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ANFIBIOS Y REPTILES: DIVERSIDAD E HISTORIA NATURAL

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Foto de portada: Dos machos adultos de *Heloderma alvarezi* peleando durante la temporada de reproducción.

Foto: Aarón Gómez Cruz.

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EDITORIAL
Goyenechea et al. — Criteria for publishing first and new geographic records — e1224 — viii-xv https://doi.org/10.22201/fc.25942158e.2024.4.1204

FIRST AND NEW GEOGRAPHIC RECORDS: GENERAL CONSIDERATIONS FOR THEIR RELEVANCE IN HERPETOLOGY

PRIMEROS Y NUEVOS REGISTROS GEOGRÁFICOS: CONSIDERACIONES GENERALES PARA SU RELEVANCIA EN HERPETOLOGÍA

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Resumen.– Documentar la distribución geográfica es fundamental para el estudio de los procesos eco-evolutivos en los que es necesario asociar la ocurrencia de los organismos con factores históricos y ambientales. Un paso clave en este proceso de documentación, es el establecimiento de criterios claros para los primeros y nuevos registros, por lo que presentamos una serie de recomendaciones y consideraciones las que permitirán mantener la precisión científica y relevancia de las publicaciones que den a conocer esta información. Invitamos a todos los colaboradores a documentar y verificar rigurosamente sus hallazgos, favoreciendo así contribuir al conocimiento científico y a la conservación de la biodiversidad herpetológica.

Palabras clave.– Biodiversidad, conservación, registros geográficos.

Abstract.– Documenting the geographical distribution is essential for studying eco-evolutionary processes when it is necessary to associate the organisms' occurrence with historical and environmental factors. A key step in this documentation process is establishing clear criteria for first and new records. We introduce a series of recommendations and considerations to maintain the integrity and relevance of the publications that disclose this information. We invite all collaborators to document and rigorously verify their findings, thus contributing to scientific knowledge and the conservation of herpetological biodiversity.

Keywords.– Biodiversity, conservation, geographic records.

Delimiting the geographic distribution of species is essential not only for a better understanding of their biology but also for describing how organisms are distributed across space. Additionally, it helps to elucidate the influence that abiotic (e.g., climate, Lomolino et al., 2006), biotic (e.g., resource availability, competition with other species, Peterson et al., 2011), and historical (e.g., geographic barriers, Brown et al., 1996) factors all have in defining their distribution. While various methods have been proposed to delimit the distributional range of a taxon (Morrone, 2009), a consensus on the most appropriate procedures to delineate these areas is still needed. These approaches rely on accurate biological data, specifically on geographical information (latitude and longitude) derived from undeniable evidence of a species' presence at a given location (Ríos-Muñoz & Espinosa-Martínez, 2019). Therefore, documenting records considered extralimital or beyond the known distribution of taxa is crucial, highlighting the importance of geographic distribution reports.

One of the most common contributions received by the Revista Latinoamericana de Herpetología (RLH) are geographic distribution notes. Up to Volume 7(3) of 2024, the journal has published 128 such notes, showing a consistent annual increase (Fig. 1). Typically, these publications report new records in a single taxon (87.5 %), with only one report documenting more than 10 records (García-Padilla et al., 2024). These records span 42 families, predominantly representing Squamata (snakes and lizards, Table 1). As an example, seven new records for the exotic snake species *Indothyphlops bramianus* have been published in

six different papers (Castañeda-Ortega & Guzmán-Guzmán, 2020; Valdez-Villavicencio et al., 2022; Morales-García & Morales-García et al., 2022; Villalobos-Juárez & García-Padilla, 2023; Sánchez-Luna et al., 2023; Reyes-Velázquez et al., 2024). Among amphibians, salamanders in the genus *Bolitoglossa* have the highest number of new observations, with records for seven species published in three papers (Ahumada-Carillo, 2020; Núñez-Robles et al., 2022; Groen et al., 2023).

Regarding geographic representation, the largest number of distributional notes have been published for Mexico (particularly Oaxaca and Veracruz), followed by Colombia, Costa Rica, and Argentina (Fig. 2). This pattern is expected given the state of herpetological knowledge in the Americas, which remain in a phase of documentation or discovery. In other words, extensive areas are poorly known, and with no amphibian or reptile surveys yet conducted, thus attracting a higher number of researchers documenting herpetological diversity in those areas.

Among the geographic distribution notes, two main types are identified: **1) First records**, which refer to the initial documented report of a species' presence at a specific location, different from the original site where the species was first described. These records are significant as they confirm the presence of a species in a new area. They may be categorized as geographical, biogeographical, ecological, or even political (based on administrative boundaries), potentially impacting its biogeography and ecology (Lomolino et al., 2006). An example of this is the study by Nahuat Cervera et al. (2024), who document a first record of the snake *Ninia diademata*. While its distribution was previously known in Campeche, on the Yucatán Peninsula, the authors report it for the first time in the state of Quintana Roo. The second main type are **2) new records or range extensions**, which are subsequent observations of the same species in surrounding areas. These records can provide information about shifts in distribution, range expansions, or the discovery of previously unknown populations in adjacent regions (Brown et al., 1996) or for documenting the spread of invasive/non-native taxa. For example, García-Grajales et al. (2024) published a new record of *Hemidactylus turcicus* on the central coast of Oaxaca, noting that its presence was already known in the region, but now it is specifically documented in a drainage canal. Both types of descriptions are fundamental for expanding the known distribution areas of taxa.

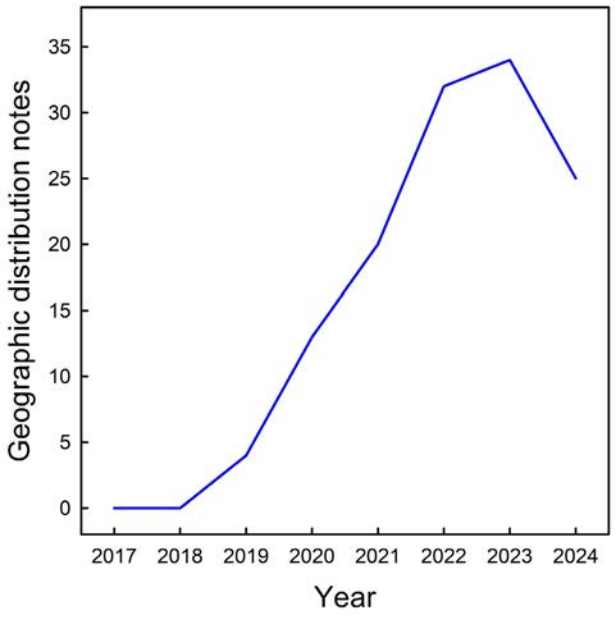

Figura 1. Comportamiento de publicación de notas de distribución geográfica por año desde el inicio de la Revista Latinoamericana de Herpetología hasta el Volumen 7(3) del 2024.

Figure 1. Number of notes on geographic distribution from the beginning of the Revista Latinoamericana de Herpetología until Volume 7(3) of 2024.

Publishing geographic distribution notes requires clear criteria to define what qualifies as a "new" or "first" record. This ensures scientific precision and relevance, similar to protocols in other taxonomic groups (e.g., Sánchez-González, 2013) where new records must meet specific criteria, such as: 1) The taxon is documented for the first time within a political entity; 2) the taxon is reported in a biotic region or altitudinal range different from those previously documented; 3) the presence of the taxon is confirmed at the study site, or a previously considered extinct taxon is rediscovered at the site; 4) a comprehensive literature review confirms that the species has not been reported previously, and 5) the new findings align with established biogeographic patterns through areas of endemism (Sánchez-González & Navarro-Sigüenza, 2009).

In the herpetological context, we propose a set of criteria to consider first and new records (range extensions):

1. **Solid evidence**. Records must be based on direct observations, collected or photographed specimens, or even vocalizations in the case of anurans, where species identity can be confirmed using clear diagnostic features to prevent taxonomic ambiguity (Ríos-Muñoz & Espinosa-Martínez, 2019). Furthermore, records should be supported by detailed documentation, including photographs, accurate descriptions, geographic coordinates, altitude, date, and time.

Tabla 1. Número de notas de distribución geográfica por familia publicadas desde el inicio de la Revista Latinoamericana de Herpetología hasta el Volumen 7(3) del 2024.
Table 1. Number of notes on geographical distribution per family published from the beginning of the Revista Latinoamericana de Herpetología until Volume 7(3) of 2024.

Order	Family	Notes per family
Anura	Alsodidae	1
Anura	Bufonidae	4
Anura	Calyptocephalellidae	1
Anura	Centrolenidae	5
Anura	Craugastoridae	1
Anura	Eleutherodactylidae	2
Anura	Hylidae	19
Anura	Leptodactylidae	4
Anura	Microhylidae	2
Anura	Strabomantidae	2
Anura	Telmatobiidae	2
Caudata	Pletodonthidae	13
Crocodilia	Crocodylidae	1
Gymnophiona	Dermophiidae	2
Squamata	Amphisbaenidae	2
Squamata	Anguidae	5
Squamata	Anolidae	5
Squamata	Boidae	3
Squamata	Colubridae	12
Squamata	Colubridae (Dipsadinae)	28
Squamata	Corytophanidae	2
Squamata	Crotaphytidae	1
Squamata	Dibamidae	1
Squamata	Elapidae	3
Squamata	Eublepharidae	1
Squamata	Gekkonidae	1
Squamata	Gymnophthalmidae	2
Squamata	Helodermatidae	2
Squamata	Hoplocercidae	1
Squamata	Iguanidae	2
Squamata	Leptotyphlopidae	1
Squamata	Natricidae	2
Squamata	Phrynosomatidae	7
Squamata	Scincidae	2
Squamata	Sphaerodactylidae	2
Squamata	Typhlopidae	8
Squamata	Viperidae	16
Squamata	Xantusiidae	2
Testudines	Emydidae	3
Testudines	Geoemydidae	1
Testudines	Kinosternidae	3
Testudines	Trionychidae	1

2. **Voucher specimen registration**. Records must be deposited in a scientific collection, with a catalog number for traceability, whether it pertains to specimens, photographs, or audio recordings. This ensures record permanence and the possibility to be reevaluated if necessary (Lee et al., 1982).

3. **Consider political-administrative boundaries**. Although these do not reflect biotic limits, a change in administrative location (e.g., a different municipality) might not be biologically significant. However, this criterion may be used for completing biotic lists of geopolitical divisions, even in states with small municipalities, which can serve purposes beyond natural studies, such as conservation efforts or biodiversity inventories (Rojas-Soto & Oliveras de Ita, 2005).

4. **Contextualize geographic and ecological distribution.** By documenting species in locations where their presence is plausible but not confirmed by existing

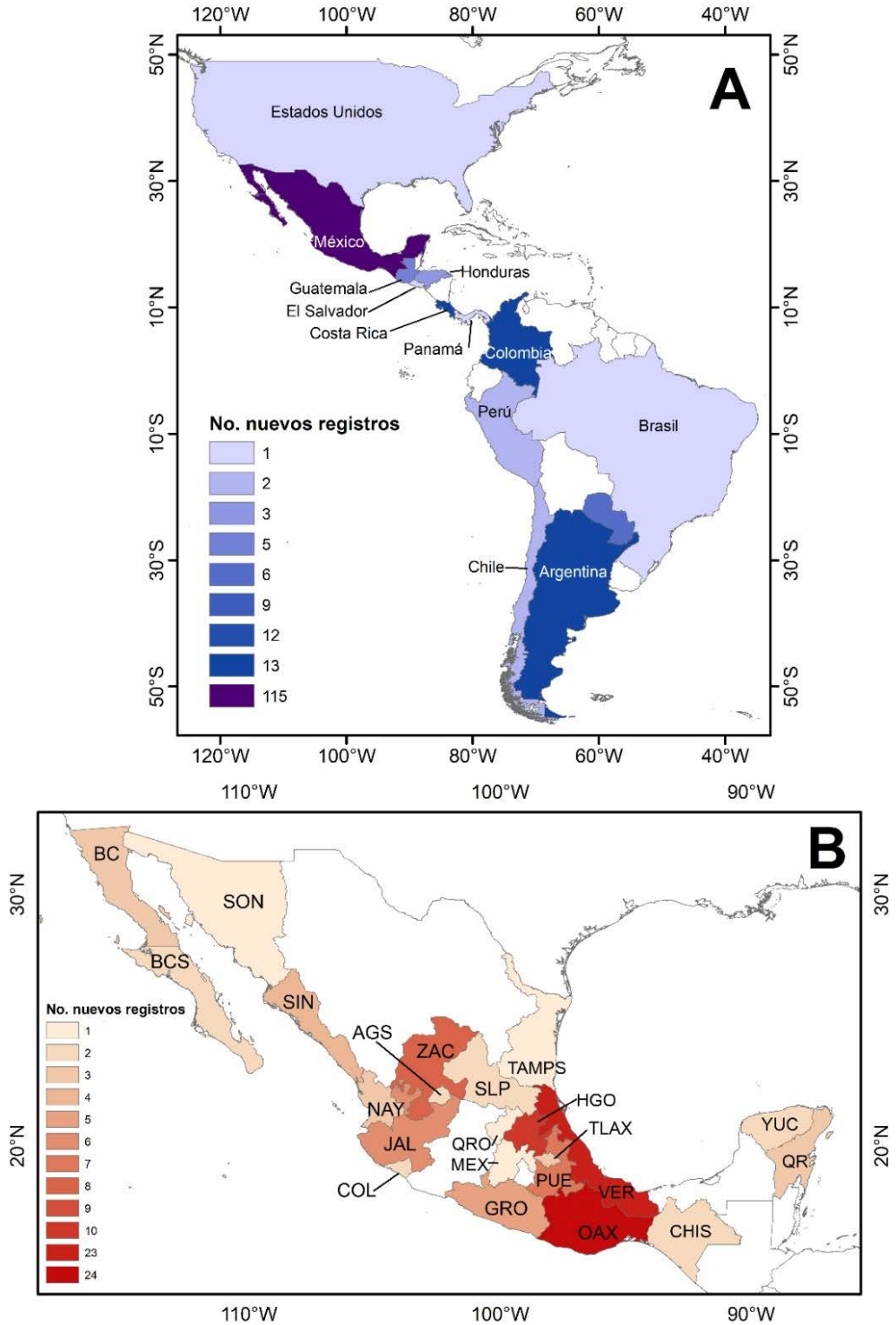

Figura 2. Representatividad geográfica de los nuevos registros publicados en la Revista Latinoamericana de Herpetología hasta el Volumen 7 (3) del 2024. A) Representación por país. B) Representación por estados en México que es el que tiene mayor concentración de registros (113). Abreviaturas en el mapa: AGS, Aguascalientes; BC, Baja California, BCS, Baja California Sur, CHIS, Chiapas; COL, Colima; GRO, Guerrero; HGO, Hidalgo, JAL, Jalisco; MEX, México; NAY, Nayarit; OAX, Oaxaca; PUE, Puebla; QR, Quintana Roo; QRO, Querétaro; SIN, Sinaloa; SON, Sonora; TAMPS, Tamaulipas, TLAX, Tlaxcala; VER. Veracruz; YUC, Yucatán; ZAC, Zacatecas.

Figure 2. Geographic representativeness of the new records published in Revista Latinoamericana de Herpetología, until Volume 7(3) of 2024. A) Representation by country. B) Representation by the Mexican states that have the highest concentration of reports (113). Abbreviations: AGS, Aguascalientes; BC, Baja California, BCS, Baja California Sur, CHIS, Chiapas; COL, Colima; GRO, Guerrero; HGO, Hidalgo, JAL, Jalisco; MEX, México; NAY, Nayarit; OAX, Oaxaca; PUE, Puebla; QR, Quintana Roo; QRO, Querétaro; SIN, Sinaloa; SON, Sonora; TAMPS, Tamaulipas, TLAX, Tlaxcala; VER. Veracruz; YUC, Yucatán; ZAC, Zacatecas.

publications. New records should be compared with existing distribution maps if available. It is vital to consider scale and spatial properties, such as anisotropy (heterogeneous distribution), beyond just map locations (Morrone, 2009; Sánchez-González, 2013; Ríos-Muñoz & Espinosa-Martínez, 2019). The geographical space occupied by records may yield crucial information (Ríos-Muñoz & Espinosa-Martínez, 2019).

5. **The geographic distance from known records should be carefully assessed and reported**. Though there is no strict rule, a new record should indicate significant separation, suggesting an expansion or actual shift in distribution. This involves considering habitat, altitude, and other ecological parameters, making geographic distance variable (Sánchez-González, 2013).

6. **Provide a clear justification of the record as a range extension or a gap filling**, and explain whether the presented data qualifies as a first or new record.

While we emphasize the importance of rigorous criteria for publishing first and new records in herpetology, the goal is to guide those who contribute to preserving valuable, scientific, and robust data to enrich the knowledge and conservation of amphibian and reptile species in Latin America. By following these standards, it is possible to ensure that geographic distribution notes have a significant and beneficial impact on herpetological knowledge, allowing it to grow across various regions and countries in Latin America and fostering greater global efforts.

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PRIMEROS Y NUEVOS REGISTROS GEOGRÁFICOS: CONSIDERACIONES GENERALES PARA SU RELEVANCIA EN HERPETOLOGÍA

Delimitar la distribución geográfica de las especies es un aspecto crucial, no sólo para entender su biología, sino también para describir cómo los organismos se distribuyen en el espacio geográfico. Asimismo, ayuda a establecer la influencia que los factores abióticos (e.g., clima, Lomolino et al., 2006,), bióticos (e.g., disponibilidad de recursos, competencia con otras especies, Peterson et al., 2011) e históricos (e.g., barreras geográficas, Brown et al., 1996), tienen en la definición de su distribución. Mientras que se han propuesto diferentes métodos para delimitar el área de distribución de un taxón (Morrone, 2009), aun se requiere de un consenso sobre los procedimientos apropiados para delimitarlas. Estos métodos requieren del uso de datos biológicos puntuales, específicamente de información sobre la localización geográfica (latitud y longitud) basada en evidencias innegables de la presencia de una especie en ese lugar (Ríos-Muñoz & Espinosa-Martínez, 2019). Por esta razón, es importante documentar los registros considerados extra limitares o fuera del área de distribución conocida de los taxones. De ahí entonces, la relevancia de los reportes de distribución geográfica.

Una de las contribuciones más comunes que recibe la Revista Latinoamericana de Herpetología (RLH) son las notas de distribución geográfica. Hasta el Volumen 7(3) del 2024, se han publicado 128 notas de distribución, con una tendencia de incremento anual constante (Fig. 1). Este tipo de publicaciones generalmente informan acerca de nuevos registros de un sólo taxón (87.5%) y únicamente se ha publicado una nota que documenta más de 10 registros (García-Padilla et al., 2024). Los registros publicados corresponden a 42 familias y la mayor cantidad de éstos corresponde a serpientes y lagartijas (Squamata) (Tabla 1). Como ejemplo, se tienen reportados siete nuevos registros en seis publicaciones distintas para una sola especie de serpiente exótica, *Indothyphlops braminus* (Castañeda-Ortega & Guzmán-Guzmán, 2020; Valdez-Villavicencio et al., 2022; Morales-García & Morales-García et al., 2022; Villalobos-Juárez & García-Padilla, 2023; Sánchez-Luna et al., 2023; Reyes-Velázquez et al., 2024). Dentro de los anfibios, el género *Bolitoglossa* es el que cuenta con el mayor número de nuevas observaciones. Se han publicado registros nuevos para siete especies en tres publicaciones (Ahumada-Carillo, 2020; Núñez-Robles et al., 2022; Groen et al., 2023).

En cuanto a representación geográfica, hay una mayor cantidad de notas de distribución publicadas para México (Oaxaca y Veracruz), seguida de Colombia, Costa Rica y Argentina (Fig. 2). Esta cantidad de notas de distribución es esperada debido al estado de conocimiento de la herpetofauna en el que se encuentra la mayoría de las regiones del continente americano, puesto que siguen en el periodo de documentación

o descubrimiento. Es decir, existen grandes extensiones de territorio poco estudiadas o donde no se han hecho estudios herpetofaunísticos, lo que atrae a una mayor cantidad de investigadores que documentan la diversidad herpetológica en dichas áreas.

Entre las notas de distribución geográfica se identifican dos tipos: **1) los primeros registros**, que corresponden al primer informe documentado de la presencia de una especie en una ubicación específica distinta a la localidad en donde se registró originalmente. Estos registros son significativos porque confirman la presencia de la especie en un área determinada, lo que puede tener importantes implicaciones para su biogeografía y ecología (Lomolino et al., 2006). Un ejemplo de esto es el trabajo de Nahuat Cervera et al. (2024), quienes documentan un primer registro de la serpiente *Ninia diademata*. Aunque previamente se conocía su distribución en Campeche, en la península de Yucatán, los autores la registran por primera vez en el estado de Quintana Roo y **2) los nuevos registros o extensiones de rango**, que hacen referencia a observaciones adicionales de la misma especie en la misma área o en áreas cercanas. Estos registros pueden proporcionar información sobre cambios en la distribución, expansión del rango de la especie, o la identificación de poblaciones cercanas previamente desconocidas (Brown et al., 1996) o para documentar la expansión de taxones invasores o no nativos. Por ejemplo, García-Grajales et al. (2024) publican un nuevo registro de *Hemidactylus turcicus* en la costa central de Oaxaca, señalando que ya se conocía su presencia en la región, pero ahora lo documentan específicamente en un canal de desagüe. Ambos tipos de descripciones son fundamentales para ampliar las áreas de distribución conocidas de los taxones.

Para publicar una nota sobre la distribución geográfica de una especie es necesario establecer criterios claros para definir qué constituye un "nuevo" o "primer" registro geográfico. Esto permite garantizar la relevancia y precisión científica, como ha ocurrido en otros grupos taxonómicos (e.g., Sánchez-González, 2013) en donde se propone que un nuevo registro debe cumplir con ciertos parámetros para ser considerado verdaderamente novedoso: 1) Se registra al taxón por primera vez en una entidad política. 2) Se reporta al taxón en una región biótica o piso altitudinal diferentes a lo previamente documentado. 3) Se confirma la presencia del taxón en un sitio de estudio; o se registra un taxón que se creía extinto del sitio. 4) Haber hecho una revisión exhaustiva de la literatura que permita establecer que realmente la especie no haya sido reportada previamente. 5) Que los nuevos hallazgos correspondan con el conocimiento biogeográfico establecido a través de las áreas de endemismo (Sánchez-González & Navarro-Sigüenza, 2009).

En el contexto herpetológico, proponemos una serie de criterios para que los primeros y nuevos registros geográficos puedan ser considerados:

1. **Contar con evidencia sólida**. Deben considerarse registros de observaciones directas, de especímenes recolectados o fotografiados, e incluso cantos en el caso de anuros, donde la identidad de la especie pueda ser evaluada por caracteres diagnósticos inequívocos, de forma que su identidad taxonómica no esté en duda (Ríos-Muñoz & Espinosa-Martínez 2019). Además, los registros deben estar respaldados por documentación detallada, incluyendo fotografías, descripciones precisas y coordenadas geográficas, altitud, así como la fecha y hora del registro.

