acutus*	UK

are poorly documented (Fukuda et al., 2015). Also, widespread access to social media makes interactions more visible, leading to unresearched reports in real time (Porras-Murillo & Mata, 2020).

The pattern of HC interactions described here is like the trend shown by Garcia-Grajales & Buenrostro-Silva (2019) in Mexico, as well as other countries, such as Costa Rica (Porras-Murillo & Mata, 2020). Data for the American alligator (*Alligator mississippiensis*) in the United States show that most of the people attacked were in the water or at the water's edge (Conover & Dubow, 1997). Caldicott et al. (2005) found that in Australia, most attacks occurred when people were in bodies of water or on the shore, especially during fatal attacks. Similar data have been found for HC incidents in Mexico (García-Grajales & Buenrostro-Silva, 2019).

Most of the attacks described here involved men, which is similar to the data gathered by Fukuda et al. (2014), García-Grajales & Buenrostro-Silva (2019) and Porras-Murillo & Mata (2020). Additionally, as reported by Fergusson (2004), Caldicott et al. (2005), García-Grajales & Buenrostro-Silva (2019) and Porras-Murillo & Mata (2020), most of the attacks took place during the day. In Mexico the prevalence of specified economic gender roles in rural areas such as agriculture and fishing, favor males; more specifically, men 18-40 years old who are more likely to be engaged in high-risk jobs because they are the most economically active group (García & Buenrostro-Silva 2019). For these reasons, we found this group to be the most vulnerable to HC incidents. Moreover, fatal and non-fatal attacks happened more frequently in the daytime, presumably because some activities such as fishing and swimming were more commonly conducted during daylight hours (Fukuda et al., 2014).

The peak periods for HC incidents (March to September) coincide with the species' nesting season and with the beginning and end of the wet season on both coasts in Mexico. These connections can be explained by three hypotheses: first, during the rainy season, crocodiles are widely dispersed because of a rise in water levels, and the possibility of negative HC interactions increases because of this. Second, crocodiles are ectothermic and are more active (and consequently, hungrier) during the hotter months of the year; therefore, the possibility of negative interactions increases during this period. Third, although there is little evidence, crocodiles are more dangerous during the breeding season because the large adult females guard their nests and fast until their hatchlings are ready to emerge (Pooley, 2015); therefore, they are intolerant to humans approaching their nesting areas, and as a result, are more aggressive towards people (Lang, 1992). According to Caldicott et al. (2005), it is uncommon for crocodiles to attack and eat humans, and data reported here showed that most incidents are due to a person's intrusion into a crocodile habitat.

Most coastal states in Mexico where there is a natural distribution of crocodiles has presented at least one case of HC interaction, but there was one curious case in Piedras Negras, Coahuila, in a state that is not included in a geographical distribution area for any of the crocodile species. Our hypothesis, however, is that a crocodile had been released into the Río Bravo generating conditions for possible negative interaction, due to the passage of immigrants into the United States.

During the time in which this work was revised (August-October 2021), other three incidents took place in Puerto Vallarta, Jalisco (n= 1), Nuevo Vallarta, Nayarit (n=1), and Villahermosa, Tabasco (n= 1); therefore, the number of cases increases to 250 cases. It should be noted that in these cases there were people in drunk, foreigners and homeless involved.

Understanding the underlying causes behind the increase in HC interactions will require careful logging of the events leading up to each incident, which is why a national, standardized database is so important (Porras-Murillo & Mata, 2020). An updated dataset would also help authorities identify priority areas, to facilitate targeted mitigation. From our new records, we believe that the environmental and tourism authorities have enough information to develop solutions for prevention and coexistence rather than focusing solely on controlling crocodile populations.

Similar to the proposal of Fukuda et al. (2014), public education through a variety of media outlets (e.g. loca television, radio, newspaper, and websites) will be the most effective means of informing the public about the potential danger of water-related activities in crocodile habitats.

Finally, we must use the information already available to transform negative interactions and conflicts into coexistence between crocodiles and humans (Porras-Murillo & Mata 2020). As far as we know, our records of HC interactions increase the number of conflicts in Mexico to 250 cases from 2000 to the first half 2021.

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DISTRESS CALL OF *SMILISCA BAUDINII* (HYLIDAE) DURING PREDATION BY *LEPTODEIRA POLYSTICTA* (DIPSADIDAE) IN CHIAPAS, MÉXICO

LLAMADA DE AUXILIO DE *SMILISCA BAUDINII* (HYLIDAE) DURANTE LA DEPREDACIÓN POR *LEPTODEIRA POLYSTICTA* (DIPSADIDAE) EN CHIAPAS, MÉXICO

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Resumen.— Las serpientes del género *Leptodeira* son depredadoras de anuros. Aquí reporto un evento de depredación de la rana arborícola mexicana *Smilisca baudinii* por *L. polysticta* y proporciono información cuantitativa de la llamada de estrés emitida por la rana. Además, comparo este evento con la información de las presas reportadas para algunas especies del género *Leptodeira*.

Palabras clave.— Anura, bioacústica, comportamiento defensivo, depredación, Serpentes.

Abstract.— *Leptodeira* snakes are frog predators. Here I report the predation of the Mexican treefrog *Smilisca baudinii* by *L. polysticta* and I provide quantitative data on the distress call emitted by the treefrog. Besides, I compare some *Leptodeira* species' prey information based on previous records.

Key words.— Anura, bioacoustic, defensive behavior, predation, Serpentes.

The Small-spotted Cat-eyed Snake (*Leptodeira polysticta*) is a nocturnal colubrid that inhabits lowlands up to 2000 m from Nayarit and southern Veracruz, México, to central Costa Rica (Duellman 1958). *Leptodeira polysticta* was formerly recognized as a subspecies within *L. septentrionalis* (Daza et al. 2009, Barrio-Amorós 2019) until Campbell (1998) recognized as a distinct species, known to feed on a wide variety of frogs (adults and eggs), lizards, and fishes (Cabrera-Guzman et al. 2009; Tepos-Ramirez et al. 2019). Here I report a predation event of a Mexican treefrog (*Smilisca baudinii*) by *L. polysticta* in Chiapas, Mexico, and I also describe the distress call of *S. baudinii* during predation.

The event was observed during field work near el Triunfo Nature Reserve in Rosarito la Piñuela, Escuintla municipality (15.388103° N, -92.578147° W, WGS84, 362 m a.s.l.) on June 14th 2017 at 02:06 a.m. Frog and snake individuals were approximately at the height of 1.8 meters, in a medium-size tree (ca. 6 meters in height) located in the small rural settlement of few houses near the main dirt road, no ponds were observed nearby. The event was noticed due to the frog's notorious distress call, whose call was quite different from the background soundscape. The snake grasped the frog from the posterior position of the frog's body, and the tree frog inflated as defensive behavior (Fig. 1). No other *S. baudinii* individuals were observed in the same locality.

A call was recorded from less than a meter away from the frog, with a digital recorder (Tascam DR-40) and a unidirectional microphone (Sennheiser K6/ME 66). The call was stored as a wave file at a sampling rate of 44.1 kHz and an amplitude resolution of 16 bits. The frog's temperature was measured directly with a digital thermometer (Benetech GM300, resolution 0.1°C). A total of 18 calls were recorded in a two-minute recording period. The recording was deposited (in WAV format) in the Biblioteca digital de Sonidos de Anfibios de México del 'Museo de Zoología Alfonso L. Herrera' (MZFC-HEC-4356). Call properties were obtained was obtained using the software Raven Pro 1.4 (Bioacoustics Research Program, 2011). The spectrogram, oscillograms and power spectrum was constructed using Seewave v. 1.6 package (Sueur et al. 2008) with a Blackman algorithm, a window size of 5 ms, and 80% overlap. Data provided for calls include mean ±

Figura 1. Registro visual del evento de depredación de *Smilisca baudinii* por *Leptodeira polysticta*.

Figure 1. Visual record of predation event of *Smilisca baudinii* by *Leptodeira polysticta*.

standard deviation. The distress call of *S. baudinii* was previously onomatopoetically described as a long, high-pitched cry by Duellman and Trueb (1966) from a male caught by *L. maculata* in Charapedo Michoacán, México. Here I provided detailed quantitative information of such call type.

Following the classification of Köhler et al. (2017), the call is a dense harmonic single note (Fig. 2) of a duration of 0.174 ± 0.034 s with a bimodal dominant frequency at 1244.6 ± 94.4 Hz and 3042.6 ± 406.4 Hz, respectively. The 90% of energy is located between 358.1 ± 299.5 Hz and 3664.0 ± 495.8 Hz. The call exhibits a series of pulses at a rate of 600.8 ± 74.2 pulses per second. This distress call may interfere in the predation event by frightening the predator (including the inflating behavior) or attracting other animals (in this case, other potential predators and/or pirates), enhancing the frog's chances of escape (Toledo et al. 2014).

Frog predation by *Leptodeira* species is known by fortuitous observations or by the stomach content of road-killed specimens (i.e., Köhler et al. 2016). Due to their wide distribution and abundance, *S. baudinii* may represent a significant prey resource for co-occurrent *Leptodeira* snakes. Indeed, predation of *S. baudinii* by *L. septentrionalis* was reported in Veracruz, Mexico (Aguilar-López et al. 2019) and Cayo District, Belize (Platt et al. 2016); Duellman and Trueb (1966) reported predation by *L. maculata* in Michoacan state in Mexico and, Köhler et al. (2016) found remains of *S. baudinii* inside a *L. frenata* specimen from Quintana Roo, México. However, it is the first record of predation of *S. baudinni* by *L. polysticta*. On Los Tuxtlas, Veracruz, Mexico there are predation records of *Smilisca cyanosticta* by *L. polysticta* and *L. septentrionalis* (Bello-Sánchez et al. 2018, Hernandez-Ríos et al. 2011), and a predation record of *Craugastor cf. loki* by *L. polysticta* (Cabrera Guzman et al. 2009). Similarly, a *L. septentrionalis* swallowing a *Leptodactylus bolivianus* was observed on the Refugio de Vida Silvestre, Golfito in Puntarenas, Costa Rica (Dehling 2009).

Frogs constitute a significant component of the diet of multiple snake species, and the frog abundance can be related to snake community composition and occurrence (Wells 2007, Zipkin et al. 2020). Considering the difficulty of monitoring snakes in the wild, the information of predation events like the one provided here can be the basis for more extensive studies about the structure and dynamic of anurans and snake communities (Toledo 2005).

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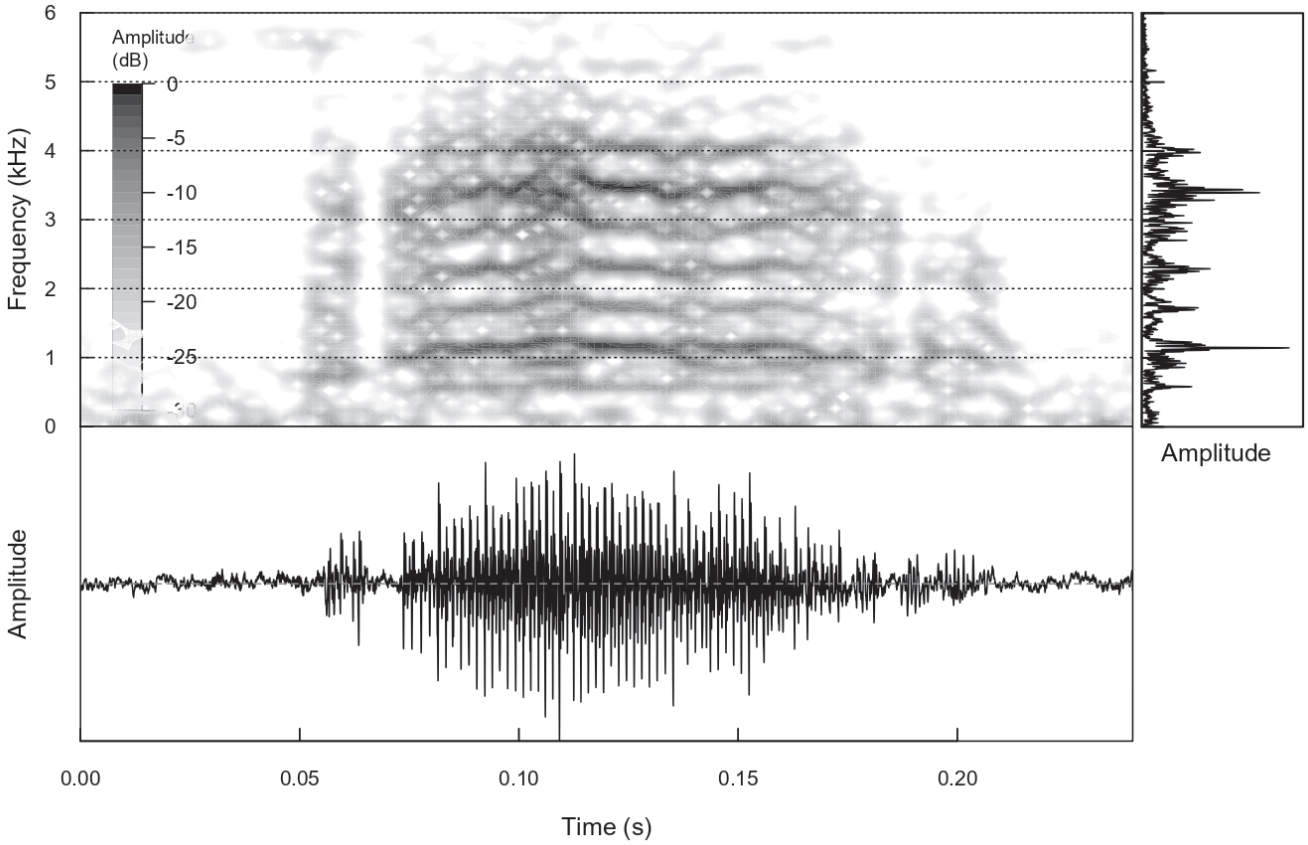

Figura 2. Espectrograma (arriba), oscilograma (abajo) y espectro de potencia (derecha) de la llamada de socorro de *Smilisca baudinii* siendo depredada. Tamaño de la ventana = 512, tasa de muestreo = 44.1 kHz, temperatura corporal = 22.0°C.

Figure 2. Spectrogram (top), oscillogram (bottom) and power spectrum (right) of the distress call of *Smilisca baudinii* being predated. Window size = 512, sampling rate = 44.1 kHz, body temperature = 22.0°C.

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PRIMER REPORTE DE ANOFTALMIA EN *ISTHMOHYLA GRACEAE* (MYERS & DUELLMAN, 1982) (ANURA: HYLIDAE) EN LA SERRANÍA DE TABASARÁ, COMARCA NGÄBE-BUGLÉ, PANAMÁ

FIRST REPORT OF ANOPHTHALMIA IN *ISTHMOHYLA GRACEAE* (MYERS & DUELLMAN, 1982) (ANURA: HYLIDAE) IN THE SERRANÍA DE TABASARÁ, NGÄBE-BUGLÉ REGION, PANAMA

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Abstract.— Here, we report an *in situ* observation of an ocular malformation known as anophthalmia (absent eye) in the continental treefrog *Isthmohyla graceae*, an endemic and critically endangered species from the Serranía de Tabasará, Ngäbe-Buglé region, Panama, in March 2020. This note documents the first reported malformation in Panama and the first record for the genus in Central America, mentioning that this type of case may be due to different factors.

Keywords.— Anophthalmia, mountain range, ocular malformation, continental divide tree frog, endemic frog.

Resumen.— Aquí reportamos una observación *in situ* de una malformación ocular conocida como anoftalmia (ojo ausente) en la rana arborícola continental, *Isthmohyla graceae*, especie endémica y en peligro crítico de extinción en la serranía de Tabasará, Comarca Ngäbe-Buglé, Panamá, en marzo 2020. Esta nota documenta la malformación como la primera reportada en Panamá y primer registro para el género en Centroamérica, mencionando que este tipo de casos puede deberse a distintos factores.

Palabras clave.— Anoftalmia, cordillera, malformación ocular, rana arborícola continental, rana endémica.

La anoftalmia es conocida como una malformación ocular que es relativamente común en poblaciones naturales de anuros (Meteyer, 2000; Peloso, 2016; Silva-Soares & Mônico, 2017; Cortés-Suárez, 2018). La malformación se reconoce por la ausencia de uno o los dos globos oculares, dejando una depresión de la órbita vacía cubierta por piel (Ganesh & Arumugam, 2015; Henle et al., 2017). La ausencia del órgano visual es altamente perjudicial y puede poner en peligro la supervivencia, ya que el órgano faltante impacta negativamente en la percepción espacial (por ejemplo, orientación, profundidad), la evitación ante la depredación y la competencia por la comida (Ingle, 1976; Ramalho et al., 2017). La anoftalmia también puede afectar el cortejo y la territorialidad, ya que estos comportamientos pueden estar muy influenciados por la visión (Toledo et al., 2007).

Se ha informado de anoftalmia en distintas familias de ranas (Anura): Bufonidae (Rengel et al., 1994; Puky & Fodor, 2002; Rogers et al., 2006; Toledo & Ribeiro, 2009; Guerra & Aráoz, 2016; Ashaharraza & Mahapatra, 2020; Castro-Torreblanca & Blancas-Calva, 2021); Hylidae (McCallum & Trauth, 2003; Mitchell & Georgel, 2005; Ramalho et al., 2017; Sousa & Costa-Campos, 2017; Brassaloti & Bertoluci, 2018; Cortés-Suárez, 2018; Sánchez-Domene et al., 2018; Anzaldua & Goldberg, 2019); Leptodactylidae (Carezzano et al., 2016; Guerra & Aráoz, 2016; Ascoli-Morrete et al., 2019; Pedroso-Santos et al., 2020); Ranidae (Mizgireuv et al., 1984; Ouellet et al., 1997; Helgen et al., 2000; Puky & Fodor, 2002; Eaton-Poole et al., 2003; Levey et al., 2003; Schoff et al., 2003; Gibson & Bulmer, 2007; Reeves et al., 2008; Hassine et al., 2011; Paetow et al., 2011; Holer & Koleska, 2018;

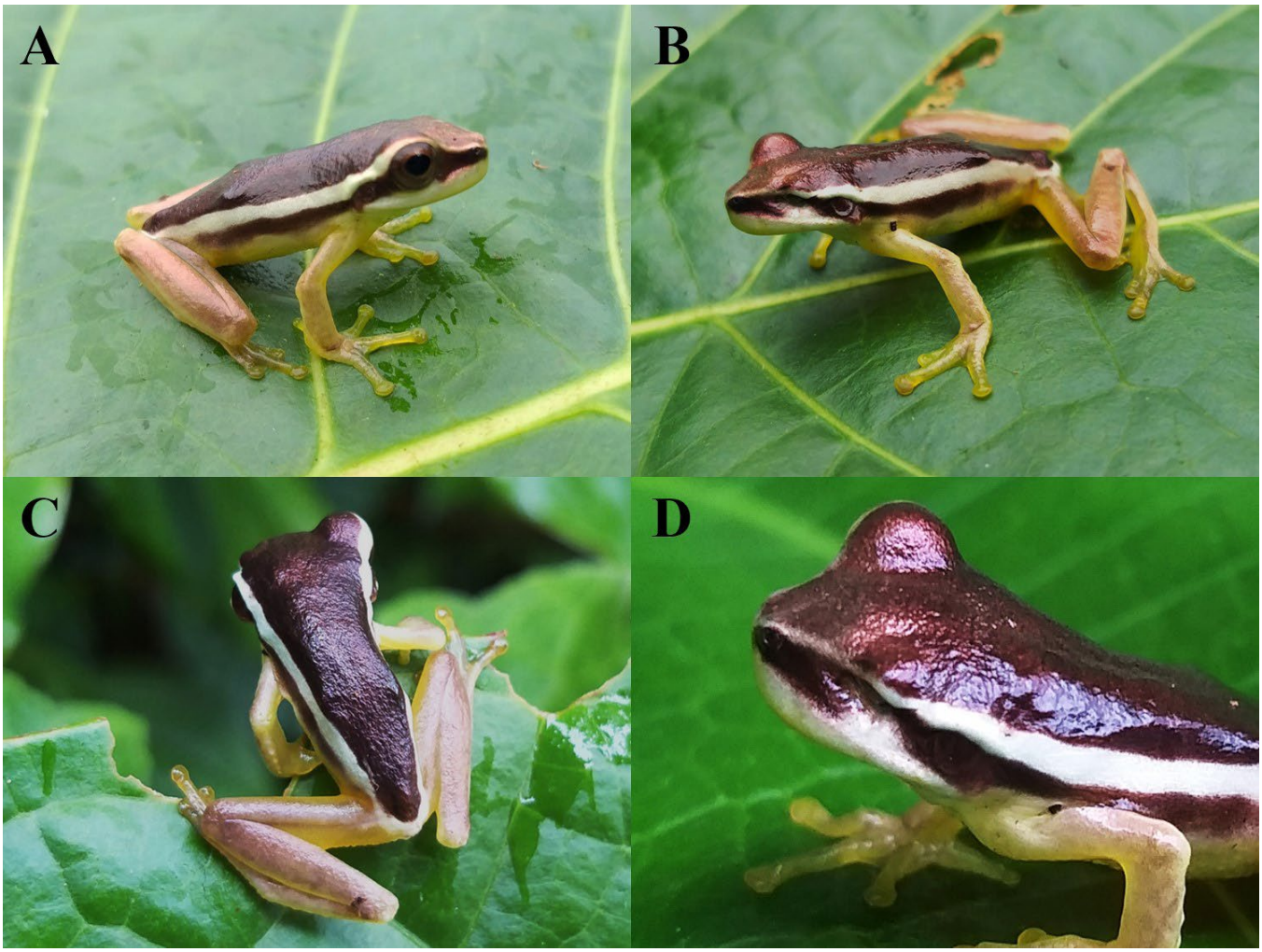

Figure 1. (A) Right lateral view showing normal eye, (B) left lateral view showing ocular abnormality, (C) dorsal view showing the comparison between both eyes, (D) and approach of the face in the adult individual of *Isthmohyla graceae* with anophthalmia in the left eye showing the continuity of the dorso lateral line to the nostrils; registered in Cerro Colorado in the Ngäbe-Buglé region, Panama.

Figura 1. (A) Vista lateral derecha mostrando el ojo normal, (B) vista lateral izquierda mostrando la anomalía ocular, (C) vista dorsal mostrando la comparación entre ambos ojos, (D) y acercamiento del rostro en el individuo adulto de *Istmohyla graceae* con anoftalmia en el ojo izquierdo mostrando la continuidad de la línea dorso lateral hasta las narinas; registrado en Cerro Colorado en la comarca Ngäbe-Buglé, Panamá.

Marushchak et al., 2019); Bombinatoridae (Puky & Fodor, 2002; Korzikov et al., 2018; Szkudlarek, 2020); Brachycephalidae (Trevine, 2011); Odontophrynidae (Brito et al., 2011; Dias & Carvalho-e-Silva, 2012; Ascoli-Morrete et al., 2019; de Souza et al. 2021); Microhylidae (Mudke et al., 2020); Dicroglossidae (Mudke et al., 2020) y Pelobatidae (Puky & Fodor, 2002; Székely & Nemes, 2003). Las causas de la anoftalmia son diversas y pueden estar relacionadas con alteraciones genéticas (Aguillón-Gutiérrez, 2018; Correia et al., 2018), enfermedades infecciosas (Aguillón-Gutiérrez et al., 2007), radiación ultravioleta (Blaustein et al., 1997; Blaustein & Johnson, 2003; Ankley et al., 2004), la endogamia (Williams et al., 2008), el parasitismo (Johnson et al., 2002; Blaustein & Johnson, 2003; Johnson & Lunde, 2005; Rajakaruna et al., 2008), metales pesados (Aguillón-Gutiérrez & Ramírez-Bautista, 2015) y plaguicidas utilizados en agricultura (Blaustein & Johnson, 2003; Ankley et al., 2004; Hayes, 2005; Hayes et al., 2006; Robles-Mendoza et al., 2009; Huang et al., 2014; Koleska & Jablonski, 2016).

Los informes publicados que describen malformaciones oculares en ranas son relativamente raros. Sin embargo, en áreas neotropicales, específicamente en la familia Hylidae, los

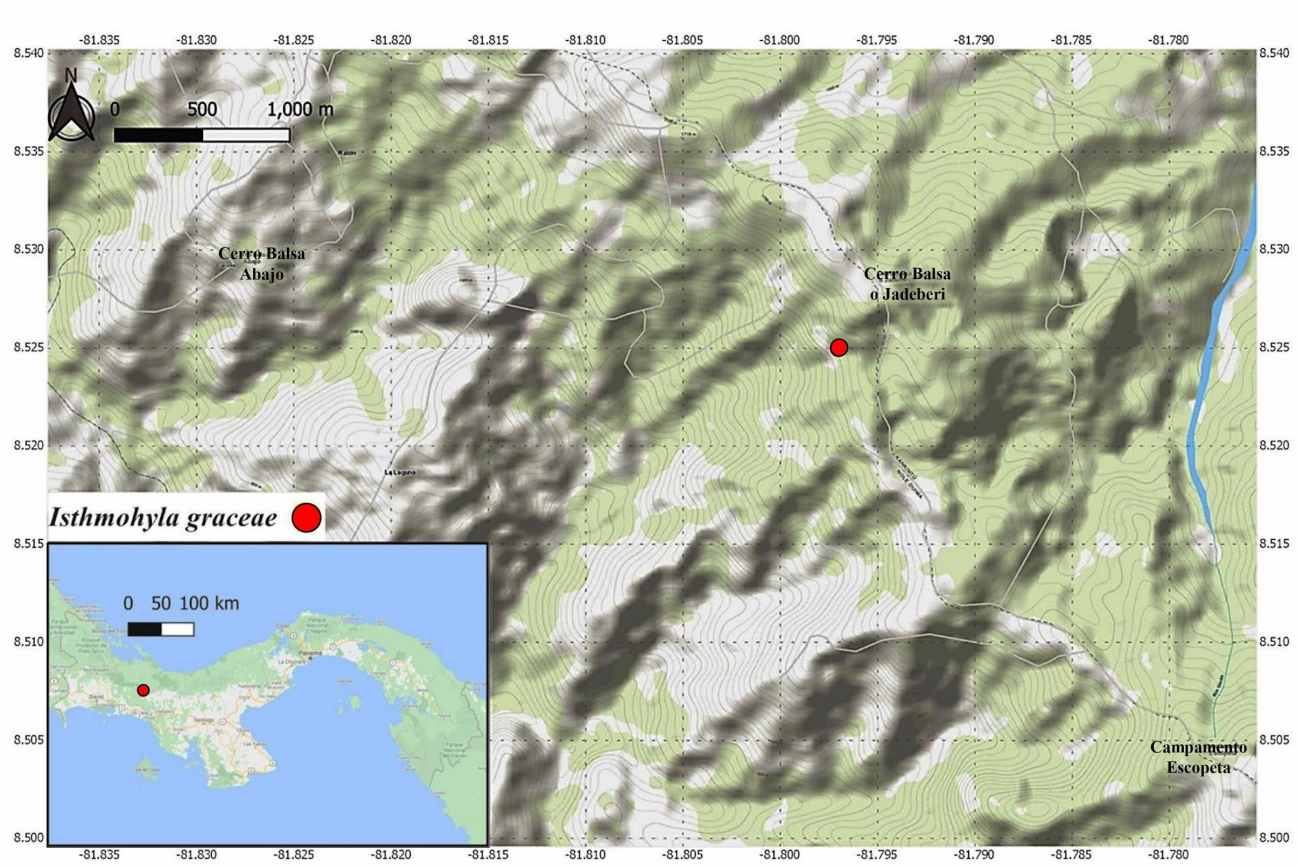

Figure 2. Site of observation of the individual of *Isthmohyla graceae* with anophthalmia in Cerro Colorado, Ngäbe-Buglé, Republic of Panama.

Figura 2. Sitio de observación del individuo de *Isthmohyla graceae* con anoftalmia en Cerro Colorado, Ngäbe-Buglé, República de Panamá.

Table 1. Representatives of the Hylidae family with the condition and type of anophthalmia present in countries of America, pointing out the case of *Isthmohyla graceae* as the first record for Panama and Central America on this ocular anomaly.

Tabla 1. Representantes de la familia Hylidae con la condición y el tipo de anoftalmia presentes en países de América, señalando el caso de *Isthmohyla graceae* como primer registro para Panamá y Centroamérica sobre esta anomalía ocular.

Especies	Etapa de vida	Tipo	Países	Referencias
Acris crepitans	?	?	USA	McCallum y Traut (2003)
Boana faber	Ad	b	Brasil	Brassaloti y Bertoluci (2018)
Dendropsophus luddeckei	Ad	u, oi	Colombia	Cortés-Suárez (2018)
Hypsiboas fasciatus	Ad	b	Brasil	Ramalho et al. (2017)
Lysapsus bolivianus	Ad	u, od	Brasil	Sousa y Costa-Campos (2017)
Osteocephalus leprieurii	Ad	b	Brasil	Ramalho et al. (2017)
Osteopilus septentrionalis	t	u, oi	USA	Anzaldua y Goldberg (2019)
Pseudacris feriarum	Ad	u, oi	USA	Mitchell y Georgel (2004)
Scinax fuscovarius	t	u, oi	Brasil	Sánchez-Domene et al. (2018)
Isthmohyla graceae	Ad	u, oi	Panamá	Este estudio

Abreviaturas: Adulto (Ad), renacuajo (t), unilateral (u), bilateral (b), ojo izquierdo (oi), ojo derecho (od), desconocido (?)