2. **Registro de especímenes váucher**. En todos los casos los registros deberán ser depositados en alguna colección científica, de manera que cuenten con un número de catálogo que permita rastrearlo, ya sea que se trate de especímenes, fotografías o cantos. Esto asegura la permanencia de los registros y la posibilidad de ser reexaminados en caso de ser necesario (Lee et al., 1982).

3. **Considerar las divisiones político-administrativas.** Aunque este tipo de fronteras no representan necesariamente un límite a nivel biótico, es posible que en ciertas circunstancias un cambio de ubicación administrativa (como un municipio diferente) no sea un registro biológicamente relevante. Sin embargo, este criterio se emplea con el objeto de completar el listado biótico de una demarcación política, incluso en estados con municipios pequeños, y puede obedecer a distintos propósitos no necesariamente relacionados con aspectos naturales, pero sí con fines de conservación o documentación del inventario de la riqueza biológica de una entidad (Rojas-Soto & Oliveras de Ita, 2005).

4. **Contextualizar la distribución geográfica y ecológica**. Para este punto es necesario documentar cuando una especie se presenta en espacios en los que es posible que exista, pero para los cuales no hay datos publicados que lo confirmen. Los nuevos registros deben compararse con mapas de distribución publicados (en caso de que existan). Es crucial considerar la escala y las propiedades espaciales, como la anisotropía (distribución heterogénea), y no limitarse únicamente a la ubicación en los mapas (Morrone, 2009; Sánchez-González, 2013, Ríos-Muñoz & Espinosa-Martínez, 2019), ya que el espacio geográfico que ocupan los registros puede dar información importante, independientemente si

representa o no un espacio ecológico diferente (Ríos-Muñoz & Espinosa-Martínez, 2019).

5. **La distancia geográfica desde registros previos debe ser evaluada cuidadosamente y reportada**. Aunque no existe una regla fija, debe representar un nuevo registro para la ciencia, por lo que debe mostrar una separación importante que sugiera una expansión o cambio real en la distribución de la especie, es decir, se deben considerar cambios en el hábitat, altitud u otros parámetros ecológicos relevantes de forma que la distancia geográfica puede ser variable (Sánchez-González & Navarro-Sigüenza, 2009).

6. **Proporcionar una justificación clara del registro como una extensión de rango** y explicar si los datos presentados califican como un primer registro o un registro nuevo.

Si bien enfatizamos la necesidad de criterios rigurosos que deben ser considerados para la publicación de nuevos y primeros registros en herpetología, el objetivo es guiar a quienes contribuyen con datos valiosos y científicamente sólidos, a fin de enriquecer el conocimiento y conservación de las especies de anfibios y reptiles en Latinoamérica. Siguiendo estos estándares, se puede asegurar que las notas de distribución tengan un impacto significativo y provechoso en el conocimiento herpetológico, de manera que este pueda incrementarse en diferentes regiones y países de Latinoamérica y existan más esfuerzos a nivel global.

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FIRST RECORD OF *SCINAX FUSCOMARGINATUS* (ANURA: HYLIDAE) FOR THE PROVINCE OF MISIONES, ARGENTINA

PRIMER REGISTRO DE *SCINAX FUSCOMARGINATUS* (ANURA, HYLIDAE) PARA LA PROVINCIA DE MISIONES, ARGENTINA

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Argentina, Misiones, Department Capital, Municipality of Posadas, Locality: Reserva Natural Urbana Arroyo "El Carpincho". 27.35853° S, 56.00394° W, WGS84, 86 m a.s.l. Two male specimens of *Scinax fuscomarginatus* (Fig. 1) were captured on February 22, 2024, around 21:00 h, vocalizing in a suburban area of "El Carpincho" stream, which contains flooded grassland and aquatic macrophytes, partially surrounded by a small patch of native forest, near the Paraná River. Specimens of *Boana punctata*, *B. raniceps*, *Dendropsophus nanus*, *Lysapsus limellum*, *Ololygon berthae*, *Leptodactylus fuscus*, and *L. podicipinus* were also vocalizing. This site is in the biogeographical region of Southern Cone Mesopotamian Savanna sensu Olson et al. (2001). This is

Figura 1. Ejemplares de referencia colectados en la Reserva Natural Urbana Arroyo "El Carpincho", Posadas, Misiones, Argentina. Barra: 10 mm. Foto: Diego Baldo.

Figure 1. Voucher specimens collected in the Reserva Natural Urbana Arroyo "El Carpincho", Posadas, Misiones, Argentina. Scale bar: 10 mm. Photo: Diego Baldo.

the first record in the province of Misiones. The specimens are housed in the herpetological collection of the Laboratorio de Genética Evolutiva (LGE) of the Instituto de Biología Subtropical (CONICET-UNaM). The voucher numbers are LGE 26626–7. The nearest record is 47 km to the Southwest, in the locality of Garape, province of Corrientes (27.61628° S, 56.38333° W) (Fig. 2). Vouchers specimens of this record are housed in the Museo Argentino de Ciencias Naturales (MACN) "Bernardino Rivadavia" (MACN 37180–8) (Faivovich, pers. comm.). Species identification was made in the field by recognizing the advertisement call (not recorded), and once the specimens were collected, the taxonomic revision was confirmed by the following combination of characters: small size in males (15.7–26.7 mm), subelliptical snout in dorsal view, head longer than wide, dorsal pattern with continuous divergent or parallel brown dorsolateral stripes on a light brown background, uniform light brown color on the posterior surfaces of thighs, immaculate or finely pointed chest and belly, longitudinal dark stripes on the forearm and shank external surface, loreal region steeply sloping toward the lip, diagonal stripes on the dorsal surface of the shank (Brusquetti et al., 2014).

The genus *Scinax* is one of the most diverse within the Hylidae family, composed of 77 species distributed from eastern and southern Mexico to Argentina and Uruguay, including Trinidad and Tobago and St. Lucia (Frost, 2024). The Brown-bordered Snouted Treefrog (Frank & Ramus, 1995), *Scinax fuscomarginatus* (Lutz, 1925), belonging to the *S. fuscomarginatus* group, is a species widely distributed in South America, occurring in Argentina, Bolivia, Brazil, Guyana, Paraguay, Suriname, and Venezuela (Araujo-Vieira et al., 2023; Frost, 2024). This species is a small treefrog that inhabits open areas, making it one of the most widely distributed Neotropical anuran species (Brusquetti et al., 2014). It occupies open habitats of several biomes with varying gradients of temperature, humidity, and seasonality; from the drier and highly seasonal Chaco and Caatinga, through Cerrado and Pantanal, to transition zones between these and the Atlantic and Amazon Forests, which are less seasonal and have much higher humidity levels (Pupin et al., 2020; Brusquetti et al., 2023). *Scinax fuscomarginatus* tolerates anthropogenic disturbances and has been found in rice cultivation areas (Duré et al., 2008; Oliveira Pacheco et al., 2018). Breeding occurs during the summer season (December to March) with tadpole development in water bodies

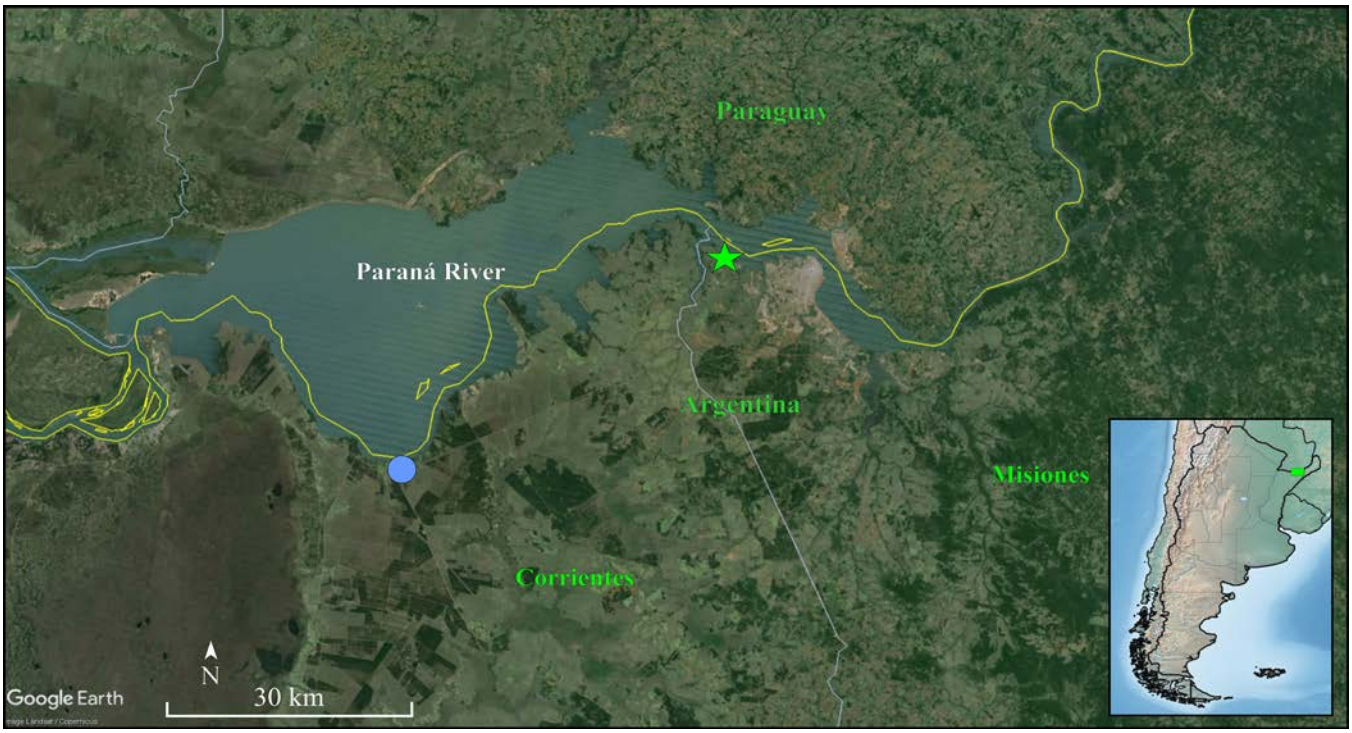

Figura 2. Imagen satelital que representa el registro más cercano conocido para *Scinax fuscomarginatus*. La estrella verde indica el nuevo registro en Misiones, Argentina. El círculo azul claro indica el registro previamente conocido en Garapé, Corrientes, Argentina.

Figure 2 . Satellite image depicting the nearest record known for *Scinax fuscomarginatus*. The green star indicates the new record from Misiones, Argentina. The light blue circle indicates the previously known record from Garapé, Corrientes, Argentina.

(Toledo & Haddad, 2005). In Argentina, *S. fuscomarginatus* occurs in open areas in the northeastern part of the country, in the provinces of Corrientes, Chaco, Formosa and Santa Fe (Vaira et al., 2012).

When the Yacyretá dam reached its maximum level in 2011, it created new lentic and semi-lentic environments in tributary streams of the Paraná River. These novel habitats, suitable for colonization by hylid frogs (Torres et al., 2021), may have facilitated the expansion of the distribution of *S. fuscomarginatus* in this area.

Over the last two decades, our understanding of amphibian diversity in Misiones has grown significantly. This surge is fueled by the discovery of new species (Cardozo & Pereyra, 2018; Baldo et al., 2019; Rosset et al., 2021; Cardozo et al., 2023) and the identification of previously unknown amphibian populations within Misiones and Argentina (Ferro et al., 2018; Torres et al., 2021). With this new record, the number of amphibians in Misiones reaches 64 species (63 natives and one exotic) (Vaira et al., 2012; Pereyra et al., 2006), solidifying its position as the most diverse province of Argentina.

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REPORTE DE VALORES MORFOMETRÍCOS ALTOS DE *TELMATOBIUS CULEUS* EN EL SITIO PRIORITARIO COMPLEJO DE LAGUNAS LAGUNILLAS, PERÚ

REPORT OF HIGH MORPHOMETRIC VALUES OF *TELMATOBIUS CULEUS* IN THE PRIORITY SITE COMPLEX OF LAGUNAS LAGUNILLAS, PERU

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Abstract.— We documented the linear morphometry of 14 specimens of *Telmatobius culeus* from the Lagunillas Lagoon Complex, collected through snorkel diving and shoreline transects at depths of 1.5 to 2 m, about total of specimens seven ($n = 7$) is from Lagunillas and seven ($n = 7$) from Ululunasa. In the Lagunillas lagoon the maximum value of Total Length LT is 292 mm; maximum and minimum range of LHC is 107 mm and 92 mm. In the Ululunasa lagoon the maximum LT value is 390 mm; the maximum and minimum range of LHC is 163 mm and 124 mm. In terms of size, these values are the highest records for the species in recent years.

Keywords.— High andean lagoons, linear morphometry, Telmatobiidae, Titicaca Basin

Resumen.— Se documenta la morfometría lineal de 14 ejemplares de *Telmatobius culeus* provenientes del Complejo de Lagunas Lagunillas, colectados por medio de buceo con snorkel y transectos a borde de orilla en profundidades de 1.5 a 2 m. Del total de especímenes siete ($n = 7$) corresponden a Lagunillas y siete ($n = 7$) a Ululunasa. En la laguna Lagunillas el valor máximo de Longitud Total LT es de 292 mm; rango máximo y mínimo de LHC es de 107 mm y 92 mm. En la laguna Ululunasa el valor máximo de LT es de 390 mm; el rango máximo y mínimo de LHC es de 163 mm y 124 mm. En cuanto al tamaño, estos valores son los mayores registros para la especie en los últimos años.

Palabras clave.— Cuenca del Titicaca, lagunas altoandinas, morfometría lineal, Telmatobiidae.

INTRODUCCIÓN

El género *Telmatobius* Wiegmann, 1834 es un grupo diverso de anfibios nativos de los Andes, con representaciones en la región altoandina y altiplano, altamente especializados a la vida acuática (Vellard, 1951; Navas & Chauí-Berlinck, 2007). La mayor riqueza de especies de este género se encuentra en bosques y valles interandinos, por encima de los 3,000 m s.n.m. (De la Riva, 2005; Lavilla & Barrionuevo, 2005; Barrionuevo, 2017).

Los anuros de mayor y menor tamaño son más propensos a la extinción por las condiciones climáticas extremas (Feijó et al., 2023), pero los de menor tamaño tienen mayor riesgo de extinción (Cardillo, 2020). Entre los Telmatobiidae de mayor tamaño como *Telmatobius macrostomus* (Castillo et al., 2021), *T. culeus* (Vitt & Caldwell, 2014; Muñoz-Saravia et al., 2018) y *T. mayoloi* (Lehr, 2005) que son de hábitos completamente acuáticos, por sus tamaños se observa una mayor superficie de respiración cutánea (Hutchison, 1976; Amphibian Web, 2024). Los *T. culeus* registrados con la piel desplegada e inmóviles (Huisa-Balcon et al., 2022) sugieren un comportamiento termorregulador que beneficiaria procesos metabólicos y fisiológicos (Muñoz-Saravia et al., 2018), también es posible que este comportamiento esté relacionado con la configuración del campo visual, lo cual podría influir en la evolución del espacio interorbital en la especie (Jiang et al., 2022). El tamaño también puede mejorar la capacidad de captura de presas por succión (Carreño & Nishikawa, 2010).

Telmatobius culeus Garman, 1876 es una especie endémica del Lago Titicaca, a una elevación de 3,810 m s.n.m. (Icochea et al., 2004), que se caracteriza por su piel holgada en el cuerpo y extremidades, cabeza marcadamente deprimida, de forma lacustre (De la Riva, 2005). Los valores morfométricos citados para *T. culeus* en relación con su longitud hocico-cloaca LHC (SVL siglas en inglés) referencian valores de 140 mm (Vitt & Caldwell, 2014), 135 mm (Vellard, 1951), 130 mm (Vellard, 1991) para el Lago Titicaca; En localidades adyacentes al Lago Titicaca como Achacachi, se informa un valor de 137.95 mm, en la laguna de Saracocha un valor de 57.13 mm y en la laguna Arapa un valor de 76.81 mm (Benavides et al., 2002). Para el Complejo de Lagunas Lagunillas, la laguna Lagunillas se señala un rango de SVL de 100 mm a 125 mm (Vellard, 1991) y 112 mm a 130 mm (Parker, 1940); para Saracocha valores de 45-49 mm (Parker, 1940). En ese sentido, se planteó como objetivo describir los valores morfométricos que definen a los especímenes de *T. culeus* de las lagunas del complejo de Lagunas Lagunillas.

MATERIALES Y MÉTODOS

Área de estudio

El área de estudio corresponde al Sitio Prioritario Complejo de Laguna Lagunillas (Fig. 1) establecida mediante Ordenanza Regional N°017-2015-GRP-CRP, está ubicada en los distritos de Santa Lucia de la provincia de Lampa y en el distrito de

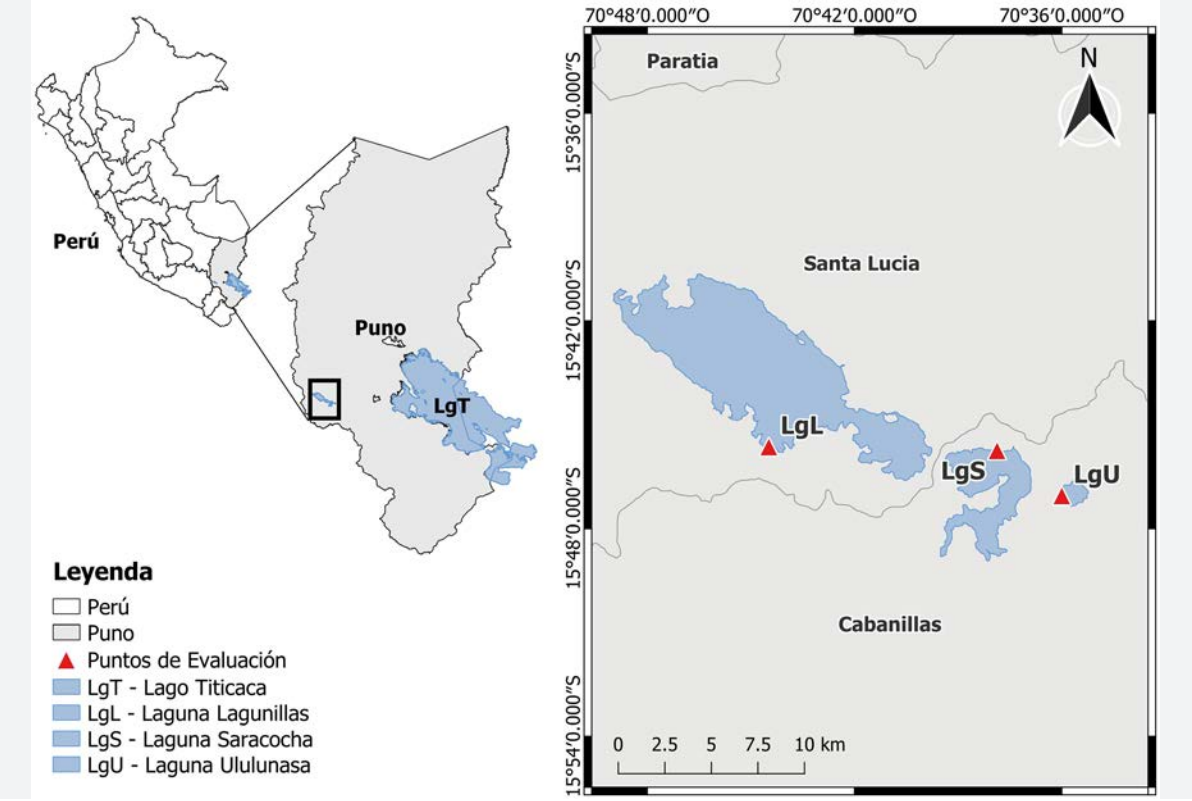

Figure 1. Location map, sampling points in the lagoons that make up the Lagunas Lagunillas Complex (red triangles), in the districts of Santa Lucia (province of Lampa) and Cabanillas (province of San Román), department of Puno. / **Figura 1.** Mapa de ubicación, puntos de muestreo en las lagunas que conforman el Complejo de Lagunas Lagunillas (triángulos rojos), en los distritos de Santa Lucia (provincia de Lampa) y Cabanillas (provincia de San Román), departamento de Puno.

Cabanillas de la provincia de San Román. El Complejo está conformado por los cuerpos de agua de laguna Lagunillas (LgL) con coordenadas 15.755522° S, 70.745843° W; laguna Saracocha (LgS) con coordenadas 15.764241° S, 70.629990° W; y laguna Ululunasa (LgU) con coordenadas 15.781414° S, 70.599534° W; estos cuerpos de agua cubren un área total de 7908.07 ha, ubicándose entre los 4,147 m s.n.m. a 4,283 m s.n.m. Las lagunas Saracocha y Ululunasa, tienen principal importancia al proteger el germoplasma de especies ícticas del género *Orestias* según la Resolución Ministerial N°482-2018-PRODUCE.

Captura, colecta y registros

Previamente se solicitó la autorización de investigación al Servicio Nacional Forestal y de Fauna Silvestre SERFOR con código N°AUT-IFS-2021-050. El muestreo se realizó en fecha 16 al 18 de octubre del 2021, entre las 09:00-13:00 h. Se capturaron un total de 14 individuos, de los cuales 12 fueron capturados temporalmente y 02 fueron colectados fijadas con formol al 10 %, posteriormente almacenados en alcohol al 70 %. Las colectas fueron depositadas en la Colección Científica de la Universidad Nacional del Altiplano (CCUNAP) con códigos de catalogo asignados CCUNAP-0001 y CCUNAP-0002 provenientes de LgL y LgU, respectivamente.

El trabajo contó con seis etapas: 1) Desinfección de materiales y equipos en la orilla, calibración de equipos (e.g., GPS, vernier), disposición de materiales: guantes de nitrilo, dos baldes con agua, el primero para contener a los individuos, y el segundo para hidratar a los individuos durante su manipulación. 2) Buceo y colecta, reconocimiento visual del área de estudio, ubicando el microhábitat sustrato rocoso-vegetación (Ramos et al., 2019), se estableció un único transecto (100 m de largo por 2 m de ancho) por cada cuerpo de agua, ubicada a una distancia paralela aproximada de 3 m a la orilla. Un buzo realizó la captura de los individuos usando una red circular de 100 cm de diámetro con mango extensible, mientras el segundo buzo dispuso las capturas en una red rectangular de 100 x 60 cm, cada animal capturado se colocó en una bolsa Ziploc con agua. 3) La morfometría fue tomada en un tiempo promedio de 15 minutos por espécimen, hidratando a los individuos en intervalos de dos minutos para evitar la desecación de su piel. 4) El sexo de los especímenes se determinó por la presencia de callo nupcial de color oscuro en el pulgar y se registró la coloración de la piel (dorso y la zona ventral), posteriormente se dispuso a los individuos en su bolsa Ziploc respectiva; posteriormente liberaron a los individuos en su lugar de captura. 5) Desinfección de materiales, equipos, movilidad y materiales con Virkon, siguiendo el protocolo de Aguirre & Lampo (2006). 6) Disposición final de las colectas en una Institución Nacional Depositaria de Material Biológico en cumplimiento de la normativa peruana.