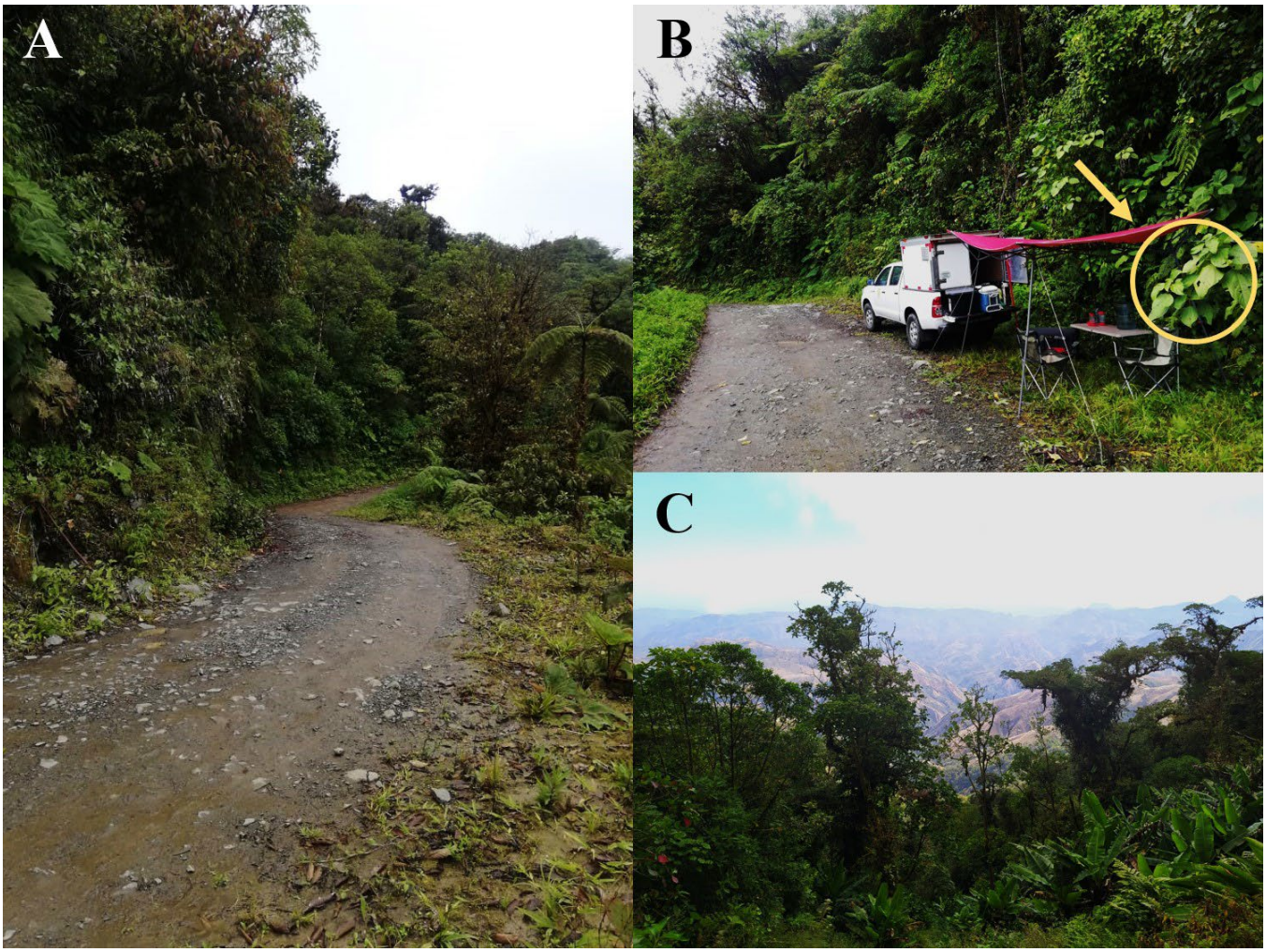

Figure 3. (A & C) view of the composition of the exact area of the forest, where the individual of I. graceae was found; (B) place in the camp where the site where the frog was located is indicated, on the side of the road to the community of Ratón in Cerro Colorado, Ngäbe-Buglé region, Panama.

Figura 3. (A & C) vista de la composición de la zona exacta del bosque, donde fue encontrado el individuo de *I. graceae;* (B) lugar del campamento donde se señala el sitio en el cual se ubicó la rana, a un costado del camino hacia la comunidad de Ratón en Cerro Colorado, Comarca Ngäbe-Buglé, Panamá.

informes son menos comunes (Tabla 1). Aquí presentamos el primer reporte de anoftalmia de ranas en Panamá. El individuo pertenece a la familia de las ranas arborícolas, Hylidae, y representa el primer caso documentado de anoftalmia en el género *Isthmohyla*. Identificamos la especie como I*sthmohyla graceae* (Myers & Duellman, 1982), basándonos en su característica de ser una especie de tamaño medio, con una franja dorsolateral pálida (blanca o amarillenta) que se extiende desde la esquina superior posterior de los ojos hasta el área sacra, distinguible de su especie hermana *Isthmohyla angustilineata*, por su línea dorsolateral más estrecha (una franja pronunciada en *I. graceae* y vientre inmaculado), esta especie es endémica de Panamá y se encuentra en peligro crítico de extinción (Myers & Duellman, 1982; IUCN, 2014).

La rana fue encontrada cerca de la localidad tipo de la especie, en Cerro Colorado, región de la comarca Ngäbe-Buglé, el 8 de marzo de 2020 a las 11:24h. JLMM, investigador de la Colección de Aves del Instituto Smithsonian de Investigaciones Tropicales (STRI), encontró solo un individuo adulto de *I. graceae*, con la ausencia de su ojo izquierdo (Fig. 1), la rana fue encontrada cerca del borde de una carretera (Figs. 2, 3) que rodea las estribaciones del Cerro Colorado (8.526° N, 81.797° W) alrededor de 1600 m s.n.m. Examinamos y fotografiamos cuidadosamente la muestra. Dado que la especie es endémica y está en peligro crítico, la rana fue liberada inmediatamente en el mismo lugar después de las observaciones.

Aunque documentar este hallazgo es de interés biológico, sólo podemos especular sobre la causa de la anoftalmia en este espécimen. Cabe señalar que el paisaje está cubierto principalmente por bosques prístinos premontanos y montanos (Fig. 3A, B), en lugar de granjas de alto impacto o asentamientos agrícolas, por lo tanto, dudamos que las poblaciones aquí estén muy expuestas a contaminantes dañinos, aunque no se puede excluir esta hipótesis. Alternativamente, la anoftalmia puede ser una malformación congénita resultante de la endogamia. Las poblaciones de Cerro Colorado son una de las pocas poblaciones conocidas de *I. graceae* que han persistido durante la introducción y diseminación del patógeno micótico *Batrachochytrium dendrobatidis*, también conocido como Bd (Hertz et al., 2012). Alguna vez se pensó que las poblaciones de la especie se distribuían a lo largo de la cordillera de Talamanca, que abarca alrededor de 15 991 km2 según ANAM (2010), pero su distribución se ha reducido considerablemente después de la introducción del hongo patógeno (Lips, 1999).

La cordillera de Talamanca representa un importante sistema de cielo-islas en Panamá, donde el endemismo es alto (Cooke, 2005) y varios taxones así como ecosistemas son vulnerables (Lotzkat, 2014; Hertz, 2015; Buitrago-Rosas et al., 2019). Por lo tanto, documentar esta especie y reportar esta malformación es importante para la conservación de los ecosistemas de las tierras altas en Panamá. Las montañas de Cerro Colorado han estado bajo presión económica debido a sus recursos de cobre (Roquebert, 2016). Si se sobreexplota, todas las poblaciones de especies de las tierras altas de la zona, especialmente la rana arborícola continental *I. graceae*, estarán en condiciones de extrema vulnerabilidad y en un estado de conservación crítico.

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REGISTROS DE *AMBYSTOMA VELASCI* (CAUDATA: AMBYSTOMATIDAE) EN AMBIENTES ANTROPIZADOS EN PACHUCA, HIDALGO, Y ALREDEDORES

RECORDS OF *AMBYSTOMA VELASCI* (CAUDATA: AMBYSTOMATIDAE) IN ANTHROPIZED ENVIRONMENTS IN PACHUCA, HIDALGO, AND SURROUNDINGS

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Abstract.– *Ambystoma velasci* is a caudate with distribution limited commonly to temperate environments of pine and oak forests, grasslands and xerophilous scrub, in water pools and streams with low temperatures. In this work we register for the first time the presence of three individuals of *A. velasci* in areas agricultural crops around the City of Pachuca and the neighboring municipality of Zempoala in Hidalgo, Mexico in anthropized environments. Which makes us suppose that this species lives in the area. These records allow us to assume that this species inhabits the area, so it is recommended to carry out monitoring of its populations and assess its risk status, in order to conserve this axolotl in anthropized environments.

Keywords.– Salamander, axolotl, records, crops, Pachuca, Zempoala.

Resumen.– *Ambystoma velasci* es un caudado con distribución limitada comúnmente a ambientes templados de bosques de pino y encino, pastizales, matorrales, en pozas de agua y arroyos con bajas temperaturas. En este trabajo registramos por primera vez la presencia de tres individuos de *A. velasci* en ambientes antropizados con cultivos agrícolas en los alrededores de la ciudad de Pachuca y en un espacio limítrofe colindante con el municipio de Zempoala en el estado de Hidalgo, México. Estos registros permiten suponer que esta especie habita en la zona, por lo que se recomienda llevar a cabo monitoreos de sus poblaciones y valorar su estado de riesgo, a fin de conservar a este ajolote en ambientes antropizados.

Palabras clave.– Salamadra, ajolote, registros, cultivos, Pachuca, Zempoala.

Ambystoma velasci Dugès, 1888, es una de las 17 especies de ambistomátidos endémicos de México (SEMARNAT, 2018), se enlista en la NOM-059-SEMARNAT-2010 como una especie en riesgo con una categoría de Protección especial (Pr; DOF, 2010) y en la Lista Roja de la UICN se considera una especie de Preocupación menor (Lc) (IUCN, 2021). Esta salamandra presenta paedomorfismo facultativo, es decir, en su forma adulta, conservan sus branquias y solo es hasta que son sexualmente maduros que llevan a cabo la metamorfosis a formas terrestres, lo que les permite hacer caminatas y desplazarse de un cuerpo de agua a otro (De la Cruz-Beltrán et al., 2017: Ávila-Akerberg et al., 2021). La especie ha sido habitualmente registrada en pozas de agua frías o arroyos (De la Cruz-Beltrán et al., 2017), también se puede encontrar en estanques, lagos, charcas y presas (Ramírez Bautista et al., 2014), en otras especies del género, solo se tienen datos de *A. mexicanum*, en cuerpos de agua en zonas urbanas, como el caso de la zona de Xochimilco y Tláhuac en la Ciudad de México (Recuero et al., 2010). Su distribución es una de las más amplias en el territorio nacional, comprende la Ciudad de México (sus zonas de bosques de pino y encino), Chihuahua, Durango, Nuevo León, Jalisco, Michoacán Colima, Querétaro, Guanajuato, San Luis Potosí, Morelos, Puebla, Estado de México, Tlaxcala e Hidalgo (Leyte-Manrique & Domínguez-Laso, 2014; Ramírez-Bautista et al., 2014; SEMARNAT, 2018; Frost, 2019). Para el estado de Hidalgo, se cuenta con registros de *A. velasci* en bosques de pino y encino en los municipios de Acaxochitlán, Mineral del Chico, Cuautepec de Hinojosa y Tepeapulco (Ramírez-Bautista et al., 2014), así como en los municipios de Actopan y San Salvador, cuya vegetación corresponde en su mayoría a pastizales y matorral xerófilo, que son característicos de las zonas áridas del estado de Hidalgo (Aguilar-Miguel, 2005; Fernández-Badillo et al., 2016) (Fig. 1). También se le ha

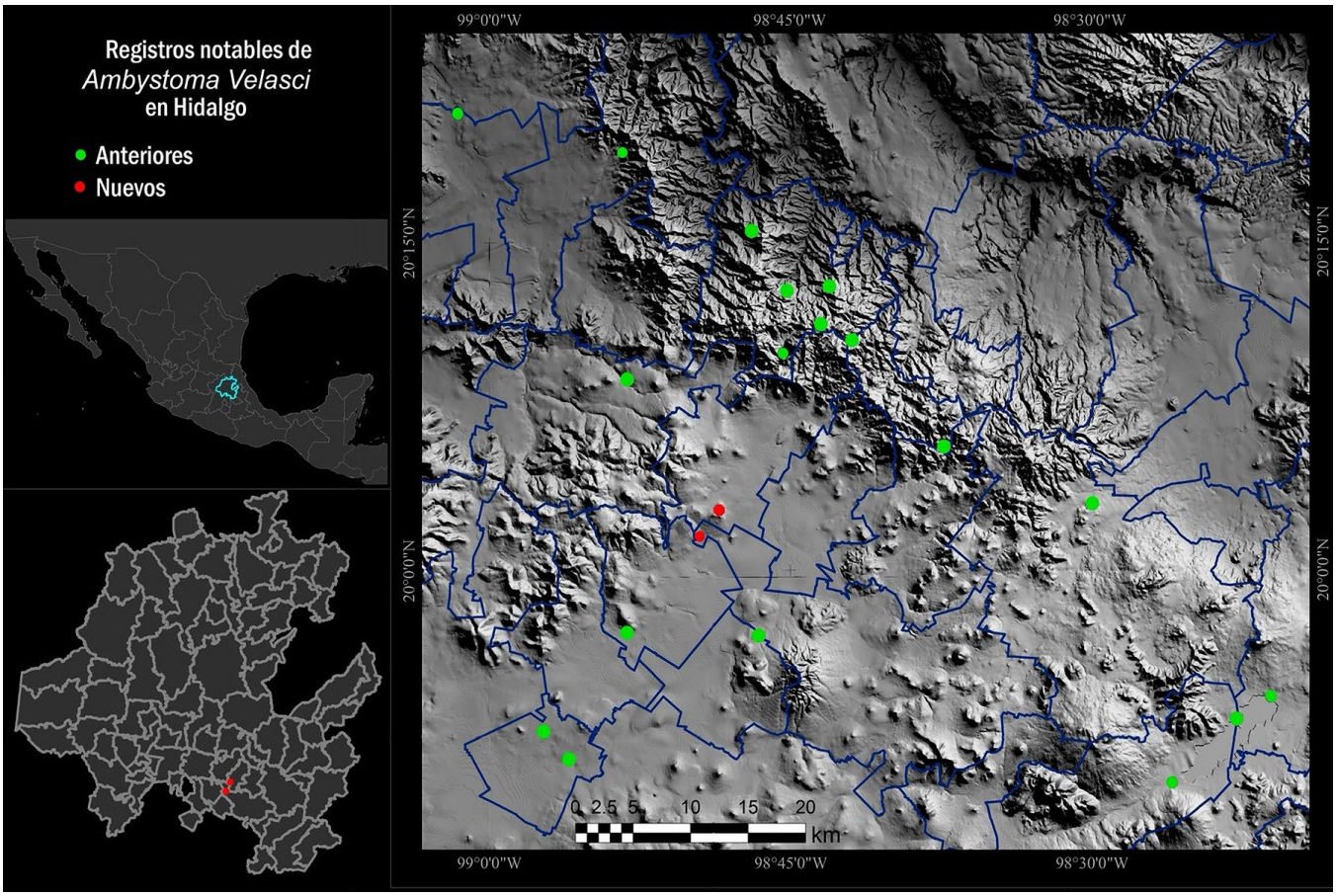

Figure 1. Records for *Ambystoma velasci* in Hidalgo, Mexico. Previous records are shown in green, and records obtained in anthropized environments in agricultural and urban crops are shown in red (this work). Note: The records in green color were taken from Lemos-Espinal and Dixon (2016) and Ramírez-Bautista et al. (2014).

Figura 1. Registros para *Ambystoma velasci* en Hidalgo, México. En color verde se muestran los registros anteriores, y en rojo, los registros obtenidos en ambientes antropizados en cultivos agrícolas y urbanos (este trabajo). Nota: Los registros en color verde, se tomaron de Lemos-Espinal y Dixon (2016), y Ramírez-Bautista et al. (2014).

registrado en los municipios de Chapantongo, Mineral del Monte, Nopala de Villagran, San Agustín Tlaxiaca, Singuilucan, Tepeji del Río de Ocampo, Tizayuca, Tlahuiltepa, Zapotlán de Juárez y Zempoala (Lemos-Espinal & Dixon, 2016).

En abril 28 de 2018, a las 22:45 horas, se registró un individuo adulto macho de *Ambystoma velasci* con una LHC (longitud hocico cloaca) de 160.2 mm (Fig. 2a) en el jardín de una casa cercana a zonas de cultivos, en un espacio colindante entre la ciudad de Pachuca y el municipio de Zempoala, Hidalgo (20° 01' 59.7" N, 98° 49' 59.7" O, WGS84; elevación: 2352 m s.n.m.). En mayo 12 de 2021, a las 18:30 horas, se observó a un ejemplar adulto macho de *A. velasci* con una LHC (longitud hocico cloaca) de aproximadamente de 162.3 mm (Fig. 2b), en una zona semiurbana con sembradíos en la zona sur de la ciudad de Pachuca (20° 02' 46.7" N, 98° 48' 31.0" O, WGS84; elevación: 2357 m s.n.m.). Ese mismo día, a las 21:40 horas, pero en el municipio de Zempoala (20° 01' 59.7" N, 98° 49' 59.7" O, WGS84; elevación: 2353 m s.n.m.), se observó desplazándose a una hembra metamórfica de 170 mm de LHC (Fig. 2c) sobre un área semiurbana de matorral xerófilo y una poza de agua entre cultivos de maíz, siendo un patrón común en los registros la presencia de lluvias en el sitio. Los tres ejemplares observados se encontraron metamorfoseados y sin branquias.

Los registros notables del ajolote *Ambystoma velasci* en los municipios de Pachuca de Soto y Zempoala, son una prueba de su alta plasticidad al registrarse en ambientes modificados, como son los cultivos agrícolas, lo que sin duda amplia el conocimiento puntal de su distribución conocida en Hidalgo, si bien se habían hecho registros anteriores en ambientes xerófilos dentro del estado (Aguilar-Miguel, 2005), no se había tenido registro de su presencia en ambientes antropizados, de manera particular en una zona semiurbana con cultivos y pozas de agua naturales adaptadas en un ambiente agropecuario, con uso de bebederos

Figure 2. *Ambystoma velasci* individuals and sites recorded in Hidalgo. a = Male with SVL = 160.2 mm; in a garden in Zempoala, b = Male with SVL = 162.3 mm; in crops outside Pachuca City, and c = Female with SVL = 170 mm; close to water pool and crops in Zempoala.

Figura 2. Sitios e individuos de *Ambystoma velasci* registrados en Hidalgo. a = Macho con una LHC = 160.2 mm; en un jardín en Zempoala, b = Macho con una LHC = 162.3 mm; en cultivos a las afueras de Pachuca, y c = Hembra con una LHC = 170 mm; cercano a poza de agua y cultivos en Zempoala.

para el ganado, agua para la población, usos cotidianos y que, además, fungen como sitios de refugio para *A. velasci* en un ambiente perturbado e insertado en la zona conurbada de la ciudad de Pachuca. Estos sitios son el único hábitat disponible para la especie en la zona, por lo que el uso regulado de estos cuerpos de agua podría asegurar la persistencia de la especie y otros taxones (Oertli, 2018). El esquema actual crítico de estos cuerpos de agua podría permitir la coexistencia de esta especie y el humano, por lo que se debe asegurar la supervivencia de esta y otras especies conservando los cuerpos de agua que son su hábitat. Mediante la planificando urbana, contemplando para ello los recursos biológicos e hídricos de la ciudad de Pachuca y sus alrededores. Dada la presencia de *Ambystoma velasci* en ambientes antropizados, es necesario y conducente la realización de monitoreos sistemáticos, que permitan conocer su estado poblacional, así como implementar acciones de

conservación local, mediante la concientización y participación de la ciudadanía, la gubernamental y comunidad científica.

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OBSERVACIONES DE DEPREDACIÓN, DIETA Y REPRODUCCIÓN DE *HOLCOSUS GAIGEAE* (SQUAMATA: TEIIDAE)

OBSERVATIONS OF PREDATION, DIET, AND REPRODUCTION OF *HOLCOSUS GAIGEAE* (SQUAMATA: TEIIDAE)

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Abstract.— *Holcosus gaigeae* is a small-sized lizard with a moderately robust body that has restricted distribution to the Mexican portion of the Yucatan Peninsula. The information about the ecology and natural history is limited. In this work, we report observations of predation, diet, and reproduction of *H. gaigeae* in different portions of the states of Campeche and Yucatan, in Mexico, providing new information about the ecological aspects of this species.

Keywords.— Breeding season, endemic species, Lycosidae, natural history.

Resumen.— *Holcosus gaigeae* es una lagartija de tamaño pequeño y cuerpo moderadamente robusto que tiene una distribución restringida a la porción Mexicana de la Península de Yucatán. La información existente acerca de su ecología e historia natural es limitada. En este escrito se presentan observaciones de depredación, dieta y reproducción de *H. gaigeae* en diferentes porciones de los estados de Yucatán y Campeche, en México, las cuales aportan nueva información acerca de los aspectos ecológicos de esta especie.

Palabras clave.— Especie endémica, historia natural, Lycosidae, temporada reproductiva.

El complejo de especies *Holcosus undulatus* es un grupo de lagartijas que se distribuye desde Nayarit, en la vertiente del Pacífico, y Tamaulipas, por la vertiente del Golfo de México, pasando por la Península de Yucatán, hasta Costa Rica (Lee, 1996). Este complejo fue recientemente evaluado por Meza-Lázaro y Nieto-Montes de Oca (2015), en donde varios taxones se elevaron a especie, incluyendo a *Holcosus gaigeae*, la cual es una lagartija diurna de tamaño pequeño y cuerpo moderadamente robusto, con una distribución restringida a la porción mexicana de la Península de Yucatán (González-Sánchez et al., 2017).

Al igual que el resto de las especies del complejo *H. undulatus*, se considera que *H. gaigeae* es de hábitos insectívoros, alimentándose de invertebrados que encuentra entre la hojarasca, y es una especie ovípara que deposita alrededor de 5 huevos durante el verano y otoño (Lee, 1996). En relación con su depredación, se ha observado que los principales depredadores del género *Holcosus* son las serpientes, lagartijas (género *Xenosaurus*), anfibios (género *Dermophis*) y aves de presa diurnas (*Buteo spp*; Avalos-Vela et al., 2020; Nahuat-Cervera et al., 2020).

Debido a que *H. gaigeae* recientemente se elevó a especie, no hay mucha información biológica y ecológica enfocada a este taxón, sino que la información existente es una extrapolación de la que se tiene para el complejo *H. undulatus*. En este escrito se reportan observaciones ocasionales de depredación, dieta y reproducción de *H. gaigeae* en diferentes zonas de la Península de Yucatán, México.

Observaciones de depredación

El 11 de marzo de 2020 a las 21:50 hrs, durante una caminata nocturna en el sendero interpretativo del campamento ecoturístico "Ya'ax Che", en la Reserva de la Biósfera de Calakmul, Campeche, México (18°29'35" N, 89°53'45" O, WGS 84, 176 m

Figure 1. Predation of juvenile *Holcosus gaigeae* by a spider of the Lycosidae family. Photo: Pedro E. Nahuat-Cervera.
Figura 1. Depredación de juvenil de *Holcosus gaigeae* por una araña de la familia Lycosidae. Foto: Pedro E. Nahuat-Cervera.

s.n.m.) rodeado por vegetación de selva mediana subcaducifolia, se observó un ejemplar juvenil de *Holcosus gaigeae* depredado por una araña de la familia Lycosidae (posible género *Lycosa*). Al momento de la observación, el arácnido tenía apresado con sus quelíceros a la lagartija, la cual ya se encontraba muerta (Fig. 1).

Otro registro de depredación se realizó el 16 de noviembre de 2020 a las 14:05 horas, en un complejo residencial rodeado por vegetación secundaria y parches de selva baja caducifolia, al norte de la ciudad de Mérida, Yucatán, México (21°07'12" N, 89°40'52" O, WGS 84, 08 m s.n.m.). Se encontró un ejemplar de *H. gaigeae,* hembra (LHC: 114 mm, LT: 339 mm) que había sido depredada por un gato doméstico (*Felis silvestris catus*). Al momento de la observación, el felino tenía capturado el cuerpo de la lagartija; sin embargo, al percatarse de nuestra presencia, este huyó abandonando su presa.

Con anterioridad, algunas especies de serpientes de la familia Colubridae (*Lampropeltis abnorma, Oxybelis fulgidus*), Dipsadidae (*Conophis lineatus*) y Elapidae (*Micrurus apiatus*) habían sido reportadas como depredadoras de *H. gaigeae* (Greene, 1973; Gómez-de Regil & Escalante-Pasos, 2017; Smith et al., 2018; Carbajal-Márquez et al., 2019), por lo cual, estos reportes representan los primeros registros publicados de depredación de *H. gaigeae* por un arácnido de la familia Lycosidae y por un gato doméstico.

Observación de dieta

El cuerpo del ejemplar adulto de *H. gaigeae* que fue depredado por el gato se examinó, y al realizar una incisión ventral, en el contenido estomacal se identificaron cuatro presas, de las cuales tres fueron arañas del género *Pardosa* (Familia Lycosidae; Fig. 2a) con una longitud total de cuerpo promedio de 14 mm [12 - 15 mm], mientras que el individuo restante fue una ninfa de odonato (Fig. 2b), con una longitud total de 25 mm.

Las lagartijas del género *Holcosus* forrajean activamente durante el día, buscando a sus presas en diferentes microhábitats terrestres (e.g., la hojarasca en el suelo de la selva; Lee, 1996). Las arañas del género *Pardosa* habitan sobre el sustrato y son abundantes en el estado de Yucatán (Pinkus-Rendón, 2010; Arana-Gamboa et al., 2014), por lo que se considera que pueden constituir una presa común para esta lagartija. En relación con la ninfa de odonato, las inundaciones provocadas por los ciclones tropicales (Cristóbal, Gamma, Delta y Zeta) que impactaron la Península de Yucatán durante el año 2020 repercutieron

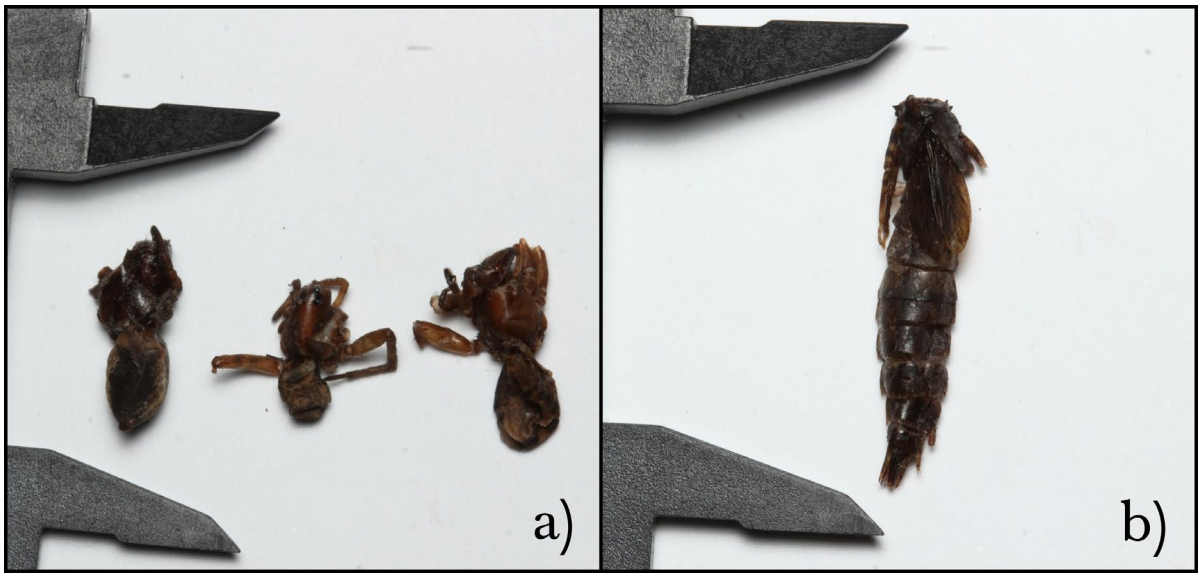

Figure 2. Invertebrate remains removed from the stomach of an adult female Holcosus gaigeae; a) spiders of the genus Pardosa, b) odonate nymph. Photo: Pedro E. Nahuat-Cervera.