Medidas morfométricas

Para obtener todas las medidas se usó un calibrador digital Digimater Plastic Caliper (158.6 mm) precisión de ± 0.203 mm. Siguiendo a De la Riva et al. (2005) se midieron las siguientes variables y las abreviaturas utilizadas por sus siglas en inglés son: la longitud hocico-cloaca (SVL), el diámetro del ojo (ED), la longitud de extremidad anterior (distancia desde el punto de flexión del húmero y radio-ulna hasta la punta de la pata en el dedo IV) (FL), la longitud del fémur (Fel), la longitud de tibio-fibula (TFL), la longitud del tarso-metatarso (distancia desde punto de flexión de la tibiofibula y calcaneum-astragalus hasta la punta de la pata IV) (TML), el ancho de la mandíbula inferior (MW), la distancia entre fosas nasales (BN), el ancho interorbital (IW), el ancho de la cabeza (HW), la distancia boca-narinas (ND), la altura de la cabeza (HH). Se procesaron las medidas hallándose la media, la desviación estándar, rango mayor y menor siguiendo a Merino-Viteri et al. (2005) y Benavides et al. (2002), la medida de Longitud Total (LT) que comprende desde el hocico hasta la punta de la pata en el dedo IV.

RESULTADOS

Se estudio la morfometría de un total de catorce individuos (n = 14) de *T. culeus*; sin embargo, a pesar de los esfuerzos realizados, no se registraron especímenes en la Laguna Saracocha. Las capturas de los especímenes de *T. culeus* se realizaron en zonas con sustrato arenoso-vegetación (LgL) y rocoso-vegetación (LgU) a una profundidad promedio de 1.5 y 2 m respectivamente.

Del total de capturas siete (n = 7) corresponden a LgL y siete (n = 7) a LgU. En el transecto de LgL cuatro (n = 4) fueron machos con valor de peso promedio de 163.8 gr de peso (185 gr, 184 gr, 111 gr, 175 gr) y tres (n = 3) son hembras con valor promedio 181 gr de peso (183 gr, 165 gr, 195 gr); en el transecto de LgU cinco (n = 5) fueron hembras con valor de peso promedio 312.2 gr (380 gr, 311 gr, 380 gr, 300 gr, 190 gr) y dos (n = 2) fueron machos con valor de peso promedio 287 gr (310 gr, 265 gr). En la LgL el valor máximo de LT de las hembras fue de 292 mm y de los machos fue de 288 mm; el rango máximo y mínimo de SVL registrado fue de 107.0 mm y 92.0 mm. En la LgU, el valor máximo de LT de las hembras fue de 390 mm y machos fue de 312 mm; el rango máximo y mínimo de SVL registrado fue de 163 mm y 124 mm (Tabla 1, Tabla 2).

En este estudio, se analizaron 13 variables morfométricas (Tabla 1), destacándose los valores obtenidos para ancho de la cabeza (HW) de los especímenes capturados en LaL, con un valor máximo de 38 mm y para LgU un valor máximo de 55 mm. En cuanto a la longitud del fémur de (FeL) en LaL se obtuvo un valor máximo de 50 mm y para LgU un valor máximo de

Table 1. Comparison of linear morphometric measurements (in mm) of adults of *Telmatobius culeus* from the Lagunas Lagunillas Complex in this study, Laguna Saracocha and Bahia Achacachi in Benavides et al. (2002). The mean, standard deviation, and range are shown in parentheses.

Tabla 1. Comparación de las medidas morfométricas lineales (en mm) de adultos de *Telmatobius culeus* procedente del Complejo de Lagunas Lagunillas presente estudio, Laguna Saracocha y Bahia Achacachi en Benavides et al. (2002). Se muestra la media, desviación estándar, y el rango en paréntesis.

Medidas morfométricas	*Telmatobius culeus*			
	Laguna Lagunillas	Laguna Ululunasa (Alonso)	Laguna Saracocha (considerado *T. crawfordi* por Benavides et al., 2002)	Bahía de Achacachi Lago Menor (Titicaca) (Benavides et al., 2002)
	n = 7	*n* = 7	*n* = 28	*n* = 40
SVL	100.6 ± 5.8 (92.0-107.0)	145.9 ± 16.4 (124.0-163.0)	51.22 ± 2.59 (47.08-57.13)	104.05 ± 16.20 (74.84-137.95)
ED	8.1 ± 0.9 (7.0-9.0)	8.3 ± 1.4 (6.0-10.0)	4.59 ± 0.29 (3.71-5.12)	6.81 ± 0.88 (4.51-8.45)
FL	47.7 ± 4.0 (43.0-54.0)	57.4 ± 3.5 (54.0-63.0)	- -	- -
FeL	45.7 ± 3.9 (39.0-50.0)	54.4 ± 7.4 (44.0-61.0)	21.66 ± 1.56 (18.29-25.16)	45.31 ± 7.97 (29.47-58.11)
TFL	51.6 ± 2.3 (48.0-54.0)	61.3 ± 3.1 (57.0-66.0)	20.75 ± 1.38 (18.11-24.07)	45.12 ± 7.65 (28.76-57.27)
TML	78.9 ± 4.1 (72.0-83.0)	94.0 ± 9.0 (80.0-105.0)	33.05 ± 2.17 (29.64-38.43)	73.28 ± 11.59 (47.58-93.24)
MW	27.1 ± 1.5 (25.0-29.0)	34.3 ± 3.8 (30.0-40.0)	-	- -
BN	6.6 ± 0.5 (6.0-7.0)	8.3 ± 1.1 (7.0-10.0)	2.95 ± 0.25 (2.51-3.66)	5.29 ± 1.08 (3.24-7.61)
IW	11.9 ± 1.6 (9.0-14.0)	19.1 ± 3.1 (15.0-24.0)	6.19 ± 0.45 (5.41-7.46)	13.05 ± 2.60 (8.77-18.48)
HW	36.4 ± 1.5 (34.0-38.0)	49.7 ± 3.8 (44.0-55.0)	17.97 ± 1.36 (15.57-22.80)	41.08 ± 7.23 (27.82-59.94)
ND	7.9 ± 0.7 (7.0-9.0)	9.7 ± 1.0 (8.0-11.0)	3.78 ± 0.33 (3.06-4.52)	7.07 ± 1.05 (4.52-9.20)
HH	17.0 ± 1.4 (15.0-19.0)	27.3 ± 4.6 (22.0-33.0)	- -	- -
LT	276.71 ± 13.9 (251.0-292.0)	355.57 ± 33.5 (312.0-390.0)	- -	- -

Table 2. Measurements of linear morphometric characters (in mm) of recorded specimens (females and males) in the Lagunas Lagunillas Complex. The mean, standard deviation, and sample range are shown within parentheses.

Tabla 2. Medidas de caracteres morfométricos lineales (en mm) de especímenes registrados (hembras y machos) en el Complejo de Lagunas Lagunillas. Se muestra la media, desviación entandar y el rango de muestra dentro de paréntesis.

Medidas morfométricas	*Telmatobius culeus*			
	Laguna Lagunillas		Laguna Ululunasa (Alonso)	
	n = 4	*n* = 3	*n* = 5	*n* = 2
SVL	104.7 ± 4.041 (100.0-107.0)	97.5 ± 5.196 (92.0-104.0)	153.4 ± 12.26 (133.0-166.3)	127.0 ± 4.243 (124.0-130.0)
ED	8.0 ± 1.00 (7.0-9.0)	8.25 ± 0.96 (7.0-9.0)	8.6 ±1.517 (6.0-10.0)	7.5 ± 0.707 (7.0-8.0)
FL	49.33 ± 0.577 (49.0-50.0)	46.50 ± 5.196 (43.0-54.0)	58.8 ± 3.194 (55.0-63.0)	54.0 ± 0.0 (54.0-54.0)
FeL	46.3 ± 4.163 (42.0-50.0)	45.0 ± 4.082 (39.00-48.0)	58.6 ± 2.3 (56.0-61.0)	44.0 ± 0.0 (44.0-44.0)
TFL	53.0 ± 1.0 (52.0-54.0)	50.5 ± 2.52 (48.0-54.0)	62.8 ± 2.05 (61.0-66.0)	57.5 ± 0.707 (57.0-58.0)
TML	80.00 ± 3.61 (76.0-83.0)	78.0 ± 4.69 (72.0-83.0)	98.2 ± 6.14 (89.0-105.0)	83.5 ± 4.950 (80.0-87.0)
MW	27.33 ± 1.155 (26.0-28.0)	27.0 ± 1.826 (25.0-29.0)	35.8 ± 3.421 (31.0-40.1)	30.5 ± 0.707 (30.0-31.0)
BN	6.67 ± 0.58 (6.0-7.0)	6.5 ± 0.58 (6.0-7.0)	8.4 ± 1.14 (7.0-10.0)	8.0 ± 1.414 (7.0-9.0)
IW	12.00 ± 1.00 (11.0-13.0)	11.75 ± 2.062 (9.0-14.0)	20.6 ± 2.302 (19.0-24.0)	15.5 ± 0.707 (15.0-16.0)
HW	37.69 ± 0.577 (37.0-38.0)	35.5 ± 1.291 (34.0-37.0)	50.4 ± 3.435 (47.0-55.0)	48.0 ± 5.657 (44.0-52.0)
ND	8.333 ± 0.577 (8.0-9.0)	7.5 ± 0.577 (7.0-8.0)	9.4 ± 0.894 (8.0-10.0)	10.5 ± 0.707 (10.0-11.0)
HH	17.67 ± 1.528 (16.0-19.0)	16.5 ± 1.291 (15.0-18.0)	29.0 ± 4.359 (22.0-33.0)	23.0 ± 4.359 (23.0-23.0)

61 mm. Respecto, a la longitud de tibio-fíbula (TFL) se obtuvo un valor máximo de 54 mm y para LgU un valor máximo de 66 mm. Asimismo, en la longitud de tarso-metatarso (TML) se registraron valores máximos de 83 mm para LgL y un valor máximo de 105 mm para LgU. A pesar del reducido número de muestras se observa que los valores más altos de morfometría corresponden a los especímenes de la Laguna Ululunasa.

Los individuos colectados se encontraron inmóviles, con la piel desplegada reflejo de su adaptación al medio acuático (Fig. 2). En

las lagunas LaL y LgU, *T. culeus* presenta una coloración dorsal plomiza, verdoso y marrón en tonalidades oscuras, con puntos minúsculos y dispersos de color negro, marrón, naranja y pardo, confundiéndose con el sustrato rocoso, arenoso y vegetación marchita. El vientre muestra un color más uniforme y claro, inversamente a la tonalidad del dorso, por ejemplo, individuo con dorso verde oscuro presenta un vientre en tonalidad verde más claro cómo se observa en las figuras 3 y 4.

Los valores registrados de SVL se compararon con los valores morfométricos de la literatura (Tabla 3), que muestran algunos valores históricos efectuados por autores como Garman (1975), Parker (1940), Vellard (1951), Vellard (1953), Vellard (1960), Vellard (1991), Benavides et al. (2002), de estos autores se tomaron las medidas de SVL de los especímenes registrados según localidad, hábitat, altitud y profundidad, dentro del rango de la distribución de la especie en la cuenca del Titicaca con prioridad en el Complejo de Lagunas Lagunillas. El valor más alto corresponde a un espécimen hembra con un valor de LT de 390 mm y con un valor de SVL de 163 mm, capturada temporalmente a una profundidad de 1.5 metros de profundidad en el sustrato rocoso-vegetación en la Laguna Ululunasa a 4,282 m s.n.m. Cabe resaltar que en las tres lagunas no se registraron individuos con proporciones que correspondan a renacuajos, metamorfos o juveniles.

DISCUSIÓN

La sistemática y taxonomía de *Telmatobius* es compleja, la morfología externa es altamente conservada y muestra una considerable variación intraespecífica principalmente en especies que viven en lugares a gran altitud (Vellard, 1951; De la Riva, 2005; Benavides, 2005), en el Complejo de Lagunas Lagunillas, específicamente la laguna Saracocha se propone a esta población como *T. escomeli crawfordi* (Vellard, 1991). Sin embargo, los primeros estudios moleculares en poblaciones de *Telmatobius* de la cuenca del Titicaca (Benavides et al., 2002; Benavides, 2005) determinarían únicamente la presencia de dos especies *T. culeus* y *T. marmoratus*, cayendo en la sinonimia una larga lista de especies y subespecies. Aunque, un estudio reciente ejecutado por Sáez et al., (2022) en su análisis recuperan a un linaje denominándo grupo G y la proponen como especie candidata; nuestro relevamiento no registró especímenes con características diferentes de los que distinguen a *T. culeus*. Es evidente que el esfuerzo de muestreo sea mayor en estas lagunas (LaL, LaS y LgU) y se incluya los riachuelos y estanques adyacentes a estos cuerpos de agua.

Los datos morfométricos presentados en este reporte provenientes de ejemplares de *T. culeus* de la Laguna Ululunasa del Complejo de Lagunas Lagunillas son los de mayor tamaño registrados en los últimos años, en la laguna Lagunillas los valores de SVL de rangos máximos son de 107 mm y mientras que para la laguna Ululunasa 163 mm. Estos últimos valores en comparación con los reportes históricos para este complejo de lagunas sobrepasan a lo registrado por Vellard (1953) que menciona para Lagunillas un valor de 61 mm (Vellard, 1953) mas no al valor de 130 mm reportado por Parker (1994). Respecto de los valores históricos en el lago Menor (Huiñaymarca), laguna Arapa y Yapupampa valores de 85 mm (Parker, 1940); en el ámbito de la laguna Saracocha en hábitat de arroyo y estanques un valor de 57.13 mm (Benavides et al., 2002); en la Laguna Arapa 76.81 mm (Benavides et al., 2002) y 65.2 mm (Vellard, 1951); en la Isla Amantani 60.5 mm (Vellard, 1951); en el rio Cabanillas (Juliaca) 110.6 mm (Vellard, 1953); en la bahía de Puno 60.5 mm (Vellard, 1951); en el rio Ilave 110.6 mm (Vellard, 1953); en la Laguna Hacienda Checayani 84 mm (Vellard, 1953); en la laguna Chajchora 66 mm (Vellard, 1953); y para Saracocha donde Benavides et al. (2002) menciona un valor de 57.13 mm.

Otros miembros del género alcanzan medidas de SVL considerables como se referencian para *T. macrostomus* entre 118 mm y 120 mm en hembras (Sinsch & Aguilar, 2021) y *T. mayoloi* entre 90.3 mm en hembras y 108.1 mm en machos (Lehr, 2005). Nuestros valores hallados de SVL en machos y hembras de la LgL es 104 mm y 107 mm, respectivamente. Para los machos y hembras de la LaU 130 mm y 163 mm, respectivamente. Sin embargo, en condiciones de cautiverio Mantilla et al. (2023) registra a un ejemplar hembra con 170 mm.

En cuanto a los valores más altos obtenidos para el Sitio Prioritario Complejo de Lagunas Lagunillas, corresponden a la laguna Ululunasa con valores máximos que resaltan como el ancho de cabeza (HW) un valor de 55 mm; longitud del fémur de (FeL) un valor de 61 mm; longitud de tibio-fíbula (TFL) un valor de 66 mm; longitud de tarso-metatarso (TML) un valor de 105 mm; Estos valores contrastan con los registrados para el Lago Titicaca, que corresponden a Achacachi con valores máximos de HW de 59.94 mm, valor de FeL de 58.11 mm, valor de TFL de 57.27 mm y valor de TML de 93.24 mm (Benavides et al., 2002). La protección de parte del estado peruano de la laguna Ululunasa para la proteccion ictica nativa podría influir en que una de sus potenciales amenazas como lo es la trucha, no estaría ejerciendo presión sobre esta población, permitiendo el desarrollo y hallazgo de especímenes de *T. culeus* con esas dimensiones, la ausencia de afluentes contaminantes sobre este cuerpo de agua es otro factor que podría influenciar en mantener las condiciones naturales propias de este cuerpo de agua. La laguna Lagunillas aumento sus dimensiones a partir de la construcción de una presa en 1995, proporcionando de esta manera mayor

Figure 2. Temporary capture of a specimen of *Telmatobius culeus* in which the characteristics that distinguish the species such as loose skin can be observed. Photo: Dennis X. Huisa-Balcón.

Figura 2. Captura temporal de espécimen de *Telmatobius culeus* en el cual se pueden observar las características que distinguen a la especie como la piel holgada. Foto: Dennis X. Huisa-Balcón.

Figure 3. Temporary capture of an individual of *Telmatobius culeus* in which the dark green back is observed, Ululunasa Lagoon, Lagunillas Lagunas Complex, Puno. Photo: Dennis X. Huisa-Balcón.

Figura 3. Captura temporal de individuo de *Telmatonbius culeus* en el cual se observa el dorso verde oscuro, Laguna Ululunasa, Complejo de Lagunas Lagunillas, Puno. Foto: Dennis X. Huisa-Balcón.

Figure 4. Temporary capture of an individual of *Telmatobius culeus* in which the light green belly can be seen, Ululunasa Lagoon, Lagunillas Lagunas Complex, Puno. Photo: Dennis X. Huisa-Balcón.

Figura 4. Captura temporal de Individuo de *T. culeus* en el cual se observa el vientre de color verde claro, Laguna Ululunasa, Complejo de Lagunas Lagunillas, Puno. Foto: Dennis X. Huisa-Balcón.

hábitat para las poblaciones de *T. culeus* lo cual podría explicar las dimensiones que en este estudio se reportan, aquí la acuicultura se desarrolla promovida por el estado peruano para la crianza de truchas en jaulas flotantes para el desarrollo económico de las poblaciones circundantes mediante el otorgamiento de concesiones. Durante nuestro muestreo no se evidenció la presencia de *Phalcoboenus megalopterus* que depreda a *T. culeus* (Quispe et al., 2024) u actividades de canibalismo (Muñoz-Saravia et al., 2020); sin embargo, un individuo de *T. culeus* hembra defeco una columna vertebral de un pez posiblemente perteneciente al género *Orestias*.

Respecto a la coloración de *T. culeus* se observó una gama que va desde el color verde, marrón y plomo, esta variedad de tonalidades es observada por Garman (1855), Parker (1940), Vellard (1951), Vellard (1960) y Vellard (1991), que describen la coloración del dorso con manchas claras y oscuras e inversamente más claro el vientre. Para especies cripticas Grenat et al. (2012) observan en *Odontophrynus americanus* y *Odontophrynus cordobae* la presencia de patrones altamente variables en coloración. Sin embargo, se destaca que se requieren estudios más detallados que involucren un mayor número de muestras para caracterizar la gama de colores evidenciados para la población de *T. culeus* en el Complejo de Lagunas Lagunillas.

La presencia de micro-contaminantes químicos provenientes de la actividad agrícola (Herbicidas), farmacológica (Bokoni et al., 2020), metales pesados (Ficken & Birne, 2012) y aguas residuales (Zeitler et al., 2021) producen efectos subletales en anuros, perjudicando a los especímenes a nivel individual y

Table 3. Comparison of historical and reported SVL/LT (mm) measurements of *Telmatobius culeus* specimens.

Tabla 3. Comparación de medidas históricas y reportadas de SVL/LT (mm) de especímenes de *Telmatobius culeus*.

Localidad (elevación en metros)	Hábitat	Profundidad del agua	SVL/LT (mm)	Autores
(1) Lago Titicaca (3810) *	Lacustre	20.1 m	>10.16	Garman (1875)
(2) Bahía de Achacachi, Lago Menor (3810) *	Lacustre	>10 m	134	Parker (1940), Vellard (1951), Vellard (1953)
(3) Laguna Lagunillas	Lacustre	-	112-130	Parker (1940)
(4) Copani (3810) *	Lacustre	2-3 m	50	Vellard (1960), Benavides et al. (2002)
(5) Bahía de Achacachi, Lago Menor (3810) *	Lacustre	>10 m	104	Benavides et al. (2002)
(6) Laguna Arapa (3820) *	Lacustre	-	65.2	Vellard (1951)
(7) Laguna Lagunillas (4250) *	Lacustre	-	<61	Vellard (1953)
(8) Rio Juliaca (3824) *	Fluvial	-	<110	Vellard (1953)
(9) Rio Ilave	Fluvial	-	<90	Vellard (1953)
(10) Laguna Hacienda Checayani (3973) *	Lacustre	-	<84	Vellard (1953)
(11) Laguna Chajchora (4156) *	Lacustre	-	<77	Vellard (1953)
(12) Laguna Saracocha (4500) *	Arroyo, estanque, lacustre	<0.5 m	>51.22	Parker (1940), Benavides et al. (2002)
(13) Centro de Investigación y Producción de Bienes y Servicios Chucuito (Puno) (3931) **	Cautiverio	-	170	Mantilla et al. (2023)
(14) Laguna Lagunillas (4250) ***	Lacustre	1-2 m	107	-
(15) Laguna Ululunasa (Alonso) (4283) ***	Lacustre	1-2 m	163	-
(16) Laguna Saracocha (4210) ***	Lacustre	-	-	-

* Históricos referenciales.

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*** Valores del presente reporte para el Complejo de Lagunas Lagunillas.

poblacional (Bókoni et al., 2020). La presencia de especímenes de gran tamaño en el Complejo Lagunillas, podría deberse a que el sector tiene cierto grado de protección respecto de efluentes o tributarios contaminantes siendo necesario estudios de calidad de agua que evidencien ello, sin embargo, se debe precisar que al igual que en el lago Titicaca en la laguna Lagunillas está permitida la acuicultura (cría de truchas en jaulas flotantes), a diferencia de Saracocha y Ululunasa donde está prohibida la acuicultura con especies exóticas como la trucha, pejerrey u otras. Se recomienda realizar estudios genéticos que ayuden a interpretar mejor estas variaciones en la morfometría de estas poblaciones aisladas geográficamente, así mismo, efectuar monitoreos de la calidad de agua cuya data debería correlacionarse con estos hallazgos.

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ACTUALIZACIÓN DE LA RIQUEZA HERPETOFAUNÍSTICA DEL MUNICIPIO DE ZAPOTITLÁN DE MÉNDEZ, PUEBLA, MÉXICO

UPDATE OF THE HERPETOFAUNISTIC RICHNESS OF THE MUNICIPALITY OF ZAPOTITLAN DE MENDEZ, PUEBLA, MEXICO

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La herpetofauna del estado de Puebla, México se compone de 89 especies de anfibios (64 anuros y 25 caudados) y 178 reptiles (174 escamosos y cuatro tortugas). Sin embargo, la riqueza de especies de Puebla varía dependiendo la región fisiográfica, siendo la Sierra Madre Oriental la región más diversa con 185 especies de anfibios y reptiles (Woolrich-Piña et al., 2017). La región fisiográfica Sierra Madre Oriental se ubica en el noreste del estado, abarcando las sierras de Zacapoaxtla, Huauchinango, Teziutlán, Tetela de Ocampo, Chignahuapan y Zacatlán. En esta región, se ubica el municipio de Zapotitlán de Méndez (20.002394° N, 97.713045° W ; WGS 84) en un rango altitudinal que va de los 600 a los 1,400 m s.n.m. (Lara-Ramos, 2013). Este municipio también forma parte de la región socioeconómica conocida como Sierra Nororiental de Puebla (Murillo, 2010) y de la parte alta de la cuenca del Río Tecolutla (conocido localmente como Río Zempoala), el cuál atraviesa el municipio de oeste a este.

El municipio de Zapotitlán de Méndez está formado por la cabecera municipal que recibe el mismo nombre (663 m s.n.m.), y las localidades de Nanacatlán (928 m s.n.m.) y Tuxtla (927 m s.n.m.; Fig. 1). La vegetación original corresponde al bosque de niebla y la selva mediana subperennifolia; sin embargo, estos ecosistemas han sufrido graves procesos de deforestación por la implementación de pastizales ganaderos, cafetales y otros cultivos (Cairns et al., 2000; Mas et al., 2004; Bonilla-Moheno et al., 2013). El clima es semicálido subhúmedo con lluvias todo el año (A) c (fm), con una temperatura media anual de 21.7°C, y una precipitación media anual de 1,977 mm (CONAGUA, 2010). Gutiérrez-Mayén & Salazar-Arenas (2006) realizaron un inventario de la herpetofauna del municipio en los años 1998 y 1999, reportando 31 especies, de las cuales nueve fueron anfibios (7 ranas y sapos, 2 salamandras), y 22 fueron reptiles (21 escamados, 1 tortuga dulceacuícola). Sin embargo, el 90 % de sus registros fueron en un rango de 2 a 3 km de la cabecera municipal, existiendo un vacío de información sobre la herpetofauna de las localidades de Tuxtla y Nanacatlán. Además, desde hace 24 años no se han realizado nuevos estudios sobre la herpetofauna del municipio. En esta nota presentamos una actualización de la riqueza herpetofaunística del municipio de Zapotitlán de Méndez, aportando nuevos registros a nivel municipal, registros para las tres localidades del municipio, e información sobre la ampliación del área de distribución de algunas especies.

Para este estudio consideramos trabajo de campo, reportes ciudadanos y revisión de ejemplares colectados por Gutiérrez-

Mayén & Salazar-Arenas (2006). Durante el desarrollo de un proyecto de investigación enfocado en anfibios (Taxonomic diversity and traditional ecological knowledge of amphibians in a Tutunakú indigenous municipality of the Northeastern Sierra of Puebla, Mexico), realizamos tres salidas al campo entre junio y noviembre de 2023. En cada salida se realizaron cuatro recorridos nocturnos donde seis personas buscamos libremente en diferentes microhábitats como cuerpos de agua, debajo de hojarasca y rocas, en los árboles, arbustos y herbáceas, bromelias, entre otros. Consideramos diferentes tipos de uso de suelo y vegetación como bosque de niebla secundario, cafetales bajo sombra, pastizales ganaderos, asentamientos humanos y cultivos agrícolas. Debido a que el muestreo estuvo dirigido a anfibios, los registros de reptiles de esta nota pueden considerarse como ocasionales. Todos los individuos encontrados fueron identificados siguiendo las guías de Canseco-Márquez & Gutiérrez-Mayén (2010) y Ramírez-Bautista et al. (2014), para posteriormente ser liberados en su sitio de captura. Un individuo de cada especie por localidad fue fotografiado previo a su liberación.

De 2021 a 2023 recibimos por celular y redes sociales (Whatsapp, Facebook e Instagram), reportes de anfibios y reptiles por parte de habitantes de las tres localidades, como parte de una campaña de divulgación científica y ciencia ciudadana titulada “Con las lluvias los anfibios”, difundida a través de las plataformas y proyectos Festixal de los Anfibios, Tlacuy y Colectivo Xanay. De cada reporte obtuvimos una fotografía del individuo y datos generales como la fecha, horario, lugar y contexto del registro, así como el nombre completo de la persona. Todas las fotografías (trabajo de campo y reportes ciudadanos) fueron catalogadas en la colección digital del Museo de Historia Natural de Los Ángeles (LACM PC). La corroboración en la identificación de las especies fue realizada por Víctor Vásquez Cruz y Carlos Alberto Hernández Jiménez.

En marzo de 2024, visitamos la Colección Herpetológica de Anfibios (PUE.AN.028.0697) y Reptiles (PUE.RE.029.0697) de la Facultad de Ciencias Biológicas, de la Benemérita Universidad Autónoma de Puebla (EBUAP), registrada en la Secretaría de Medio Ambiente y Recursos Naturales. En esta visita revisamos

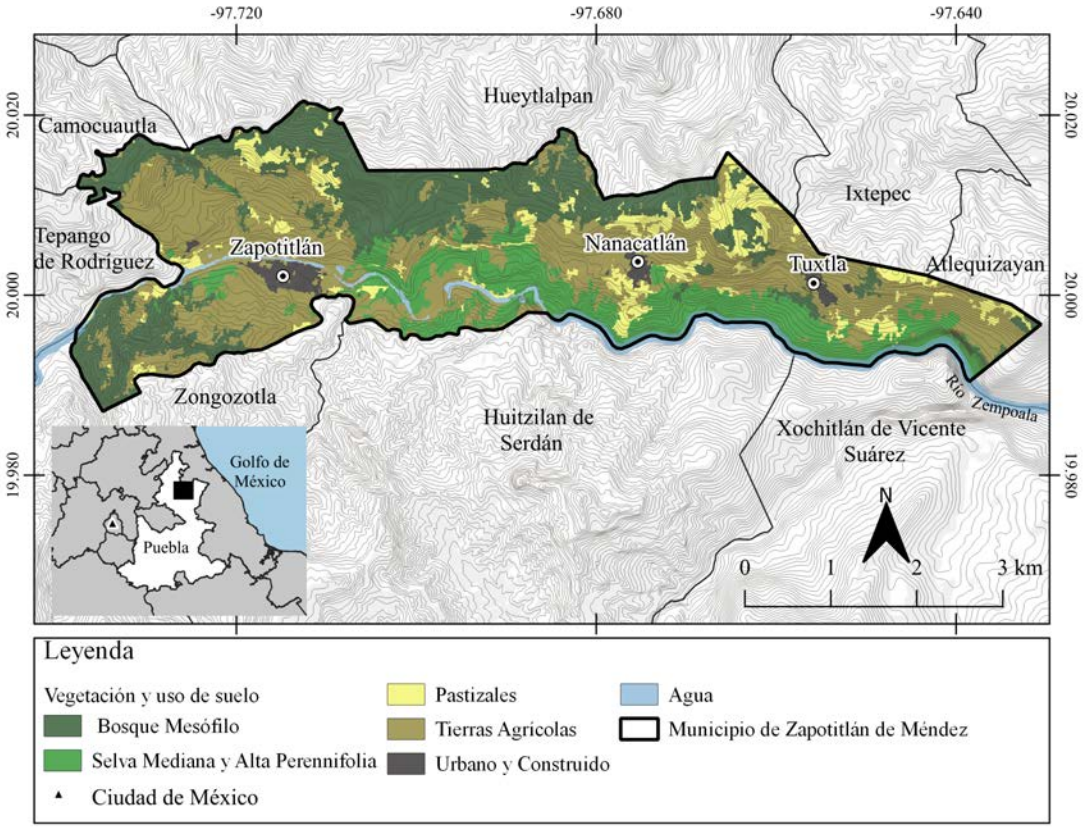

Figure 1. Study area, vegetation types and land use in the municipality of Zapotitlán de Méndez, Puebla, Mexico. Source: modified from CONABIO (2018). Prepared by María Chanel Juárez Ramírez.

Figura 1. Área de estudio, tipos de vegetación y uso de suelo del municipio de Zapotitlán de Méndez, Puebla, México. Fuente: modificado de CONABIO (2018). Elaborado por María Chanel Juárez Ramírez.

individuos colectados por Gutiérrez-Mayén & Salazar-Arenas (2006) identificados como *Incilius valliceps* (EBUAP-1254, EBUAP-1255 y EBUAP-1257). Sin embargo, actualmente en la colección están identificados como *I. nebulifer*, con ayuda de las claves taxonómicas mencionadas pudimos corroborar que los individuos pertenecen a esta especie. Finalmente, actualizamos los nombres de todas las especies registradas siguiendo las bases de datos Amphibian Species of the World (Frost, 2024) y The Reptile Data Base (Uetz et al., 2023).

La herpetofauna del municipio de Zapotitlán de Méndez está constituida por 43 especies, distribuidas en 11 especies de anfibios (9 Anura, 2 Caudata) y 32 especies de reptiles (31 Squamata, 1 Testudines). La cabecera municipal presentó el mayor número de especies registradas (10 anfibios, 22 reptiles), seguida por la localidad de Tuxtla (siete anfibios, 14 reptiles), y finalmente por la localidad de Nanacatlán con solo dos especies de anfibios y cinco de reptiles (Tabla 1). A continuación, aportamos información detallada de los nuevos registros municipales, los registros en cada localidad, y la ampliación del área de distribución de algunas especies.

Anfibios

Bufonidae

Sapo de las llanuras costeras. *Incilius nebulifer* (Girard, 1854). El 14 de septiembre de 2023 encontramos un individuo adulto en un patio con plantas ornamentales en el hotel Zempoala en Zapotitlán (20.003371° N, 97.713071° W; 664 m s.n.m.; LACM PC 3050; Fig. 2B1). El 18 de noviembre de 2023 encontramos un individuo adulto sobre la hojarasca en un cafetal bajo sombra en Tuxtla (19.983564° N, 97.633579° W; 831 m s.n.m.; LACM PC 3062; Fig. 2F). Adicionalmente, durante los muestreos registramos 33 individuos adultos en pastizales ganaderos y cafetales bajo sombra en Tuxtla, y cuatro individuos en asentamientos humanos de Zapotitlán

Sapo de la caña. *Rhinella horribilis* (Wiegmann, 1833). El 14 de septiembre de 2023 encontramos un individuo adulto sobre una roca ubicada en medio del cauce del río Zempoala en Zapotitlán (20.003765° N, 97.714303° W; 657 m s.n.m.; LACM PC 3047; Fig. 2G1). Adicionalmente, durante los muestreos observamos cuatro individuos en las orillas del río Zempoala en Zapotitlán.

Craugastoridae

Rana de hojarasca decorada. *Craugastor decoratus* (Taylor, 1942). El 16 de julio de 2023 encontramos un individuo adulto perchado en un arbusto del género *Piper* en un bosque de niebla secundario en Tuxtla (20.000811° N, 97.643980° W; 953 m s.n.m.; LACM PC 3068; Fig. 2D). En la misma zona, grabamos las vocalizaciones de otro individuo (20.001518° N, 97.644881° W; 1,103 m s.n.m.), las cuales fueron depositadas en la Fonoteca de Anfibios de la Facultad de Ciencias de la Universidad Nacional Autónoma de México (MZFC-HEC4469). Estos registros representan los primeros reportes de la especie en el municipio y llena un vacío de información en la distribución de la especie. Las localidades más cercanas conocidas son Cuetzalan del Progreso, Puebla a 14 km al sureste (Canseco-Márquez et al., 2000) y Papaxtla, Hidalgo a 132 km al noroeste (Flores-Villela, 1998).

Rana de hojarasca. *Craugastor rhodopis* (Cope, 1867). El 18 de noviembre de 2023 encontramos un individuo adulto sobre la hojarasca en un cafetal bajo sombra en Tuxtla (19.983563° N, 97.633456° W; 835 m s.n.m; LACM PC 3067; Fig. 2B). El 15 de abril de 2022 encontramos un individuo adulto sobre la hojarasca en un fragmento de selva mediana subperennifolia en Nanacatlán (20.003826° N, 97.685083° W; 804 m s.n.m.; LACM PC 3077; Fig. 2U).

Centrolenidae

Ranita de cristal norteña. *Hyalinobatrachium viridissimum* (Taylor, 1942). El 18 de septiembre de 2023 registramos las vocalizaciones de un individuo adulto a orilla de la carretera Zapotitlán – Nanacatlán, en un paisaje de bosque de niebla secundario (20.003138° N, 97.702429° W; 654 m s.n.m.). Las vocalizaciones fueron depositadas en la Fonoteca de Anfibios de la Facultad de Ciencias de la Universidad Autónoma de México (MZFC-HEC4470 - MZFC-HEC4472). Estos registros representan los primeros reportes de la especie en el municipio, y amplían su área de distribución y el límite septentrional a 33. 5 km al noreste de Paso Real municipio de Hueyapan, Puebla la localidad más norteña previamente conocida (Melgarejo-Vélez et al., 2010).

Eleutherodactylidae

Rana chirrionera orejona. *Eleutherodactylus verrucipes* (Cope, 1885). El 16 de julio de 2023 registramos un individuo adulto en un cafetal bajo sombra en Tuxtla (20.000389° N, 97.649128° W; 1028 m s.n.m.; LACM PC 3065, Fig. 2G). Adicionalmente, durante los muestreos registramos 68 individuos en cafetales bajo sombra, pastizales ganaderos, y asentamientos humanos en Tuxtla.

Hylidae

Rana calate de orejas chicas. *Rheohyla miotympanum* (Cope, 1863). El 22 de noviembre de 2022 registramos un individuo

Table 1. Amphibians and reptiles of the three localities of the municipality of Zapotitlán de Méndez, Puebla. X = Presence record with field work and citizen science reports in this study. The asterisk (*) indicates that the species was reported previously by Gutiérrez-Mayén and Salazar-Arenas (2006).

Tabla 1. Anfibios y reptiles de las tres localidades del municipio de Zapotitlán de Méndez, Puebla. X = Registro de presencia con el trabajo de campo y reportes de ciencia ciudadana de este estudio. El asterisco (*) indica que la especie fue reportada previamente por Gutiérrez-Mayén y Salazar-Arenas (2006).

	Zapotitlan de Méndez	Nanacatlán	Tuxtla
ANFIBIOS			
Anura			
Bufonidae			
Incilius nebulifer	X*		X
Rhinella horribilis	X*	*	
Craugastoridae			
Craugastor decoratus			X
Craugastor rhodopis	X*	X	X
Centrolenidae			
Hyalinobatrachium viridissimum	X		
Eleutherodactylidae			
Eleutherodactylus verrucipes	*		X
Hylidae			
Rheohyla miotympanum	X*		X
Smilisca baudinii	*		X
Ranidae			
Lithobates berlandieri	X*		X
Caudata			
Plethodontidae			
Aquiloeurycea cephalica	*		
Bolitoglossa platydactyla	X*		
Riqueza de especies	10	2	7
REPTILES			
Squamata			
Anguidae			
Gerrhonotus ophiurus	*		
Gerrhonotus sp.		X	X
Anolidae			
Anolis laeviventris	*		
Anolis naufragus	*		
Anolis sp.			X
Boidae			
Boa imperator	*		
Colubridae			
Drymarchon melanurus	*	X	
Drymobius margaritiferus	*	X	X
Ficimia streckeri			X
Lampropeltis polyzona	*		
Leptophis mexicanus	*		X
Mastigodryas melanolomus	X		
Tantilla rubra			X
Corytophanidae			
Corytophanes hernandesii			X

Table 1. Amphibians and reptiles of the three localities of the municipality of Zapotitlán de Méndez, Puebla. X = Presence record with field work and citizen science reports in this study. The asterisk (*) indicates that the species was reported previously by Gutiérrez-Mayén and Salazar-Arenas (2006) (cont.).

Tabla 1. Anfibios y reptiles de las tres localidades del municipio de Zapotitlán de Méndez, Puebla. X = Registro de presencia con el trabajo de campo y reportes de ciencia ciudadana de este estudio. El asterisco (*) indica que la especie fue reportada previamente por Gutiérrez-Mayén y Salazar-Arenas (2006) (cont.).

	Zapotitlan de Méndez	Nanacatlán	Tuxtla
Dipsadidae			
Adelphicos quadrivirgatum	*		
Coniophanes fissidens			X
Coniophanes sp	*		
Imantodes gemmistratus			X
Leptodeira splendida		*	
Leptodeira septentrionalis			X
Ninia diademata	*		X
Rhadinaea decorata	*		
Elapidae			
Micrurus bernadi	*		
Natricidae			
Thamnophis proximus	*		
Phrynosomatidae			
Sceloporus variabilis	*		X*
Scincidae			
Scincella silvicola	*		
Scincella gemmingeri			X
Teiidae			
Holcosus amphigrammus	X*		
Viperidae			
Bothrops asper	*	X	X
Metlapilcoatlus nummifer	*		
Xantusiidae			
Lepidophyma sylvaticum	*		
Testudines			
Kinosternidae			
Kinosternon herrerai	*		
Riqueza de especies	22	5	14

adulto en una herbácea dentro del jardín del Hotel Yei Nakú en Zapotitlán (20.003593° N, 97.718982° W; 665 m s.n.m.; LACM PC 3048, Fig. 2F1). El 19 de noviembre de 2023 registramos un individuo adulto en una herbácea en la orilla de un manantial de agua dulce en Tuxtla (20.000078° N, 97.655919° W; 894 m s.n.m.; LACM PC 3057, Fig. 2C). Adicionalmente, durante los muestreos registramos siete individuos en cafetales bajo sombra y asentamientos humanos en Tuxtla.

Rana arborícola mexicana. *Smilisca baudinii* (Duméril & Bibron, 1841). El 17 de septiembre de 2023 registramos un individuo adulto en un arbusto dentro de un cafetal bajo sombra en Tuxtla (19.983563° N, 97.633456° W; 835 m s.n.m.; LACM PC 3054, Fig. 2A). Adicionalmente, durante los muestreos registramos 21 individuos en cafetales bajo sombra, pastizales ganaderos y milpa en Tuxtla.

Plethodontidae

Salamandra lengua de hongo. *Bolitoglossa platydactyla* (Gray, 1831). El 17 de septiembre de 2023 registramos un individuo adulto posado en un pasto en la orilla del Río Zempoala en Zapotitlán (20.003902° N, 97.714482° W; 664 m s.n.m.; LACM PC 3052, Fig. 2E). Adicionalmente, durante los muestreos registramos cuatro individuos en el mismo sitio.

Ranidae

Rana manchada. *Lithobates berlandieri* (Hillis & Frost, 1985). El 15 de julio de 2023 recibimos un reporte ciudadano de un individuo adulto en la orilla del río Zempoala en Zapotitlán (20.004306° N, 97.721666° W; 663 m s.n.m.; LACM PC 3049; Fig. 2C1). El 19 de noviembre de 2023 registramos un individuo adulto en la orilla de un manantial de agua dulce en Tuxtla (20.000078° N, 97.655919° W; 894 m s.n.m.; LACM PC 3059; Fig. 2H). Adicionalmente, durante los muestreos registramos tres individuos en pastizales ganaderos en Tuxtla.

Reptiles

Anguidae

Lagartija caimán sureña. *Gerrhonotus* sp. (Wiegmann, 1828). El 21 de diciembre de 2022 recibimos un reporte ciudadano de un individuo atrapado en una cubeta con agua dentro de una casa habitación en Nanacatlán (20.002480° N, 97.676674° W; 918 m s.n.m.; LACM PC 3074; Fig. 2Y). El 26 de julio de 2023 recibimos un reporte ciudadano de un individuo adulto en cafetal bajo sombra en Tuxtla (19.996731° N, 97.650108° W; 830 m s.n.m.; LACM PC 3064; Fig. 2Z).

Anolidae

Abaniquillo. *Anolis* sp. (Wiegmann, 1834). El 17 de julio de 2023 encontramos un individuo adulto sobre un arbusto en un cafetal bajo sombra en Tuxtla (19.983563° N, 97.633456° W; 835 m s.n.m.; LACM PC 3073; Fig. 2O). Adicionalmente, durante los muestreos registramos dos individuos en cafetales bajo sombra en Tuxtla.

Colubridae

Ratonera negra. *Drymarchon melanurus* (Duméril et al., 1854). El 19 de enero de 2021 recibimos un reporte ciudadano de un individuo encontrado muerto en una zona de cultivos en Nanacatlán (20.006852° N, 97.672926° W; 1,096 m s.n.m.; LACM PC 3076; Fig. 2V).

Culebra corredora de petatillos. *Drymobius margaritiferus* (Schlegel, 1837). El 5 de agosto de 2021 recibimos un reporte ciudadano de un individuo en un cafetal bajo sombra en Tuxtla (19.999248° N, 97.647659° W; 811 m s.n.m.; LACM PC 3066; Fig. 2W). El 13 de agosto de 2023 recibimos un reporte ciudadano de un individuo adulto en un cafetal bajo sombra en Nanacatlán (20.007814° N, 97.675634° W; 1153 m s.n.m.; LACM PC 3075; Fig. 2X).

Culebra naricilla mexicana. *Ficimia streckeri* (Taylor, 1931). El 16 de julio de 2023 encontramos un individuo adulto en un cafetal bajo sombra en Tuxtla (19.988876° N, 97.632411° W; 831 m s.n.m.; LACM PC 3070; Fig. 2Q). Este registro representa el primer reporte de la especie en el municipio, y se encuentra a 16.76 km al oeste del registro más cercano en Cuetzalan del Progreso, Puebla (Canseco-Márquez et al., 2000).

Culebra perico. *Leptophis mexicanus* (Duméril et al., 1854). El 17 de julio de 2023 encontramos un individuo adulto sobre un arbusto dentro de un cafetal bajo sombra en Tuxtla (20.000006° N, 97.633498° W; 1076 m s.n.m.; LACM PC 3060; Fig. 2J).

Culebra lagartijera. *Mastigodryas melanolomus* (Cope, 1868). El 24 de noviembre de 2022 encontramos el primer registro de la especie en el municipio. El individuo era un adulto atacado por un gato en la orilla del Río Zempoala en Zapotitlán (20.003997° N, 97714845° W; 661 m s.n.m.; LACM PC 3079; Fig. 2D1). Los registros más cercanos de esta especie se encuentran en el municipio de Cuetzalan del Progreso, Puebla a 20 km al suroeste (Canseco-Márquez & Gutiérrez-Mayén, 2006).