Figura 2. Restos de invertebrados retirados del estómago de un ejemplar hembra adulta de *Holcosus gaigeae*; a) arañas del género *Pardosa*, b) ninfa de odonato. Foto: Pedro E. Nahuat Cervera.

en la formación de cuerpos de agua temporales que fueron aprovechados por la fauna nativa. Se especula que esto favoreció la interación entre *H. gaigeae* y la ninfa de odonato. Así mismo, esta observación representa el primer registro publicado de la depredación de esta especie.

Observación de reproducción

Durante la incisión ventral del ejemplar hembra anteriormente mencionado, se encontraron dos huevos oviductales, los cuales tenían una longitud de 11.5 mm y 9.5 mm de largo por 7.5 mm y 6.5 mm de ancho, respectivamente (Fig. 3). Aunado a esta observación, el 01 de febrero de 2016 a las 14:00 h se observó un

Figure 3. Oviductal eggs found during the ventral incision of the corpse of the female *Holcosus gaigeae*. Photo: Luis Roberto Pérez-Martínez.

Figura 3. Huevos oviductales encontrados durante la incisión ventral al cadáver del ejemplar hembra de *Holcosus gaigeae*. Foto: Luis Roberto Pérez-Martínez.

Figure 4. Juvenile specimens of *Holcosus gaigeae*. a) specimen observed in the archaeological zone of Uxmal, Yucatán, during the month of February, b) specimen observed in the archaeological zone of Xcambó, Yucatán, during the month of March. Photo: Pedro E. Nahuat-Cervera.

Figura 4. Ejemplares juveniles de *Holcosus gaigeae*. a) ejemplar observado en la zona arqueológica de Uxmal, Yucatán, durante el mes de febrero, b) ejemplar observado en la zona arqueológica de Xcambó, Yucatán, durante el mes de marzo. Fotografías por Pedro E. Nahuat Cervera.

ejemplar juvenil de *H. gaigeae* (longitud total aprox. 120 mm; Fig. 4a) sobre una construcción maya de la zona arqueológica Uxmal, en Yucatán, México (20°21'39" N, 89°46'15" O, WGS 84, 60 m s.n.m.); así mismo, el 03 de marzo de 2016 a las 11:45 h, en la zona arqueológica de Xcambó, Yucatán (21°18'48" N, 89°21'14" O, WGS 84, 07 m s.n.m.), se observó otro ejemplar juvenil de una longitud similar al ejemplar observado en la zona arqueológica de Uxmal (Fig. 4b).

El conocimiento de la reproducción de *H. gaigae* se basa en la colecta de ejemplares grávidos en Campeche y Yucatán, durante los meses de junio y julio, donde se determinó que la temporada reproductiva de esta especie es durante el verano y otoño, depositando entre 2 y 7 huevos (Gaige, 1936; Fitch, 1970; Lee, 1996). Sin embargo, en otras especies del género *Holcosus*, como *H. festivus*, se tiene registro de ejemplares juveniles durante los primeros meses del año (Duellman, 1963), por lo que se considera que su reproducción también puede ocurrir en los meses de noviembre y diciembre (Lee, 1996).

Las observaciones de reproducción aquí reportadas concuerdan con lo previamente observado acerca de la producción mínima de huevos de *H. gaigeae*, y tanto la presencia de huevos oviductales en noviembre, como los ejemplares juveniles observados en febrero y marzo indican que *H. gaigeae* también se reproduce durante los meses cercanos al principio y fin de año.

Holcosus gaigeae es una especie común en la Península de Yucatán, sin embargo, el conocimiento que existe en torno a esta especie es limitado. Las observaciones aquí presentadas aportan valiosa información sobre la ecología y la historia natural de *H. gaigeae*, señalando el primer registro de depredación por parte de un invertebrado, así como observaciones sobre su dieta y reproducción.

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NUEVO REGISTRO DE DEPREDADOR PARA LA LAGARTIJA DE ÁRBOL DE NARIZ NEGRA, *SCELOPORUS MELANORHINUS* (PHRYNOSOMATIDAE)

NEW PREDATOR RECORD FOR THE BLACKNOSE TREE LIZARD, *SCELOPORUS MELANORHINUS* (PHRYNOSOMATIDAE)

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Abstract.— We report for the first time the lizard *Sceloporus melanorhinus* as part of the *Pitangus sulphuratus* diet in Oaxaca, Mexico.

Keywords.— Bird, diet, Mexico, reptile.

Resumen.— Reportamos por primera vez a la lagartija *Sceloporus melanorhinus* como parte de la dieta de *Pitangus sulphuratus* en Oaxaca, México.

Palabras clave.— Ave, dieta, México, reptil.

La lagartija *Sceloporus melanorhinus* (Bocourt, 1876), es una especie diurna arborícola asociada a bosques secos tropicales, semicaducifolios y bosques de pino, localizados en altitudes entre el nivel del mar y los 2000 m, con distribución en México y Guatemala (Köhler, 2008). Los registros sobre sus depredadores son escasos, ya que solo se conoce a las culebras de cabeza surcada *Manolepis putnami* (Jan, 1893) (Ramírez-Bautista, 1994) y bejuquilla parda *Oxybelis aeneus* (Wagler, 1824) (López-De la Cruz et al., 2016), así como al zanate mexicano *Quiscalus mexicanus* (Gmeli, 1788) (Cupul-Magaña et al., 2018). En esta nota documentamos por primera vez al tiránido luis bienteveo *Pitangus sulphuratus* (Linnaeus, 1766), distribuida desde el sur de los Estados Unidos de América hasta la parte central de Argentina (Meyer de Schauensee, 1966; Howell & Webb, 1995)

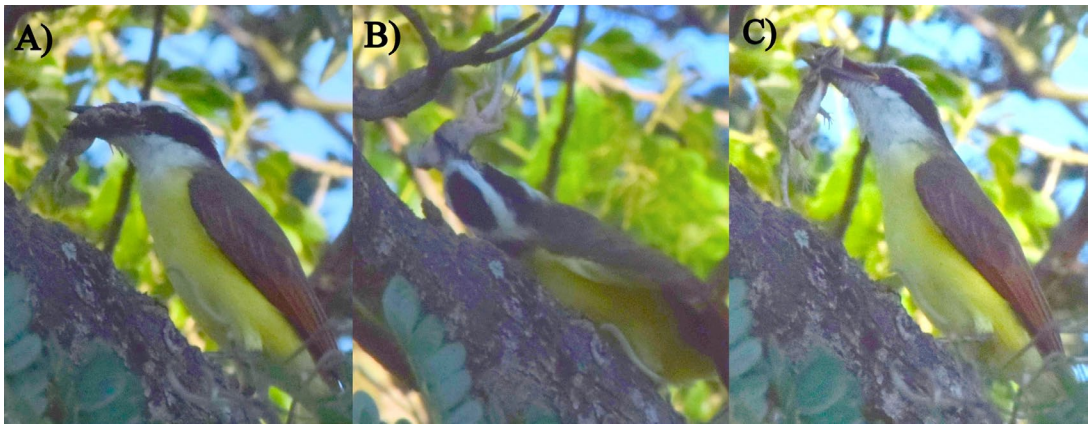

Figure 1. *Pitangus sulphuratus* feeding on *Sceloporus melanorhinus* in Oaxaca, Mexico. A) Catch, B) Hit against the tree branch, C) Catch by the head after throwing it into the air. Photo: Luis Francisco Nieto-Toscano.

Figura 1. *Pitangus sulphuratus* alimentándose de *Sceloporus melanorhinus* en Oaxaca, México. A) Captura, B) Golpeo contra la rama del árbol, C) captura por la cabeza después de lanzarla al aire. Foto: Luis Francisco Nieto-Toscano.

y cuya dieta incluye pequeños vertebrados e invertebrados, así como frutas y flores (Argel-de-Oliveira et al., 1998; Latino & Beltzer, 1999; Gabriel & Pizo, 2005; Fischer et al., 2010), como depredador de *S. melanorhinus*.

El 4 de diciembre de 2020 a las 17:40 h en la localidad conocida como Rancho El Santo, municipio de Santiago Pinotepa Nacional, Oaxaca, México (16.370555° N, 98.175833° W; WGS 84; elev. 202 m s.n.m.) observamos y fotografiamos un ejemplar adulto de sexo no determinado de luis bienteveo durante el proceso de depredación de un juvenil de *S. melanorhinus*. El luis bienteveo fue identificado por presentar una cabeza grande, alas y cola rojizas, y partes inferiores amarillas (Hilty & Brown, 1986) y *S. melanorhinus* por presentar barras oscuras a lo largo del hocico y la parte superior de la cabeza (Smith, 1939). El ave con su presa en el pico, estaba posada sobre la rama de un árbol a aproximadamente 5 m sobre el suelo. El luis bienteveo atrapó con su pico a la lagartija por la parte media del cuerpo. Posteriormente, la golpeó repetidamente contra las ramas. Con la lagartija muerta, pues no se observaba movimiento alguno, el ave la dispuso en su pico para tragarla. La maniobra observada para lograrlo, consistió en lanzarla al aire y atraparla con la cabeza dirigida hacia la cavidad oral para engullirla completamente (Fig. 1). El tiempo transcurrido en el proceso fue de cerca de un minuto.

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NOTEWORTHY RECORDS OF FRESHWATER TURTLES IN OAXACA, MEXICO

REGISTROS DESTACADOS DE TORTUGAS DE AGUA DULCE EN OAXACA, MÉXICO

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Resumen.— Las tortugas dulceacuícolas representan un grupo diverso de reptiles en México, con la diversidad más alta distribuida principalmente en los estados tropicales del sur. Desafortunadamente, el conocimiento sobre su ecología, conducta, importancia cultural, distribución geográfica verificable es todavía insuficiente; esto dificulta los análisis espaciales, que ayudan a generar una serie de planes de conservación para su protección efectiva, contra los riesgos de extinción. Aquí proporcionamos registros adicionales, a los ya conocidos, de cuatro especies amenazadas de tortugas dulceacuícolas en el estado de Oaxaca. Estos registros no solo expanden el rango de distribución, sino que también proporcionan información adicional sobre el hábitat, y posibles amenazas ambientales. Cabe resaltar que el registro de *Chelydra rossignonii* confirma su presencia en la cuenca del Río Papaloapan; y los registros de *Dermatemys mawii* y *Claudius angustatus* se consideran entre los primeros para el estado. Adicionalmente, proporcionamos otra localidad para *Staurotypus triporcatus* en Oaxaca.

Palabras clave.— *Chelydra rossignonii, Claudius angustatus, Dermatemys mawii, Staurotypus triporcatus.*

Abstract.— Freshwater turtles represent a diverse group of reptiles in Mexico, with the highest diversity being distributed mostly in the southern tropical states. Unfortunately, knowledge regarding their ecology, behavior, cultural importance, and reliable geographic distribution is still scarce; consequently, preventing in-depth spatial analyses that aim to provide a set of conservation plans that effectively shield them from high risks of extinction. Herein, we provide additional geographic records for four endangered species of freshwater turtles in the state of Oaxaca. These records not only expand their distribution range, but also provide information on habitat, and possible environmental threats. Importantly, the record of *Chelydra rossignonii* confirms its presence in the Papaloapan river basin; and the records of *Dermatemys mawii* and *Claudius angustatus* are among the first for the state. Furthermore, we provide an additional locality for *Staurotypus triporcatus* in Oaxaca.

Keywords.— *Chelydra rossignonii, Claudius angustatus, Dermatemys mawii, Staurotypus triporcatus.*

Mexico is the second richest country with respect to freshwater turtles (van Dijk et al., 2014; Macip-Ríos et al., 2015). However, knowledge on ecology, natural history, and geographic distribution is still incipient for most species (Macip-Ríos et al., 2015). Unfortunately, this group of vertebrates currently faces a set of serious environmental threats, such as habitat loss and overexploitation. Consequently, this has resulted in 64% of these species to be categorized as threatened by the Mexican government (SEMARNAT, 2019), 60% included in the IUCN red list (IUCN, 2021), and on average 30% of these species are considered with high environmental vulnerability by the EVS system (Wilson et al., 2013; Macip-Ríos et al., 2015).

Currently, 15 species of freshwater turtles are known to occur in the state of Oaxaca (Mata-Silva et al., 2015). Of those, the distribution of *Chelydra rossignonii, Dermatemys mawii, Staurotypus triporcatus*, and *Claudius angustatus* still remain poorly known (Mata-Silva et al., 2015). For instance, before 2015 the presence of *C. rossignonii* was still uncertain. To this respect, Ramírez-González and Canseco-Márquez (2015) commented on

Figura 1. *Chelydra rossignonii* de la Laguna Aparicio, Santa Teresa, municipio de San Juan Bautista Tuxtepec (UTEPObs: Herp: 197).

Figure 1. *Chelydra rossignonii* from Laguna Aparicio, Santa Teresa, municipality of San Juan Bautista Tuxtepec (UTEPObs: Herp: 197).

a record provided by Pérez-Higareda (1978) that was regarded as dubious by Legler and Vogt (2013). This individual was collected in Laguna La Campana, 7 km west of Valle Nacional, and transported and kept at the "Estación de Biología Tropical de Los Tuxtlas, Veracruz". Then, Ramírez-González and Canseco-Márquez (2015) provided photographic evidence of *C. rossignonii* in semi evergreen tropical forest in the municipality of Santa María Guienagati, in the southeastern extreme of the Sierra Madre de Oaxaca physiographic region (Mata-Silva et al., 2015).

Presently, the distribution of *Dermatemys mawii* in the state falls in the Planicie Costera del Golfo (Gadow, 1905; Iverson, 1992) and presumably in the Sierra Madre de Chiapas (USNM 66666-69, 67732) physiographic regions (Mata-Silva et al., 2015); and *Staurotypus triporcatus* is distributed in the Planicie Costera del Golfo and Depresión Istmica de Tehuantepec physiographic regions (Mata-Silva et al., 2015), with more distribution records than the former. Lastly, *Claudius angustatus* is known to occur in the Planicie Costera del Golfo, Depresión Istmica de Tehuantepec, and Sierra Madre de Chiapas physiographic regions (Mata-Silva et al., 2015).

Reliable knowledge on species geographic distribution and especially on those regarded as endangered is among

Figura 2. *Chelydra rossignonii* de Escolapa (= Escuilapa), municipio de Santa María Chimalapa (UTEPObs: Herp: 198).
Figure 2. *Chelydra rossignonii* from Escolapa (= Escuilapa), municipality of Santa María Chimalapa (UTEPObs: Herp: 198).

the first valuable tools for the design and eventual execution of conservation plans. With that in mind, our purpose of this contribution is to document the presence of freshwater turtles in the state of Oaxaca. As it has been demonstrated, geographic records improve the modeling and interpretation of actual distributions of species (Berriozabal-Islas et al., 2020). Furthermore, these records also augment information concerning ecology, behavior, and potential threats, among others. Photo vouchers were deposited in The University of Texas at El Paso (UTEP) Biodiversity Collections (UTEPObs: Herp).

Chelydra rossignonii. On 19 August 2011, JAR-S photographed an individual (Fig.1; UTEPObs: Herp: 197) in Laguna Aparicio, Ejido de Santa Teresa, municipality of San Juan Bautista Tuxtepec (18.12504° N, 96.10552° W, 22 m a.s.l.; Fig. 7a). The length of the plastral forelobe of this species usually is less than 40% of carapace length, and the dorsal surface of the neck is covered with pointed tubercles (Gibbons et al., 1988). After being photographed, the specimen was left undisturbed at the original site. The locality is surrounded by plantain (*Musa paradisiaca*), and grazing fields (*Brachiaria spp*.). The area includes many permanent water bodies that are fed by the Papaloapan River when overflowing events occur. According to several local villagers, this species is captured in the region using fishing line with chicken guts as bait.

Then, on 13 December 2017, another individual (juvenile; Fig. 2; UTEPObs: Herp: 198) was photographed by EGP at a household in the village of Escolapa (= Escuilapa), municipality of Santa María Chimalapa (16.8500° N, 94.76638° W, 314 m a.s.l.; Fig. 7a), in the Sierra Madre de Chiapas physiographic region. According to the house owner, this individual, which was kept as a pet, was found at a small river named Escolapa. The vegetation at the site is represented by a mix of medium evergreen forest and riparian vegetation.

Claudius angustatus. On 24 December 2020, JAR-S found an individual of *Claudius angustatus* (Fig. 3; UTEPObs: Herp:

Figura 3. *Claudius angustatus* de los alrededores de Chichizapa, municipio de San Miguel Soyaltepec (UTEPObs: Herp: 199).

Figure 3. *Claudius angustatus* from near Chichizapa, municipality of San Miguel Soyaltepec (UTEPObs: Herp: 199).

199) crossing the state road La Granja–Temascal, near Ejido Chichizapa, municipality of San Miguel Soyaltepec (18.29123° N, 96.35205° W, 50 m a.s.l.; Fig. 7b). This site is surrounded by sugarcane fields. It is worth mentioning that the day before this observation took place, some sugarcane fields had been burned for subsequent cutting and harvesting. The turtle was immediately removed from the road, and then released in a pond near the reported locality but away from the sugarcane fields.

Dermatemys mawii. On 13 December 2017, EGP photographed a shell of *Dermatemys mawii* (Fig. 4; UTEPObs: Herp: 200) at a household in the village of Escolapa (= Escuilapa), municipality of Santa María Chimalapa (16.8500° N, 94.76638° W, 314 m a.s.l.; Fig. 7c), in the Sierra Madre de Chiapas physiographic region. This individual was found at Río El Corte, a tributary of Río Coatzacoalcos. The vegetation at the collecting site is represented by tropical evergreen forest. According to the house owner this turtle is consumed in the region.

Figura 4. *Dermatemys mawii* del Río El Corte y fotografiado en Escolapa (= Escuilapa), municipio de Santa María Chimalapa (UTEPObs: Herp: 200).

Figure 4. *Dermatemys mawii* from Río El Corte and photographed in Escolapa (= Escuilapa), municipality of Santa María Chimalapa (UTEPObs: Herp: 200).

Figura 5. *Dermatemys mawii* del Arroyo Sal, Santa Ursula, municipio de San Juan Bautista Tuxtepec (UTEPObs: Herp: 201).

Figure 5. *Dermatemys mawii* del Arroyo Sal, Santa Ursula, municipality of San Juan Bautista Tuxtepec (UTEPObs: Herp: 201).

Figura 6. *Staurotypus triporcatus* de la Laguna del Diablo, municipio de San Juan Bautista Tuxtepec (UTEPObs: Herp: 202).

Figure 6. *Staurotypus triporcatus* from Laguna del Diablo, municipality of San Juan Bautista Tuxtepec (UTEPObs: Herp: 202).

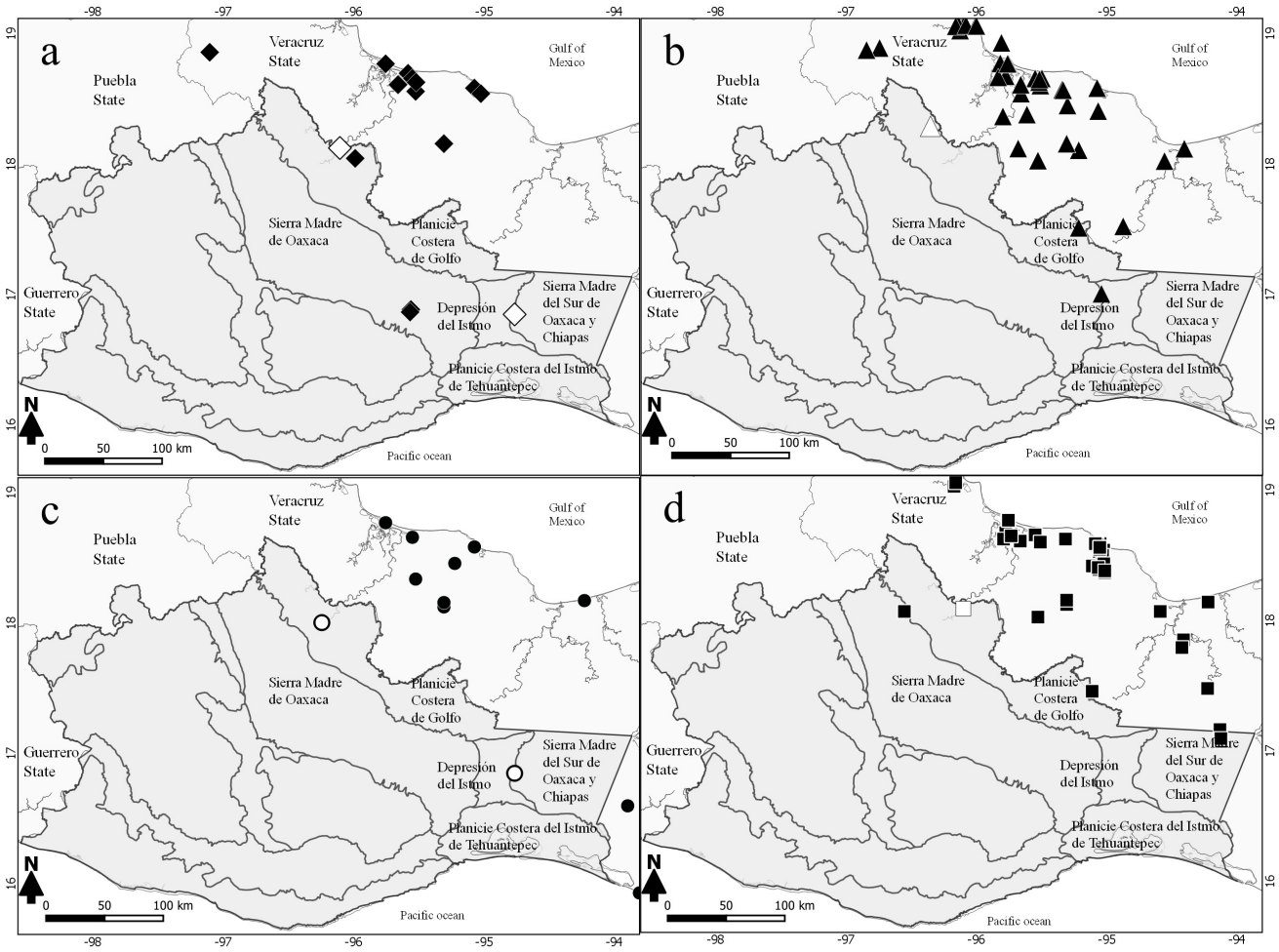

Figura 7. Registros de tortugas de agua dulce en el sur de México. a) *Chelydra rossignonii*. Los diamantes negros representan los registros conocidos (GBIF 2020), el diamante gris representa el registro de Ramírez-González and Canseco-Marques (2015), y los diamantes blancos representan los nuevos registros. b) *Claudius angustatus*. Los triángulos negros representan los registros conocidos (GBIF 2020), y los triángulos blancos los nuevos registros. c) *Dermatemys mawii*. Los puntos negros representan registros conocidos (GBIF 2020a); y los puntos blancos representan los nuevos registros. d) *Staurotypus triporcatus*. Los cuadros negros representan los registros conocidos (GBIF 2020), y los cuadros blancos los nuevos registros.

Figure 7. Records of freshwater turtles in southern Mexico. a) *Chelydra rossignonii* in southern Mexico. Black diamonds represent known records (GBIF 2020), gray diamond represents the record by Ramírez-González and Canseco-Marques (2015), and the white diamonds the new records. b) *Claudius angustatus* in southern Mexico. Black triangles represent known records (GBIF 2020), and white triangle the new record. c) *Dermatemys mawii*. Black dots represent known records (GBIF 2020); and white dots represents the new records. d) *Staurotypus triporcatus* in southern Mexico. Black squares represent known records (GBIF 2020), and white square the new record.

A second individual of *Dermatemys mawii* (Fig. 5; UTEPObs: Herp: 201) photographed by JAR-S was randomly captured on 1 September 2019 by a local villager using a fish net in Arroyo Sal, in the vicinity of Santa Úrsula, municipality of San Juan Bautista Tuxtepec (18.00469° N, 96.24397° W, 32 m a.s.l.; Fig. 7c). The specimen had been kept alive for eventual consumption. Arroyo Santa Ursula is presently embedded in fields with sugarcane. The arboreal vegetation along this creek is dominated mostly by *Pachira aquatica*, *Guazuma ulmifolia*, *Ochroma pyramidale*, and *Ceiba pentandra*. According to the collector, this species used to be relatively common in the area, but currently individuals are rarely seen.

Staurotypus triporcatus. On 28 February 2011, JAR-S photographed an individual of this species (Fig. 6; UTEPObs: Herp: 202) near Laguna del Diablo, municipality of San Juan Bautista Tuxtepec (18. 09332° N, 96.09995° W, 27 m a.s.l.; 7d). This site contains remnants of evergreen high forest dominated by arboreal species such as *Schizolobium parahyba*, *Bursera simaruba*, *Attalea butyracea*, and *Ceiba pentandra*.

These records increase our knowledge regarding the current geographic distribution of four species of turtles for the state of Oaxaca, Mexico. We add two important records for *Chelydra rossignonii* to those already reported by Pérez-Higareda (1978), and Ramírez-González and Canseco-Márquez (2015). We also identified three more records of this species in Global Biodiversity Information Facility (GBIF, 2020a), with two of them reported in 2017 at a locality approximately 30 km west of that reported by Ramírez-González and Canseco-Márquez (2015), (Fig. 7a). The third record is from an arroyo that feeds the Yosocuta reservoir in the Mixteca region. Given the characteristics of the known habitat and elevation range of *C. rossignonii*, we do not think this locality is part of its natural distribution.

Field observations indicate that fishing of freshwater turtles, at least for *Dermatemys mawii* and *Chelydra rossignonii*, is still a relatively common practice by local communities in northern Oaxaca. Even though it seems that turtles have been resilient to the significant agricultural activities in the region, their populations are likely being affected by all kinds of waste that end up in the Papalopan River. For instance, in Arroyo Sal, Santa Úrsula, where *Dermatemys mawii* was recorded, we observed a significant loss of native vegetation cover and habitat pollution. Furthermore, serious threats to the site increased temporarily in 2008, when a hydroelectric power plant was planned to be built; however, this project did not prosper as the local communities strongly opposed this construction citing lack of consultation and violation of their land rights.

As noted earlier, currently freshwater turtles face numerous environmental threats, and consequently are regarded as a group with high extinction risk (Macip-Ríos et al., 2015). Among the species reported herein, the conservation status for *Chelydra rossignonii* has not been determined by the Mexican environmental laws (SEMARNAT, 2019), and this is likely in part because until recently this species was considered a subspecies of *C. serpentina*, which is considered as under Special Protection (Sujeta a Protección Especial). On the other hand, the IUCN red list places this species in the category of Vulnerable due to the development of urban settlements and hunting (van Dijk et al., 2007). More recently, using the EVS system, *C. rossignonni*i was determined to be a species with high environmental vulnerability (EVS = 17; Wilson et al., 2013).

Dermatemys mawii is known to be facing serious conservation problems, so that is listed as a high risk by national and international conservation assessment systems. Currently, it is classified as Endangered (En Peligro) by SEMARNAT (2019), as Critically Endangered by IUCN, it is included in appendix II of CITES (https://checklist.cites.org), and considered with high environmental vulnerability (EVS = 17) by the EVS system (Wilson et al., 2013). This large turtle is primarily threatened by activities such as agriculture, aquaculture, fishing, hunting, and habitat pollution (Vogt et al., 2006).

Regarding *Staurotypus triporcatus*, this species is listed as Threatened (Amenazada) and *Claudius angustatus* is listed as Threatened (En Peligro) (SEMARNAT, 2019). Both of these species are listed as Nearly Threatened by IUCN, with scarce information on their threats (Tortoise and Freshwater Turtle Specialist Group 1996a, 1996b). Furthermore, these two species are considered with high environmental vulnerability (EVS = 14) by Wilson et al. (2013).

Given the current situation of these species on their viability, their exploitation is only allowed with limited and required permits; thereof, the information provided herein is vital for the effective assessment of their populations and the steps that need to be taken to ensure their presence.

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NEW RECORDS OF THE INTRODUCED SNAKE *INDOTYPHLOPS BRAMINUS* (SQUAMATA: TYPHLOPIDAE) IN THE STATE OF VERACRUZ, MEXICO.

NUEVOS REGISTROS DE LA SERPIENTE INTRODUCIDA *INDOTYPHLOPS BRAMINUS* (SQUAMATA: TYPHLOPIDAE) EN EL ESTADO DE VERACRUZ, MÉXICO.

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Resumen.— *Indotyphlops braminus* es una serpiente introducida en el territorio mexicano la cual ha sido registrada en diferentes estados de la república. En el estado de Veracruz anteriormente se ha reportado en tres municipios. Nuestras observaciones aportan cuatro nuevos registros para la distribución de *I. braminus* en Veracruz.

Palabras clave.— Culebrilla ciega, especie introducida, distribución, biogeografía, Veracruz.

Abstract.— *Indotyphlops braminus* is a snake introduced into Mexican territory; it can be found in different republic states. In Veracruz, it has previously been reported from three municipalities. Our observations in the present note provide four new records for the distribution of *I. braminus* in Veracruz.

Keywords.— Brahminy blind snake, introduced species, distribution, biogeography, Veracruz.

Indotyphlops braminus (Daudin, 1803) is a snake species native to the Indo-Malayan region (Broadley & Wallach, 2009; Wallach, 2009; Hedges et al., 2014). All individuals of this species are female, and it is obligatorily parthenogenic (Ota et al., 1991). Although it is considered a species of low vagility and limited dispersal capacity (Mateo, 2013), it may be the most widely distributed snake globally (Bamford & Prendergast, 2017; Uezt et al., 2021) due to its ability to survive in flower pots and small containers used for growing plants as well as its ability to reproduce.

In Mexico it has been reported from the states of Aguascalientes, Baja California Sur, Campeche, Chiapas, Chihuahua, Durango, Guanajuato, Guerrero, Hidalgo, Jalisco, Morelos, Michoacán, Nayarit, Nuevo León, Oaxaca, Puebla, Querétaro, Quintana Roo, Sinaloa, Sonora, Tamaulipas, Veracruz, Yucatán and Zacatecas (Álvarez-Romero et al., 2008; Wallach, 2020; Uetz et al., 2021). Recently, González-Sánchez et al. (2021) provided a map of distribution of *I. braminus* in México and briefly discussed its range, nevertheless, does not provide precise locations or information on specimens. We consider only locations with verified vouchers deposited in collections (see Clause et al., 2016). For Veracruz, it has been reported formally from the municipalities of Xalapa (Guzmán-Guzmán & Aranda, 2016; Castañeda-Ortega & Guzmán-Guzmán, 2020), Coatepec (Aguilar-López & Estrada-Contreras, 2021), and Veracruz (Mendoza et al., 1993).

In the present contribution, we report four new municipal records for I. *braminus* from the state of Veracruz (Table 1). These records are the result of casual observations rather than formal surveys for the species. We deposited either a specimen voucher

Figura 1. Individuos de *Indotyphlops braminus* de Veracruz, México. A) Municipio de Amatlán de los Reyes. B) Municipio de Alvarado. C) Municipio de Cosamaloapan. D) Municipio de Fortín de las Flores. Foto por EMPG (A), AFM (B), VVC (C, D).

Figure 1. Individuals of *Indotyphlops braminus* from Veracruz, Mexico. A) Municipality of Amatlán de los Reyes. B) Municipality of Alvarado. C) Municipality of Cosamaloapan. D) Municipality of Fortín de las Flores. Photo by EMPG (A), AFM (B), VVC (C, D).

Table 1. Previous and current records of the distribution of *Indotyphlops braminus* in Veracruz, Mexico.

Tabla 1. Registros previos y actuales de la distribución de *Indotyphlops braminus* en Veracruz, México.

Municipality	Locality	Georeference	Voucher/Reference
Alvarado	Colonia Los Aguacates	18.77747° N, 95.769° W	LACM PC 2704/ this work
Coatepec	Coatepec	19.45217° N, 96.9697° W	CARIE 1293/ Aguilar-López and Estrada-Contreras, 2021
Cosamaloapan	Gabino Barreda	18.18987° N, 96.09536° W	ITSZ-R- 261; LACM PC 2705/ this work
Fortín de las Flores	Old railway station	18.90169° N, 97.0001° W	ITSZ-R- 262/ LACM PC 2706/ this work
Amatlán de los Reyes	Venta Parada	18.8528° N, 96.8469° W	LACM PC 2703/ this work
Veracruz	Playa Macambo	19.20889° N, 96.11889°W	MZFC 05480 / Mendoza et al., 1993
Xalapa	"5 de Febrero" cemetery (Xalapa old municipal cemetery)	19.5342° N, 96.91777° W	UV 0899, UV 0900, UV 0901/ Guzmán-Guzmán and Aranda, 2016; Castañeda-Ortega and Guzmán-Guzmán, 2020
Xalapa	Calle Betancourt	19.53204° N, 96.92677° W	UV 0920 / Castañeda-Ortega and Guzmán-Guzmán, 2020
Xalapa	Avenida Manuel Ávila Camacho	19.52862° N, 96.92899° W	UV 0935 / Castañeda-Ortega and Guzmán-Guzmán, 2020
Xalapa	Calle General Adalberto Tejeda	19.529712° N, 96.912170° W	UV 0902 / Castañeda-Ortega and Guzmán-Guzmán, 2020

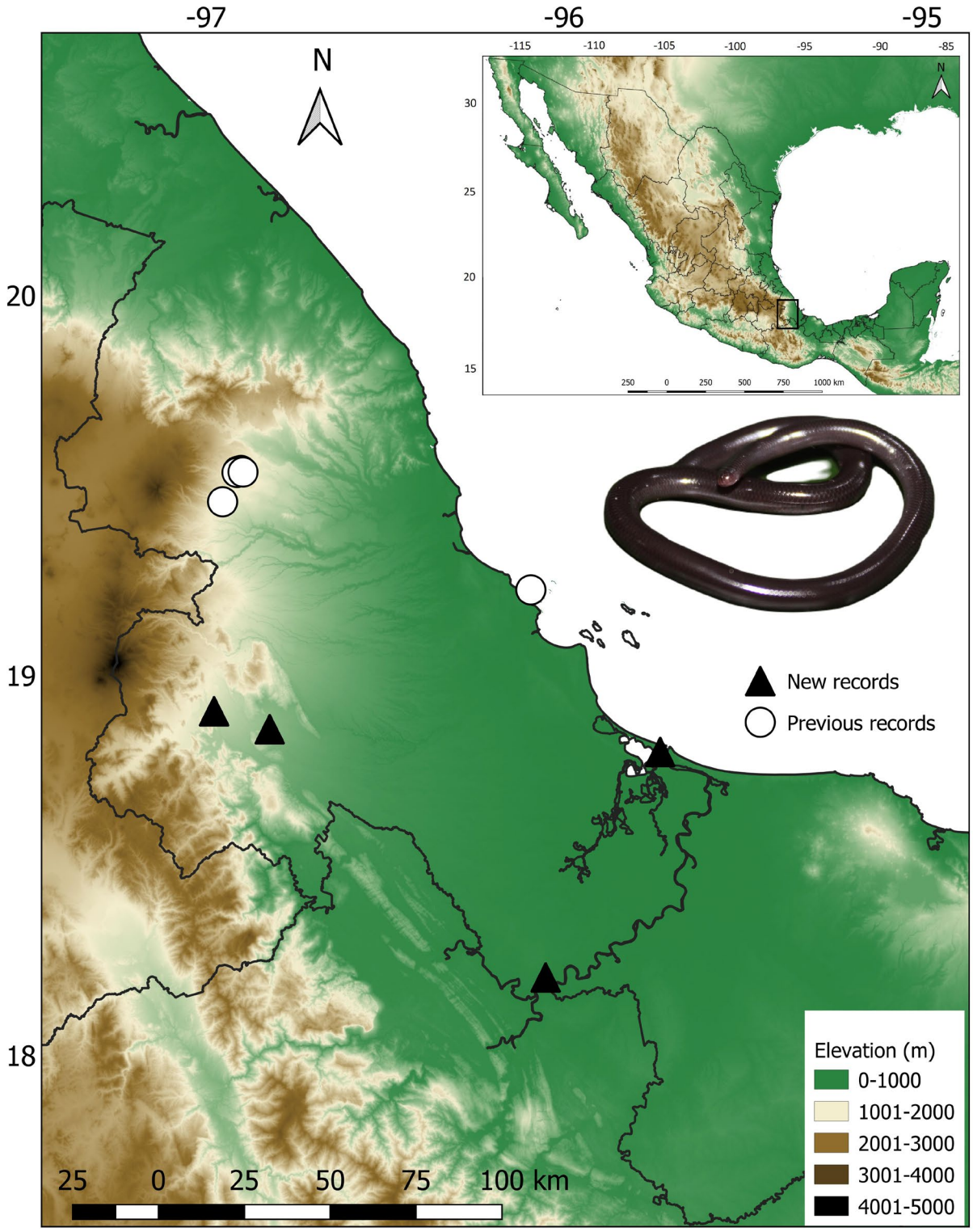

Figura 2. Mapa de distribución de *Indotyphlops braminus* en los estados de Veracruz, México. Registros con vouchers en museos.

Figure 2. Distribution map of *Indotyphlops braminus* in the state of Veracruz, Mexico. Reports with museum voucher.

at the herpetological collection of the Instituto Tecnológico Superior de Zongolica (ITSZ-R), or a digital photographic voucher at the Natural History Museum of Los Angeles County (LACM PC). We identified *I. braminus* based on two diagnostic characters: ocular scale separated from lip by supralabial, and 20 scale rows around the body (Canseco-Márquez & Gutierrez-Mayén, 2010; Heimes, 2016).

On 9 September 2019, at 18:40h, we observed an individual (LACM PC 2703; Fig. 1A) on the federal highway Córdoba-Boca del Río, at Venta Parada, municipality of Amatlán de los Reyes (18.8528° N, 96.8469° W, WGS 84; elev. 605 m a.s.l.). This record is located at 68 km S (airline distance) from the closest previously reported locality in the municipality of Coatepec (Colección de Anfibios y Reptiles del Instituto de Ecología A. C.; CARIE 1293; Aguilar-López & Estrada-Contreras, 2021).

On 18 June 2020, at 12:30h, we observed an individual (LACM PC 2704; Fig. 1B) in the garden at the Aguacates neighborhood of municipality of Alvarado (18.77747° N, 95.769° W, WGS 84, elev. 35 m a.s.l.). On 30 June 2020, around 13:30h, we observed a second individual at the same locality. This record is located at 60 km SW (airline distance) from the closest previously reported locality Playa Mocambo, municipality of Veracruz (Museo de Zoologia, Facultad de Ciencias, Universidad Nacional Autonoma de Mexico; MZFC 05480; Mendoza et al., 1993).

On 19 November 2020, at approximately 12:00h, we observed an individual (SVL=132 mm; TL= 4 mm) at Gabino Barreda in the municipality of Cosamaloapan de Carpio (18.1898° N, 96.0953° W, WGS 84, elev. 40 m a.s.l.) in a nursery of ornamental plants. This record (LACM PC 2705; ITSZ-R- 261; Fig. 1C) is 111 km S (airline distance) from the closest previously reported from Playa Mocambo, municipality of Veracruz (MZFC 05480; Mendoza et al., 1993).

On 12 February 2021 around 22:00, we observed an individual (LACM PC 2706; Fig. 1D) near the old railway station in Fortín de las Flores, municipality of Fortín de las Flores (18.901686°N, 97.0001°W, WGS 84, elev. 1010 m) under a concrete slab. Additionally, other individual (SVL=122 mm; TL=3 mm) was collected at the same site on 14 May of 2021 (ITSZ-R- 262). This record is 62 km S (airline distance) from the closest previous report in the municipality of Coatepec (CARIE, 1293; Aguilar-López & Estrada-Contreras, 2021).

Based on the records with the most certain of georeference, we consider the distribution of *Indotyphlops braminus* has been documented formality from 10 localities in seven municipalities in the state of Veracruz (Table 1; Fig. 2). These new records are found to the west and south the state of Veracruz. Although we were only able to observe one or two individuals in the localities, the reproductive characteristics of *I. braminus* allows a single individual can to establish a new population (Vitt & Caldwell, 2014). It should be noted that *I. braminus* had not been previously considered in the region known as "Las Altas Montañas" in the center-west of the state of Veracruz, despite the studies on its distribution in Mexico (Wallach, 2020; González- Sánchez et al., 2021) and the recent studies on the diversity of amphibians and reptiles in this region (e.g. Almaráz-Vidal & Cerón, 2016).

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ACCIDENTAL DEATH OF AMAZON TURTLE *PODOCNEMIS EXPANSA* (TESTUDINATA: PELOMEDUSIDAE) DURING SPAWNING ON THE CRIXÁS-AÇÚ RIVER IN GOIÁS, BRAZIL

MUERTE ACCIDENTAL DE TORTUGA AMAZÓNICA *PODOCNEMIS EXPANSA* (TESTUDINATA: PELOMEDUSIDAE) DURANTE EL DESOVE EN EL RÍO CRIXÁS-AÇÚ EN GOIÁS, BRASIL

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Resumen.— Presentamos un evento importante aún no reportado de muerte accidental de *Podocnemis expansa* por enterramiento causado por otras hembras anidantes durante el desove, que parece estar relacionado con la competencia por los sitios de anidación. Este evento posiblemente ocurrió durante la noche anterior, durante el pico de desove en esta playa, con aproximadamente 1.500 posturas, muchas de ellas superpuestas. Se descartó cualquier evento depredador, ya que, las tortugas estaban intactas, sin marcaje y enterradas, lo cual es inusual. En general, estas tortugas eligen los lugares más altos en las playas, aumentando las posibilidades de supervivencia de las crías debido a la estacionalidad (crecidas y estiajes) de los ríos, con la anidación en el río Crixás-Açu durante la estación seca. Sin embargo, este es el primer reporte de muerte accidental de tortugas por otros cambios durante el período reproductivo que puede ayudar a comprender mejor los procesos detrás de la competencia por los nidos en las playas de desove.

Palabras clave.— Anidamiento, cuenca Tocantins-Araguaia, enterramiento, monitoreo.

Abstract.— We present an important event not yet reported of accidental death by burying *Podocnemis expansa* by grounding caused by other breending females. This event possibly occurred during the previous night, during the spawning peak activity on this beach with approximately 1,500 spawns, many of them overlapping. Any predatory event was not considered, as the turtles were intact, unmarked and buried, which is unusual. In general, they choose higher places on the beaches, increasing the chances of survival of the young due to the seasonality (high and low flows) of the rivers, with the nesting on the Crixás-Açu River during the dry season. However, this is the first report of accidental death of turtles by other changes during the reproductive period and can help to better understand the processes behind the competition for nests on spawning beaches.

Keywords.— Ground, monitoring, nesting, Tocantins-Araguaia basin.

The Amazon turtle *Podocnemis expansa* is the largest species of the genus and inhabits large rivers, flooded forests, and lakes in the largest tributaries of the Orinoco, Essequibo, and Amazon River drainages in Colombia, Venezuela, Guyana, French Guiana, Suriname, northeastern Peru, eastern Ecuador, northern Bolivia, and northern and central-western Brazil (Vogt, 2008; Ferrara et al., 2017; Uetz, 2021). It is considered one of the most endangered species in the Amazon due to excessive egg collection and predatory hunting (Peres, 2000; Forero-Medina et al., 2019) and categorized as, "Near Threatened" (NT) in the

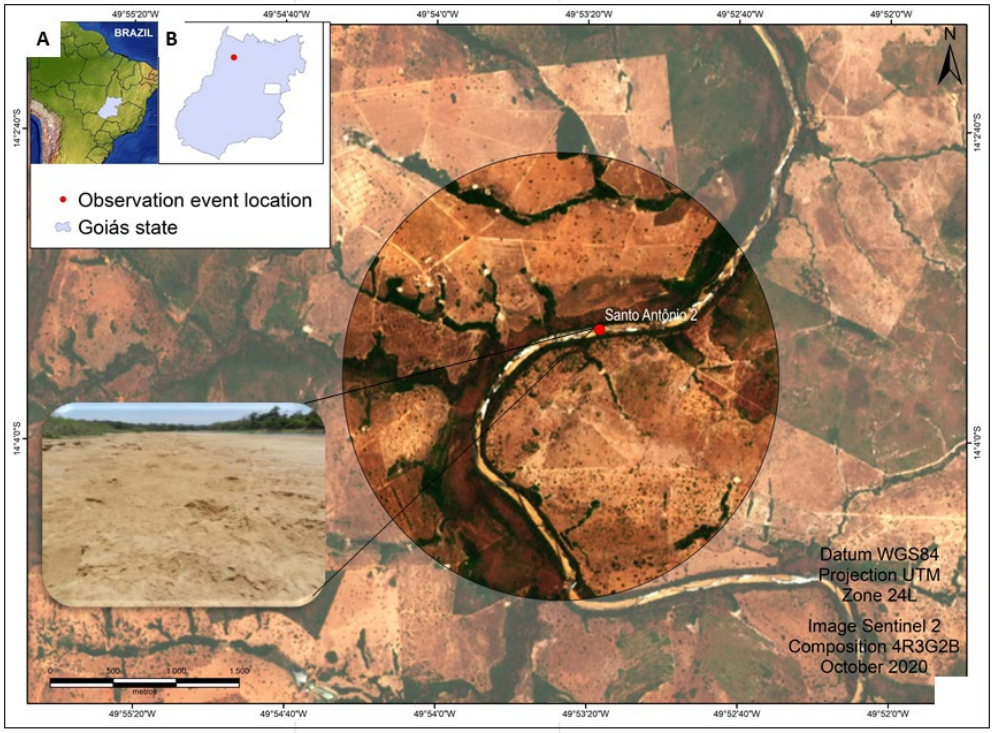

Figura 1. Ubicación geográfica del área de estudio en (A) Brasil; (B) Estado de Goiás y sitio de observación (C). Destacado en la parte inferior izquierda, el lugar con múltiples nidos de *P. expansa* donde ocurrió el evento. Elaboración: Maurivan Vaz Ribeiro.

Figure 1. Geographic location of the study area in (A) Brazil; (B) Goiás state, and the observation site (C). Highlighted in the lower left, the place with multiple nests of *P. expansa* where the event occurred. Elaboration: Maurivan Vaz Ribeiro.

Brazilian Red List (Brasil, 2014; ICMBIO, 2018; IBAMA, 2019) and as Lower Risk: Conservation Dependent (LR/cd) on IUCN Red List (Group of Experts on Turtles and Freshwater, 1996). However, the recommendation of the Turtle Taxonomy Working Group (2017) to change the category to Critically Endangered and it appears in Appendix II of CITES (CITES, 2019).

The specie has a collective spawn (Vanzolini, 1967; Alho & Pádua, 1982; Pantoja-Lima et al., 2009; Segundo et al., 2015) during the dry season, when the river flow is lower (Vogt, 2008). This behavior can cause competition for nesting sites, since this species prefers higher places (Rueda-Almonacid et al., 2007), coarse and closer to vegetation sand (Vogt, 2008), which seems to have relationship with the growth rate of the offspring (Pantoja-Lima et al., 2009). An unclear fact is the impact of this density on the loss of nests by excavation by other specimens (Pantoja-Lima et al., 2009).

Here, we present an important event not yet reported of accidental death by burying of *Podocnemis expansa* by other females during spawning, which seems to be related to the competition for nesting sites. Our observation event took place on October 5, 2018 at 10:28 h (videos available at https://figshare.com/s/dd4b3aba0257b86a262d) on the Crixás-Açu River, in Goiás, Brazil (Fig. 1). At the time, two females of *Podocnemis expansa* were buried and killed (Fig. 2A) at the spawning site (beach Santo Antônio 2, GPS coordinates 13°26.608' S 50°32.633' O). This event possibly occurred during the previous night, during the spawning peak activity on this beach with approximately 1,500 spawns, many of them overlapping. Any predatory event was discarded, as the turtles were intact, unmarked and buried, which is unusual. The aggregate pattern known for a species (Pantoja-Lima et al., 2009) and high nest density (Segundo et al., 2015) may have caused individuals to accidentally turn around, since in many cases, one individual literally stands on top of the other during the spawning event, when they compete for the same nesting site and the burial occurs during the stage of closing the nest by another female (Fig. 2B).

Choosing a nesting site can guarantee a suitable incubation environment, improve the young's chances of success, maximize their safety and modify the offspring phenotype (Refsnider

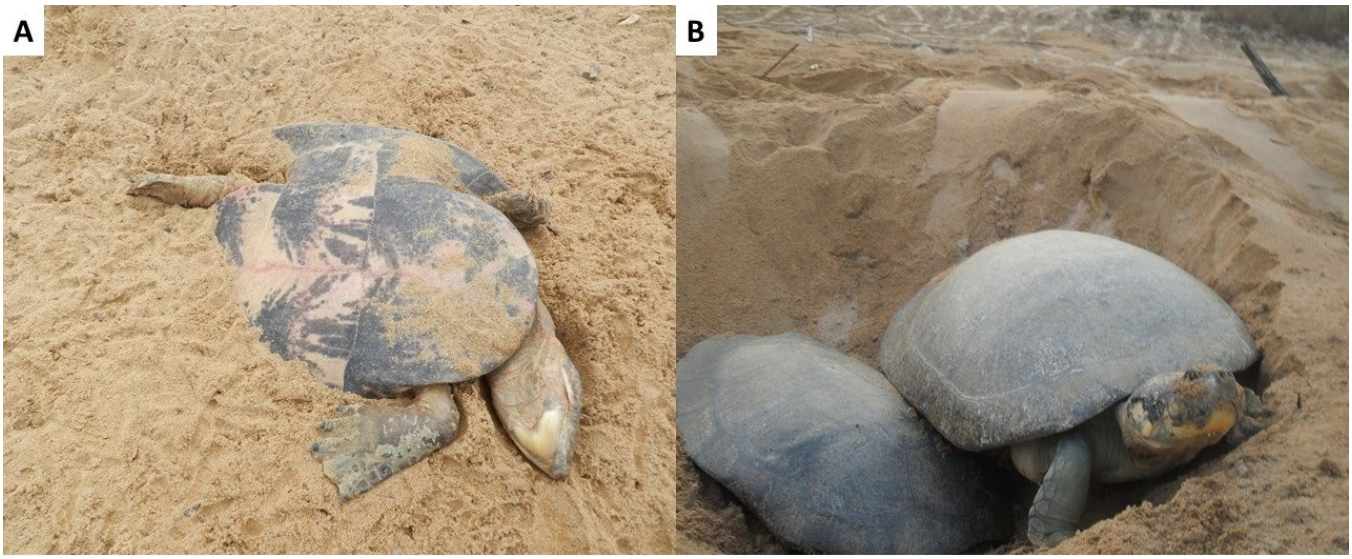

Figura 2. (A) Hembra encontrada accidentalmente rechazada y asesinada por otra hembra, (B) Competencia por el mismo sitio de anidación. Fotos: (A) Maurivan Vaz Ribeiro y (B) Instituto Brasileño de Medio Ambiente y Recursos Naturales Renovables - IBAMA

Figure 2. (A) Female individual found accidentally turned down and killed by another female, (B) Competition for the same nesting site. Photos: (A) Maurivan Vaz Ribeiro and (B) Brazilian Institute of the Environment and Renewable Natural Resources – IBAMA.

& Jansen, 2010) and, therefore, competing for ideal sites may seem advantageous. In general, they choose higher places on the beaches (Pantoja-Lima et al., 2009; Segundo et al., 2015), increasing the chances of survival of the young due to the seasonality (high and low flows) of the rivers, with the nesting on the Crixás-Açu River during the dry season (Bataus, 1998). However, this is the first report of accidental death of turtles by other changes during the reproductive period and can help to better understand the processes behind the competition for nests on spawning beaches.

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LEPIDOPHYMA RADULA (SQUAMATA: XANTUSIDAE)

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Editor: Oscar A. Flores-Villela, México.

México: Oaxaca: Municipality of San José del Progreso: 2.3km S of San José del Progreso, near Mirador La Peña (16.660738° N; 96.678834° W; WGS 84), 1910 m elev. 13 March 2019; Iván T. Ahumada-Carrillo and Edén Ángeles Castro. Verified by Luis Canseco Márquez. A photo voucher of the individual was deposited in The University of Texas at Arlington Digital Collection (UTADC-9712). This record (Fig. 1) extends the distribution 47 km SW from Mitla and 70 km WNW from San Isidro Manteca (Flores-Villela et al., 2001). The lizard was found *Lepidophyma radula* (UTADC-9712) under rocks in tropical deciduous forest-oak woodland ecotone.

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Figura 1. *Lepidophyma radula* (UTADC-9712). Municipio de San José del Progreso: cerca del Mirador la Peña. Foto: Iván T. Ahumada-Carrillo.
Figure 1. *Lepidophyma radula* (UTADC-9712). Municipality of San José del Progreso: near Mirador la Peña. Photo: Iván T. Ahumada-Carrillo.

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EXERODONTA SMARAGDINA (ANURA: HYLIDAE)

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Editor: Ireri Suazo-Ortuño, México.

Mexico: Jalisco: Municipality of Zapopan: 2km NW of Hacienda Monticello (20.913573° N; 103.442107° W; WGS 84), 1500 m a.s.l. elev., 22 August 2017; Iván T. Ahumada-Carrillo and Salvador Siordia. Verified by Christoph I. Grünwald. A photo voucher of the individual of *Exerodonta smaragdina* was deposited in The University of Texas at Arlington Digital Collection (UTADC-9527). This record (Fig. 1) extends the distribution 92 km NE from 21 km WSW of Ameca (Duellman, 2001). The frog was found amongst rocks in an intermittent stream in a tropical deciduous forest-oak woodland ecotone.

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Figura 1. *Exerodonta smaragdina* (UTADC-9527). Municipio de Zapopan: 2km NW de Hacienda Monticello. Foto: Iván T. Ahumada-Carrillo.
Figure 1. *Exerodonta smaragdina* (UTADC-9527). Municipality of Zapopan: 2km NW of Hacienda Monticello. Photo: Iván T. Ahumada-Carrillo.

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HYALINOBATRACHIUM VIRIDISSIMUM (CENTROLENIDAE)

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México: Veracruz: Rafael Delgado: San Juan del Río (18.822359° N, 97.066216° W; WGS84; 1200 m s.n.m). 10 de junio de 2021. Encontramos un individuo macho adulto de la especie *Hyalinobatrachium viridissimum* (longitud hocico-cloaca = 2.49 cm) posado sobre una herbácea a 1.5 metros del suelo en la orilla de un arroyo (Fig. 1). Este registro ocurrió en un paisaje del Río Matzinga formado por bosque ripario dominado por hayas (*Platanus mexicana*), bosque de niebla, cultivos agrícolas, pastizales ganaderos y asentamientos humanos. El individuo representa el primer registro de la especie para el municipio de Rafael Delgado, Veracruz, ubicado en la región nahua de la Sierra de Zongolica. Recientemente, un individuo de la especie fue registrado en la localidad colindante de Rincón Grande, perteneciente al municipio de Ixtaczoquitlán (Peralta-Hernández, 2019). La identificación de la especie se realizó a partir de las descripciones de Taylor (1942) y Mendoza-Henao et al. (2020). La corroboración de la identificación y el sexo del individuo la realizó Adriana Sandoval-Comte. Se depositaron dos fotografías del ejemplar en la colección digital del Natural History Museum of Los Angeles, California (LACM PC-2785 y 2876).

Agradecimientos.– A Neftalí Camacho por el registro de las fotografías en la colección digital del Natural History Museum

Figure 1. (A) Adult male of *Hyalinobatrachium viridissimum* observed in the municipality of Rafael Delgado, Veracruz. (B) Bottom view of the observed *H. viridissimum male.* Photo: Jorge Ramos-Luna (LACM PC-2785 y 2876).

Figura 1.(A) Macho adulto de *Hyalinobatrachium viridissimum* observado en el municipio de Rafael Delgado, Veracruz. (B) Vista inferior del individuo macho de *H. viridissimum.* Foto: Jorge Ramos-Luna (LACM PC-2785 y 2876).

of Los Angeles. A Adriana Sandoval Comte por la corroboración en la identificación del ejemplar.

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GEOPHIS LORANCAI (SQUAMATA: DIPSADIDAE) EN EL CENTRO DE VERACRUZ

GEOPHIS LORANCAI (SQUAMATA: DIPSADIDAE) IN THE CENTER OF VERACRUZ

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La Culebra Minera de Zongolica, *Geophis lorancai* fue descrita recientemente (Canseco-Márquez et al., 2016); es una serpiente endémica de México, habita en el bosque mesófilo de montaña y sitios de ecotono asociación con bosque de pino-encino. Se ha registrado en el estado de Puebla en el municipio de Chichiquila; en Veracruz en los municipios de Los Reyes, Zongolica (Canseco-Márquez et al., 2016), Mixtla de Altamirano, San Juan Texhuacan y Tequila (De La Torre-Loranca et al., 2020) y se encuentra entre los 1,210 y 1,887 m s.n.m. (Canseco-Márquez et al., 2016; De La Torre-Loranca et al., 2020).

Es de tamaño mediano (LHC: 268 mm), los adultos presentan un cuerpo robusto, la cabeza se puede distinguir bien del cuerpo, es alargada y el hocico ovalado, presenta ojos pequeños; la coloración de la cabeza hasta la 12ava escama medio-dorsal es negra, el resto del cuerpo hasta la cola presenta bandas negras sobre un color de fondo naranja o rojizo. Es una especie de hábitos fosoriales al igual que otras especies del mismo género; se le puede encontrar en microhábitats como hojarasca y bajo troncos podridos (Canseco-Márquez et al., 2016).