Culebra cabeza negra. *Tantilla rubra* (Cope, 1875). El 3 de junio de 2020 recibimos un reporte ciudadano de un individuo dentro de una casa habitación en Tuxtla (20.000116° N, 97.654513° W; 911 m s.n.m.; LACM PC 3053; Fig. 2E1). Este registro representa el primer reporte de la especie en el municipio, y el cuarto en la Sierra Nororiental de Puebla. Los registros más cercanos son en Cuetzalan del Progreso a 16.6 km al noreste (Canseco-Márquez & Gutiérrez-Mayén, 2006).

Corytophanidae

Turipache de montaña. *Corytophanes hernandesii* (Wiegmann, 1831). El 23 de mayo de 2022 recibimos un reporte ciudadano de un individuo en un bosque de niebla secundario en Tuxtla (19.993746° N, 97.649909° W; 819 m s.n.m.; LACM PC 3069; Fig. 2T). Este registro representa el primer reporte de la especie en el municipio. Esta especie se ha registrado a 8 km al este en Cuetzalan del Progreso, Puebla (Canseco-Márquez et al., 2000; Canseco-Márquez & Gutiérrez-Mayén, 2006).

Dipsadidae

Culebra vientre amarillo. *Coniophanes fissidens* (Gunther, 1858). El 17 de julio de 2023 encontramos un individuo sobre la hojarasca en un cafetal bajo sombra en Tuxtla (19.99238° N, 97.63515° W; 835 m s.n.m.; LACM PC 3071; Fig. 2I). Este registro representa el primer reporte de la especie en el municipio, los registros

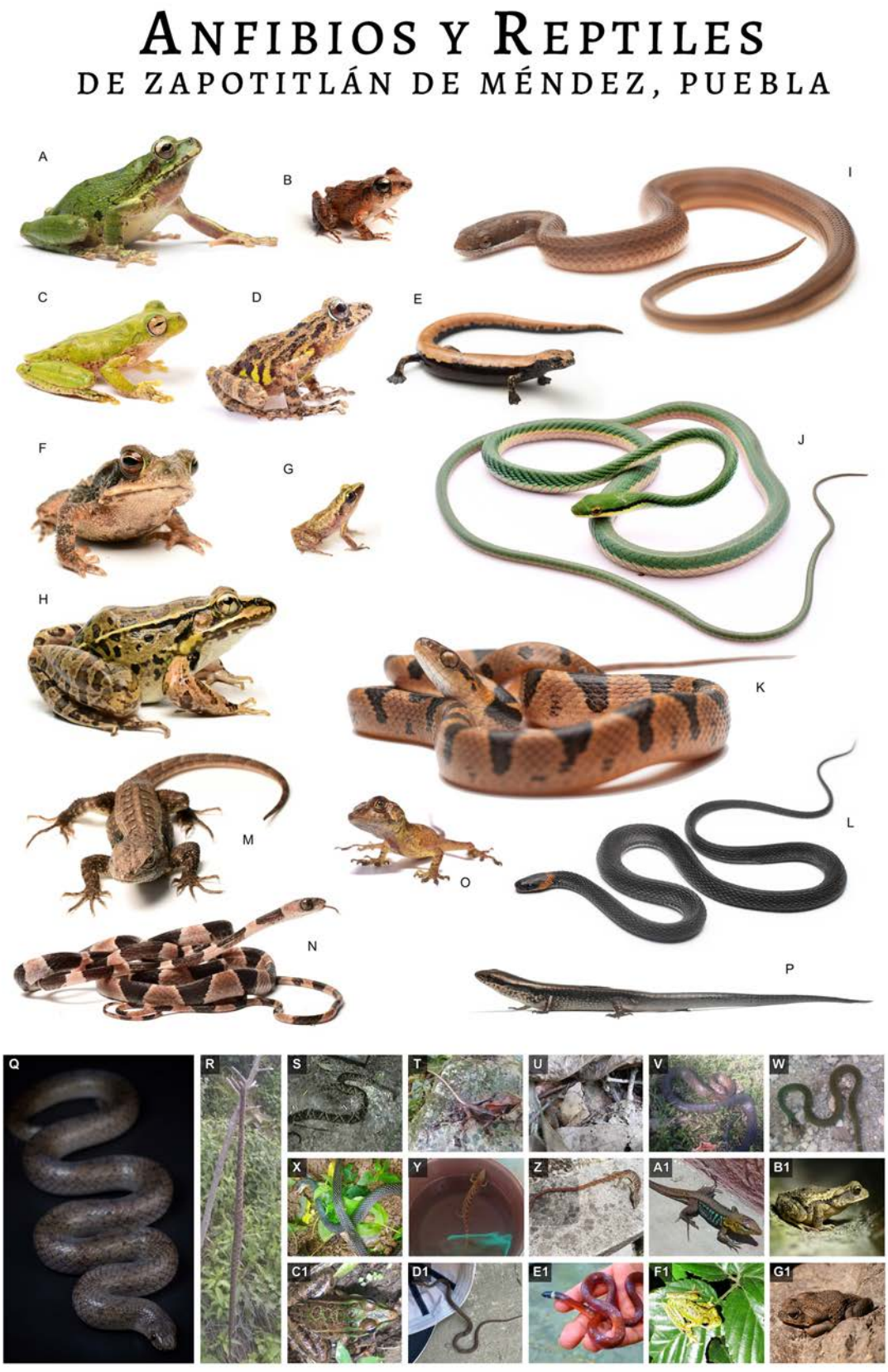
ANFIBIOS Y REPTILES
DE ZAPOTITLÁN DE MÉNDEZ, PUEBLA
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Figure 2 (previous page). Amphibians and reptiles of the municipality of Zapotitlán de Méndez, Puebla photographed during field work and additional citizen science contributions. A = *Smilisca baudinii* (LACM PC 3054); B = *Craugastor rhodopis* (LACM PC 3067); C = *Rheohyla miotympanum* (LACM PC 3057); D = *Craugastor decoratus* (LACM PC 3068); E = *Bolitoglossa platydactyla* (LACM PC 3052); F = *Incilius nebulifer* (LACM PC 3062); G = *Eleutherodactylus verrucipes* (LACM PC 3065); H = *Lithobates berlandieri* (LACM PC 3059); I = *Coniophanes fissidens* (LACM PC 3071); J = *Leptophis mexicanus* (LACM PC 3060); K = *Leptodeira septentrionalis* (LACM PC 3061); L = *Ninia diademata* (LACM PC 3058); M = *Sceloporus variabilis* (LACM PC 3056); N = *Imantodes gemmistratus* (LACM PC 3063); O = *Anolis* sp. (LACM PC 3073); P = *Scincella gemmingeri* (LACM PC 3055); Q = *Ficimia streckeri* (LACM PC 3070); R,S = *Bothrops asper* (LACM PC 3078); T = *Corytophanes hernandesii* (LACM PC 3069); U = *Craugastor rhodopis* (LACM PC 3077); V = *Drymarchon melanurus* (LACM PC 3076); W,X = *Drymobius margaritiferus* (LACM PC 3066; LACM PC 3075); Y,Z = *Gerrhonotus* sp. (LACM PC 3064; LACM PC 3074); A1 = *Holcosus amphigrammus* (LACM PC 3051); B1 = *Incilius nebulifer* (LACM PC 3050); C1 = *Lithobates berlandieri* (LACM PC 3049); D1 = *Mastigodryas melanolomus* (LACM PC 3079); E1 = *Tantilla rubra* (LACM PC 3053); F1 = *Rheohyla miotympanum* (LACM PC 3048); G1 = *Rhinella horribilis* (LACM PC 3047). Photos: Juán Manuel Díaz García, Jorge Ramos Luna, Daniel Joaquín Sánchez Ochoa, Diego Lucas Lucas, Yasmín Castañeda, Ismar Rodríguez Ramos, Hazel Lobato Lucas, Etel Juárez, and Felipe Lucas.

Figura 2 (página anterior). Anfibios y reptiles registrados en el municipio de Zapotitlán de Méndez fotografiados a partir de trabajo de campo y reportes adicionales de ciencia ciudadana. A = *Smilisca baudinii* (LACM PC 3054); B = *Craugastor rhodopis* (LACM PC 3067); C = *Rheohyla miotympanum* (LACM PC 3057); D = *Craugastor decoratus* (LACM PC 3068); E = *Bolitoglossa platydactyla* (LACM PC 3052); F = *Incilius nebulifer* (LACM PC 3062); G = *Eleutherodactylus verrucipes* (LACM PC 3065); H = *Lithobates berlandieri* (LACM PC 3059); I = *Coniophanes fissidens* (LACM PC 3071); J = *Leptophis mexicanus* (LACM PC 3060); K = *Leptodeira septentrionalis* (LACM PC 3061); L = *Ninia diademata* (LACM PC 3058); M = *Sceloporus variabilis* (LACM PC 3056); N = *Imantodes gemmistratus* (LACM PC 3063); O = *Anolis* sp. (LACM PC 3073); P = *Scincella gemmingeri* (LACM PC 3055); Q = *Ficimia streckeri* (LACM PC 3070); R,S = *Bothrops asper* (LACM PC 3078); T = *Corytophanes hernandesii* (LACM PC 3069); U = *Craugastor rhodopis* (LACM PC 3077); V = *Drymarchon melanurus* (LACM PC 3076); W,X = *Drymobius margaritiferus* (LACM PC 3066; LACM PC 3075); Y,Z = *Gerrhonotus* sp. (LACM PC 3064; LACM PC 3074); A1 = *Holcosus amphigrammus* (LACM PC 3051); B1 = *Incilius nebulifer* (LACM PC 3050); C1 = *Lithobates berlandieri* (LACM PC 3049); D1 = *Mastigodryas melanolomus* (LACM PC 3079); E1 = *Tantilla rubra* (LACM PC 3053); F1 = *Rheohyla miotympanum* (LACM PC 3048); G1 = *Rhinella horribilis* (LACM PC 3047). Fotos: Juán Manuel Díaz García, Jorge Ramos Luna, Daniel Joaquín Sánchez Ochoa, Diego Lucas Lucas, Yasmín Castañeda, Ismar Rodríguez Ramos, Hazel Lobato Lucas, Etel Juárez y Felipe Lucas.

más cercanos están en Huitzilan de Serdán a 3.7 km al sureste (Gutiérrez-Mayén & Salazar-Arenas, 2006).

Culebra cordelilla. *Imantodes gemmistratus* (Cope, 1861). El 16 de noviembre de 2023 encontramos un individuo cruzando una vereda dentro de un cafetal bajo sombra en Tuxtla (19.988876° N, 97.632411° W; 995 m s.n.m.; LACM PC 3063; Fig. 2N). Este registro representa el primer reporte de la especie en el municipio y el primero en la Sierra Nororiental de Puebla. El registro más cercano dentro del estado está a 121 km al suroeste en el municipio de Puebla (iNaturalist, 2021). Por otro lado, el registro más cercano de la especie se encuentra en el estado de Veracruz a 94.5 km al este (Scheinberg et al., 1971).

Ojo de gato. *Leptodeira septentrionalis* (Kennicott, 1859). El 17 de septiembre de 2023 encontramos un individuo adulto en un cafetal bajo sombra en Tuxtla (20.000101° N, 97.650225° W; 992 m s.n.m.; LACM PC 3061; Fig. 2K). Este individuo representa el primer reporte de la especie en el municipio, el cual llena un vacío de información en la distribución de la especie previamente existente entre los municipios de Tepango de Rodríguez (15 km al oeste) y Cuetzalan del Progreso (11 km al este; Camarillo & Aguilar, 1995; Canseco-Márquez & Gutiérrez-Mayén, 2006).

Culebra de cafetal de collar. *Ninia diademata* (Baird & Girard, 1853). El 17 de septiembre de 2023 encontramos un individuo adulto sobre la hojarasca en un cafetal bajo sombra en Tuxtla (20.000389° N, 97.649128° W; 1028 m s.n.m.; LACM PC 3058; Fig. 2L). Adicionalmente, durante los muestreos registramos seis individuos en bosques de niebla secundarios y cafetales bajo sombra en Tuxtla.

Phrynosomatidae

Lagartija espinosa de vientre rosado. *Sceloporus variabilis* (Wiegmann, 1834). El 18 de noviembre de 2023 encontramos un individuo adulto sobre una roca dentro un cafetal bajo sombra en Tuxtla (20.000101° N, 97.650225° W; 995 m s.n.m.; LACM PC 3056; Fig. 2M). Adicionalmente, durante los muestreos registramos cinco individuos en milpas en Tuxtla.

Scincidae

Eslizón de la Sierra Madre Oriental. *Scincella gemmingeri* (Cope, 1864). El 16 de julio de 2023, encontramos un individuo adulto en un contenedor de agua potable en el área urbana de Tuxtla (20.000029° N, 97.655595° W; 879 m s.n.m). El 18 de septiembre de 2023 encontramos un individuo adulto en un cafetal bajo sombra en Tuxtla (19.983563° N, 97.633456° W; 835 m s.n.m.; LACM PC 3055; Fig. 2P). Estos individuos representan los primeros reportes de la especie en el municipio. Esta especie cuenta con numerosos registros en la Sierra Nororiental de Puebla, siendo los más cercanos en el municipio de Tepango de Rodríguez a 10.8 km al oeste (Sánchez-Cordero et al., 2021) y a 11 km al este en Cuetzalan del Progreso (Gutiérrez-Mayén, 2000).

Teiidae

Ameiva. *Holcosus amphigrammus* (Smith & Laufe, 1945). El 15 de septiembre de 2023 recibimos un reporte ciudadano de un individuo adulto en el estacionamiento del Hotel Zapotitlán en Zapotitlán de Méndez (20.003338° N, 97.713804° W; 665 m s.n.m.; LACM PC 3051; Fig. 2A1).

Viperidae

Nauyaca. *Bothrops asper* (Garman, 1883). El 18 de mayo de 2020 recibimos un reporte ciudadano de un individuo en el patio de una casa habitación en Tuxtla (19.999206° N, 97.650108° W; 819 m s.n.m.; LACM PC 3069; Fig. 2S). El 17 de febrero de 2023 recibimos un reporte ciudadano de un individuo muerto y colgado en una estaca de madera en Nanacatlán (20.006531° N, 97.679818° W; a 1,024 m s.n.m.; LACM PC 3078; Fig. 2R).

Los registros de este estudio incrementan el conocimiento de las especies de anfibios y reptiles del municipio de Zapotitlán de Méndez, y destacan la importancia de la Sierra Madre Oriental como una región diversa dentro del estado de Puebla, México (Woolrich-Piña et al. 2017) y con potencial para realizar futuros estudios en zonas inexploradas. A pesar de encontrarse en un paisaje forestal extenso, resulta interesante estudiar el impacto del cambio de uso de suelo en las comunidades de anfibios y reptiles debido al alto grado de perturbación del bosque de niebla en el municipio (Bonilla-Moheno et al., 2013; Fig. 1). Solo el 36% de las especies de anfibios reportadas para el municipio (*C. decoratus*, *C. rhodopis*, *H. viridissimum* y *A. cephalica*) tienen afinidad por los bosques maduros mientras que el resto son de hábitos principalmente generalistas (Díaz-García et al. 2020). Asimismo, es preocupante que *A. cephalica* no haya sido registrada 24 años después de los últimos registros dentro del municipio (Gutiérrez-Mayén & Salazar-Arenas, 2006), lo cual podría indicar que existe un impacto severo por la modificación del hábitat sobre especies dependientes de las condiciones ambientales del bosque de niebla. Es necesario implementar estrategias de restauración del bosque de niebla y monitorear el manejo de los cafetales bajo sombra para apoyar la conservación de estos vertebrados a nivel regional. Asimismo, este estudio refleja la importancia de los reportes sistematizados de ciencia ciudadana como fuente para incrementar el conocimiento de la biodiversidad local. Particularmente, los reportes de individuos encontrados muertos abren la oportunidad de implementar actividades de divulgación de la ciencia enfocadas en desmitificar a las especies consideradas peligrosas entre los habitantes.

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NUEVO REGISTRO DE *HEMIDACTYLUS TURCICUS* (SQUAMATA: GEKKONIDAE) EN LA COSTA CENTRAL DE OAXACA, MÉXICO

NEW RECORD OF *HEMIDACTYLUS TURCICUS* (SQUAMATA: GEKKONIDAE) IN THE CENTRAL COAST OF OAXACA, MEXICO

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Las especies exóticas invasoras son aquellas que prosperan fuera de su área natural de distribución sin la intervención del ser humano; además, presentan alta capacidad de sobrevivencia y reproducción (MacGregor-Fors et al., 2009). En México, su presencia es una de las principales causas de pérdida de biodiversidad, pues alteran los ecosistemas, afectan a las especies nativas, provocan daños a los servicios ambientales y a la salud pública, por lo que causan cuantiosas pérdidas económicas (Naranjo & Dirzo, 2009; Vié et al., 2009; CANEI, 2010).

El gecko del Mediterráneo (*Hemidactylus turcicus*) es una especie exótica invasora originaria de la región del Mediterráneo y Medio Oriente, de tamaño pequeño (longitud hocico-cloaca de 4 a 5 cm) y hábitos nocturnos, con el dorso cubierto por escamas granulares pequeñas, con ojos sin párpados, pupila vertical y elíptica, coloración variable (generalmente combinaciones de gris claro, rosa y marrón con numerosas manchas obscuras); además, los tubérculos son blanquecinos y presenta de cuatro a 10 poros preanales que forman una serie angular (Álvarez-Romero et al., 2005).

Aunque para el estado de Oaxaca no existen registros formales publicados sobre la presencia de *H. turcicus*, la revisión de las páginas en línea de ciencia ciudadana iNaturalistMX y el Sistema Global de Información sobre Biodiversidad (GBIF, por sus siglas en inglés) presentan tres localidades de ocurrencia para el estado: Jalapa del Marquéz (GBIF Id: 609560150) en la región del Istmo de Tehuantepec, San Pedro Amuzgos (GBIF Id: 18933227502) al oeste de la Sierra Sur de Oaxaca, y el centro de la ciudad de Oaxaca de Juárez (iNaturalistMX Número de observación: 185696833).

En esta nota documentamos un nuevo registro de *H. turcicus*, el primero para la planicie costera de Oaxaca, a partir de la observación y registro fotográfico de un ejemplar el 28 de mayo de 2024 a las 09:45 h, encontrado accidentalmente sobre la parte superior de una pequeña barda de hormigón (Fig. 1a) de un canal de desagüe de agua pluvial (17° 57' 67'' N, 97° 06' 37'' W, Fig. 1b), en las instalaciones de la Universidad del Mar en Puerto Escondido, Oaxaca (Fig. 1c).

Determinamos positivamente al ejemplar como *H. turcicus* a partir de la coloración del dorso cubierto por escamas granulares, la ausencia de párpados y presencia de tubérculos blanquecinos. La identificación fue corroborada por José Rogelio Cedeño y Javier A. Ortiz Medina. El registro fotográfico se depositó en la Colección Nacional de Anfibios y Reptiles (CNAR) del Instituto de Biología de la Universidad Nacional Autónoma de México (CNAR-IBH-RF 981).

Revisamos en iNaturalistMX y GBIF, no solo localidades de registro de la especie en Oaxaca, sino incluimos también las localidades de estados vecinos en el centro y sur del país (https://mexico.inaturalist.org/taxa/34435-Hemidactylus-turcicus; https://www.gbif.org/es/species/5221528). Así, obtuvimos una localidad para Oaxaca en iNaturalistMX y 24 en GBIF, estas últimas distribuidas por los estados de Campeche, Chiapas, Guerrero, Puebla, Tabasco y Veracruz. Los sitios de registro los representamos en un mapa de localidades elaborado con el programa QGIS versión 3.20.

En la figura 2, observamos que aún existen notables vacíos geográficos en los registros documentados para Oaxaca,

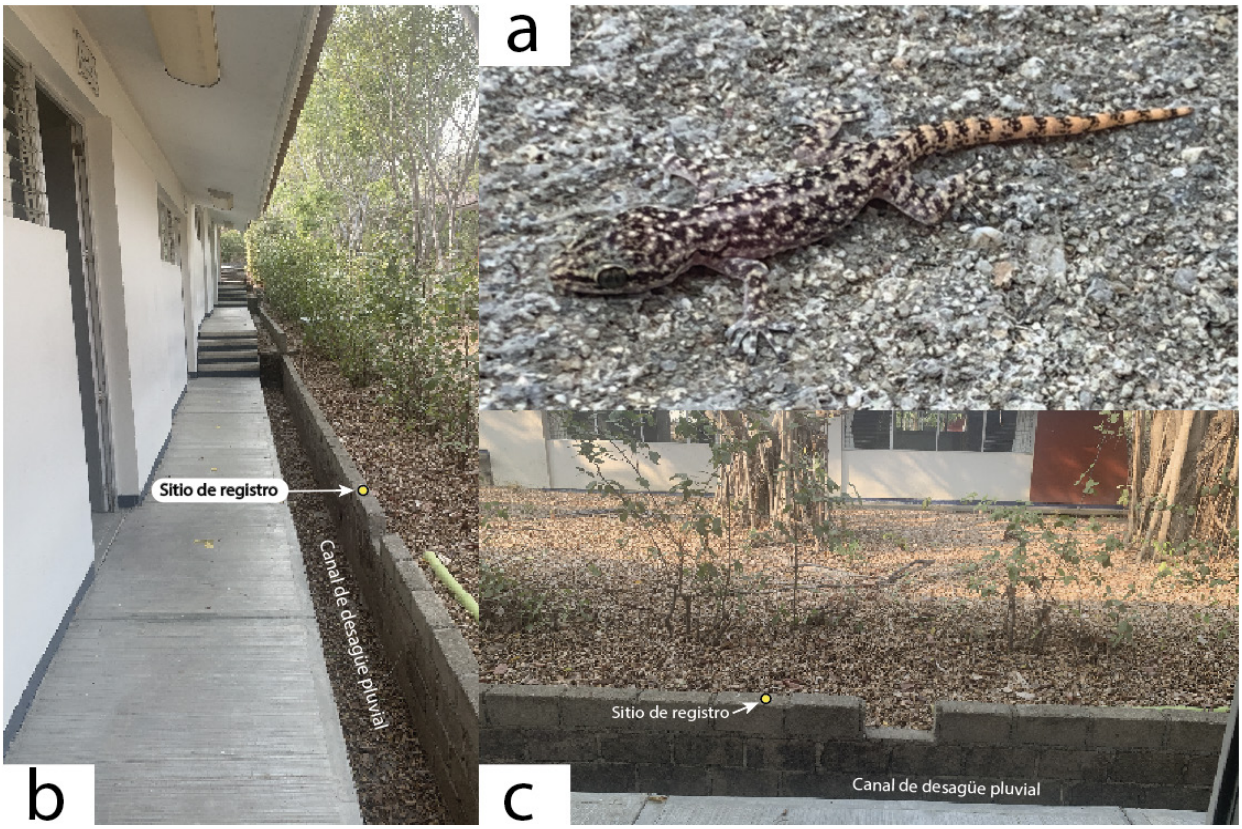

Figure 1. a) Specimen of *Hemidactylus turcicus* recorded in the Universidad del Mar en Puerto Escondido, Oaxaca (CNAR-IBH-RF 981). b) y c) Observation site close to the storm drain channel (Photos: Jesús García-Grajales). / **Figura 1.** a) Ejemplar de ***Hemidactylus turcicus*** registrado en las instalaciones de la Universidad del Mar en Puerto Escondido, Oaxaca (CNAR-IBH-RF 981). b) y c) Sitio de observación cercano al canal de desagüe pluvial (Fotos: Jesús García-Grajales).

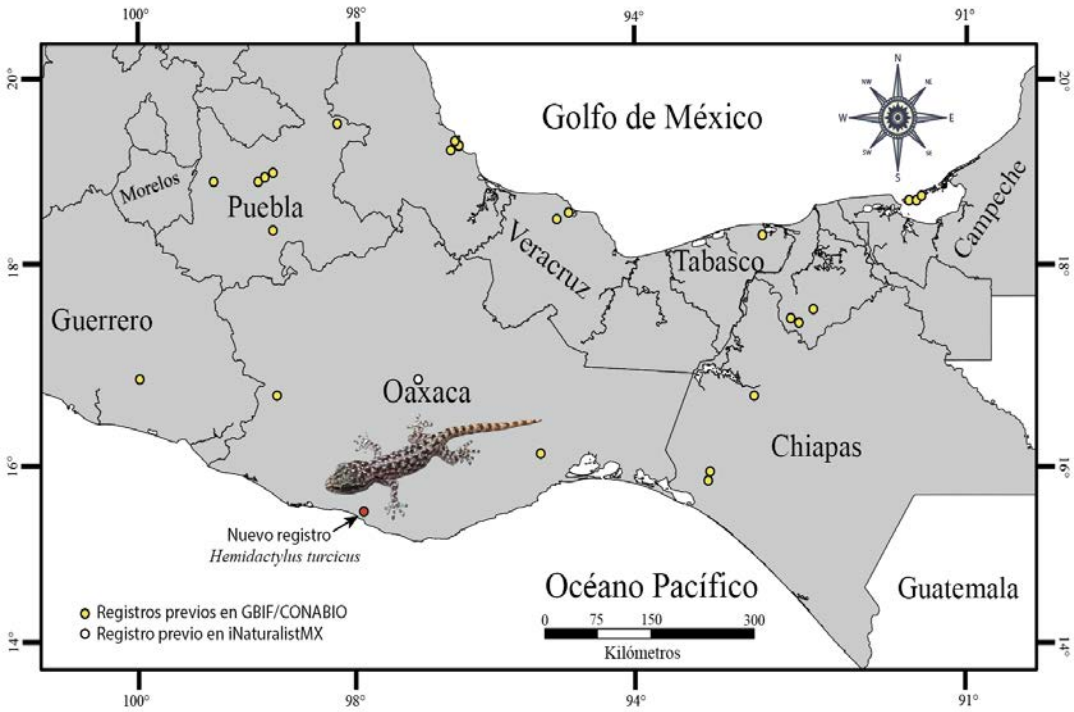

Figure 2. Map with record localities for *Hemidactylus turcicus*, including the new record from the central Oaxacan coast, in central-south Mexico. Prepared from data provided by online citizen science pages iNaturalistMX and the Global Biodiversity information System (GBIF).

Figura 2. Mapa de localidades de registro de *Hemidactylus turcicus*, incluida la nueva localidad para la costa central de Oaxaca,para el centro y sur de México. Elaborado a partir de datos de las páginas en línea de ciencia ciudadana iNaturalistMX y el Sistema Global de Información sobre Biodiversidad (GBIF).

seguramente por la escases de muestreos, lo que lleva a contar con subregistros de la especie, tal como como se ha demostrado para otros países (Basset & Forstner, 2023).

Aunque el impacto negativo de la presencia de *H. turcicus* sobre los ecosistemas y especies nativas en la región se desconoce, en otros países se ha registrado que sus poblaciones pueden alcanzar densidades superiores a los 2,000 individuos por ha (Selcer, 1986), con impactos significativos en la abundancia de las presas de artrópodos como Orthoptera, Lepidoptera e Isopoda (Saenz, 1996). También, es probable que compita con las especies nativas de gecónidos (como *Phyllodactylus tuberculosus* o *Sphaerodactylus glaucus*) como resultado de sus hábitos generalistas en su dieta (Álvarez-Romero et al., 2005). Además, posee el potencial de actuar como vector de otras especies patógenas y parasitarias de importancia para la biodiversidad (Criscione & Font, 2001).

Una de las acciones de "la estrategia nacional sobre especies invasoras en México" , es la generación de información científica y técnica, relevante, oportuna y accesible, que genere capacidades en diversos sectores para atender las prioridades relacionadas con las especies invasoras (Comité Asesor Nacional sobre Especies Invasoras, 2010), por lo que el registro de *H. turcicus* es importante para sentar bases sobre su proceso de colonización en México (Álvarez-Romero et al., 2005; Álvarez-Romero et al., 2008; Valdéz-Villavicencio et al., 2021).

Así, su detección temprana, identificación confiable y actualización de la distribución geográfica, constituyen uno de los primeros pasos de acción señalados por la citada estrategia (Comité Asesor Nacional sobre Especies Invasoras, 2010). Por tanto, será necesario desarrollar trabajos de investigación ecológica (abundancia, comportamiento, características del hábitat, reproducción) de la especie en sitios donde se ha registrado para desarrollar estrategias de manejo y control (Pineda-López et al., 2013).

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PREDATION OF THE GREEN IGUANA *IGUANA RHINOLOPHA* (SQUAMATA: IGUANIDAE) BY THE RUFOUS MOTMOT *BARYPHTHENGUS MARTII* (CORACIIFORMES: MOMOTIDAE), COSTA RICA

DEPREDACIÓN DE LA IGUANA VERDE *IGUANA RHINOLOPHA* (SQUAMATA: IGUANIDAE) POR EL MOMOTO CANELO *BARYPHTHENGUS MARTII* (CORACIIFORMES: MOMOTIDAE), COSTA RICA

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Resumen.– Reportamos el primer evento de depredación de la Iguana Verde *Iguana rhinolopha* por el Momoto Canelo *Baryphthengus martii* en Costa Rica. Es probable que las interacciones de depredación entre las dos especies sean comunes debido a que comparten hábitats y comportamientos similares. Este nuevo registro contribuye al conocimiento sobre la historia natural, comportamiento y la ecología de estas especies.

Palabras clave.– Ave, comportamiento, depredador, dieta, ecología, Sauria.

Abstract.– We report the first event of predation of the Green Iguana *Iguana rhinolopha* by the Rufous Motmot *Baryphthengus martii* in Costa Rica. Predatory interactions between the two species are likely to be common due to shared habitats and behaviors. This report contributes to the knowledge about the natural history, behavior and ecology of these species.

Key words.– Behavior, bird, diet, ecology, predator, Sauria.

The green iguana *Iguana rhinolopha* (Linnaeus, 1758) is a Neotropical lizard that inhabits lowland rainforests and gallery forests from southern Mexico to western Panama, as well as on several eastern Caribbean islands, from near sea level to 1,000 m (Leenders, 2019; Breuil et al., 2019; Breuil et al., 2022). Young iguanas are preyed on by reptiles (*Crocodylus acutus*, *Basiliscus basiliscus*, *B. plumifrons*, *Boa imperator*, *Corallus enydris*, *Oxybelis koheleri*; Greene et al., 1978; Alvarado et al., 2022), birds (*Sarcoramphus papa*, *Elanoides forficatus*, *Buteogallus meridionalis*, *Caracara plancus*, *Harpagus bidentatus*, *Pandion haliaetus*, *Ramphastos sulfuratus*, *Crotophaga major*, *Megaceryle torquata*, *Nyctanassa violacea*, *Athene cunicularia floridana* and *Pulsatrix perspicillata*, Greene et al., 1978; Engeman et al., 2005; McKie et al., 2005; Filipiak et al., 2012) and mammals (*Nasua narica*, *Eira barbara*, *Leopardus pardalis* and *Procyon lotor*; Greene et al., 1978; Smith et al., 2006). Here, we document two events of predation of *I. rhinolopha* by the Rufous Motmot (*Baryphthengus martii*), in Costa Rica.

The Rufous Motmot a bird that inhabits the primary and secondary humid forests from northeastern Honduras to southern Brazil and northeastern Argentina, in the lowlands, up to 1,600 m (Stiles & Skutch, 1989; Master, 2020). Its diet is wide and includes fruits, many invertebrates (e.g., insects, arachnids, centipedes, millipedes and crustaceans), fishes, frogs and lizards (Stiles & Skutch, 1989; Remsen et al., 1993; Master, 2020).

On June 7th, 2024 at 09:11 h, at Tirimbina Biological Reserve, La Virgen, Sarapiquí, Heredia, Costa Rica (10.416667° N, 84.116667 W; 180 m a.s.l.), the second author observed an adult *B. martii*, preying on a juvenile *I. rhinolopha*, in the reserve's garden. A group of small juvenile iguanas was basking in the sun when the motmot, perched on a nearby branch, took advantage of the opportunity to capture one of them. The motmot then carried the iguana to another branch, where it began striking the iguana against the branch. The bird then descended to the ground and continued to hit the iguana against the ground until it was killed

(Fig. 1). Finally, it swallowed the iguana whole. The entire event lasted at least 4 min.

The second event occurred on June 10th, 2024 at 08:10 h, in the same area as the first event. The second author observed an adult individual of *B. martii*, preying on a juvenile individual of *I. rhinolopha*. The young iguana was basking, when the motmot took advantage to catch it and take it to a branch. Then, it began to hit it against the branch until kill and swallow it posteriorly. This event lasted at least 3.5 minutes (Fig. 2).

Young iguanas spend a large part of the daytime sitting and basking on the ground, relatively immobile and forming large groups (Greene et al., 1978; Savage, 2002; Leenders, 2019). During this time, they are exposed to many predators, although they have developed several antipredator strategies, such as camouflage, remaining motionless, head shaking, and tail lashing (Greene et al., 1978; Savage, 2002). *Baryphthengus martii* prefers to capture lizards that are on the ground or in low vegetation (Stiles & Skutch, 1989; Master, 2020). Therefore, it is possible that juvenile

Figura 1. *Baryphthengus martii* depredando a *Iguana rhinolopha*, Reserva Biológica Tirimbina, Costa Rica, 7 de junio, 2024. Fotos: Luis Fernández Sanchéz.

Figure 1. *Baryphthengus martii* preying on *Iguana rhinolopha*, Tirimbina Biological Reserve, Costa Rica, June 7, 2024. Photos: Luis Fernández Sanchéz.

Figura 2. *Baryphthengus martii* depredando a *Iguana rhinolopha*, Reserva Biológica Tirimbina, Costa Rica, 10 de junio, 2024. Fotos: Luis Fernández Sanchéz.
Figure 2. *Baryphthengus martii* preying on *Iguana rhinolopha*, Tirimbina Biological Reserve, Costa Rica, June 10, 2024. Photos: Luis Fernández Sanchéz.

green iguanas are part of its diet. To our knowledge, this is the first record of *B. martii* predating *I. rhinolopha*.

The primary component of motmot diets is arthropods, supplemented by fruits (Remsen et al., 1993). Nevertheless, some motmot species also consume vertebrates (Stiles and Skutch, 1989). Recent studies have documented events of motmots preying on vertebrates (e.g. Alvarado et al., 2022; Mora & Rodríguez, 2023). Predatory interactions are more likely when predator and prey share similar habitats and behaviors (Villegas, 2020; Alvarado et al., 2022). In this case, both *B. martii* and *I. rhinolopha* are diurnal, inhabit lowland and foothill rainforests and occur at similar altitudinal ranges in Costa Rica (Stiles and Skutch 1989; Leenders, 2019). We hypothesize that, as a result, encounters between both species are common.

Understanding predation is one of the initial steps to understand the ecology, ethology and natural history of wildlife

(Curio, 2012; Villegas-Retana & Picado-Masís, 2021; Hernández-Hernández et al., 2024). This evidence contributes to the knowledge about the natural history, behaviors and ecology of *B. martii* and *I. rhinolopha*.

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APPENDICES

Apéndice 1. *Baryphthengus martii* depredando a *Iguana rhinolopha*, Reserva Biológica Tirimbina, Costa Rica, 7 de junio, 2024. Video: Luis Fernández Sanchéz. https://youtu.be/KR5FCLj5k3E

Appendix 1. *Baryphthengus martii* preying on *Iguana rhinolopha*, Tirimbina Biological Reserve, Costa Rica, June 7, 2024. Video: Luis Fernández Sanchéz. https://youtu.be/KR5FCLj5k3E

Apéndice 2. *Baryphthengus martii* depredando a *Iguana rhinolopha*, Reserva Biológica Tirimbina, Costa Rica, 7 de junio, 2024. Video: Luis Fernández Sanchéz. https://youtu.be/CCDI3CSHwzU

Appendix 2. *Baryphthengus martii* preying on *Iguana rhinolopha*, Tirimbina Biological Reserve, Costa Rica, June 7, 2024. Video: Luis Fernández Sanchéz. https://youtu.be/CCDI3CSHwzU

Nota Editorial

It is important to highlight that the Reptile Database 2024 does not recognize *Iguana rhinolopha* as a separate species from *Iguana Iguana* (http://reptile-database.reptarium.cz/species?genus=Iguana&species=iguana&search_param=%28%28search%3D%27iguana+rhinolopha%27%29%29,; accessed in October 16, 2024); however, it seems that it is an unresolved issue since there are no conclusive arguments at least in the webpage. The authors seem to have followed the taxonomy of Breuil (2022), which does not seem to have been refuted by other kind of analyses so far.

Rerefence

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DEPREDACIÓN DE CRÍAS DE TORTUGA NEGRA (*CHELONIA MYDAS*) EN ISLA CLARIÓN DEL PARQUE NACIONAL REVILLAGIGEDO, MÉXICO

PREDATION OF BLACK TURTLE HATCHLINGS (*CHELONIA MYDAS*) ON CLARION ISLAND IN REVILLAGIGEDO NATIONAL PARK, MEXICO

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Abstract.– We present the first documented photographic evidence of the raven (*Corvus corax*) as the main predator of black turtle hatchlings (*Chelonia mydas*) on Clarion Island, in the Revillagigedo National Park. Additionally, we identified the Clarion Island whip snake (*Masticophis anthonyi*) and the Land crab (*Johngarthia oceanica*) as opportunistic predators or scavengers.

Keywords.– Protected natural area, predator, raven, sea turtles.

Resumen.– Presentamos el primer caso documentado en fotografía del cuervo (*Corvus corax*) como principal depredador de crías de tortuga negra (*Chelonia mydas*) en Isla Clarión, en el Parque Nacional Revillagigedo. Además, identificamos a la culebra chirriadora de Isla Clarión (*Masticophis anthonyi*) y el cangrejo de tierra (*Johngarthia oceanica*) como depredadores oportunistas o carroñeros.

Palabras clave.– Área natural protegida, cuervo, depredador, tortugas marinas.

El Parque Nacional Revillagigedo por la gran densidad de rastros, hembras anidadoras y nidos en sus playas, representa un sitio crucial de reproducción y anidación para la tortuga verde del Pacífico Oriental (*Chelonia mydas*), localmente conocida como tortuga negra o prieta (Holroyd & Trefry, 2010; Dutton et al., 2014; Álvarez-Varas et al., 2021; Tiscareño et al., 2023). Durante las últimas décadas, las poblaciones de tortuga negra han experimentado disminuciones significativas debido a la sobreexplotación, y aunque su recuperación ha sido exitosa en los últimos años, aún se enfrentan a diversas amenazas en sus diferentes etapas de vida (Gardner & Nichols, 2001). Son especialmente susceptibles a la depredación en la etapa de huevo; sin embargo, una de las fases más vulnerables se presenta cuando las crías emergen del nido y se dirigen al mar (Gaona & Barragán, 2016). En Isla Clarión no existe evidencia de depredación de las hembras adultas anidadoras ni de sus nidos, ya que la fauna autóctona de la isla se compone principalmente de pequeños reptiles, aves y artrópodos (Brattsrom, 1955; Howell & Webb, 1989), mientras que el único mamífero es el conejo común (*Oryctolagus cuniculus*) introducido por el humano (Méndez-Guardado, 2001). En contraste, existen registros de aves y reptiles que depredan a las crías recién emergidas durante su trayecto al mar (Brattsrom, 1955; Brattsrom, 1982; Awbrey et al., 1984) lo que puede aumentar la mortalidad en esta etapa del ciclo de vida.

Durante los meses de octubre y noviembre (pico de anidación) de 2022 y 2023 se llevaron a cabo monitoreos de tortugas marinas en Isla Clarión para la elaboración de la línea base de información sobre la anidación de tortugas negras en la isla. En el transcurso de los monitoreos diurnos (10:00-19:00 h) se observó recurrentemente la presencia de grupos de cuervos (*Corvus corax*) realizando vuelos circulares sobre Playa Grande, la principal zona de anidación de tortuga negra en Isla Clarión (Fernández-Sanz et al., 2024). Se registró el aterrizaje de cuervos alrededor de nidos con crías emergiendo, así como la depredación de las crías (Figs. 1 y 2). Estos eventos se observaron intermitentemente a lo largo de todo el día hasta aproximadamente las 19:00 h, horario a partir del cual la actividad de los cuervos disminuía. Normalmente, las crías eclosionan de forma sincronizada durante la noche, respondiendo a señales ambientales y químicas que las estimulan a emerger simultáneamente (Leslie et al., 1996; Koch et al., 2007). Este comportamiento facilita el ascenso a la superficie, minimiza el riesgo de deshidratación y de depredación. No obstante, en ocasiones, diversos cambios ambientales pueden detonar la eclosión durante el día, por ejemplo, una disminución en la temperatura de la arena. Durante los monitoreos matutinos y nocturnos (22:00-05:00 h) se observó a la culebra chirriadora de Isla Clarión (*Masticophis anthonyi*) buscando alimento en nidos recién exhumados (Fig. 3), y se registró a los cangrejos de tierra (*Johngarthia oceanica*) alimentándose de crías de tortuga negra que se encontraban a lo largo de la playa (Fig. 4). Estas observaciones permitieron clasificar a las culebras chirriadoras como posibles carroñeras y a los cangrejos de tierra como depredadores oportunistas.

A lo largo del último siglo, diversos autores han reportado posibles depredadores de crías de tortuga marina en Isla Clarión. Entre ellos, se encuentran la culebra chirriadora de Isla Clarión (*Masticophis anthonyi*) (Brattsrom, 1955), el tecolote llanero de Clarión (*Athene cunicularia*) (Brattsrom, 1982), varios peces y aves como los bobos patas rojas (*Sula sula*), las fragatas (*Fregata* sp.), los cuervos (*Corvus corax*) y el delfín (*Tursiops* sp.) (Awbrey et al., 1984). Este estudió confirma que el cuervo es el principal depredador

Figure 1. Black turtle hatchling (*Chelonia mydas*) depredated by a raven (*Corvus corax*) on Playa Grande, Clarion Island. November 2022. Photo: Helena Fernández Sanz.
Figura 1. Cría de tortuga negra (*Chelonia mydas)* depredada por un cuervo (*Corvus corax*) en Playa Grande, Isla Clarión. Noviembre de 2022. Foto: Helena Fernández Sanz.

Figure 2. Raven (*Corvus corax*) feeding on a black turtle hatchling (*Chelonia mydas)* on Playa Grande, Clarion Island. October 2023. Photo: Fernando Iván Hernández Burgos.
Figura 2. Cuervo (*Corvus corax*) alimentándose de cría de tortuga negra (*Chelonia mydas*) en Playa Grande, Isla Clarión. Octubre de 2023. Foto: Fernando Iván Hernández Burgos.

Figure 3. Clarion Island whip snake (*Masticophis anthonyi*) searching for food in recently exhumed black turtle nest. November 2022. Photo: Fernando Iván Hernández Burgos.
Figura 3. Culebra chirriadora de Isla Clarión (*Masticophis anthonyi*) buscando alimento en nido recién exhumado de tortuga negra. Noviembre de 2022. Foto: Fernando Iván Hernández Burgos.

Figure 4. Land crab (*Johngarthia oceanica)* as an opportunistic predator feeding on black turtle hatchling (*Chelonia mydas*). October 2023. Photo: Laura Andrea Flores Gasca.

Figura 4. Cangrejo de tierra (*Johngarthia oceanica)* como depredador oportunista alimentándose de cría de tortuga negra (*Chelonia mydas*). Octubre de 2023. Foto: Laura Andrea Flores Gasca.

de crías de tortuga negra en la isla, registrado por primera vez en fotografía, y sustenta que existen otros organismos que pueden ser depredadores o especies potencialmente carroñeras.

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CONTORTIONIST TREE FROG: NEW RECORDS AND AN UPDATED LIST OF ANTIPREDATOR MECHANISMS IN *BOANA* (ANURA: HYLIDAE) AND *PRISTIMANTIS* (ANURA: STRABOMANTIDAE)

PERERECA CONTORCIONISTA: NOVOS REGISTROS E ATUALIZAÇÃO DA LISTA DE MECANISMOS ANTIPREDATÓRIOS EM *BOANA* (ANURA: HYLIDAE) E *PRISTIMANTIS* (ANURA: STRABOMANTIDAE)

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Resumo.– Mecanismos antipredatórios são formas eficientes de lidar com as tentativas de predação e existem vários tipos na natureza. Anuros possuem um repertório diversificado de mecanismos defensivos por também desempenharem um papel crucial na cadeia trófica. No entanto, devido à vasta diversidade de anuros, pouco se sabe sobre o repertório de mecanismos antipredatórios de cada espécie. Aqui, apresentamos uma lista atualizada de mecanismos registrados para dois gêneros de anuros, *Pristimantis* e *Boana*, incluindo nove novos comportamentos antipredatórios para *Pristimantis* aff. *guianensis* e *Boana pardalis*. Um destes comportamentos é o entrelaçamento de membros ("limbs interweave"), um mecanismo raro relatado para apenas 14 espécies de anuros. Nossas descobertas destacam a importância da pesquisa empírica e da observação direta da história natural. Mesmo para espécies bem conhecidas, o conhecimento da história natural pode ser limitado.

Palavra chave.–*Boana pardalis*, comportamento defensivo, membros entrelaçados, pernas entrelaçadas, *Pristimantis guianensis*

Abstract.– Antipredator mechanisms are efficient ways to avoid attempted predations, and various forms exist in nature. Anurans play a crucial role in the trophic chain and show a diverse repertoire of mechanisms. However, due to the vast diversity of anurans, little is known about the antipredator mechanism repertoire of each species. Here, we present an updated list of mechanisms reported for two genera of anurans, *Pristimantis* and *Boana*, including nine new antipredator behaviors for *Pristimantis* aff. *guianensis* and *Boana pardalis*. One of those behaviors is the limbs interweave, a rare mechanism reported for only 14 anuran species. Our findings highlight the importance of empirical research and direct natural history observation. Even for well-known species, knowledge on natural history can be limited.