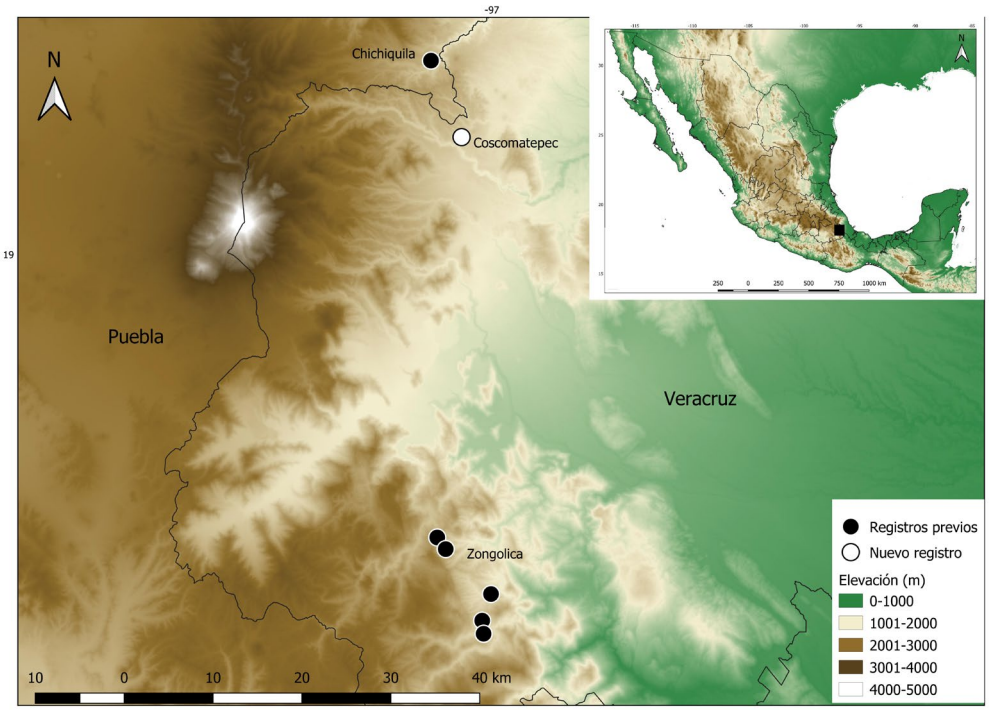

Figure 1. Distribution map of *Geophis lorancai*. / **Figura 1.** Mapa de distribución de *Geophis lorancai*.

Figure 2. Four individuals of *Geophis lorancai* from the locality of Cuautolontitla, municipality of Coscomatepec, Veracruz, México, A (LACM PC 2693), B (LACM PC 2694), C (LACM PC 2695), D (LACM PC 2696).

Figura 2. Cuatro individuos de *Geophis lorancai* de la localidad de Cuautolontitla, municipio de Coscomatepec, Veracruz México, A (LACM PC 2693), B (LACM PC 2694), C (LACM PC 2695), D (LACM PC 2696).

En este trabajo presentamos una nueva población en la localidad de Cuautolontitla, Municipio de Coscomatepec, Veracruz, México (Fig. 1). Todos los organismos se fotografiaron y se liberaron en el sitio de observación. Los registros fotográficos se depositaron en la colección digital de la Natural History Museum of Los Angeles County (LACM PC).

El 24 de octubre del 2020, a las 1100 h, se observó un individuo adulto (LACM PC 2693; Fig. 2A), que se encontraba oculto entre la hojarasca en un fragmento de vegetación secundaria colindante a un parche con cultivo de aguacate (*Persea americana*) y pequeños fragmentos con relictos de bosque mesófilo de montaña (19.115772° N, 97.034167° W; WGS84; elev. 1680 m s.n.m.; Fig. 3A).

El 25 de diciembre del 2020, aproximadamente a las 1400 h, se observó un individuo joven (LACM PC 2694, Fig. 2B) el cual se desplazaba entre la vegetación secundaria y hojarasca del patio trasero de una vivienda (19.11733° N, 97.035448° W; WGS84; elev. 1675 m s.n.m.), observamos algunas aves de corral intentado depredar a este individuo (Fig 3B).

El 21 de enero del 2021, a las 1600 h, debido a las fuertes lluvias, se deslavó una pequeña pared de tierra; mientras se realizaban trabajos de remoción se encontraron 6 individuos (LACM PC 2695,2696, 2697, 2698, 2699, 2700, Fig. 2C,D) entre toda la acumulación de tierra (19.115333° N, 97.035996° W; WGS84; elev. 1660 m s.n.m. Fig. 3C), los individuos fueron reubicados en la misma localidad.

Table 1. Previous and current records of the distribution and habitat of *Geophis lorancai* in Mexico.

Tabla 1. Registros previos y actuales de la distribución y hábitat de *Geophis lorancai* en México.

Estado	Municipio	Localidad	Tipo de vegetación	Coordenadas	Referencia
Puebla	Chichiquila	Chichiquila	Bosque de pino-encino	19.1930°N, 97.0658°O	Canseco-Márquez et al., 2016
Veracruz	Coscomatepec	Cuautolontitla	Vegetación secundaria-cultivo de aguacate	19.115°N, 97.034°W	Este estudio
Veracruz	Coscomatepec	Cuautolontitla	Vegetación secundaria (cerca de viviendas)	19.117° N, 97.035° W	Este estudio
Veracruz	Los Reyes	Cercanías de Atlanca	Bosque mesófilo de montaña	18.6966°N, -97.0558°O	Canseco-Márquez et al., 2016
Veracruz	Mixtla de Altamirano	Apoxteca	Bosque mesófilo de montaña	18.61027°N, 97.01638°O	De La Torre-Loranca et al., 202
Veracruz	San Juan Texhuacan	Cuestalostock	Bosque mesófilo de montaña	18.62361°N, 97.01777°O	De La Torre-Loranca et al., 202
Veracruz	Tequila	Cumbre de Tequila	Bosque mesófilo de montaña	18.70861°N, 97.06472°O	De La Torre-Loranca et al., 202
Veracruz	Zongolica	Instituto Tecnológico Superior de Zongolica	Bosque mesófilo de montaña	18.6505°N, 97.0080°O	Canseco-Márquez et al., 2016

Figure 3. Habitats and sites where individuals of *Geophis lorancai* were observed in the locality of Cuautolontitla, Veracruz. Avocado cultivation (A), backyard shelter (B) and mud wall washout (C).

Figura 3. Hábitats y sitios donde se observaron individuos de *Geophis lorancai* en la localidad de Cuautolontitla, Veracruz. Cultivo de aguacates (A), el patio trasero de vivienda (B) y deslave de pared de tierra (C).

Esta población se encuentra a 9.2 km (línea aérea) al sur de la localidad reportada más cercana en el municipio de Chichiquila, Puebla (MZFC 28404; Canseco-Márquez et al., 2016) y a 45.2 km al norte de la localidad reportada más cercana en Veracruz en el municipio de Tequila, en la sierra de Zongolica (ITSZ-R-260; De La Torre-Loranca et al., 2020). Representa el sexto municipio registrado en la distribución de la Culebra Minera de Zongolica en el estado de Veracruz.

Desafortunadamente, se desconoce gran parte de la biología de esta especie, solo se cuenta con datos disponibles en su descripción y recientemente referencias a nuevas localidades dentro de la sierra de Zongolica. Sabemos que esta especie está asociada a bosque mesófilo de montaña (Tabla 1), tipo de vegetación considerado uno de los más afectados por causas antropogénicas (Ochoa-Ochoa et al., 2017) además, la tasa de deforestación en el estado de Veracruz es una de las más altas del país (Muñiz-Castro et al., 2015). Por lo cual resaltamos la importancia de la presencia de *G. lorancai* en vegetación secundaria y en zonas de cultivos de aguacate, siendo estos sitios refugio al disponer de microhábitats adecuados o bien, como conexiones entre los parches de vegetación original, por ello, es importante documentar su distribución y señalar su potencial tolerancia a la perturbación.

Agradecimientos.– Agradecemos a los habitantes de la localidad de Cuautolontitla, Coscomatepec y a Neftali Camacho del Natural History Museum of Los Angeles County por catalogar las fotografías.

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AMASTRIDIUM SAPPERI (SQUAMATA: DIPSADIDAE)

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México: Estado de Hidalgo: Municipio de Pacula, Localidad de Adjuntas, Parque Nacional Los Mármoles (20.938903° N, 99.278347° W, 1232 m s. n. m.), 11 de mayo de 2021 a las 14:21 h. Un ejemplar adulto (Fig. 1) fue encontrado en una barranca con vegetación de selva baja caducifolia, cruzando un camino de terracería, por Antonio Melo Melo, miembro de la Brigada de Rescate y Conservación de Serpientes del Parque Nacional Los Mármoles.

El organismo presenta las características de coloración distintivas de la especie, descritas en los trabajos de Smith (1971) y Heimes (2016), además de que *A. sapperi* es la única especie del género reconocida para México (Heimes, 2016). La identificación de la especie fue corroborada por Luis Canseco Márquez. Este avistamiento representa el primer registro de la especie para el municipio de Pacula y es el segundo ejemplar conocido para Hidalgo (Lara-Tufiño et al., 2014).

Además, esta especie no había sido registrada en los estudios realizados previamente dentro del Parque Nacional Los Mármoles (Cruz-Elizalde et al., 2015; Flores-Hernández, 2017), lo que demuestra la importancia de la participación y vinculación ciudadana en los proyectos de monitoreo y conservación de las especies, sobre todo dentro de Áreas Naturales Protegidas, así como la necesidad de realizar un mayor número de estudios dirigidos en registrar la diversidad herpetofaunística en regiones poco exploradas. Este registro amplía la distribución de la especie 46.57 km al suroeste en línea recta del registro más cercano conocido, en el municipio de Pisaflores, Hidalgo (Lara-Tufiño et al., 2014). Existen otros dos registros cercanos, uno de ellos en la localidad de El Madroño, en el estado de Querétaro y el otro en la localidad de las Pozas, Xilitla, en el estado de San Luis Potosí (Calzada-Arciniega & Toscano-Flores, 2014). La fotografía se depositó en la Colección Digital de Vertebrados de la Facultad de Estudios Superiores Zaragoza, Universidad Nacional Autónoma de México (MZFZ-IMG 358).

Agradecimientos.–Al Consejo Nacional de Ciencia y Tecnología (CONACyT) por la beca de doctorado otorgada para el primero autor LFB (número de becario 371195). Al proyecto PROCODES 2020 por el recurso otorgado para la impartición del curso de capacitación para conformar la Brigada de Rescate y Conservación de las Serpientes del Parque Nacional Los Mármoles (Acta 2247) y a todas las personas que conforman dicha Brigada. Al entonces director del Parque Nacional Los Mármoles, Edgar Hugo Olvera Delgadillo, así como a los técnicos de esta Área Natural Protegida, Karina Calva Soto y Juan Carlos García Loperena. A Uri Omar García Vázquez, por permitirnos depositar la fotografía en la MZFZ.

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Figure 1. Adult of *Amastridium sapperi* from Adjuntas, Pacula, Hidalgo, México. Photo: Antonio, Melo Melo.

Figura 1. Adulto de *Amastridium sapperi* de Adjuntas, Pacula, Hidalgo, México. Foto: Antonio Melo Melo.

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NUEVO REGISTRO DE *DRYMOBIUS CHLOROTICUS* (COPE, 1886) (SQUAMATA: COLUBRIDAE) EN EL ESTE DE GUERRERO, MÉXICO

NEW RECORD OF *DRYMOBIUS CHLOROTICUS* (COPE, 1886) (SQUAMATA: COLUBRIDAE) IN EASTERN GUERRERO, MÉXICO

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El género *Drymobius* (Squamata: Colubridae) consta de cuatro especies actualmente descritas que se distribuyen desde el sur de Texas, Estados Unidos hasta Venezuela en la vertiente Atlántica y desde el estado de Sonora, México hasta Perú en la vertiente Pacífica (Wilson, 1975a). Dentro del género, *D. chloroticus* es una de las especies con distribución amplia en Mesoamérica, abarcando desde San Luis Potosí, México en el Atlántico (Wilson, 1970) y desde Guerrero, México por el Pacífico (Mendoza-Hernández et al., 2011) hasta Honduras. Sin embargo, Savage (2002) ha sugerido que *D. chloroticus* Cope, "1885" (1886) podría representar un sinónimo de *D. melanotropis* Cope, 1875; debido a la inconsistencia de los caracteres diagnósticos y la contigüidad de los mismos. En caso de que fuera demostrado que ambas especies son sinónimos su distribución se extendería hacia el sur abarcando Nicaragua y Costa Rica (Wilson, 1975b; Savage, 2002).

Figure 1. Run over specimen of *Drymobius chloroticus* found in the municipality of Malinaltepec, Guerrero, Mexico. Modified image from UTADC 9708 a, b.

Figura 1. Ejemplar atropellado de *Drymobius chloroticus* encontrado en el municipio de Malinaltepec, Guerrero, México. Imagen modificada de UTADC 9708 a, b.

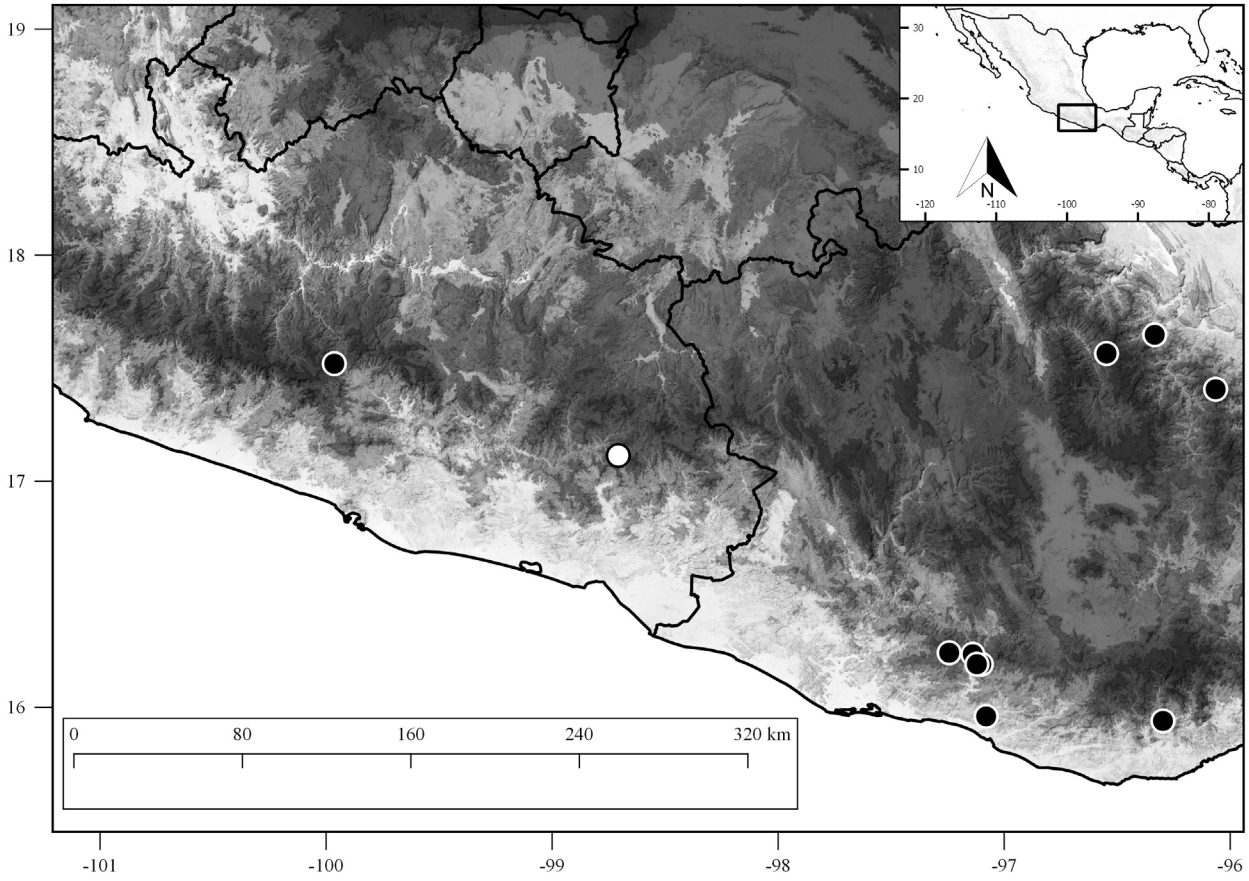

Figure 2. Map of the distribution of *Drymobius chloroticus* in the states of Guerrero and Oaxaca, Mexico. The black symbols represent previous records, while the white symbol the new record presented here.

Figura 2. Mapa de la distribución de *Drymobius chloroticus* en los estados de Guerrero y Oaxaca, México. Los símbolos negros representan registros previos, mientras que el símbolo blanco el nuevo registro aquí presentado.

A pesar de la amplitud de distribución de *D. chloroticus*, ésta es discontinua y generalmente restringida a formaciones vegetales indicadoras de ambientes húmedos (Wilson, 1970; McCranie, 2011), en un intervalo altitudinal entre los 780 y los 2200 m s.n.m. Esta distribución discontinua y su asociación a tipos particulares de vegetación se ha traducido en nuevos registros de la especie a medida que nuevas localidades han sido muestreadas, tal es el caso de registros en los estados mexicanos de Hidalgo (Badillo-Saldaña et al., 2014), Veracruz (López-Luna et al., 2001) y Guerrero (Mendoza-Hernández et al., 2011), este último ampliando el límite noroccidental conocido para la especie.

En el presente trabajo reportamos un nuevo registro de *D. chloroticus* en el sureste del estado de Guerrero, México, una región relativamente poco explorada de la Sierra Madre del Sur y que ayuda a conectar registros aislados en el oeste de Guerrero y el estado de Oaxaca.

El 06 de enero 2017, a las16:28 h, Jose Luis Gálvez Ochoa encontró un adulto de *Drymobius chloroticus* atropellado sobre la carretera cerca de Colombia de Guadalupe, próximo a la desviación a Iliatenco, Municipio de Malinaltepec, Guerrero, México (17.11388° N, 98.70737° W; WGS 84; elev. 2185 m). El ejemplar fue fotografiado y dejado en el sitio. Se depositaron los registros fotográficos en The University of Texas at Arlington, Collection of Vertebrates Digital Collection (UTADC 9708a y b; Fig, 1). La determinación fue verificada por Rufino Santos Bibiano.

Tabla 1. Locality records of *Drymobius chloroticus* included in Figure 2. /**Tabla 1.** Localidades de registro de *Drymobius chloroticus* incluidas en la Figura 2.

Ejemplar	Especie	Localidad	Latitud	Longitud
UTADC 9708	*Drymobius chloroticus*	GRO: cerca de Colombia de Guadalupe	17.11388	-98.70737
MZFC 17051	*Drymobius chloroticus*	GRO: 10 km S Yextla	17.52007	-99.96379
UTEP_Obs112	*Drymobius chloroticus*	OAX: ca. 5 km E of Santa Catarina Juquila	16.241427	-97.243522
CAS 101425	*Drymobius chloroticus*	OAX: Puerto Escondido Rd., km. 195, 4200 ft.	15.96	-97.08
KUH 137657	*Drymobius chloroticus*	OAX: 25.2 km N of San Gabriel Mixtepec	16.19095	-97.10153
UCM 39920	*Drymobius chloroticus*	OAX: Santa Rosa Lachao	16.235	-97.13917
LSUMZ 7569	*Drymobius chloroticus*	OAX: 18 road miles N San Gabriel Mixtepec	16.1908	-97.12089
UCM 44486	*Drymobius chloroticus*	OAX: Juquila Municipality, Lachao, Rio Sal 5000 ft	15.93966	-96.29782
KUH 87441	*Drymobius chloroticus*	OAX: 2 km S Vista Hermosa	16.77	-95.02
UCM 49334	*Drymobius chloroticus*	OAX: Vista Hermosa, Comaltepec, Ixtlán	17.56502	-96.54748
USNM 224549	*Drymobius chloroticus*	OAX: Vista Hermosa, 1.5 mi N of, on Highway 175	17.64798	-96.33411
AMNH 895573	*Drymobius chloroticus*	OAX: Distrito de Villa Alta, Yelagago	17.40711	-96.06467

El registro aquí presentado contribuye con una localidad intermedia en un vacío de aproximadamente 335 km en la distribución reportada de la especie, encontrándose 146.7 km al E de los alrededores de Yextla, Guerrero (Mendoza-Hernández et al., 2011) y 189.5 km al NO de Santa Catarina Juquila, Oaxaca (Mata-Silva et al., 2017; Fig. 2, Tabla 1).

Exploraciones recientes de esta región han resultado en el descubrimiento de especies nuevas (García-Vázquez et al., 2021) y el registro de otras conocidas únicamente en Oaxaca (Bautista del Moral et al., 2021, García-Vázquez et al., 2009; García-Vázquez y Durán-Fuentes, 2012), lo que sugiere que la diversidad de la región es mayor de lo actualmente conocido.

Agradecimientos.–Queremos agradecer a Gregory Pandelis (UTA) por facilitarnos los números de catálogo asignados a los registros fotográficos aquí reportados. Rufino Santos Bibiano corroboró la determinación del ejemplar reportado. A Antonio Yolocalli Cisneros Bernal por elaborar la "Figura 1".

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DRYOPHYTES EUPHORBIACEUS (ANURA: HYLIDAE)

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Mexico: Oaxaca: Distrito de Zaachila: Municipality of San Antonio Huitepec, Buena Vista locality (16.938236° N, 97.156556° W; WGS 84; 2114 m a.s.l.). 18 August 2019 at 08:30 h. An adult individual (Fig. 1) was found active and then photographed on the base of a rock. The area where the specimen was found was mainly dominated by oak forest, agricultural fields and the soil is classified as calcic cambisol. The specimen represents the first verified record for the Municipality of San Antonio Huitepec (Fig. 2), based on examination of records on the Sistema Nacional de Información Sobre Biodiversidad (SNIB, 2021). The nearest previously known record for this species in the state is 23.72 km to the southeast in Municipality of Santa María Lachixio (Kansas University Herpetological Collection [KUH] 100915; GBIF, 2021). This species is known from four physiographic regions of the state of Oaxaca (Sierra Madre de Oaxaca, Mixteca Alta, Depresión del Balsas and Valles Centrales) and between 90-2830 m a.s.l. (Duellman, 2001; GBIF, 2021). A photographic voucher of the specimen was deposited in the Digital Collection of the Amphibian and Reptile Diversity Research Center, University of Texas at Arlington (UTADC 9714), Texas, USA. The specimen identification was verified by Alejandro Calzada-Arciniega.

Figura 1. Espécimen de *Dryophytes euphorbiaceus* en la localidad de Buena Vista, municipio de San Antonio Huitepec, Oaxaca (UTADC 9714). Foto: César Camilo Julián Caballero.
Figure 1. Specimen of *Dryophytes euphorbiaceus* from the locality of Buena Vista, Municipality of San Antonio Huitepec, Oaxaca (UTADC 9714). Photo: César Camilo Julián-Caballero.

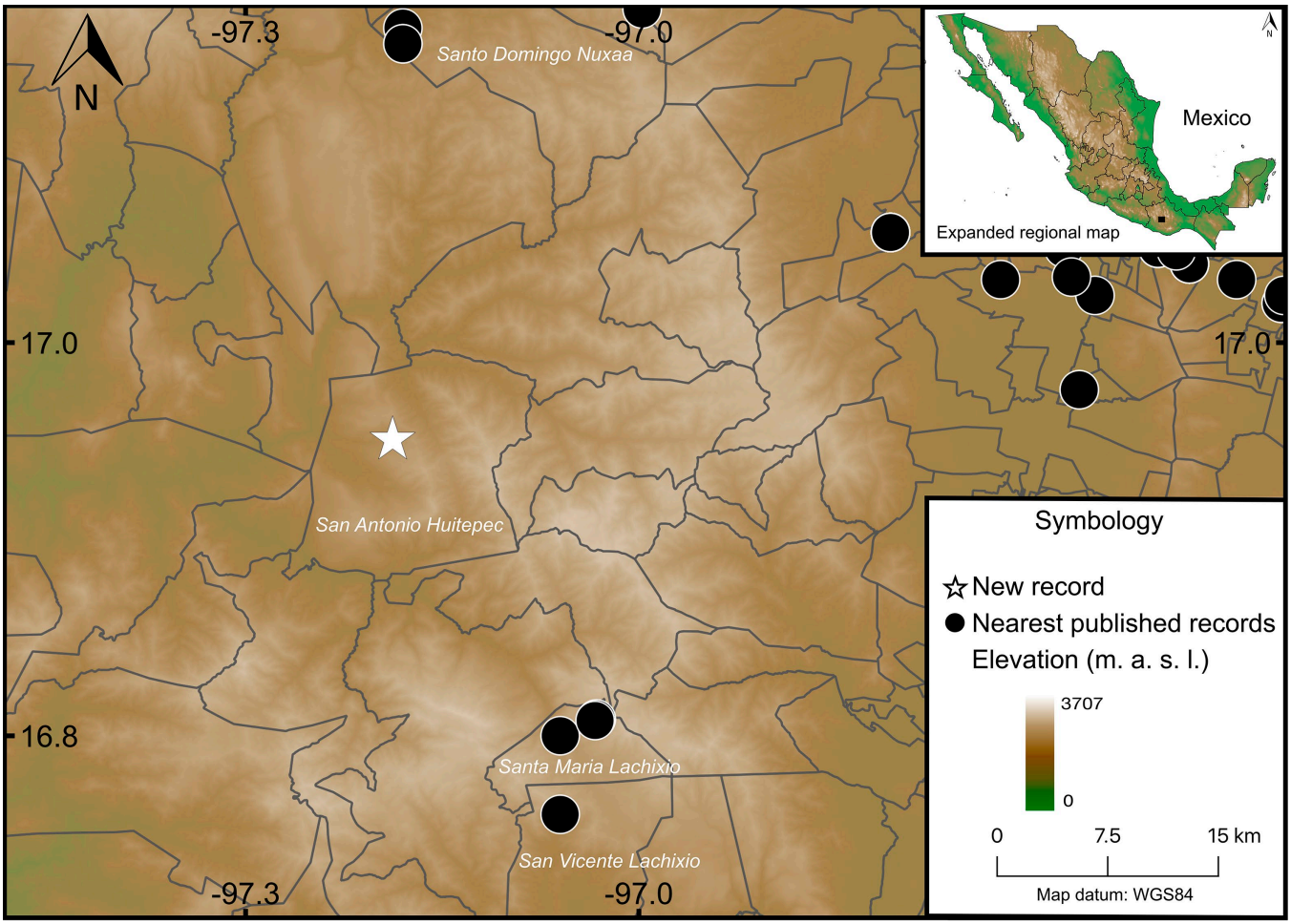

Figura 2. Nuevo registro de *Dryophytes euphorbiaceus* (estrella blanca) y los registros publicados más cercanos (puntos negros) del estado de Oaxaca, México.

Figure 2. New record of *Dryophytes euphorbiaceus* (white start) and nearest published records (black points) from state of Oaxaca, Mexico.

Acknowledgements.–Thanks to Alejandro Calzada-Arciniega for species verification. To Gregory G. Pandelis for cataloguing the digital photograph.

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REGISTROS NOTABLES DE *THAMNOPHIS CONANTI* Y *AQUILOEURYCEA CAFETALERA* EN LA SIERRA NEGRA DE PUEBLA, MÉXICO

NOTABLE RECORDS OF *THAMNOPHIS CONANTI* AND *AQUILOEURYCEA CAFETALERA* IN THE SIERRA NEGRA OF PUEBLA, MEXICO

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México destaca por su gran diversidad de organismos a nivel mundial, siendo el segundo país con mayor número de especies de reptiles (Flores-Villela & García-Vázquez, 2014; Uetz et al., 2020) y el quinto en especies de anfibios (Parra-Olea et al., 2014). De esta gran diversidad nacional de herpetofauna, corresponden al estado de Puebla 267 especies, distribuidas en seis regiones fisiográficas (Woolrich-Piña et al., 2017). De estas regiones, la Sierra Madre Oriental es la que presenta el mayor número de especies de herpetozoos (Woolrich-Piña et al., 2017). No obstante, siguen existiendo zonas dentro de esta región, principalmente en la porción sureste conocida como Sierra Negra, con pocos registros publicados, que permitan ampliar el conocimiento de la distribución de especies, particularmente de aquellas endémicas o con problemas de conservación. En la Sierra Negra se encuentra el municipio de Coyomeapan, cuya herpetofauna ha sido escasamente documentada. En este trabajo se reportan dos registros herpetofaunísticos notables, la serpiente *Thamnophis conanti* y la salamandra *Aquiloeurycea cafetalera* para este municipio. Las fotografías de estos registros fueron depositadas en la Colección Digital, Museo de Zoología, Facultad de Estudios Superiores Zaragoza, Universidad Nacional Autónoma de México.

El 26 de junio de 2006 se encontraron dos individuos adultos de *T. conanti* a las 15:40 h (Fig. 1A; MZFZ-IMG-339), desplazándose en el suelo de un pastizal rodeado de bosque de pino-encino, en

Figure 1. Adult specimens of *Thamnophis conanti* (A) and *Aquiloeurycea cafetalera* (B) found in the municipality of Coyomeapan, Puebla, Mexico.

Figura 1. Ejemplares adultos de *Thamnophis conanti* (A) y *Aquiloeurycea cafetalera* (B) encontrados en el municipio de Coyomeapan, Puebla, México.