Key words.–*Boana pardalis*, defensive behavior, limbs interweave, legs interweaving, *Pristimantis guianensis*

Predators pressure induce diverse traits in prey (e.g., Riessen, 1992; Üveges et al., 2019), leading to varied mechanisms including behavioral, morphological, and physiological adjustments (Brodie et al., 1991; Caro, 2014). Commonly known as antipredator behaviors, these strategies are employed by prey to reduce predation success (Brodie et al., 1991; Caro, 2014). Anurans, as crucial components of the trophic web, serve as both prey and predator for numerous species (Toledo et al., 2007; Ceron et al., 2018; Souza et al., 2023). Therefore, they exhibit various antipredator mechanisms, such as remaining motionless, fleeing, and displaying colors for defense (Toledo et al., 2011; Ferreira et al., 2019).

The Neotropical region is renowned for its richness in anuran diversity with many yet to be discovered (Moura & Jetz, 2021). Among this remarkable diversity, the genera *Pristimantis* and

Boana are prominent both in number of species and geographic range. *Pristimantis*, recognized as the most diverse genus among anurans, encompasses over 600 described species and *Boana*, with 99 known species, shares a similar Neotropical distribution (Padial et al., 2014; Frost, 2024).

Despite their vast diversity, only eight species of *Pristimantis* and 32 species of *Boana* have at least one antipredator mechanism reported (Ferreira et al., 2019). Here we describe six new antipredator mechanisms for *Pristimantis* aff. *guianensis*, a lineage distributed in Madeira River interfluve (Fouquet et al., 2022; Mônico et al., 2022; Mônico, 2023), and three for *Boana pardalis*, a species inhabiting open and forested areas in the Atlantic Forest of southeastern Brazil (Caramaschi & Napoli, 2004). In addition, we updated the previous list of antipredator mechanisms provided by Ferreira et al. (2019) for both genera and the list of events of the rare limb interweave behavior.

To update the list of antipredator mechanisms we reviewed the literature published between January 2019 and December 2023 following van den Burg (2020). We consulted 12 natural history journals: Caribbean Herpetology, Cuadernos de Herpetología, Copeia, Herpetologia Brasileira, Herpetological Review, Herpetology Notes, Herpetozoa, Phyllomedusa, Reptiles & Amphibians, Revista Lationoamericana de Herpetología, Sauria, and The Herpetological Bulletin. Besides that, we also conducted a bibliographic search using published and peer-reviewed articles in Google Scholar (scholar.google.com.br), Scientific Electronic Library Online — Scielo (www.scielo.br), Web of Science (www.webofknowledge.com), and Research Gate (www.researchgate.com). The survey was conducted using the combination of the following words: "*Boana*", "*Pristimantis*" "defensive behavior", "defensive behaviour", "antipredator mechanism", "amphibian", "predation", and "prey".

Our first record was made during a field expedition to Rio Manicoré (6°35'42.38" S, 61°22'06.27" W; datum WGS84; 48 m a.s.l.), state of Amazonas, Brazil, on June 10, 2022. One individual of *Pristimantis* aff. *guianensis* (snout-vent length = 18.99 mm; body mass = 0.5 g) was captured in the igapó forest during the day, when we were inspecting pitfall traps; the individual jumped in front of us. We carried it to the field lab, where it was kept in a plastic bag with one leaf and water. On June 13, 2022, at 14:01 h, we started to handle the individual to take pictures. During preparation and handling, the animal twisted its legs and remained motionless, displaying (1) limbs interweave behavior (Fig. 1A). After a few seconds (about 60 s), when we touched it, the individual returned to normal posture and rapidly bent down its body to lower than usual, displaying the (2) crouching down behavior (Fig. 1B). The limbs remained next to the body and the eyes open, remaining motionless for a few minutes (1-2 min) until we touched the individual again. It remained immobile (3) in normal posture for 2 min (Fig. 1C). To take some pictures of the ventral view of the individual, we turned it upside down; however, it turned to a normal position. In a second attempt, it remained for a few minutes (1-2 min), displaying the (4) death-feigning behavior (Fig. 1D). During the handling process, the individual (5) jumped away several times. Additionally, we formally described the camouflage of background matching (6) as a defensive mechanism exhibited by *Pristimantis* aff. *guianensis*, a species with cryptic coloration. The species' coloration closely resembles the trunk and leaves of its habitat, providing effective camouflage against predator detection (Toledo & Haddad, 2009a; Ferreira et al., 2019). The specimen was deposited at the Amphibians and Reptiles Collection from the Instituto Nacional de Pesquisas da Amazônia (INPA-H), under voucher number INPA-H044572.

The second record was made occasionally on August 19, 2023, at 12:38 h, in a rural area of Alto Rio Doce, Minas Gerais, Brazil (21°02'07.00" S, 43°29'06.00" W; datum WGS84; 773 m a.s.l.). M.A.P.C. Dias was harvesting collard when an individual of *Boana pardalis* jumped away from a collard leaf and down on the floor with legs twisting over each other, displaying (1) limbs interweave behavior and remaining motionless (Fig. 1E-F). During the defensive behavior, the individual exhibited a contrasting yellow color, acting as (2) hidden aposematism (Fig. 1E-F). After a few minutes (1-2 min), when he approached the frog to take more pictures, it turned to normal posture and (3) jumped away. The frog was neither captured nor measured.

Limbs interweave (or legs interweaving) is a rare defensive behavior, with only six records for anuran species in the scientific literature by 2019 (Ferreira et al., 2019), as follows: for *Acris blanchardi*, *Dryophytes cinereus* and *Hylomantis aspera*, from the Hylidae family; for *Hylambates keithae*, from the Hyperoliidae family; for *Leptodactylus macrosternum*, from the Leptodactylidae family; and for *Rana temporaria*, from the Ranidae family. After Ferreira et al. (2019), the behavior was recorded six more times, as follows: for *Frostius pernambucensis*, from the Bufonidae family (Ramos et al., 2021); for *Boana semilineata* (Campos et al., 2023), *Boana geographica* (Campos & Silva-Soares, 2023), *Bokermannohyla oxente* (Souza et al., 2020a), and *Ololygon tripui* (Vieira et al., 2022) from the Hylidae family; and for *Haddadus binotatus* (Rojas-Padilla et al., 2019), from the Craugastoridae family. Therefore, our records coupled with the literature show the compilation of 14 anuran species exhibiting the defensive behavior of limbs interweave. Besides that, this study is the first

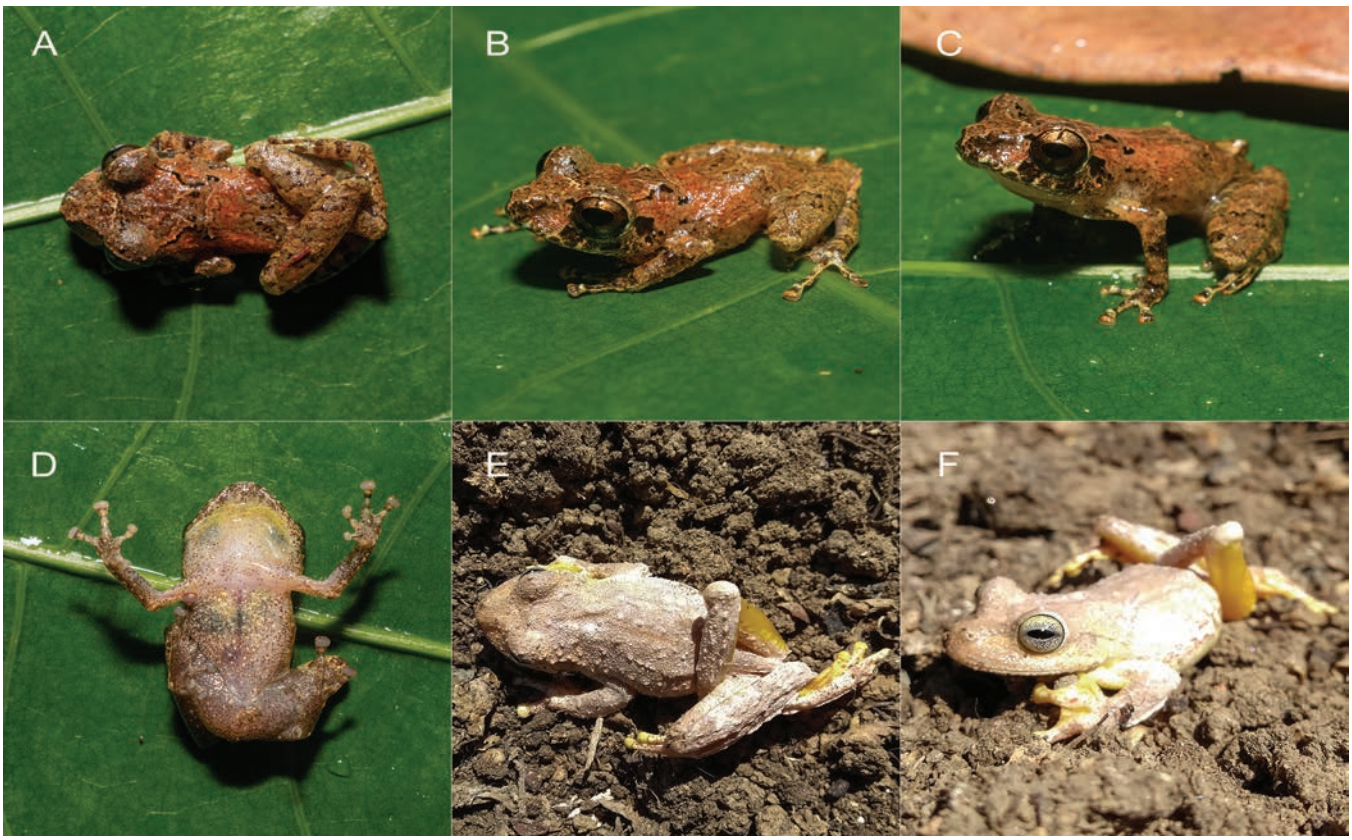

Figura 1. Comportamentos antipredatórios registrados para *Pristimantis* aff. *guianensis* (A-D) e *Boana pardalis* (E-F). A, E e F: entrelaçamento de membros; B: agachamento; C: imobilidade; D: tanatose. Fotos: Lucas R. Mendonça (*Pristimantis* aff. *guianensis*) e Marcelo A. P. C. Dias (*Boana pardalis*).

Figure 1. Antipredator behaviors reported for *Pristimantis* aff. *guianensis* (A-D) and *Boana pardalis* (E-F). A, E, and F: limbs interweave; B: crouching down; C: immobility; D: death feigning. Photos: Lucas R. Mendonça (*Pristimantis* aff. *guianensis*) and Marcelo A. P. C. Dias (*Boana pardalis*).

record of limbs interweave for the family Strabomantidae, for the genus *Pristimantis*, and for the *Boana faber* group, and also the third record for the genus *Boana* (Table 1).

Limbs interweave behavior may be associated with the exhibition of aposematic coloration and facilitation of the spread of skin secretion (Toledo et al., 2011; Ferreira et al., 2019). In *Pristimantis* aff. *guianensis* this behavior does not seem to be associated with aposematic coloration, similar to what was observed in *Bokermannohyla oxente* and *Ololygon tripui* (Souza et al., 2020a; Vieira et al., 2022). However, for *B. pardalis*, limbs interweave is associated to hidden aposematism, as observed in *Frostius pernambucensis* (Ramos et al., 2021). When *B. pardalis* rotates its legs, the bright yellow color present on the ventral surface of its legs becomes visible, acting as a warning signal to the predators regarding the presence of toxins and the lack of palatability (Ferreira et al. 2019). While the association of limb interweave with skin secretion is not observed in both species, it remains a possibility for *B. pardalis*, considering recorded skin secretion instances in the species and other members of the genus (Table 1).

Immobility and jumping are common defensive behaviors in anurans, observed across all species in nature (Toledo et al., 2011). Remaining immobile enhances the chances of avoiding visual detection by potential predators, especially when combined with cryptic coloration (Toledo et al., 2010; Ferreira et al., 2019). During immobility, individuals often prepare to jump away from predators, either by flattening against the ground or performing crouching down behavior, as seen in *Pristimantis* aff. *guianensis* (Fig. 1C; Toledo et al., 2010; Ferreira et al., 2019). Jumping away facilitates hiding and can be coupled with other defensive behaviors, as observed in *B. pardalis*, which exhibits limb interweave following a jump (Toledo et al., 2010; Ferreira et al., 2019).

Tabela 1. Lista atualizada de mecanismos antipredatórios de *Boana* e *Pristimantis*. 1. Camuflagem correspondente ao fundo; 2. Camuflagem disruptiva; 3. Imobilidade; 4. Canto interrompido; 5. Aposematismo escondido; 6. Investida; 7. Inflação corporal; 8. Contração; 9. Entrelaçamento de membros; 10. Abertura da boca; 11. Alongamento de membros; 12. Tanatose; 13. Reflexo unken; 14. Escalada; 15. Esconder-se; 16. Saltar para longe; 17. Nadar; 18. Som de aviso; 19. Descarga cloacal; 20. Secreção adesiva; 21. Secreção odorífera; 22. Secreção escorregadia; 23. Secreção venenosa; 24. Mordida; 25. Cabeçada; 26. Chute; 27. Perfurar; 28. Chamada de socorro; 29. Polifenismo; 30. Proteção ocular; 31. Agachamento.

Table 1. An updated list of antipredator mechanisms of *Boana* and *Pristimantis*. 1. Matching background camouflage; 2. Disruptive camouflage; 3. Immobility; 4. Interrupted calling; 5. Hidden aposematism; 6. Charging; 7. Body inflation; 8. Contraction; 9. Interweaving limbs; 10. Mouth gape; 11. Stretching limbs; 12. Death feigning; 13. Unken reflex; 14. Climbing; 15. Hiding; 16. Jump away; 17. Swim; 18. Warning sound; 19. Cloacal discharge; 20. Adhesive secretion; 21. Odoriferous secretion; 22. Slippery secretion; 23. Poisonous secretion; 24. Bite; 25. Headbutt; 26. Kick; 27. Puncture; 28. Distress call; 29. Polyphenism; 30. Eye protection; 31. Crouching down.

Species	Antipredator mechanism																															References
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
***Boana albomarginata** (Spix 1824)**	1		3		5		7	8				12				16			19		21	22				26		28					Toledo & Haddad, 2009b; Figueiredo-de-Andrade et al., 2010; Toledo et al., 2010; Toledo et al., 2011; Baracho et al., 2013; Haddad et al., 2013; Just & Zocche, 2017; Ferreira et al., 2019
***Boana albopunctata* (Spix 1824)**	1		3		5		7	8				12							19									28		30			Sazima, 1972; Toledo & Haddad, 2009b; Toledo et al., 2010; Haddad et al., 2013; Costa et al., 2014; Toledo et al., 2011; Ferreira et al., 2019
***Boana beckeri* (Caramaschi and Cruz 2004)**		2			5			8																									Toledo et al., 2010
***Boana bischoffi* (Boulenger 1887)**	1				5			8		10		12							19		21							28					Toledo & Haddad, 2009b; Toledo et al., 2010; Toledo et al., 2011; Haddad et al., 2013; Foerster et al., 2017
***Boana boans* (Linnaeus 1758)**	1				5	6	7			10	11					16								24			27	28					Bogert, 1960; Hödl & Gollmann, 1986; Lima et al., 2005; Rocha & López-Baucells, 2014

Tabela 1 (cont.). Lista atualizada de mecanismos antipredatórios de *Boana* e *Pristimantis*. 1. Camuflagem correspondente ao fundo; 2. Camuflagem disruptiva; 3. Imobilidade; 4. Canto interrompido; 5. Aposematismo escondido; 6. Investida; 7. Inflação corporal; 8. Contração; 9. Entrelaçamento de membros; 10. Abertura da boca; 11. Alongamento de membros; 12. Tanatose; 13. Reflexo unken; 14. Escalada; 15. Esconder-se; 16. Saltar para longe; 17. Nadar; 18. Som de aviso; 19. Descarga cloacal; 20. Secreção adesiva; 21. Secreção odorífera; 22. Secreção escorregadia; 23. Secreção venenosa; 24. Mordida; 25. Cabeçada; 26. Chute; 27. Perfurar; 28. Chamada de socorro; 29. Polifenismo; 30. Proteção ocular; 31. Agachamento.

Table 1 (cont.). An updated list of antipredator mechanisms of *Boana* and *Pristimantis*. 1. Matching background camouflage; 2. Disruptive camouflage; 3. Immobility; 4. Interrupted calling; 5. Hidden aposematism; 6. Charging; 7. Body inflation; 8. Contraction; 9. Interweaving limbs; 10. Mouth gape; 11. Stretching limbs; 12. Death feigning; 13. Unken reflex; 14. Climbing; 15. Hiding; 16. Jump away; 17. Swim; 18. Warning sound; 19. Cloacal discharge; 20. Adhesive secretion; 21. Odoriferous secretion; 22. Slippery secretion; 23. Poisonous secretion; 24. Bite; 25. Headbutt; 26. Kick; 27. Puncture; 28. Distress call; 29. Polyphenism; 30. Eye protection; 31. Crouching down.

Species	Antipredator mechanism																															References
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
***Boana caingua* (Carrizo 1991)**	1				5			8																				28				Toledo & Haddad, 2009b; Toledo et al., 2010; Haddad et al., 2013
***Boana caipora* (Antunes, Faivovich & Haddad 2008)**	1																											28				Antunes et al., 2008; Toledo & Haddad, 2009b; Haddad et al., 2013
***Boana calcarata* (Troschel 1848)**	1				5			8																							31	Angulo & Funk, 2006; Pedroso-Santos et al., 2020a; Pedroso-Santos et al., 2022
***Boana cinerascens* (Spix 1824)**	1					6										16																Ferreira et al., 2019
***Boana courtoisae* Fouquet, Marinho, Réjaud, Carvalho, Caminer, Jansen, Rainha, Rodrigues, Werneck, Lima, Hrbek, Giaretta, Venegas, Chávez & Ron 2021**	1											12																				Pedroso-Santos et al., 2022
***Boana crepitans* (Wied-Neuwied 1824)**	1		3		5		7					12				16						22				26		28				Toledo & Haddad, 2009b; Haddad et al., 2013; Ferreira et al., 2019
***Boana curupi* (Garcia, Faivovich & Haddad 2007)**	1				5																21											Haddad et al., 2013

Tabela 1 (cont.). Lista atualizada de mecanismos antipredatórios de *Boana* e *Pristimantis*. 1. Camuflagem correspondente ao fundo; 2. Camuflagem disruptiva; 3. Imobilidade; 4. Canto interrompido; 5. Aposematismo escondido; 6. Investida; 7. Inflação corporal; 8. Contração; 9. Entrelaçamento de membros; 10. Abertura da boca; 11. Alongamento de membros; 12. Tanatose; 13. Reflexo unken; 14. Escalada; 15. Esconder-se; 16. Saltar para longe; 17. Nadar; 18. Som de aviso; 19. Descarga cloacal; 20. Secreção adesiva; 21. Secreção odorífera; 22. Secreção escorregadia; 23. Secreção venenosa; 24. Mordida; 25. Cabeçada; 26. Chute; 27. Perfurar; 28. Chamada de socorro; 29. Polifenismo; 30. Proteção ocular; 31. Agachamento.

Table 1 (cont.). An updated list of antipredator mechanisms of *Boana* and *Pristimantis*. 1. Matching background camouflage; 2. Disruptive camouflage; 3. Immobility; 4. Interrupted calling; 5. Hidden aposematism; 6. Charging; 7. Body inflation; 8. Contraction; 9. Interweaving limbs; 10. Mouth gape; 11. Stretching limbs; 12. Death feigning; 13. Unken reflex; 14. Climbing; 15. Hiding; 16. Jump away; 17. Swim; 18. Warning sound; 19. Cloacal discharge; 20. Adhesive secretion; 21. Odoriferous secretion; 22. Slippery secretion; 23. Poisonous secretion; 24. Bite; 25. Headbutt; 26. Kick; 27. Puncture; 28. Distress call; 29. Polyphenism; 30. Eye protection; 31. Crouching down.

Species	Antipredator mechanism																															References
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
***Boana dentei* (Bokermann 1967)**																												28	29	30		Figueiredo et al., 2020; Pedroso-Santos et al., 2020b
***Boana diabolica* (Fouquet, Martinez, Zeidler, Courtois, Gaucher, Blanc, Lima, Souza, Rodrigues & Kok 2016)**					5			8																								Pedroso-Santos et al., 2022
***Boana exastis* (Caramaschi & Rodrigues 2003)**	1																										27	28				Loebmann et al., 2008; Toledo & Haddad, 2009b; Haddad et al., 2013
***Boana faber* (Wied-Neuwied 1821)**	1		3		5		7	8		10	11	12	13	14	15	16	17	18	19		21	22				26	27	28				Toledo & Haddad, 2009b; Toledo et al., 2010; Toledo et al., 2011; Forti & Bertoluci, 2012; Haddad et al., 2013; Manoel & Almeida, 2017; Ferreira et al., 2019; Dias-Silva et al., 2021
Boana fasciata (Günther 1858)**	1		3		5			8																								Angulo & Funk, 2006
Boana* cf. *fasciata																												28				Forti & Costa-Campos, 2020

Tabela 1 (cont.). Lista atualizada de mecanismos antipredatórios de *Boana* e *Pristimantis*. 1. Camuflagem correspondente ao fundo; 2. Camuflagem disruptiva; 3. Imobilidade; 4. Canto interrompido; 5. Aposematismo escondido; 6. Investida; 7. Inflação corporal; 8. Contração; 9. Entrelaçamento de membros; 10. Abertura da boca; 11. Alongamento de membros; 12. Tanatose; 13. Reflexo unken; 14. Escalada; 15. Esconder-se; 16. Saltar para longe; 17. Nadar; 18. Som de aviso; 19. Descarga cloacal; 20. Secreção adesiva; 21. Secreção odorífera; 22. Secreção escorregadia; 23. Secreção venenosa; 24. Mordida; 25. Cabeçada; 26. Chute; 27. Perfurar; 28. Chamada de socorro; 29. Polifenismo; 30. Proteção ocular; 31. Agachamento.