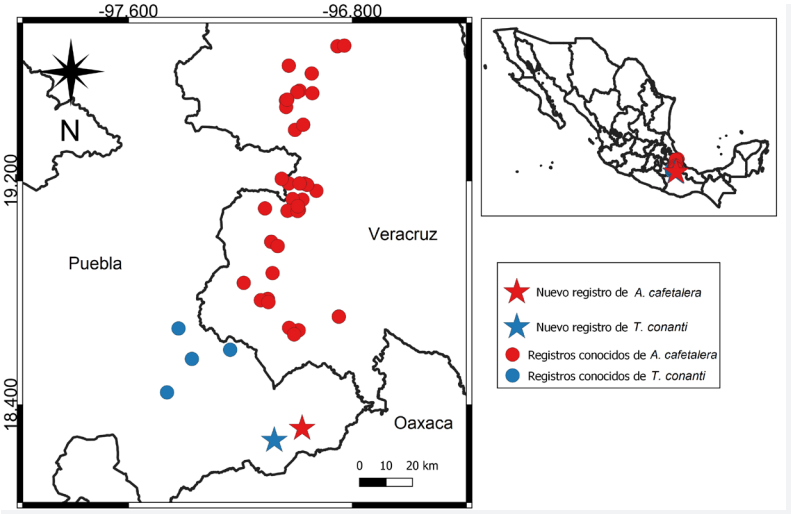

Figure 2. Known localities of *Aquiloeurycea cafetalera* and *Thamnophis conanti* (circles) and the new records for the Sierra Negra in Puebla (stars).

Figura 2. Localidades conocidas de *Aquiloeurycea cafetalera* y *Thamnophis conanti* (círculos) y los nuevos registros para la Sierra Negra de Puebla (estrellas).

la localidad de Cuitzala (18.272944° N, -97.078916° O, WGS 84, 2532 m s.n.m.). Este registro amplía el área de distribución de la especie aproximadamente 42 km (en línea recta) al sureste de la localidad más cercana conocida (Fig. 2), ubicada a 1.5 millas (2.4 km) al sur de Puerto del Aire (Rossman & Burbrink, 2005).

Posteriormente, el 1 de marzo de 2017 se encontró un individuo adulto de *A. cafetalera* a las 23:35 h (Fig. 1B; MZFZ-IMG-340) mientras permanecía inmóvil en la hojarasca acumulada entre las rocas del río Xocotla, en un bosque de pino-encino en la localidad de Xocotla (18.315725° N, -96.979461° O, WGS 84, 1745 m s.n.m.). Este registro amplía el área de distribución de la especie aproximadamente 39 km (en línea recta) al sur de la localidad más cercana conocida (Fig. 2), ubicada en El Tenango, municipio de Zongolica, Veracruz (Contreras-Calvario et al., 2019). Los individuos aquí reportados representan los primeros registros de estas especies para la Sierra Negra de Puebla. La importancia de estos radica en que ambas especies son endémicas de México, y no han sido evaluadas por la Unión Internacional para la Conservación de la Naturaleza, aunque Aguilar-López et al. (2017) sugieren la inclusión de *A. cafetalera* en la categoría de Vulnerable. Finalmente, el registro de esta especie en la Sierra Negra de Puebla se encuentra ligeramente fuera de su área de distribución potencial predicha (Aguilar-López et al., 2017), lo cual refuerza la necesidad de muestrear zonas aledañas a las potenciales, para ampliar el conocimiento de los límites ambientales y geográficos de la distribución de las especies.

Agradecimientos.–A Luis Canseco Márquez por verificar la identificación de los organismos, y a Uri Omar García Vázquez por catalogar las fotografías.

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ABRONIA FUSCOLABIALIS (ANGUIDAE; GERRHONOTINAE)

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The lizard genus *Abronia* is composed of 37 recognized species (Uetz et al., 2020). Most species inhabit *Pinus*, *Pinus-Quercus*, Quercus, and cloud forests, mainly between 1500 and 2800 meters above sea level (m a.s.l.), although some species are found at lower elevation ranges: *A. bogerti* (760-1540 m a.s.l.; Bille, 2001; Clause et al., 2016), *A. chiszari* (660-800 m a.s.l.; Flores-Villela & Vogt, 1992; Pérez-Higareda et al., 2002), *A. ramirezi* (probably between 800-1350 m a.s.l.; Campbell, 1994; Campbell & Muñoz-Alonso, 2007) and *A. reidi* (1000-1635 m a.s.l.; Thesing et al., 2017). The known distribution of the genus extends from Tamaulipas and Michoacán on the Atlantic and Pacific slopes of Mexico, respectively, south and east to western Panama, although most species have small geographic distributions (Campbell & Frost, 1993; Centenero-Alcalá et al., 2009; Gutiérrez-Rodríguez et

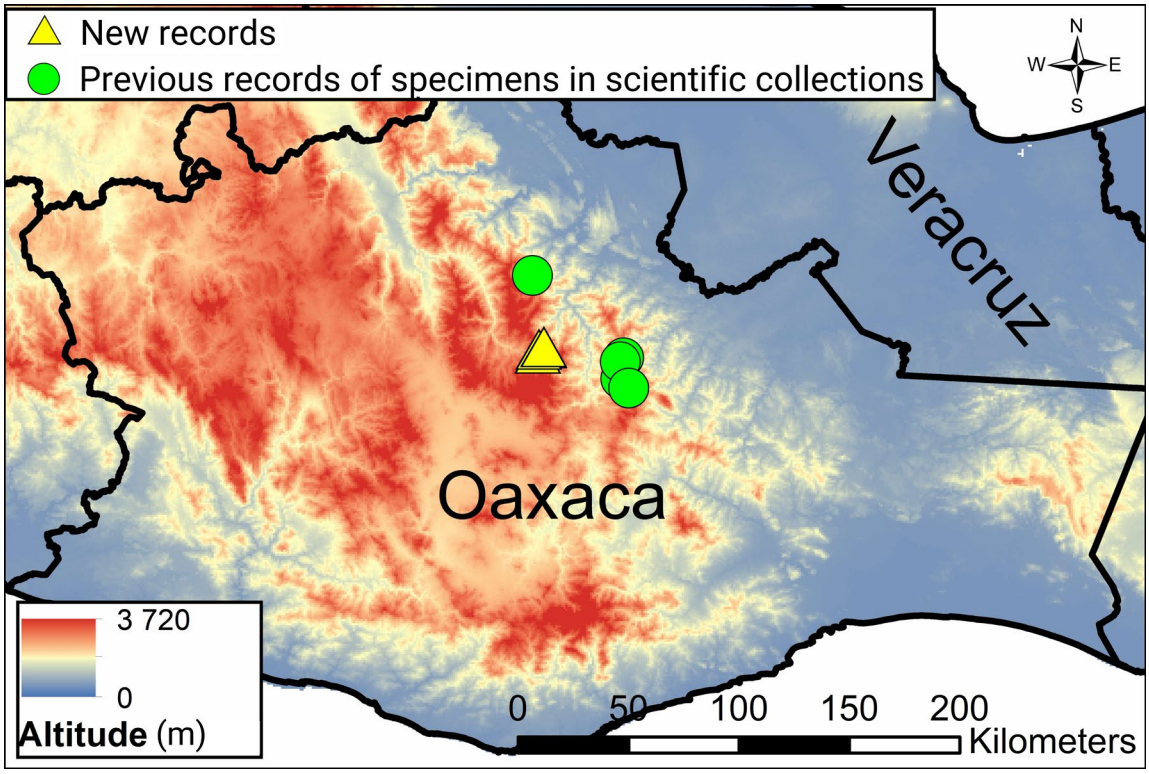

Figura 1. Registros previos y nuevos de *A. fuscolabialis*. / **Figure 1.** Previous and new records of *A. fuscolabialis*.

Figura 2. *Abronia fuscolabialis* descansando sobre un pino caído en Llano Verde (MZFZ-IMG-353).

Figure 2. *Abronia fuscolabialis* resting over a fallen pine tree in Llano Verde (MZFZ-IMG-353).

al., 2021; Solano-Zavaleta & Nieto-Montes de Oca, 2018). The *Abronia* species with arboreal habits (see Gutiérrez-Rodríguez et al., 2021) exhibit cryptic coloration, have secretive habits, and usually are found in remote habitats that used to be considered inaccessible, all of which hamper their study (Bogert & Porter, 1967; Campbell & Frost, 1993); even basic information about their natural history and distribution remains unknown. Moreover, their natural reduced extent of occurrence, together with a continuous habitat reduction because of land use change, have led to a conservation concern for most species of this family (Campbell, 2007; Campbell & Frost, 1993).

The Mount Zempoaltepec alligator lizard, *Abronia fuscolabialis* (Tihen, 1944), is one of the 22 endemic *Abronia* species of Mexico (Uetz et al., 2020). Its distribution is restricted to the northern Sierra of Oaxaca (Campbell, 2007; Güizado Rodríguez & Porto Ramírez, 2018). To date there exist six specimens of *A. fuscolabialis* deposited in herpetological collections, one from Sierra Juárez (MVZ-177806) and five from Sierra Mixe (AMNH-

Figura 3. *Abronia fuscolabialis* desplazándose por el suelo en Arroyo Cuache (MZFZ-IMG-354).

Figure 3. *Abronia fuscolabialis* moving on the ground in Arroyo Cuache (MZFZ-IMG-354).

Figura 4. *Abronia fuscolabialis* descansando sobre una bromelia en La Aplanada (MZFZ-IMG-355). .

Figure 4. *Abronia fuscolabialis* resting over a bromeliad in La Aplanada (MZFZ-IMG-355)

85634, LACM-15132, MZFC-26562, UTA R-14147, UTA R-9899). The species is highly vulnerable (Campbell, 2007; Güizado Rodríguez & Porto Ramírez, 2018) and its population is decreasing (Campbell, 2007). It is considered as Threatened by the Mexican Government (SEMARNAT, 2010) and Endangered by the IUCN (Campbell, 2007). Thus, more information on its distribution and ecology urges to protect, study, and preserve the species (Güizado Rodríguez & Porto Ramírez, 2018).

Here, we describe four new records of *A. fuscolabialis* at Sierra Juárez, northern Oaxaca (Fig. 1). No specimen was collected. All records' photographs (Figs. 2-5) were catalogued at the Colección digital de Vertebrados de la Facultad de Estudios Superiores Zaragoza, UNAM (MZFZ-IMG). These records are separated by 33-35 km to the south of the previously reported specimen from Sierra Júarez (MVZ-177806), and 34-36 km to the west of the nearest specimen reported from Sierra Mixe (UTA R-9899). Following Clause et al. (2020) we have masked the locality data by rounding coordinates to the nearest hundredth of a decimal degree and rounded all reported linear distances to the nearest kilometer. Despite being reported only for cloud forests (Campbell, 2007; Campbell & Frost, 1993) we recorded it in pine-oak forests.

The first individual was observed on May 26th, 2015 (Fig. 2). It was resting over a fallen tree on the ground, in the locality named Llano Verde (17.31˚ N, 96.37˚ W, WGS 84, 2280 m a.s.l.), within the municipality of Santiago Xiacuí. This area is under forestry management, and it is covered by humid oak-pine forests with *Quercus laurina* and the Mexican Weeping Pine (*Pinus patula*) as dominant species. Particularly, *P. patula* is extracted from the site to produce boards.

A second individual was found in the municipality of Santiago Xiacuí by May 10th, 2016 (Fig. 3). It was moving on the ground at a site known as Arroyo Cuache (17.28˚ N, 96.40˚ W, WGS 84, 2456 m a.s.l.), 150 m away from a stream. This locality was covered by pine-oak forests, mainly dominated by *P. patula* and *Q. laurina*, but there was also an important presence of laurel (*Laurus* sp.), miconia (*Miconia* sp.), madrone (*Arbutus sp.*), alder (*Alnus* sp.), and Neatleaf Oak (*Quercus rugosa*). This site was under forestry management over 10 years ago, for the use of *P. patula* and Smooth-bark Mexican Pine (*Pinus pseudostrobus*).

By June 15th, 2016, we found a third individual of the species at the site named La Aplanada (17.30˚ N, 96.39˚ W, WGS 84, 2399 m a.s.l.), in the municipality of Santiago Xiacuí (Fig. 4).

Figura 5. *Abronia fuscolabialis* asoleándose en una rama en la punta de un *Q. laurina* en El Embudo (MZFZ-IMG-356).

Figure 5. *Abronia fuscolabialis* basking on a branch at the top of a *Q. laurina* in El Embudo (MZFZ-IMG-356).

It was resting on a bromeliad attached to a madrone, at 1.5 m over the ground. Pine-oak forests covered the area, which were intensively managed for timber extraction. *Pinus rudis*, Douglas Pine (*Pinus douglassiana*), *P. patula*, Leather Leaf Mexican Oak (*Quercus crassifolia*), and *Arbutus sp.* represented the dominant tree species in the site.

Finally, we came across a fourth individual in June 25th, 2016 (Fig. 5), at the municipality of Capulálpam de Méndez, in the locality named El Embudo (17.31˚ N, -96.37˚ W, WGS 84, 2345 m a.s.l.). It was basking on a branch at the top of a *Q. laurina*. The tree was already dead and dry, it was approximately 15 m height and was covered with bromeliads, orchids, liquens, and ferns. A small river ran about 10 m from the tree. The area was covered with humid pine-oak forests, and it was located nearby an area that was under intensive forestry management. The dominant tree species in the area were *Q. laurina*, *P. pseudostrobus*, and *P. patula*.

The local conservation of *A. fuscolabialis* depends on communities through the preservation and sustainable management of forests, given that there are no federal protected areas across the region. More support to communal conservation initiatives might aid in the preservation of the species. Community-based monitoring might help reduce the fear that local people show to the lizard, as well as to increase the ecological and distributional knowledge of the species.

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PRIMEROS REGISTROS PARA LA HERPETOFAUNA DEL MUNICIPIO DE HUILOAPAN DE CUAUHTÉMOC, VERACRUZ, MÉXICO

FIRST RECORDS FOR THE HERPETOFAUNA OF THE MUNICIPALITY OF HUILOAPAN DE CUAUHTÉMOC, VERACRUZ, MEXICO

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Veracruz es considerado a nivel nacional como el estado con la tradición de recolecta más larga en cuanto a anfibios y reptiles se refiere (Ochoa-Ochoa & Flores-Villela, 2011), a pesar de lo anterior, existen regiones que permanecen pobremente muestreadas (por ejemplo: la zona centro oriental, Almaraz-Vidal & Cerón de la Luz, 2016; Sierra de Zongolica, De La Torre-Loranca et al., 2020). En particular en la región denominada las montañas o altas montañas, la cual se encuentra ubicada en el centro del estado y que está integrada por 57 municipios comprendidos en un área de 6 053 km^2 (SEFIPLAN, 2013), caracterizada por su amplia heterogeneidad topográfica (Rivera Hernández et al., 2018); se han descrito nuevas especies en años recientes (Canseco-Márquez et al., 2016; García-Bañuelos et al., 2020), así como también se han publicado los primeros registros en la distribución de algunas especies en uno o más de los municipios que la conforman (Contreras-Calvario et al., 2019; De la Torre-Loranca et al., 2019; Kelly-Hernández et al., 2019; De La Torre-Loranca et al., 2020; Peralta-Hernández et al., 2020).

En este estudio reportamos los primeros registros de anfibios y reptiles encontrados en el municipio de Huiloapan de Cuauhtémoc, el cual forma parte de la región de las altas montañas (SEFIPLAN, 2013); en específico el área muestreada corresponde al cerro el Gentil, el cual está ubicado en la porción oriente de dicho municipio y colinda con el municipio de Rafael Delgado, Veracruz (Fig. 1). La vegetación con mayor extensión en el sitio es el bosque mesófilo de montaña, aunque también hay zonas de bosque perturbado (Vargas-Rueda, 2018) y bosque mixto en las zonas de mayor elevación, en cuyo dosel predominan árboles del género *Cupressus, Quercus* y *Pinus*. Los registros reportados se encontraron durante visitas casuales a la zona de estudio, desde el mes de octubre del 2020 y hasta el mes de marzo del 2021, las cuales consistieron únicamente en recorridos diurnos, en un área que comprende un intervalo altitudinal de 1680 – 2390 m s.n.m. La búsqueda de organismos consistió en revisar los microhábitats que son utilizados de manera recurrente por anfibios y reptiles, por ejemplo debajo de objetos localizados en la superficie del suelo y en bromelias epifitas (Aguilar-López et a., 2017; Parra-Olea et al., 2020). Todos los organismos encontrados se fotografiaron para ser identificados posteriormente mediante el uso de literatura especializada (Flores-Villela et al., 1995; López-Luna et al., 1999; Parra-Olea et al., 2010; García-Bañuelos et al., 2020), también depositamos una fotografía de cada especie en la colección digital del Museo de Historia Natural del Condado de Los Ángeles (LACM PC), las cuales fueron catalogadas y verificadas por el administrador de la colección herpetológica. Adicionalmente la identificación de las salamandras fue verificada por Sean M. Rovito.

Registros:

Amphibia

Salamandra de cafetal, *Aquiloeurycea cafetalera* (Parra-Olea, Rovito, Márquez-Valdelmar, Cruz, Murrieta-Galindo y Wake, 2010): (18.802787° N, 97.130485° O; WGS 84; 2370 m s.n.m; Fig. 2). Se observaron un total de ocho individuos durante las visitas al área de estudio, los cuales fueron encontrados debajo de troncos caídos, en sitios correspondientes al bosque mesófilo de montaña y al bosque mixto. La localidad reportada se encuentra a 3.25 km en línea recta al norte de la población conocida más cercana, ubicada en la localidad de Zoncolco, municipio de Rafael

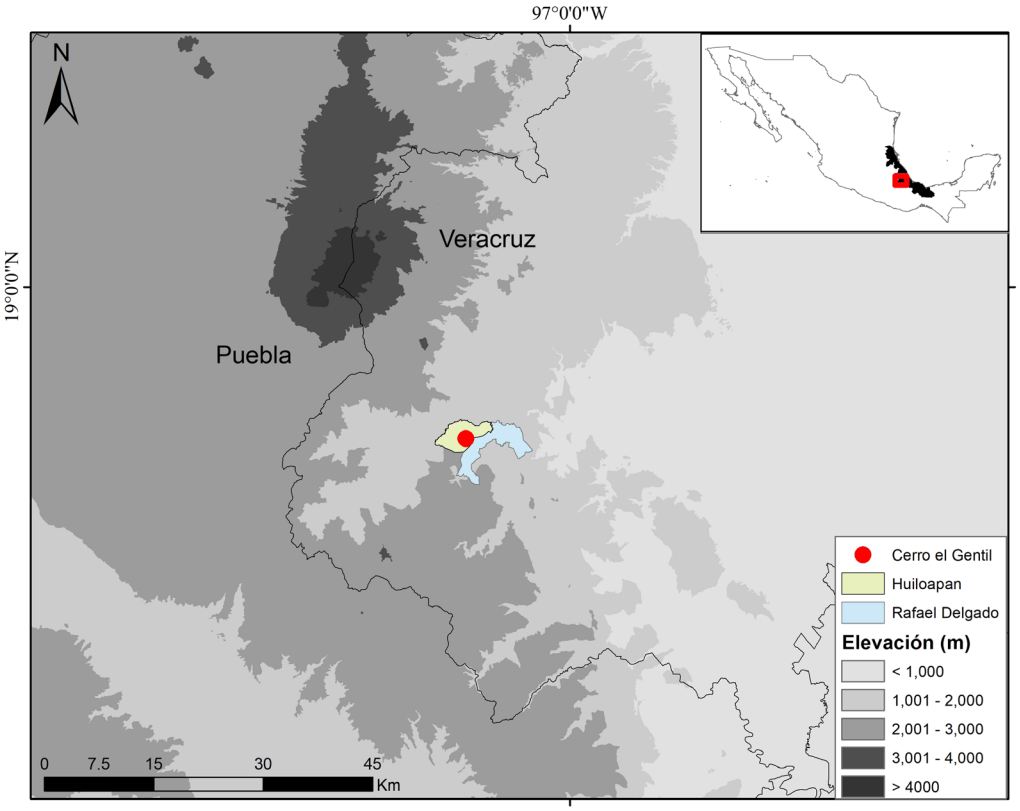

Figure 1. Map of the locality sampled during this study and the location of the municipalities of Huiloapan de Cuauhtémoc and Rafael Delgado, Veracruz.

Figura 1. Mapa de la localidad muestreada durante este estudio y la ubicación de los municipios de Huiloapan de Cuauhtémoc y Rafael Delgado, Veracruz.

Delgado (Parra-Olea et al., 2010) y representa una ampliación del intervalo altitudinal superior de la especie de 150 m (Aguilar-López et al., 2017).

Salamandra enana de la Sierra Madre Oriental, *Parvimolge townsendi* (Dunn, 1922): (18.813175° N, 97.128864° O; WGS 84; 2209 m s.n.m.; Fig. 3). El 11 de febrero a las 13:30 h, encontramos dos organismos, que dado su reducido tamaño clasificamos como jóvenes (longitud total < 25 mm; en comparación con la longitud total máxima de 42 mm, Dunn, 1922), así como dos hembras grávidas, en una brecha con abundante hojarasca, en un sitio correspondiente al bosque mesófilo de montaña. Uno de los organismos juveniles y una de las hembras se encontraron entre la hojarasca, mientras que los otros se encontraron debajo de troncos caídos. Una de las hembras fue colectada y mantenida en cautiverio durante cinco días, para posteriormente ser liberada; el 14 de febrero se observó que ésta había depositado un total de nueve huevos. La localidad aquí reportada se encuentra a 3.93 km en línea recta al sureste del registro conocido más cercano, en el cerro del Borrego, municipio de Orizaba (Contreras-Calvario et al., 2019), además representa una ampliación del intervalo

Figure 2. Specimen of *Aquiloeurycea cafetalera*, with catalog number LACM PC 2716. Photo: Rafael Peralta Hernández.

Figura 2. Ejemplar de *Aquiloeurycea cafetalera*, con número de catálogo LACM PC 2716. Foto: de Rafael Peralta Hernández

Figure 3. Adult female of *Parvimolge townsendi* with egg-laying clutch while kept in captivity; catalog number LACM PC 2713. Photo: Rafael Peralta Hernández.

Figura 3. Hembra adulta de *Parvimolge townsendi* con la nidada ovopositada mientras fue mantenida en cautiverio; número de catálogo LACM PC 2713. Foto: Rafael Peralta Hernández.

altitudinal superior de la especie de 259 m (Sandoval-Comte et al., 2012). Por otro lado, el registro de camada presentado corresponde al segundo reporte de camada de la especie, con tres huevos menos que lo reportado con anterioridad, además de ocurrir un mes antes (Duellman, 1959). La hembra grávida fue colectada y mantenida en cautiverio con el permiso de colecta SEMARNAT: SGPA/DGVS/03194/20 otorgado a Leticia M. Ochoa Ochoa.

Tlaconete de Acultzingo, *Pseudoeurycea firscheini* Shanon y Werler, 1955: (18.80602° N, 97.129872° O; WGS 84; 2324 m s.n.m; Fig. 4). El 11 de octubre a las 15:00 h, se registró un individuo adulto debajo de un tronco caído sobre el camino, la vegetación presente en el sitio correspondía a bosque mixto. Este registro se encuentra ubicado a 4.37 km en línea recta al noroeste de la población conocida más cercana, en la localidad cerro de Petlalcala, municipio de San Andrés Tenejapan (Kelly-Hernández et al., 2019).

Salamandra de color granito, *Pseudoeurycea granitum* García-Bañuelos, Aguilar-López, Kelly-Hernández, Vásquez-Cruz, Pineda-Arredondo y Rovito, 2020: (18.809863° N, 97.1262° O; WGS 84; 2187 m s.n.m.; Fig. 5). Durante las visitas a la localidad de estudio se observaron nueve individuos, de los cuales siete fueron encontrados en bromelias epifitas y dos debajo de tablas de madera, en sitios correspondientes al bosque mesófilo de montaña y al bosque perturbado respectivamente. La localidad reportada se encuentra a 4.4 km al noroeste de la población conocida más cercana, en el cerro de Petlalcala, municipio de San Andrés Tenejapan (García-Bañuelos et al., 2020).

Salamandra pigmea de Acultzingo, *Thorius dubitus* Taylor, 1941: (18.813175° N, 97.128864° O; WGS 84; 2209 m s.n.m.; Fig. 6). El día 11 de febrero a las 13:30 h encontramos un organismo debajo de un tronco caído en una brecha con abundante hojarasca, en un sitio de bosque perturbado. Este registro corresponde a la segunda localidad confirmada para la especie y se encuentra ubicado a 25.2 km en línea recta al este de la primer localidad, en Puerto del Aire, municipio de Acultzingo (Rovito et al., 2013); además representa el registro altitudinal más bajo, ampliando el intervalo altitudinal de distribución de la especie 171 m (Hanken y Wake, 1998).

Reptilia

Abaniquillo de Schiede, *Anolis schiedii* (Wiegmann, 1834): (18.81174° N, 97.122988° O; WGS 84; 1970 m s.n.m.; Fig. 7). Durante las visitas al área de estudio se observaron un total de cuatro individuos, de los cuales dos se encontraron sobre la hojarasca y dos sobre las ramas de árboles jóvenes, en sitios correspondientes al bosque mesófilo de montaña. La localidad reportada llena una brecha en la distribución de la especie de aproximadamente 8.7 km en línea recta entre las localidades conocidas más cercanas, en el cerro de Petlalcala, municipio de San Andrés Tenejapan y el cerro del Borrego, municipio Orizaba (Kelly-Hernández et al., 2018; Peralta-Hernández et al., 2019).

Corredora de Liebmann, *Chersodromus liebmanni* Reinhardt, 1861: (18.81174° N, 97.122988° O; WGS 84; 1970 m s.n.m.; Fig. 8). Un ejemplar adulto muerto fue hallado a la orilla del camino el día 11 de febrero, alrededor de las 12:00 h, en un sitio de bosque

Figure 4. Specimen of *Pseudoeurycea firscheini*, with catalog number LACM PC 2715. Photo: Rafael Peralta Hernández.
Figura 4. Ejemplar de *Pseudoeurycea firscheini*, con número de catálogo LACM PC 2715. Foto: Rafael Peralta Hernández.

Figure 5. Specimen of *Pseudoeurycea granitum,* with catalog number LACM PC 2714. Photo: Rafael Peralta Hernández.
Figura 5. Ejemplar de *Pseudoeurycea granitum*, con número de catálogo LACM PC 2714. Foto: Rafael Peralta Hernández.

Figure 6. Specimen of *Thorius dubitus*, with catalog number LACM PC 2712. Photo: Jorge Luis Castillo Juárez.

Figura 6. Ejemplar de *Thorius dubitus*, con número de catálogo LACM PC 2712. Foto: Jorge Luis Castillo Juárez.

perturbado. Este registro se encuentra ubicado a 4.36 km al noroeste de la localidad conocida más cercana para la especie, en el cerro de Petlalcala, municipio de San Andrés Tenejapan (Kelly-Hernández, 2017).

Hojarasquera de Forbes, *Rhadinaea forbesi* Smith, 1942: (18.809863° N, 97.1262° O; WGS 84; 2187 m s.m.m.; Fig. 9). Un ejemplar juvenil fue encontrado debajo de una roca en un área descubierta de vegetación arbórea el día 18 de enero, alrededor de las 13:15 h. Este registro se encuentra a 4.03 km al noroeste de la localidad conocida más cercana para la especie, en el cerro de Petlalcala, municipio de San Andrés Tenejapan (De la Torre-Loranca, 1999).

Figure 7. Specimen of *Anolis schiedii*, with catalog number LACM PC 2720. Photo: Rafael Peralta Hernández. / **Figura 7.** Ejemplar de *Anolis schiedii*, con número de catálogo LACM PC 2720. Foto: Rafael Peralta Hernández.

Nauyaca del Cerro Petlalcala, *Cerrophidion petlalcalensis* López-Luna, Vogt y De la Torre-Loranca, 1999: (18.80602° N, 97.129872° O; WGS 84; 2324 m s.n.m.; Fig. 10). Un ejemplar adulto fue observado en la orilla de una brecha con abundante hojarasca, mientras tomaba el sol el día 10 de noviembre, alrededor de las 13:00 h, en un sitio de bosque perturbado. Este registro se encuentra ubicado a 4.02 km al noroeste de la localidad tipo de la especie, en el cerro de Petlalcala, municipio de San Andrés Tenejapan (López-Luna et al., 1999) y representa la localidad más septentrional de su área de distribución (De la Torre-Loranca et al., 2019).

Los registros aquí presentados muestran la importancia de dirigir estudios de campo a zonas que no han sido muestreadas con anterioridad, ya que durante este estudio fue posible

Figure 8. Dead specimen of *Chersodromus liebmanni*, with catalog number LACM PC 2718. Photo: Rafael Peralta Hernández.

Figura 8. Ejemplar encontrado muerto de *Chersodromus liebmanni*, con número de catálogo LACM PC 2718. Foto: Rafael Peralta Hernández.

Figure 9. Specimen of *Rhadinaea forbesi*, with catalog number LACM PC 2717. Photo: Rafael Peralta Hernández.

Figura 9. Ejemplar de *Rhadinaea forbesi*, con número de catálogo LACM PC 2717. Foto: Rafael Peralta Hernández.

encontrar registros que ampliaron el intervalo altitudinal de algunas especies, lo cual puede representar que la tolerancia ambiental de dichas especies es más amplia de lo que se conocía (Maciel-Mata et al., 2015), ofreciendo de este modo la oportunidad de realizar predicciones más certeras sobre su área de distribución en estudios posteriores (Bystraiakova et al., 2012). Otra posible explicación es que la ampliación del intervalo altitudinal de las especies ocurra debido al calentamiento global (Thomas, 2010), ya que ante las condiciones ambientales cambiantes, las especies pueden desplazarse rastreando las condiciones óptimas para su supervivencia (Williams y Blois, 2018).

Debido a que cuatro de las nueve especies reportadas se encuentran catalogadas en alguna categoría de riesgo de la IUCN (*Aquiloeurycea cafetalera:* "Vulnerable", *Parvimolge townsendi*: "Vulnerable", *Pseudoeurycea firscheini:* "Endangered" y *Thorius dubitus:* "Critically Endangered") y otras cuatro no han sido evaluadas debido a que se considera que no se cuenta con datos suficientes (*Anolis schiedii*, *Cerrophidion petlalcalensis*, *Pseudoeurycea granitum* y *Rhadinaeae forbesi*; IUCN, 2021), consideramos que está localidad puede ser relevante para la implementación de leyes y estrategias que promuevan la conservación de dichas especies. Adicionalmente el registro de la camada de *Parvimolge townsendi* proporciona información sobre el tamaño de camada más pequeño de la especie, así como la fecha exacta en que ocurre la ovoposición de los huevos (de la cual no había registro, Duellman, 1959), contribuyendo de esta forma al conocimiento de su biología reproductiva, él cual resulta esencial para la planeación de estrategias de conservación de especies en riesgo (Castro, 2009).

Figure 10. Specimen of *Cerrophidion petlalcalensis*, with catalog number LACM PC 2719. Photo: Rafael Peralta Hernández.

Figura 10. Ejemplar de *Cerrophidion petlalcalensis*, con número de catálogo LACM PC 2719. Foto: Rafael Peralta Hernández.

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KINOSTERNON VOGTI (KINOSTERNIDAE)

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México: Nayarit: municipio de Bahía de Banderas: localidad específica no proporcionada debido a la rareza de la especie y por encontrarse en peligro de extinción (Secretaría de Medio Ambiente y Recursos Naturales, 2019). Dos registros: 23 de agosto de 2018 a las 11:53 h y 17 de agosto de 2020 a las 12:28 hrs. Ambas localidades separadas por una distancia de 1.23 km. Se registraron dos machos de longitud de caparazón (LC) de 89 mm (voucher fotográfico, Colección Nacional de Anfibios y Reptiles, CNAR, Instituto de Biología, Universidad Nacional Autónoma de México, IBH-RF 635; Fig. 1a-d) y LC = 87 mm (voucher fotográfico IBH-RF 636; Fig. 1e-h), respectivamente. Los especímenes se identificaron como *K.vogti* por su talla

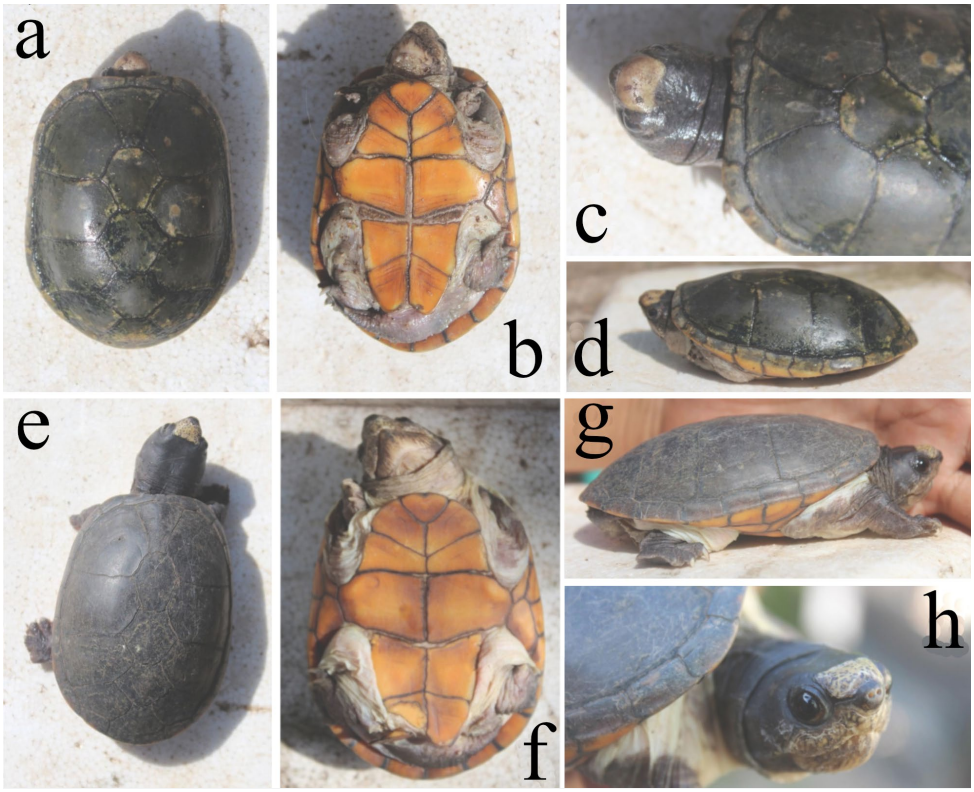

Figure 1. *Kinosternon vogti*. a-d) Male specimen, carapace length 89 mm and photographic voucher IBH-RF 635, in dorsal, ventral, anterodorsal and left lateral views. e-h) Male specimen, carapace length 87 mm and photographic voucher IBH-RF 636, in dorsal, ventral, right lateral and right anterolateral views. Unscaled.

Figura 1. *Kinosternon vogti*. a-d) Ejemplar macho, longitud de caparazón de 89 mm y voucher fotográfico IBH-RF 635, en vista dorsal, ventral, anterodorsal y lateral izquierda. e-h) Ejemplar macho, longitud de caparazón de 87 mm y voucher fotográfico IBH-RF 636, en vista dorsal, ventral, lateral derecha y anterolateral derecha. Sin escala.

pequeña, plastrón angosto y conspicuo escudo rostral amarillo de los machos (López-Luna et al., 2018). Los hallazgos son los primeros, tanto para el municipio como para el estado, y se encuentran a una distancia aproximada de 5.5 km al noroeste de la localidad más cercana en el campus de la Universidad de Guadalajara en el municipio de Puerto Vallarta, Jalisco (López-Luna et al., 2018). Precisamente por esta cercanía entre estados, se esperaba encontrar a la especie en el sur de Nayarit. De hecho, López-Luna y colaborares (2018), en la descripción de *K. vogti* como nueva especie, consideraron que su distribución debería ser mucho más amplia de lo observada.

El área de distribución o ámbito hogareño de la especie, calculada con el método del polígono mínimo convexo (Refsnider et al., 2012) y los datos disponibles de localidades de registro (López-Luna et al., 2018; Ramírez-Ramírez et al., 2019; Montaño et al., 2020; Naturalista-CONABIO, 2021), permitió estimarla en 38.1 km^2. Esta cifra aún está por debajo de los de 300 km^2 propuesta por López-Luna et al. (2018) como área de distribución potencial en la cuenca de drenaje hidrológico de la Bahía de Banderas; resultado que, probablemente, refleje la necesidad de intensificar estudios de campo sobre su distribución y, a la par, su estado de conservación.

Los dos especímenes presentaban traumas en su economía corporal. El ejemplar 1 de LC = 89 mm con daño en el ojo derecho (probablemente ceguera), y el ejemplar 2 de LC = 87 mm con amputación de la mano del miembro anterior izquierdo y fractura del escudo anal derecho del plastrón. El ejemplar 1 fue observado mientras caminaba dentro de un canal de drenaje pluvial revestido con concreto, mientras que el ejemplar 2 nadaba en una charca permanentemente de poca profundidad con presencia de popal *Thalia geniculata* L., sauce *Salix humboldtiana* Willd., parota *Enterolobium cyclocarpum* (Jacq.) Griseb. e higuera *Ficus* spp. Los dos sitios de observación documentados en esta nota, al igual que el resto de los registros conocidos para esta especie de distribución muy restringida y en peligro de extinción, se encuentran dentro de espacios urbanizados o perturbados (López-Luna et al., 2018; Ramírez-Ramírez et al., 2019; Loc-Barragán et al., 2020; Montaño-Ruvalcaba et al., 2020; Naturalista-CONABIO 2021). Sin embargo, para rechazar la posibilidad de atribuir estas observaciones a la presencia de tortugas liberadas accidentalmente, será necesario obtener registros para la especie en otras localidades dentro y fuera de las zonas urbanas o periurbanas del municipio. Una vez revisados, los ejemplares fueron dejados donde se encontraron.

Agradecimientos.– A los dos revisores anónimos por sus valiosos comentarios. A U. Sebastián Flores Guerrero por su apoyo para el cálculo del área del polígono de distribución. Permiso de colecta SEMARNAT Núm. FAUT-0064.

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RHINOCLEMMYS RUBIDA PERIXANTHA (GEOEMYDIDAE)

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México: Jalisco: Municipio de Puerto Vallarta, Colonia San Esteban (20.64972° N, 105.19916° W, WGS84, 15 m s.n.m.). 15 de junio de 2021. El sitio de observación se encuentra en el extremo este de la mancha urbana de Puerto Vallarta, en el límite con el bosque tropical caducifolio (S. Quijas, 2021 com. pers.). El ejemplar, un macho adulto de longitud de caparazón de 99.72 mm (voucher fotográfico, Colección Nacional de Anfibios y Reptiles, CNAR, Instituto de Biología, Universidad Nacional Autónoma de México, IBH-RF 646; Fig. 1), fue reportado por un niño que lo observó deambulando cerca de un árbol de la colonia.

El espécimen se identificó como *R. rubida perixantha* por el color marrón claro uniforme de los escudos marginales del caparazón, un punto amarillo rodeado de negro en los escudos laterales, mancha pálida en forma de herradura entre los ojos y plastrón con una ancha banda central longitudinal oscura (Mosimann & Rabb, 1953; García & Ceballos, 1994; Legler & Vogt, 2013; Fig. 2). Además, presentaba amputación completa de la mano del miembro anterior izquierdo y cicatrización de la lesión. *Rhinoclemmys rubida perixantha* es una tortuga terrestre endémica de bosques tropicales secos y es activa principalmente durante la estación de lluvias (Butterfeld et al., 2018). De hecho, durante los primeros días del mes de junio antes de la observación del ejemplar, el volumen acumulado de lluvia en la zona fue de 37.2 mm (V. Cornejo & J.C. Morales, 2021 *com. pers.*).

El registro aquí presentado, es el primero para el municipio de Puerto Vallarta y el más norteño para la subespecie, pues se localiza a una distancia lineal aproximada de 118 km al noroeste del sitio más cercano previamente documentado, ubicado en las inmediaciones del km 53 de la carretera estatal a Villa Purificación con el entronque con la carretera federal 200 (Ernst, 1981; Turtle Taxonomy Working Group, 2017; Ueda, 2021). Asimismo, restos óseos de *R. rubida* se encontraron en el sitio arqueológico Arroyo

Figure 1. *Rhinoclemmys rubida perixantha.* Dorsolateral view of male exemplar, carapace length 99.72 mm, from Puerto Vallarta, Jalisco (photographic voucher IBH-RF 646).

Figura 1. *Rhinoclemmy rubida perixantha.* Vista dorsolateral de ejemplar macho de longitud de caparazón de 99.72 mm de Puerto Vallarta, Jalisco (voucher fotográfico IBH-RF 646).

Figure 2. Localities record of *Rhinoclemmys rubida perixantha*. Map made with data from Mosimann & Rabb (1953), Smith & Smith (1979), Cupul-Magaña et al. (2016), and GBIF Secretariat (2021)

Figura 2. Localidades de registro de *Rhinoclemmys rubida perixantha*. Mapa elaborado con datos de Mosimann & Rabb (1953), Smith & Smith (1979), Cupul-Magaña et al. (2016) y GBIF Secretariat (2021).

Piedras Azules, perteneciente a la cultura Aztatlán y que data del año 1215 de nuestra era, distante a 58 km al suroeste del nuevo registro (Cupul-Magaña et al., 2016). No se encontró contenido gástrico en el espécimen después de someterlo a la técnica de lavado estomacal (Legler, 1977). El ejemplar no fue recolectado.

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INCLUSION IS NOT REPRESENTATIVENESS: THE CONTEXT OF COLOMBIAN SAMPLES IN THE TAXONOMIC AND SYSTEMATIC MID-LARGE HERPETOLOGICAL LITERATURE

LA INCLUSIÓN NO ES REPRESENTATIVIDAD: EL CONTEXTO DE LAS MUESTRAS COLOMBIANAS EN LA LITERATURA TAXONÓMICA Y SISTEMÁTICA HERPETOLÓGICA A MEDIANA-GRAN ESCALA

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Colombia is considered as one of the most biodiverse countries in the world (Samper, 1998; Myers et al., 2000; Arbeláez-Cortés, 2013; Zachos & Habel, 2014), but at the same time, sampling efforts have been constrained historically by socio-political issues, limiting the possibility of understanding several aspects of that biodiversity. For instance, scientist in some neighboring countries (e.g., Brazil and Ecuador) discover and describe new taxa at a relatively more rapid rate than Colombia (Rivera-Correa, 2012), and at the same time conduct integrative studies of those groups. Therefore, it comes as no surprise that many comprehensive taxonomic and systematic studies of amphibians and reptiles incorporate little to no data from Colombia (see Appendix I).

While some regard taxonomy as a primarily descriptive and hampering science (Garnett & Christidis, 2017), others perceive it as part of the backbone of many areas such as ecology, evolution and systematics, and as a necessary activity in biology (Thomson et al., 2018). In addition, poorly developed taxonomy causes problems and bottlenecks in the biodiversity sciences (Kaiser et al., 2013; Vogel-Ely et al., 2017). The Neotropical biota has a complex evolutionary history closely related to geological history (Hoorn et al., 2010; Antonelli & Sanmartin, 2011; Antonelli et al., 2018). In these historical processes, the area where Colombia is currently located has played a significant role as a mid-point between Central and South America (Samper, 1998; Jaramillo & Oviedo, 2017). For this reason, studies with considerable sampling gaps address the evolutionary history of lineages partially only, and may be masking genetic structure or species threats (Hillis, 2019; Chambers & Hillis 2020, Cordier et al. 2021). Additionally, these sampling gaps may cause taxonomic instability, since the identity of the unsampled taxa or of taxa in unsampled regions are normally ignored or questioned but not resolved, therefore increasing the number of paraphyletic groups or species complexes. As well, taxonomic and systematic uncertainty generated affects the appropriation of knowledge by local communities and researchers, and also delay the generation of new knowledge.

Herein I will discuss two main topics: 1) the inclusion and representativeness concepts, focused on the herpetological context of Colombia; and 2) possible causes and consequences of systematic inclusion gaps.

In order to do so I performed a bibliographic analysis by mean of an advanced search through the Web of Science Core Collection (WoS, http://webofknowledge.com) for taxonomic and systematic studies of amphibians and reptiles in the Neotropical region during the last 20 years. I defined the beginning of the century as starting point for the bibliographic analysis, because from there, technological advances in computation and communication favored and expanded the accessibility to data and information. For the purposes of this study, I defined two criteria for considering a publication: the taxa studied must

occur in at least two countries (including Colombia), and studies must to be comprehensive, that is, they should to be focused on one or several traits (e.g., morphology, genetics, evolution, bioacoustics, distribution) of a taxon or taxa in a generalized way. I explicitly excluded Colombian only studies because they will include Colombian samples by definition, and this analysis aims to evaluate groups in which Colombian data are not used or limited, compared with the data used for the same group from neighboring countries.

Searches were conducted on the title, abstract and keywords, using as criteria three key elements: SUBJECT = Amphibia OR Reptilia + AREA = South America OR Neotrop* + TOPICS = Taxonom* OR Systematics OR Phylogen* OR Review OR Biogeograp* OR Distribution (* are text wildcards). Results were manually filtered in order to remove publications different to the main topics defined, extinct taxa, and explicitly delimited to a specific area out of the target. Subsequently some studies not recovered in the search were added manually.

I grouped the publications categorically according to whether they included samples from Colombia or not (i.e., yes, no, or partial when not for all lines of evidence used). The studies that included samples from Colombia were then grouped according to the source of those samples (national or foreign museums), and author's nationality or place of residency (natives or established). Author's nationality/residence was corroborated based on their names, historical institutional affiliations or education, personal information available in social networks, CvLAC, ResearchGate, Google Scholar, personal/institutional web sites, or by asking colleagues who possibly know or had worked with them. The idea behind using author's nationality/residence as classification criteria, lies in the fact that Colombian or Colombia resident authors may have a broader notion of the institutions housing biological specimens, their taxonomic and geographic coverage, or their accessibility. Therefore, an author's nationality/residence may affect the probability of choosing a source of data, either national, foreign or both. Subsequently, I calculated the conditional probability of using national and/or foreign museums P(A), given the nationality/rersidence of authors P(B).

$$P(A|B) = \frac{P(B|A)\ x\ P(A)}{\sum P(B|A) x\ P(A)}$$

As I discuss below, there are marked differences in data from national and foreign museums, a reason why the selection of the data sources may be related to the degree of inclusion and representativeness of a taxa in a particular study. To quantify and validate the data for Colombia in biological collections, I downloaded the list and associated information from the Registro Nacional de Colecciones Biológicas (RNC, http://rnc.humboldt.org.co), and a dataset for amphibians and reptiles with country "Colombia" from the Global Biodiversity Information Facility (GBIF, https://www.gbif.org), both to February 8, 2021 (Appendix II). For Colombian museums, the invisibility of the data was calculated as the proportion of data in GBIF divided by the total number of specimens reported in RNC, since this list contains the official number of housed specimens in each collection. Finally, I performed a descriptive analysis of the geographic coverage and data quality in national and foreign museums using the previously mentioned datasets. These data from museums coverage a 180 years span.

After cleaning the search results, a total of 160 studies (77 for amphibians and 83 for reptiles) meeting the inclusion criteria were selected (Appendix I). Most of them included at least one sample from Colombia for their interest groups, followed by those which did not, and a small proportion for which it was impossible to assess the origin of the sample since neither the methods nor the supplementary materials stated explicitly

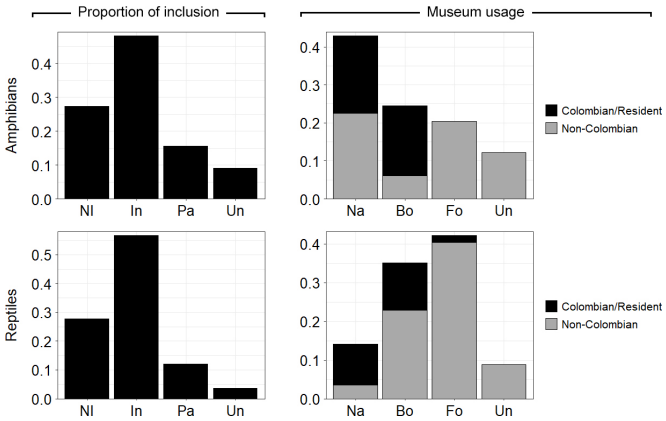

Figura 1. Proporción de inclusión de muestras colombianas y uso de museos en la literatura herpetológica analizada. NI = No incluido, In = Incluido (al menos una muestra), Pa = Parcial (al menos una muestra pero no para todas las líneas de evidencia), Un = Desconocido (no se indicó la localidad). Na = Museos nacionales, Bo = Ambos (nacionales + extranjeros), Fo = Museos extranjeros, Un = Desconocido (no se indicó la fuente de datos).

Figure 1. Proportion of inclusion of Colombian samples and museum usage in the herpetological literature analyzed. NI = Not included, In = Included (at least one sample), Pa Partial = (at least one sample but not for all lines of evidence), Un = Unknown (studies do not state localities). Na = National museums, Bo = Both (national + foreign), Fo = Foreign museums, Un = Unknown (studies do not state the source of data).

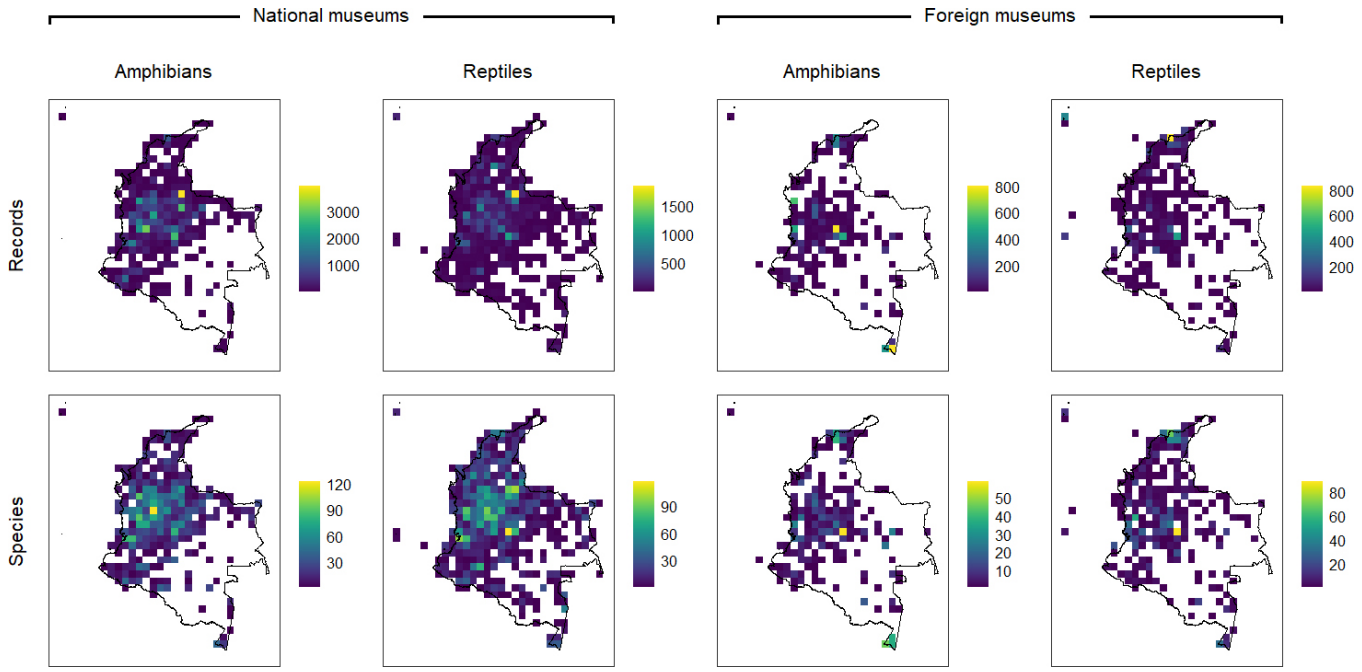

Figura 2. Panorama general de la representatividad geográfica y taxonómica de los anfibios y reptiles recolectados en Colombia, y depositados en museos nacionales y extranjeros. Los mapas están basados solo en registros georreferenciados. El periodo temporal de los museos extranjeros va desde ~ 1840 (probablemente 1800) a 2020, y desde 1875 para museos nacionales. Tamaño del pixel 0.5° x 0.5° en WGS84. Datos tomados del RNC y GBIF (al 8 de febrero, 2021). Las capas raster están disponibles en el Apéndice III.

Figure 2. Overview of the geographic and taxonomic representativeness of the amphibians and reptiles collected in Colombia, and held in national and foreign museums. Maps are based only on georeferenced records. Foreign museums temporal span goes from ~ 1840 (probably 1800) to 2020, and from 1875 in national museums. Pixel size 0.5° x 0.5° in WGS84. Data from RNC and GBIF (accessed February 8, 2021). Rasters are available in Appendix III.

the localities (Fig. 1). Regarding the museum usage, national collections were predominant for amphibians, while foreign were for reptiles (Fig. 1). Conditional probabilities (Table 1) showed that for amphibians it is more likely that in a randomly chosen paper, authors will include Colombian samples from national collections independent of their nationalities. However, for reptiles it is more likely that authors will include samples from foreign museums if they are foreigners, whereas for Colombian/Resident authors the probability of also including national collections increases substantially. Interestingly, data show that foreign museums have less taxonomic and geographic representativeness of Colombian herpetofauna (Fig. 2), and also specimens have less associated geographic information (Fig. 3). Both national and foreign museums possess a similar and significant proportion of specimens taxonomically identified to Family, Genus and Species levels. Georeferenced records also

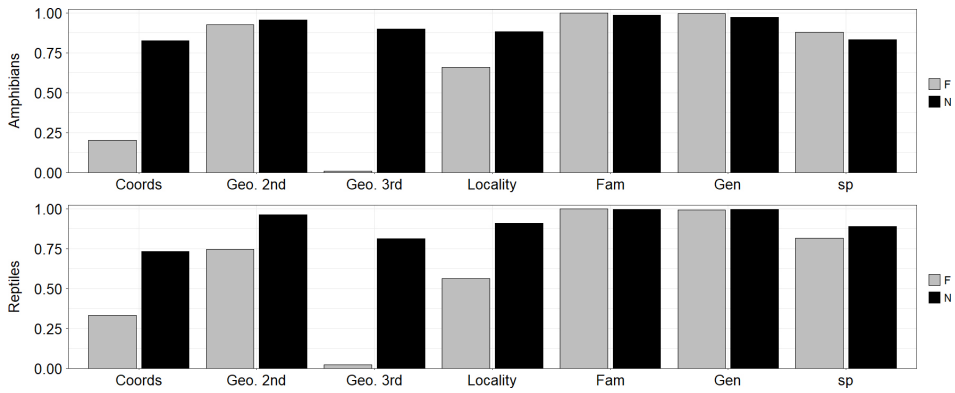

Figura 3. Proporción de datos asociados a anfibios y reptiles. N = Museos nacionales (barras negras), F = Museos extranjeros (barras grises). Geo. 2nd y 3rd hacen referencia al segundo y tercer nivel de división político administrativa (para Colombia departamentos y municipios, respectivamente). Datos tomados del RNC y GBIF (al 8 de febrero, 2021).

Figure 3. Proportion of associated data for amphibian and reptile specimens. N = national museums (black bars), F = foreign museums (gray bars). Geo. 2nd and 3rd refers to the second and third level of administrative political division (for Colombia department and municipality, respectively). Data from RNC and GBIF (accessed February 8, 2021).

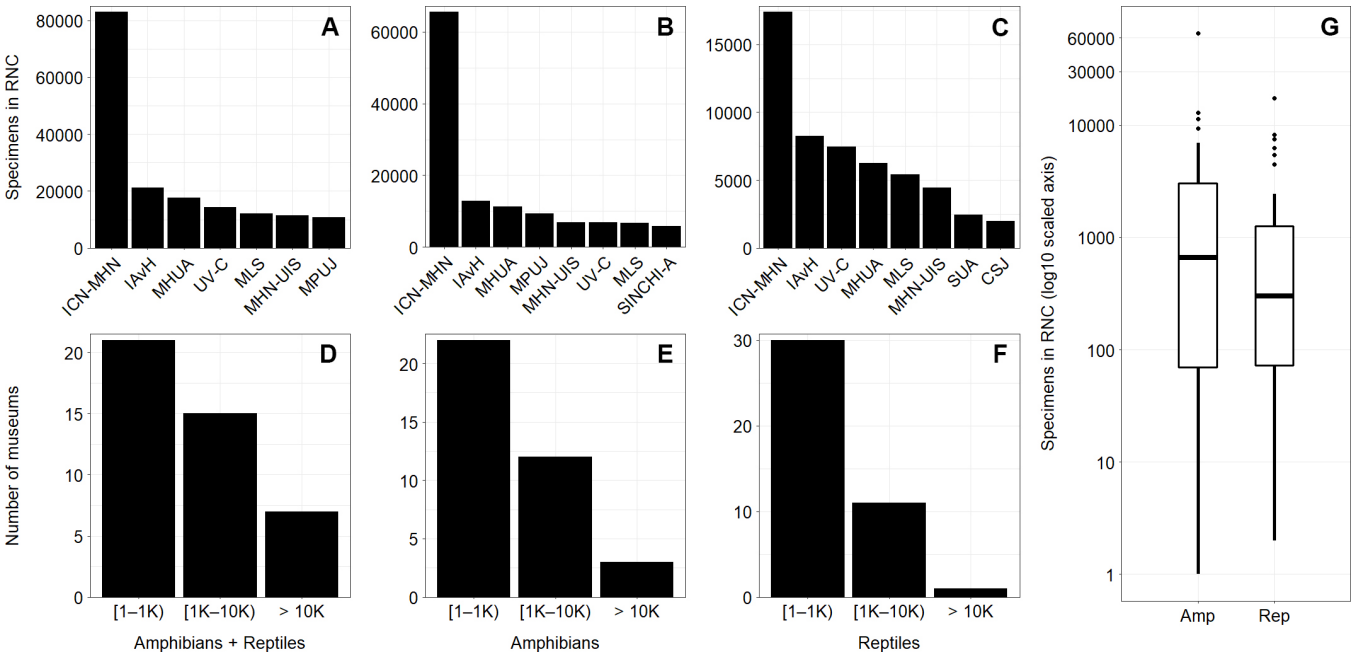

Figura 4. Colecciones herpetológicas colombianas más grandes por número total de especímenes de acuerdo al RNC, ambos grupos (A), anfibios (B), reptiles (C). Número de museos de acuerdo a la proporción de especímenes que albergan, ambos grupos (D), anfibios (E), reptiles (F). Distribución del número de anfibios y reptiles en museos colombianos de acuerdo al RNC. Para los acrónimos de los museos véase el Apéndice II.

Figure 4. Largest Colombian herpetological collections by total number of specimens according to RNC, both groups (A), amphibians (B), and reptiles (C). Number of museums according to the proportion of total number specimens, both groups (D), amphibians (E), and reptiles (F). Distribution of the number of specimens of amphibians and reptiles in Colombian museums according to RNC (G). For museum acronyms see Appendix II.

show that foreign museums have focused their sampling efforts in two areas, Sierra Nevada de Santa Marta in the Caribbean region, and Leticia and nearby areas of Amazonas, whereas national museums have focused on the central and north portion of the Andes of Colombia.

Excluding zoos and live collections, there are 43 herpetological museums formally registered in the RNC, of which 37 have both amphibian and reptile subdivisions, for a total of 80 collections. The approximate total number of preserved specimens (amphibians + reptiles) with country listed as "Colombia" is about 58 000 in foreign museums, and just over 214 000 in national collections (Table 2). Almost 80% of the latter are housed in seven museums, each of which has more than 10 000 specimens (Fig. 4A). Looking at each biological group independently, the ICN collection by far exceeds the number of specimens both for amphibians and reptiles when compared to the other largest museums (Fig. 4B-C). Most of the herpetological museums and collections in Colombia are small, having less than 1000 specimens, followed by those which have between 1000 and 10 000, and the largest ones with more than 10 000 (Fig. 4D–G). According to GBIF, 62.5% of the herpetological collections in Colombia do not have public data in that platform. For the available datasets, the invisibility of the specimens is quite variable, ranging from 0 to 98%, while some collections have more records in GBIF than those declared in the RNC (Fig. 5).

Tabla 1. Probabilidades del uso de museos P(A) en la literatura herpetológica, por nacionalidad/establecimiento de los autores P(B), expresado como una probabilidad condicional P(A|B). Los cálculos están basados en la proporción de artículos que incluyen al menos una muestra de Colombia. Ver Apéndice I.

Table 1. Probabilities of museums usage P(A) in the herpetological literature, by authors nationality/residence P(B), expressed as a conditional probability P(A|B). Calculations are based on the proportion of papers including at least one Colombian sample. See Appendix I.

Museum	Amphibians (n = 43)		Reptiles (n = 52)	
	Colombian/ Resident	Non-Colombian	Colombian/ Resident	Non-Colombian
National	0.6604	0.6294	0.2264	0.0193
Both	0.3396	0.0981	0.6604	0.3140
Foreign	0.0000	0.2725	0.1132	0.6667

According to the data of inclusion of Colombian samples in the literature analyzed, it seems there are more studies including samples (independently of their origin) than those do not. Here, I am considering the degree of inclusion in a given publication as the number of samples relative to the species' distribution, different from sampling proportion, which comprises the number of samples relative to the total, and representativeness, as the variation encompassed by those samples. However, it is important to keep in mind that both inclusion and representativeness are dependent on taxon-distribution and sample availability (Fig. 6). This means that they are not directly comparable among studies on a continuous or discrete scale, because even the same proportional sampling may be more or less inclusive and representative for certain taxa. Thus, in order to account for the overall inclusion, the use of categories is necessary (e.g., included vs. non-included). The primary limitation of this method is its trend to inflate the proportions, masking the true extent of the gaps, since just one single sample is sufficing to consider a study as inclusive. This is why in many taxonomic or systematic studies in herpetology the degree of inclusion and representativeness of Colombian samples is apparently high, when in reality is low to null, often limited to a few samples which do not reflect their actual availability in biological collections. Although it is easily explainable for rare taxa for which large samplings are not expectable, it is less understandable in the case of widespread or common groups.

This problem is a vicious circle, since the known distributions of many taxa represent theoretical approaches, normally reflecting sampling effort (Hortal et al., 2015), but they cannot be refined if data from specimens are not included in the studies. However, to discuss the degree of inclusion and representativeness, it is also important to consider that inclusion does not necessarily reflect representativeness. To better illustrate the inclusion-representativeness relationship, I have summarized some patterns of inclusion and representativeness based on hypothetical scenarios (Fig. 6). The first pattern is evidenced when there are few samples of a given taxon that has a small distribution range in site 1 relative to site 2; in this case it is expected for 1 to have a low proportional sampling, but the inclusion is high and representativeness should be considered good (Fig. 6A). The second pattern is identified when a taxon is widely distributed in two or more sites, but some of them are significantly more heavily sampled (Fig. 6B–C). In this case the inclusion is low and the representativeness poor to medium, because variation in the less sampled sites is uneven compared to variation in the more well-sampled sites, therefore inferences will be biased towards the latter. For the example B

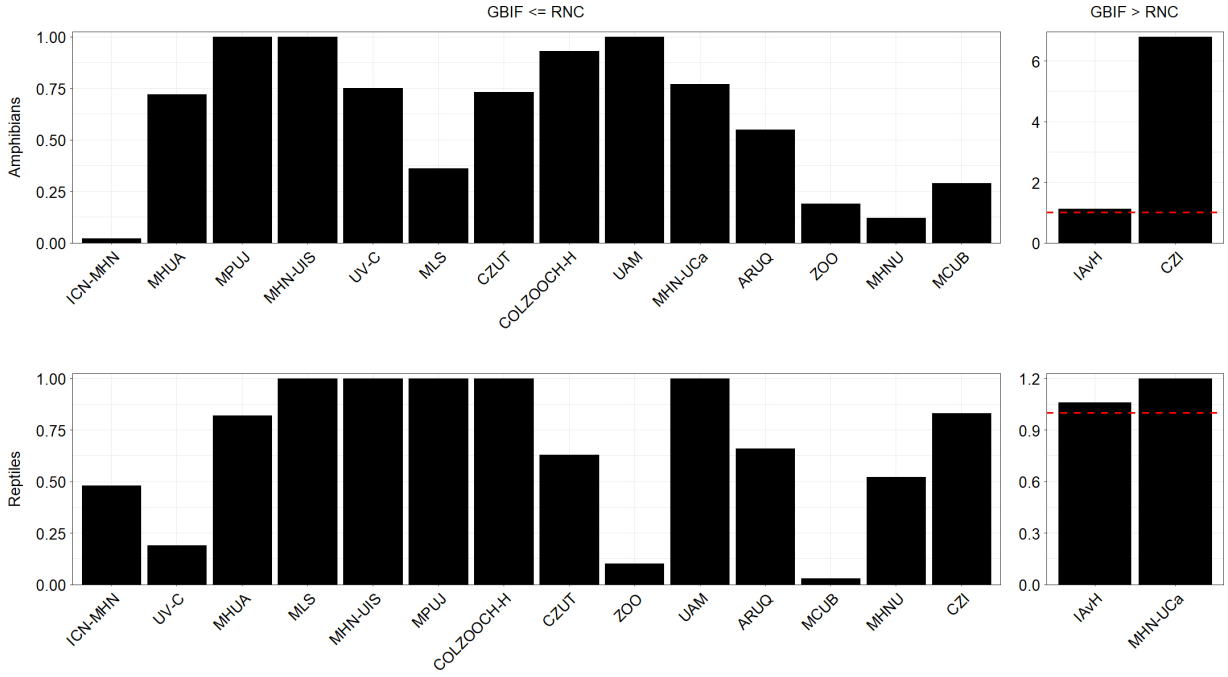

Figura 5. Visibilidad de los datos asociados a anfibios y reptiles en museos colombianos, como la proporción de datos publicados en GBIF sobre los del RNC (para GBIF ≤ RNC). La línea roja indica el número total de especímenes en el RNC (para GBIF > RNC). Para los acrónimos de los museos véase el Apéndice II.

Figure 5. Visibility of amphibians and reptile data in Colombian museums as the proportion of published records in GBIF datasets compared to of RNC (for GBIF ≤ RNC). The red dashed line represents the total number of specimens in RNC (for GBIF > RNC). For museum acronyms see Appendix II.

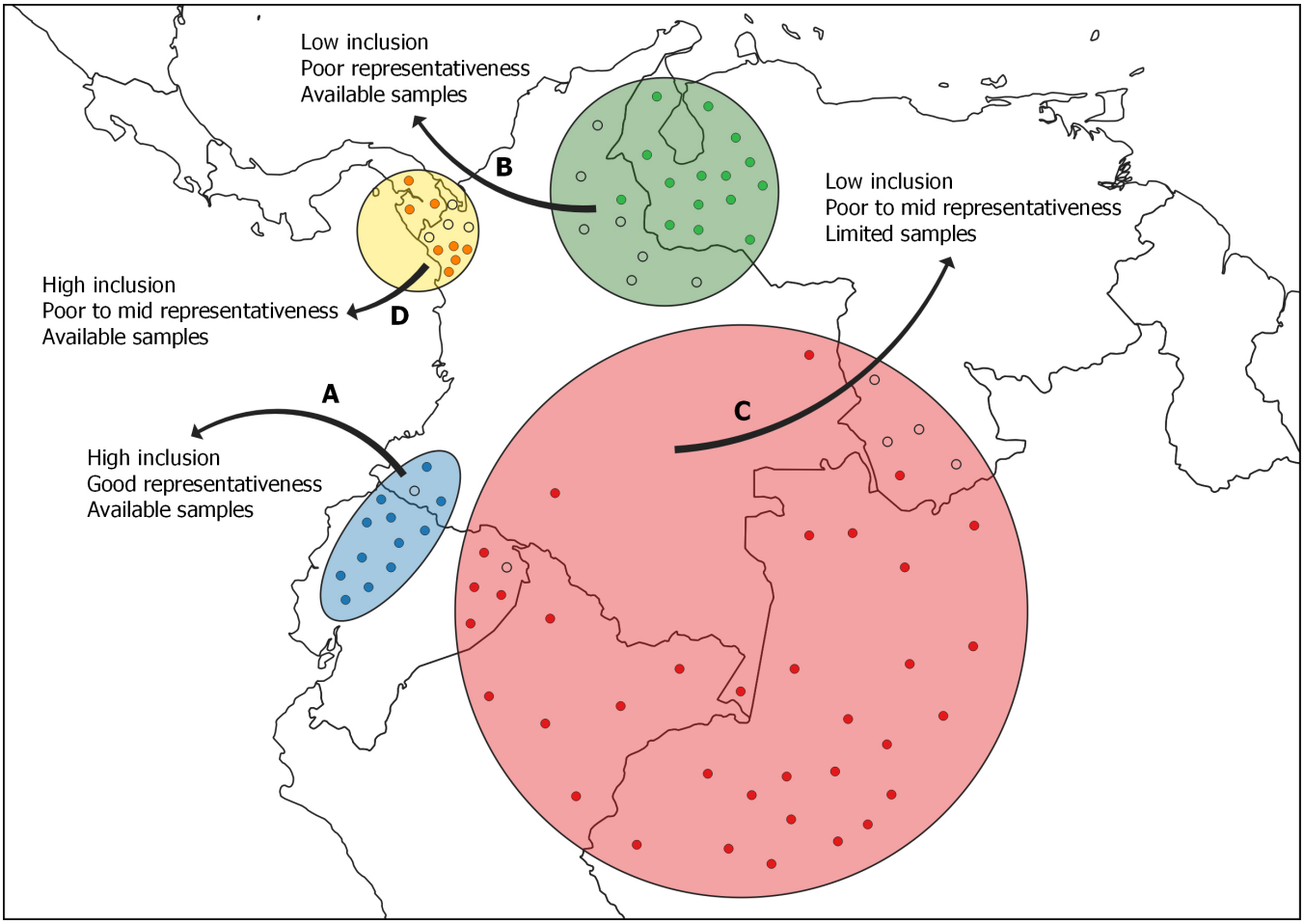

Figura 6. Patrones de inclusión y representatividad de acuerdo a la distribución de los taxones y disponibilidad de muestras en escenarios hipotéticos. Los puntos coloreados representan los registros incluidos en tres escenarios hipotéticos, mientras que los vacíos representan los no incluidos pero disponibles en colecciones biológicas. Para una descripción detallada véase el texto.

Figure 6. Patterns of taxonomic inclusion and representativeness according to taxa distributions and sampling availability in hypothetical scenarios. Solid circles represent included records in the three hypothetical scenarios, whereas open circles represent non-used but available specimens in biological collections. For detailed description see the text.

in the Fig. 6, low inclusion is non-justified given the availability of samples, contrary to the observed in the scenario C. It is worth noting that inclusion may increase without an increase in representativeness, when there is sampling but it does not imply more variation (Fig. 6D). There are not numerical criteria to define what is low or high, poor or good, the scenarios presented represent a referential conceptualization. In real life, the degree of inclusion and representativeness for a taxonomic group may be influenced by different reasons, that will be the subject of discussion later.

For instance, with Colombia as a reference point, the first pattern is commonly found in Amazonian taxa for many of the amphibians in the literature that was analyzed. Nonetheless, it is important to consider that the Colombian Amazon and Orinoquía are largerly unexplored, thus the real distribution of many groups may be underestimated (Wallacean shortfall). On the contrary, the second pattern is more frequent in reptiles' literature, for groups distributed in northwestern South America or extending from Central to South America. Historically, Colombian amphibians have attracted more attention than reptiles, this is the reason why they have been more thoroughly studied, and therefore their inclusion pattern is more accentuated.

As shown, at a large taxonomic scale inclusion and representativeness of Colombian samples may be masked by the difficulties of comparing among studies. For this reason,

Tabla 2. Especímenes de anfibios y reptiles en museos colombianos y extranjeros de acuerdo al RNC y GBIF. La invisibilidad está calculada como la proporción GBIF/RNC según los datos publicados (al 8 de febrero, 2021).

Table 2. Amphibian and reptile specimens in Colombian and foreign collections according to RNC and GBIF. Proportion of invisibility based on GBIF/RNC published data (accessed February 8, 2021).

Group	National				Foreign	
	Number of collections	Specimens RNC	GBIF/SiB	Invisibility proportion	Number of collections	GBIF
Amphibians	37	147 927	54 955	0.63	42	38 714
Reptiles	43	66 387	37994	0.43	59	19 814

it is necessary an approach based on an indirect measure. One criterion is to use the differences in geographic coverage and data associated with the specimens between national and foreign museums, which may limit the usage of some of them. Most specimens from foreign museums lack georeferenced data and/or information at the municipality level (3rd administrative level), hence generating a broad margin of error when spatializing them in if the locality does not supply that information. This is particularly true when records come from an orographically and ecologically heterogeneous zone like the Andes. For example, mainland Colombian departments range from ca. 1800 to 110 000 km², therefore, just with 2nd level information, locality uncertainty is larger than the area of Hong Kong (~ 1100 km²), El Salvador (~ 20 800 km²), Costa Rica (~ 51 000 km²) or Cuba (~ 109 800 km²). In this manner, if we consider foreign museums as the preferred source for foreign researchers, together with the amount of invisible data from Colombian museums, the number of spatializable specimens as a necessary condition for a comprehensive study in taxonomy and systematics is reduced. Another important problem arises when looking at the tables, appendices or supplementary data in the literature, because the traceability of some specimens because the traceability of some specimens (mainly genetic samples) is often messy because field numbers or provisional codes are normally provided, but not notes clarifying the ultimate disposition of the sample.

Regarding data quality for older specimens, it is also important that there is a historical bias for the capital cities to have many records and species, even if they do not occur there. For instance, despite the fact Bogotá is highly represented in foreign museums (the yellow pixel in central Colombia in Fig. 2), several records may be misattributed to this locality, a frequent mistake in specimens sent out from major cities during the XIX and XX centuries, which were assumed to be the locality of origin. This bias may induce errors by omission if researchers are unfamiliar with the history of collections in Colombia, or simply inhibit them from utilizing data if distributions are suspicious.

Another factor that may mask the sampling inclusion are the types of data used, which vary according to the objective of the study. Essentially, data may be of four types: geographic, morphologic, genetic and bioacoustic. Among them, geographical data are the easiest to obtain, since they merely require a GBIF download or a literature review, reason why studies employing this kind of information tend to have more inclusion and representativeness for Colombian samples. By comparison, morphology, genetics and bioacoustic data require the greatest effort to obtain, thus their inclusion and representativeness tend to be lower.

To conclude, I have explored five possible reasons that may explain the phenomena what have I been pointing out along the text. I do not consider these points to be isolated from each other, on the contrary, they may be synergetic among them and vary in importance and occurrence through time.

The true absence of sampling. It is well known that among living beings there are some groups/species that are particularly difficult to find. This difficulty may be due to: 1) the biology/habitat of the species (e.g., aquatic, fossorial or canopy-dwelling); 2) the spatial distribution or density of target populations; and 3) the inaccessibility of the sampling areas, because of conditions of both terrain or due to socio-political issues. This last is particularly true for Colombia, where internal armed conflict and its derivatives, have constrained the exploration of many territories during the last 60 years. The absence of sampling represents the most significant limitation, because it represents a real absence of data.

Within the absence of sampling, it is also necessary to highlight the absence of tissue samples for DNA extraction. In

Colombia taking tissue samples is an activity that dates back to 1998 (Arbeláez-Cortés et al., 2015), but it is limited given the resources and equipment required for storage, a reason why not all museums have a tissue collection, or if they do, it is relatively recent. Although molecular data do not represent a necessary condition for taxonomic studies, it is an important and comprehensive source of information in the -omics age (Will et al., 2005). This brings us to the problem that most collections from Colombia do not have associated genetic samples, either because they are old collections, or because researchers collect but do not extract tissues for DNA. At this point, it is important to highlight that the absence of genetic data for older collections does not make them useless, museum specimens are and have been traditionally used beyond molecular taxonomy (Castillo-Figueroa, 2018; Meineke et al., 2018; Guedes, 2021).

Now, the question is how to deal with the true absence of sampling? The most straightforward answer is to do more sampling. Nevertheless, this is easier on paper than in practice. Here, I am limiting myself to remark on some strategies that might help to address the problem of the true absence of sampling. First is the implementation of the integrative taxonomy approach when possible, by using various lines of evidence rather only one (Dayrat, 2005). This allows exploitation of old collections that may contain rare specimens or have accumulated a more complete geographic representation over time. Second, taking advantage of environmental consulting activities to fill in the sampling gaps in several taxa (i.e. taxonomic, geographical or genetic gaps). Environmental consulting activity is probably the chief source of new specimens to museums in Colombia, more than research itself, and normally companies that provide these services have budgets within which the collection activities are or may be included. Third, the implementation of novel techniques for recovering DNA from specimens that have been processed using formaldehyde (see Hykin et al. 2015 for an example in reptiles). I am aware that these last procedures may be expensive, however, they offer an option for very rare or even recently extinct taxa.

The bureaucracy. Bureaucracy depends on legislation, and laws are not static in time. Dealing with the bureaucracy is part of doing science, and to some extent a necessary one. Nevertheless, it is a critical factor to consider when conducting a research project, because it can generate delays, discourage researchers when processes are expensive or slow, and may even propitiate biopiracy (Fukushima et al., 2020).

For biological studies there are two principal ways to obtain data, museums and fieldwork, each has its limitations, although the former is among the most versatile (Meineke et al., 2018). In any case, in Colombia temporary or definitive collecting requires collection permission, and if definitive, the material must be deposited in a museum legally registered in the RNC.

The Colombian government issues permissions for commercial and non-commercial uses of biodiversity, and within these, for collecting specimens or accessing genetic resources (Decree 1076/2015). Collection permission without commercial purposes also include genetic research. These permissions are given by the environmental authorities to people or institutions interested in catching, removing or extracting, either temporarily or permanently, individuals from the wild. The request for permission may require several months for resolution, along with the requirements of submitting many forms and documents in support of the request (Supplementary Fig. 7A). For this reason, the most convenient solution is to conduct the research in association with a local institute that already has an umbrella permission, such as universities or scientific and governmental institutions.

Another issue arises when we want to sequence DNA. If the process is carried out in Colombia under an umbrella permission, there are no problems. But most institutions in Colombia do not have a sequencer, thus the most viable option is to send the samples outside the country for processing. Here is when bureaucracy may delay research, because additional permission is required to export biological specimens or samples (Supplementary Fig. 7B). As a result, researchers may avoid using genetic data from Colombia if it is not previously available in online repositories such as GenBank (https://www.ncbi.nlm.nih.gov/genbank), or if it cannot be generated locally. However, export permits are required for biological specimens, samples of them or their derivatives. This last point leaves an unsolved question, a loophole subject to interpretation, to what extent is an artificial product a derivative? Consider for example a PCR product, which is a synthetic soup of unordered nucleotides, an artificial model based on a mold, like a plaster cast of a mammal footprint, or like photographs and illustrations, which do not constitute the specimen itself or a sample of that specimen.

Finally, an additional consideration is the compensatory tax for wildlife hunting (Decree 1272/2016), which increases the economic cost of studies, given that the hunting concept includes temporal or definitive captures, and their subsequent processing, transportation and/or storage (Páez, 2016). This tax is calculated by specimen/sample, and employing a formula that considers the species and habitat conservation status, researcher's nationality, anthropic pressures, social

and environmental cost of the samples, commercial value of the species, and even how charismatic they are. Ironically, this creates a vicious circle, because the tax calculations require ecological data, but at the same time they are an impediment for the gathering of these data.

Then, how to deal with the bureaucracy? As I mentioned previously, one of the easiest solutions is to cooperate with local researchers and institutions. Furthermore, as I will discuss below, the use of online databases enhances the visibility of the existing specimens and facilitates their examination, since local researchers may help with data, reducing costs and time, at the same time building up the local researcher's visibility.

The invisibility of the data. One of the greatest advantages of the internet is that it brings the world just a click of distance away, and it is a powerful tool for museums and researchers. When a research project is planned, two of the first questions we need to think about are, what data are available? And, what data do I need to generate? There is an increasing trend towards making biodiversity data available through the internet, either through researchers or institutional web pages or by using repositories like GBIF.

But how this related to the problems of inclusion and representativeness? Fundamentally, the invisibility of data constitutes a false absence of sampling. This invisibility may be total if the museums do not utilize any electronic resources (or worse if they are secretive with their collection information), or partial if they utilize the resources but do not update information regularly, upload incomplete datasets, or if communication with the staff is not fluid and results in delays.

Biological collections in Colombia are regulated by Decree 1375/2013. According to this, museums assume the responsibility to keep updated the information associated with their specimens and upload it to SiB (Sistema de Información sobre Biodiversidad de Colombia, https://sibcolombia.net), a local repository of biodiversity similar to GBIF and also a source of information for the latter. This platform is centralized with a standardized format which offers an advantage over institutional museum webpages, which may not have advanced search tools, bulk download options, or may change their URL overtime or go offline.

Interestingly, the data from the biological collections in Colombia show that there are hundreds of thousands of amphibians and reptiles collected, covering a large spatial and temporal span, but it is important to note that spatial and temporal coverage does not imply taxonomic coverage, and some taxa may be oversampled while some others are undersampled. Then, why is there so little representativeness in the mid-large herpetological literature? It is important to keep in mind several considerations. First, literature reviewed herein encompasses a time period of 20 years, and probably the digitalization of many museum catalogues is more recent, as is the gradual increase in geographic coverage. In the same way, the extended use of the internet, digital resources and technology has increased enormously during the last decade, and some researchers have incorporated these changes faster than others. Therefore, it is impossible to expect that a researcher 15 years ago to have had the same access to the data that we have today. However, for some taxa with obtainable information (by whatever means), the invisibility of available samples has been, and will continue to be a problem.

Currently, the invisibility of specimens varies considerably among Colombian herpetological museums, being relatively high when grouped (Table 2), but smaller when individual collections are depicted (Fig. 5). This is explained by the large number of non-available records in some of the collections with the largest number of specimens, which shifts the general mean to higher values. On the other hand, some museums possess "extra" data when GBIF and RCN are compared. The latter reveals a phenomenon of inefficient handling of the platforms where the data can be uploaded or summarized. Given that not all the online platforms retrieve the data from a unique source, these differences are to be expected, for example, because curators may more frequently update the source they are more familiar with, or which its institution requires for most often. I am also aware that the entropy level (as a measure of disorder) in a biological collection will increase exponentially with the number of specimens they have, which makes easier the data curatorship and handling in smaller ones. Entropy is fine and expectable in a collection being used, but extreme entropy or entropy in unused collection are not desirable. As well, at least for the Colombian museums attached to university institutions, curators usually also play a role as professors, which also limit greatly the time and effort they can spend in curatorial activities.

To bypass this problem the implementation of good practices during data curatorship and collecting are required, not only inside individual museums but in the field at large. For example, taking the time to identify the specimens more than assign IDs based on localities or at bird's-eye view, using traceable unique identification vouchers, unifying databases in single or linked files, avoiding uncommon or non-universal abbreviations, georeferencing records, using copy functions instead of

transcribing, having data backups, and adding metadata when possible. It is also important to standardize the museum databases implementing tools or platforms specifically designed for that purpose, so that information can be ordered, available, and updated.

The market of local researchers. If you think scientific collections as a marketplace where researchers and specimens are the products, the limited inclusion of Colombian samples in the mid-large scale herpetological literature could be said due to by two essential factors: the poor offer for the actual demand, or the reduced visibility of the products. The decline or inertia in the taxonomic work has been much discussed in the literature, including in the Colombian context (e.g., Hopkins & Freckleton, 2002; Rivera-Correa, 2012; Tancoigne & Dubois, 2013). Among the causes there are the perceptions of taxonomy as an old and boring discipline, novel ways to perform research, and new research interest beyond classifying. This results in a lack of trained taxonomists to meet the demand when a comprehensive study in taxonomy, systematics or biogeography is planned or conducted. The limited visibility of local researchers is also a problem, and may be driven by several causes, such as the perception that they lack appropriate academic degrees, they have little connection with more experienced researchers, they are young researchers with low impact, or they do not use or regularly update scientific networks (e.g., ResearchGate, ORCID, Google Scholar, Publons).

These two factors may explain in part the low inclusion of Colombian samples in the herpetological literature. To correct this requires the teaching of taxonomy not as a discipline that merely describes new taxa, but as a valuable tool that must be integrated with whatever question we want to answer (e.g., in ecology, evolution, genetics, or biogeography). In the same way we choose a statistical analysis according to our data and what we want to answer, we should be equally cautious about the taxonomy, because the principle of "garbage-in garbage-out" is applicable.

The selfish problem. Science is in principle composed and made by a human community, and is not always a peaceful and ideal one. Within science, disagreement among researchers and institutions is not a novel problem (Sherwood, 2011), and historically it has been related not solely to conflicting interest with respect to ongoing research, but to personal, political, racial or gender reasons (Lemaitre, 2015; Lemaitre, 2017; Grosso et al., 2021). Addressing this problem is really hard since it does not imply a technical, methodological or budgetary impediment, but personal beliefs and mixed feelings. Of the five reasons discussed here, it is not the most prevalent, but without a doubt it is the most dangerous.

The problem of inclusion and representativeness is not a novel issue, and it is not unique to herpetology or restricted to Colombia, but in this particular case it exhibits an historical and systematic pattern. Data from other taxa are needed to validate whether the causes proposed herein represent a phenomenon extending to other fields. I am aware that it is not always possible to include the ideal number of samplings, but I encourage authors to be prudent with the titles, inferences and conclusions derived from comprehensive studies with considerable sampling gaps, since those gaps may be masking evolutionary, biogeographic and genetic patterns. To conclude, it is important to emphasize that I am not arguing that the low inclusion of Colombian samples be debt that must be paid by including Colombian authors, on the contrary, the main objective of this text is to expose the volume of underutilized data that are waiting to be used.

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SUPPLEMENTARY INFORMATION

The electronic version contains supplementary material available at https://drive.google.com/drive/folders/1_nyPjwH1P9BrGJfuc7KCVwtKPGbpnEm6?usp=sharing

and https://doi.org/10.6084/m9.figshare.14368742

Appendix I. Reviewed literature for amphibians and reptiles where the Colombian samples inclusion was evaluated.

Appendix II. Museums with Colombian samples (nationals + foreigners) and data summaries.

Appendix III. Figure 2 raster maps (in WGS84 datum, cell-size 0.5° x 0.5°).

Appendix IV. Spanish version of this manuscript.

Supplementary Fig. 7. Workflow diagram of the process to request a collection permission for non-commercial scientific research in Colombia (A), and to request permission to export and/or import non-CITES biological specimens (B). Adapted from Autoridad Nacional de Licencias Ambientales (ANLA, http://portal.anla.gov.co).

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