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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
***Boana geographica* (Spix 1824)**	1		3		5		7	8	9	10		12							19		21							28	29	30	31	Azevedo-Ramos, 1995; Lima et al., 2005; Angulo et al., 2007; Toledo et al., 2010; Pedroso-Santos et al., 2020a; Pedroso-Santos et al., 2022; Campos & Silva-Soares, 2023; Soares et al., 2023
***Boana guentheri* (Boulenger 1886)**	1											12																				Toledo et al., 2010; Haddad et al., 2013
***Boana lanciformis* (Cope 1871)**	1						7					12				16			19									28				Höld & Gollmann, 1986; Ferreira et al., 2019; Pedroso-Santos et al., 2020a
***Boana latistriata* *** (Caramaschi & Cruz 2004)**		2						8																				28				Toledo & Haddad, 2009b; Toledo et al., 2010; Haddad et al., 2013
***Boana leptolineatus* (Braun & Braun 1977)**		2						8																								Toledo et al., 2010; Haddad et al., 2013
***Boana leucocheila* (Caramaschi & Niemeyer 2003)**	1									10																		28				Santana et al., 2013

Tabela 1 (cont.). Lista atualizada de mecanismos antipredatórios de *Boana* e *Pristimantis*. 1. Camuflagem correspondente ao fundo; 2. Camuflagem disruptiva; 3. Imobilidade; 4. Canto interrompido; 5. Aposematismo escondido; 6. Investida; 7. Inflação corporal; 8. Contração; 9. Entrelaçamento de membros; 10. Abertura da boca; 11. Alongamento de membros; 12. Tanatose; 13. Reflexo unken; 14. Escalada; 15. Esconder-se; 16. Saltar para longe; 17. Nadar; 18. Som de aviso; 19. Descarga cloacal; 20. Secreção adesiva; 21. Secreção odorífera; 22. Secreção escorregadia; 23. Secreção venenosa; 24. Mordida; 25. Cabeçada; 26. Chute; 27. Perfurar; 28. Chamada de socorro; 29. Polifenismo; 30. Proteção ocular; 31. Agachamento.

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***Boana lundii* (Burmeister 1856)**	1						7																					28				Toledo & Haddad, 2009b; Haddad et al., 2013; Nascimento et al., 2020
***Boana marginata* (Boulenger 1887)**	1							8																								Toledo et al., 2010; Haddad et al., 2013
***Boana microderma* (Pyburn 1977)**	1											12				16																Ferreira et al., 2019
***Boana multifasciata* (Günther 1859)**																												28				Forti & Costa-Campos, 2020
***Boana pardalis* (Spix 1824)**	1		3	4	**5**		7	8	**9**	10						**16**			19		21				25		27	28				**This study**; Toledo & Haddad, 2009b, Toledo et al., 2011; Heitor et al., 2012; Haddad et al., 2013; Koski et al., 2018; Ferreira et al., 2019
***Boana polytaenia* (Cope, 1870)**		2						8																								Toledo et al., 2010; Haddad et al., 2013
***Boana pombali* (Caramaschi, Pimenta & Feio 2004)**	1		3		5			8																						30		Haddad et al., 2013; Ferreira et al., 2019; Souza et al., 2020b
***Boana prasina* (Burmeister 1856)**	1				5														19													Toledo et al., 2011; Haddad et al., 2013

Tabela 1 (cont.). Lista atualizada de mecanismos antipredatórios de *Boana* e *Pristimantis*. 1. Camuflagem correspondente ao fundo; 2. Camuflagem disruptiva; 3. Imobilidade; 4. Canto interrompido; 5. Aposematismo escondido; 6. Investida; 7. Inflação corporal; 8. Contração; 9. Entrelaçamento de membros; 10. Abertura da boca; 11. Alongamento de membros; 12. Tanatose; 13. Reflexo unken; 14. Escalada; 15. Esconder-se; 16. Saltar para longe; 17. Nadar; 18. Som de aviso; 19. Descarga cloacal; 20. Secreção adesiva; 21. Secreção odorífera; 22. Secreção escorregadia; 23. Secreção venenosa; 24. Mordida; 25. Cabeçada; 26. Chute; 27. Perfurar; 28. Chamada de socorro; 29. Polifenismo; 30. Proteção ocular; 31. Agachamento.

Table 1 (cont.). An updated list of antipredator mechanisms of *Boana* and *Pristimantis*. 1. Matching background camouflage; 2. Disruptive camouflage; 3. Immobility; 4. Interrupted calling; 5. Hidden aposematism; 6. Charging; 7. Body inflation; 8. Contraction; 9. Interweaving limbs; 10. Mouth gape; 11. Stretching limbs; 12. Death feigning; 13. Unken reflex; 14. Climbing; 15. Hiding; 16. Jump away; 17. Swim; 18. Warning sound; 19. Cloacal discharge; 20. Adhesive secretion; 21. Odoriferous secretion; 22. Slippery secretion; 23. Poisonous secretion; 24. Bite; 25. Headbutt; 26. Kick; 27. Puncture; 28. Distress call; 29. Polyphenism; 30. Eye protection; 31. Crouching down.

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***Boana pulchella* (Duméril & Bibron 1841)**	1				5			8																								Toledo et al., 2010; Haddad et al., 2013
***Boana punctata* (Schneider 1799)**	1											12				16																Haddad et al., 2013; Ferreira et al., 2019
***Boana raniceps* (Cope 1862)**	1		3		5		7			10		12			15	16			19		21	22				26	27	28				Höld & Gollmann, 1986; Toledo & Haddad, 2009b; Toledo et al., 2011; Haddad et al., 2013; Guerra et al., 2018; Ferreira et al., 2019
***Boana semilineata* (Spix 1824)**	1		3				7	8	9							16			19		21	22				26						Azevedo-Ramos, 1995; Toledo et al., 2010; Haddad et al., 2013; Ferreira et al., 2019; Campos et al., 2023
***Boana wavrini* (Parker 1936)**	1				5					10																		28				Lima et al., 2005
***Pristimantis altamazonicus* (Barbour & Dunn 1921)**	1															16																Ferreira et al., 2019
***Pristimantis chiastonotus* (Lynch & Hoogmoed 1977)**	1											12																				Pedroso-Santos et al., 2022
***Pristimantis conspicillatus* (Günther 1858)**	1						7									16			19													Ferreira et al., 2019

Tabela 1 (cont.). Lista atualizada de mecanismos antipredatórios de *Boana* e *Pristimantis*. 1. Camuflagem correspondente ao fundo; 2. Camuflagem disruptiva; 3. Imobilidade; 4. Canto interrompido; 5. Aposematismo escondido; 6. Investida; 7. Inflação corporal; 8. Contração; 9. Entrelaçamento de membros; 10. Abertura da boca; 11. Alongamento de membros; 12. Tanatose; 13. Reflexo unken; 14. Escalada; 15. Esconder-se; 16. Saltar para longe; 17. Nadar; 18. Som de aviso; 19. Descarga cloacal; 20. Secreção adesiva; 21. Secreção odorífera; 22. Secreção escorregadia; 23. Secreção venenosa; 24. Mordida; 25. Cabeçada; 26. Chute; 27. Perfurar; 28. Chamada de socorro; 29. Polifenismo; 30. Proteção ocular; 31. Agachamento.

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***Pristimantis diadematus* (Jiménez de la Espada 1875)**	1				5											16																Ferreira et al., 2019
***Pristimantis fenestratus* (Steindachner 1864)**	1											12																				Lima et al., 2005; Ferreira et al., 2019
***Pristimantis gutturalis* (Hoogmoed, Lynch & Lescure 1977)**	1											12																				Pedroso-Santos et al., 2022
***Pristimantis inguinalis* (Parker 1940)**					5							12																				Pedroso-Santos et al., 2022
***Pristimantis paulodutrai* (Bokermann 1975)**	1											12																				Haddad et al., 2013; Ferreira et al., 2019
***Pristimantis racemus* (Lynch 1980)**																												28				Pisso-Florez et al., 2023
***Pristimantis ramagii* (Boulenger 1888)**	1									10		12																				Haddad et al., 2013; Ferreira et al., 2019
***Pristimantis skydmainos* (Flores & Rodriguez 1997)**	1						7									16																Ferreira et al., 2019

Tabela 1 (cont.). Lista atualizada de mecanismos antipredatórios de *Boana* e *Pristimantis*. 1. Camuflagem correspondente ao fundo; 2. Camuflagem disruptiva; 3. Imobilidade; 4. Canto interrompido; 5. Aposematismo escondido; 6. Investida; 7. Inflação corporal; 8. Contração; 9. Entrelaçamento de membros; 10. Abertura da boca; 11. Alongamento de membros; 12. Tanatose; 13. Reflexo unken; 14. Escalada; 15. Esconder-se; 16. Saltar para longe; 17. Nadar; 18. Som de aviso; 19. Descarga cloacal; 20. Secreção adesiva; 21. Secreção odorífera; 22. Secreção escorregadia; 23. Secreção venenosa; 24. Mordida; 25. Cabeçada; 26. Chute; 27. Perfurar; 28. Chamada de socorro; 29. Polifenismo; 30. Proteção ocular; 31. Agachamento.

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***Pristimantis vinhai* (Bokermann 1975)**	1											12																			Haddad et al., 2013; Ferreira et al., 2019
Pristimantis* aff. *guianensis	1		3						9			12				16														31	**This study**

* Ferreira et al. (2019) used *Boana albomarginatus*; ** Ferreira et al. (2019) used *Boana fasciatus*; *** Ferreira et al. (2019) used *Boana latistriatus*

The crouching down behavior, not covered in the recent antipredator mechanism review by Ferreira et al. (2019), is described by Toledo et al. (2011) as a defensive strategy to avoid subjugation by predators. This behavior may be associated with skin secretion and body puffing, but these synergies were absent during crouching down in *Pristimantis* aff. *guianensis*. A similar not synergistic behavior was recently observed by Pedroso-Santos et al. (2020a) in *Boana geographica* and *B. calcarata*.

Death feigning behavior (thanatosis), commonly observed in anurans and triggered by handling, has potential interactions with aposematic color and odoriferous secretions (Toledo et al., 2010; 2011; Ferreira et al., 2019). However, the synergy of death feigning and odoriferous secretion was not observed in *Pristimantis* aff. *guianensis*. Instead, aposematism, achieved by contrasting the light ventral color with the dark background after death feigning, might be present (Gamberale-Stille, 2001; Toledo & Haddad, 2009a; Barnett et al., 2016). The species' light cream ventral view with tiny gray dots creates a strong contrast with the substrate, potentially serving as an aposematic signal against the predators. In this case, further studies are required to test this hypothesis.

Documenting defensive strategies provides valuable data on the autoecology of the species. This natural history information plays a crucial role in comparative investigations, enhancing our understanding of the evolutionary, behavioral, and trophic aspects of anuran biology. The elucidation of six novel defensive behaviors in an undocumented species (*Pristimantis* aff. *guianensis*) and three in a well-established species (*B. pardalis*) highlights the importance of fieldwork and direct natural history observation in species sampling. Our findings emphasize the importance of ongoing empirical research, even for well-known species like *B. pardalis*, where comprehensive knowledge of natural history remains limited.

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NEW PREY RECORDS FOR CAT-EYED SNAKES OF THE GENUS *LEPTODEIRA* (SQUAMATA: DIPSADIDAE) WITH HISTORICAL REVIEW OF THE SPECIES' DIET

NUEVOS REGISTROS DE DEPREDACIÓN POR SERPIENTES OJO DE GATO DEL GÉNERO *LEPTODEIRA* (SQUAMATA: DIPSADIDAE), CON REVISIÓN HISTORICA DE ESPECIES CONSUMIDAS

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Resumen.– Las serpientes ojo de gato presentan una amplia variedad de presas compuesto principalmente por ranas y lagartijas. En este trabajo realizamos una revisión de las presas registradas para el género *Leptodeira*, y reportamos nuevos registros de dieta para varias especies de estos ofidios.

Palabras clave.– Colombia, dieta, *Leptodeira*, nuevos registros de presas.

Abstract.– Cat-eyed snakes consume a wide variety of prey items, mostly including frogs and lizards. In this paper, we report new dietary records for snakes of the genus *Leptodeira*, and perform a review of prey items recorded for the genus.

Keywords.– Colombia, diet, *Leptodeira*, new prey records.

Leptodeira is a genus of opisthoglyphous nocturnal snakes with marked terrestrial or semi-arboreal habits, which can be found near bodies of water, especially during the reproductive season of anurans (Bello-Sánchez et al., 2018; Costa & Andrade, 2020). Currently 18 species are recognized within the genus, all of which are considered potential amphibian hunters, however, they may have a fairly general diet, feeding on lizards, other snakes, fish and even birds (Skehan, 1959; Russell et al., 1999; Dueñas & Báez, 2003; Maitland, 2003; Entiauspe-Neto et al., 2016; van Buurt & Dilrosun, 2017; Cortés-Ortiz et al., 2022). Here, we review the diet of different *Leptodeira* species, and report new prey for *L. ashmeadii*, *L. bakeri* and *L. ornata*. The literature review is based on published scientific papers describing predation events recorded for the different species of the genus *Leptodeira* in Central and South America. The information was obtained through different sources and databases (Google Scholar, PubMed, SciELO, ScienceDirect and Web of Science), restricting the search in different languages of the information to the following words or search terms: diet, *Leptodeira*, predation, consumption, foraging, trophic ecology, predator-prey interaction, ecological

interactions, feeding, producing information for 12/18 *Leptodeira* species.

The snakes were identified based on characters and distribution areas proposed in the literature (Barrio-Amorós, 2019; Uetz et al., 2023; Costa et al., 2022). We differentiate *Leptodeira ashmeadii* by the presence of (7–9/7–9) supralabial scales, two parallel dark brown stripes in the parietal region that run towards the occipitals merging with the first dorsal spot in the occipital region in the shape of a horseshoe and its distribution to the northeast of South America. *L. ornata* by the presence of (8–9/7–9) supralabial scales, back of the head brown, usually without spots and occipital region light brown with a broad median line, the presence of a dark butterfly-shaped spot in the occipital region and, its distribution throughout the Magdalena River basin, Colombia. But *L. bakeri* can be differentiated by its pattern of large dorsal spots (generally not exceeding 24 spots), these can extend widely, involving the first row of dorsal scales, without continuing on the ventral scales.

We refer as *L.* cf. *ornata* to the specimen recorded in Santa Marta, District of San Lorenzo in Panama, *L.* aff. *ornata* to the one recorded in Rancho Quemado, Costa Rica, and *L. annulata* to the one recorded in Bridge Pond, Gamboa, Province of Colon in Panama (Crawford, 2007) given the information we have for identification. This is mainly due to recent taxonomic updates for the genus, where some of these taxa show morphological similarity, as well as evidence of possible cryptic diversity related to the *L. ornata* group (Costa et al., 2022).

Leptodeira ashmeadi, *L. bakeri* and *L. ornata* are nocturnal snakes with terrestrial habits, but they can be found on small bushes or near bodies of water (Abarca et al., 2021; Ali & Ali, 2022). These can inhabit a wide variety of warm environments and dry vegetation (van Buurt and Dilrosun, 2017). The limited information available on the diet of *L. ashmeadi* comes from northern Colombia and northwest Venezuela, and in the case of *L. ornata* from northwest Costa Rica, south-central Panama and northwest Colombia. For the three species, anurans are the most common prey, followed by lizards (Manzanilla et al., 1998; Ugueto & Rivas, 2006; Vargas-Salinas & Aponte-Gutiérrez, 2013; Nuñez & Garro, 2020; Abarca et al., 2021; Ali & Ali, 2022; Dougherty & Lisondro, 2023).

On 16 October 2020 at 10:24 h in a family home in Girón, Santander, Colombia (7.038889° N, 73.141389° W; 842 m a.s.l.), an adult individual of *Leptodeira ashmeadii* with a total length (TL) of 650 mm was recorded and photographed feeding on an adult Yellow-headed gecko (*Gonatodes albogularis*), with a snout-vent length (SVL) of 60 mm. The event that lasted approximately 15 minutes occurred at ground level on some rubble, where the snake was seen biting the lizard by the neck and coiling it around the body. Later, he ingests it from head (see Appendix 1).

On 16 October 2020 at 19:20 h in Buritaca, Santa Marta, Magdalena, Colombia (11.262041° N, 73.768519° W; 8 m a.s.l.), an adult individual of *Leptodeira bakeri* with a total length of 450 mm was recorded and photographed feeding on an adult Common house gecko (*Hemidactylus frenatus*, 50 mm SVL). The event lasted approximately 15 minutes on the ground, where the snake was seen biting the lizard on the ventral part of the neck and ingesting it from head (Fig. 1).

Figura 1. Depredación de *Hemidactylus frenatus* por *Leptodeira bakeri*. Foto: Mónica Beltrán. / **Figure 1.** Predation on *Hemidactylus frenatus* by *Leptodeira bakeri*. Photo: Mónica Beltrán.

On 24 January 2021 at 20:18 h on the Melchor Ecogranja, in Las Llanadas, Sucre, Colombia (9.136944° N, 75.28500° W; 109 m a.s.l.), an adult individual of *Leptodeira ashmeadii* (TL 610 mm) was found feeding on an adult Four-eyed toad (*Pleurodema brachyops*, 30 mm SVL). The event lasted approximately 15 minutes on grass at ground level. There, the snake grabbed the anuran from the anterior area and ingested it from the head (Fig. 2A).

On 31 December 2021 at 20:33 h in the backyard of a family home in Las Llanadas, Sucre, Colombia (9.149444 N°, 75.278889° W; 131 m a.s.l.), an adult individual of *Leptodeira ashmeadii* (TL 660 mm) was recorded and photographed hunting an adult of iridescent-eyed banana frog (*Boana pugnax*, 80 mm SVL). The event lasted approximately 20 minutes on the branch of a lemon bush (*Citrus* × *latifolia*). In this case the snake grabbed the anuran by the posterior lateral area and ingested it from head (see Appendix 2).

On 28 August 2022 at 09:07 h on the Melchor Ecogranja in Las Llanadas, Sucre, Colombia (9.136944° N, 75.28500° W; 109 m a.s.l.), an adult individual of *Leptodeira ashmeadii* (TL 602 mm) was recorded and photographed hunting an adult Warty toad (*Rhinella humboldti*, 40 mm SVL). The event lasted approximately 18 minutes at ground level. In this case, the snake grabbed the anuran by the posterior lateral area of the body and ingested it from the hind legs (Fig. 2C).

On 21 December 2022 at 21:45 h in Jurubida, Nuquí, Chocó (5.842787° N, 77.274305° W; 7 m a.s.l.), an adult individual of Leptodeira ornata (TL 582 mm) was recorded and photographed preying a juvenile Basilisk (*Basiliscus basiliscus*, 130 mm SVL). The event lasted approximately 34 minutes next to a stream at ground level. In this case, the snake grabbed the lizard by the head and ingested it head first (Fig. 2B).

Figura 2. Depredación por *Leptodeira* spp: *L. ornata* depredando un individuo adulto de *Pleuroderma brachyops* (A), *L. ornata* consumiendo un individuo de *Basiliscus basiliscus* (B), *L. ashmeadii* depredando un adulto de *Rhinella humboldti* (C), *L. ornata* consumiendo un individuo de *Scinax* aff. *ruber* (D), *L. ashmeadii* consumiendo huevos de *Phyllomedusa venusta* (E), *L. ashmeadii* depredando un individuo de *R. humboldti* (F), *L. bakeri* consumiendo un individuo de *R. humboldti* (G), *L. ashmeadii* depredando un individuo de *Loxopholis rugiceps* (H), y *L. ornata* consumiendo un individuo de *Rhinella* sp (I). Fotos: Oscar Sierra-Serrano (A, C y E), Nuqui Herping (B), Juan Jiménez-Bolaño (D), Luz Peralta (F), Ronald A. Díaz-Flórez (G), Hernán Granda-Rodríguez (H), Gerardo Marulanda (I).

Figure 2. Predation by *Leptodeira* spp: *L. ornata* preying on an adult individual of *Pleuroderma brachyops* (A), *L. ornata* consuming an individual of *Basiliscus basiliscus* (B), *L. ashmeadii* preying on an adult individual *Rhinella humboldti* (C), *L. ornata* consuming an individual of *Scinax* aff. *ruber* (D), *L. ashmeadii* consuming *Phyllomedusa venusta* eggs (E), *L. ashmeadii* preying on an individual of *R. humboldti* (F), *L. bakeri* consuming an individual of *R. humboldti* (G), *L. ashmeadii* preying on an individual of *Loxopholis rugiceps* (H), *L. ornata* consuming an individual of *Rhinella* sp (I). Photos: Oscar Sierra-Serrano (A, C and E), Nuqui Herping (B), Juan Jiménez-Bolaño (D), Luz Peralta (F), Ronald A. Díaz-Flórez (G), Hernán Granda-Rodríguez (H), Gerardo Marulanda (I).

On 27 February 2023 at 10:20h. at Media Luna, San Juan Nepomuceno, Bolívar, Colombia (9.957638° N, 75.152656° W; 312 m a.s.l.), an adult individual of *Leptodeira ornata* (TL 470 mm) was recorded and photographed feeding on an adult Striped tree frog (*Scinax* aff. *ruber*, 37 mm SVL). The event lasted approximately seven minutes on some fallen palm leaves over a body of water, where the snake was seen biting the frog on the back and ingesting it while it was still alive (Fig. 2D).

On 28 August 2023 at 19:54h at Vda. El canal, Chalán, Sucre, Colombia (9.577500° N, 75.347500° W; 323 m a.s.l.), an adult individual of *Leptodeira ashmeadii* (TL 550 mm) was recorded and photographed feeding on Red-eyed monkey Frog (*Phyllomedusa venusta*) eggs. These were found on an avocado leaf (*Persea americana*) and were approximately 5 mm in diameter each (Fig. 2E).

On 10 November 2023 at 20:43h on the premises of the Universidad del Magdalena, Santa Marta, Magdalena, Colombia (11.224760° N, 74.184278° W; 96 m a.s.l.), an adult individual of *Leptodeira ashmeadii* (TL 530 mm) was hunting an adult warty toad (*Rhinella humboldti*, 60 mm RCL). The event lasted approximately 25 minutes at ground level, where the snake was seen holding the anuran from the anterior dorsal area of the body (Fig. 2F). Although the toad constantly resisted try to free itself, the snake did not let go and it was evident the prey lost strength until it died. Once the snake subdued the toad, it was ingested it head first.

On 15 November 2023 at 20:00h on the Universidad del Magdalena, Santa Marta, Magdalena, Colombia (11.225769° N, 74.185778° W; 90 m a.s.l.), an adult individual of *Leptodeira ashmeadii* (TL 550 mm) was observed feeding on an adult Four-eyed toad (*Pleurodema brachyops*, 40 mm RCL). The event lasted approximately 10 minutes on grass at ground level. There, the snake grabbed the anuran from the anterior area and ingested it from the head.

On 5 March 2024 at 18:27h during field work in the Ranchería de Panacira, municipality of Maicao, La Guajira, Colombia (11.190283° N, 72.313505° W; 138 m a.s.l.), an Aruban cat-eyed snake (*Leptodeira bakeri*) with total length of 376 mm was located. This was kept for approximately 20 minutes inside a cloth bag and when it was removed, a regurgitated Warty toad (*Rhinella humboldti*) was found. This toad was without head and arms, and had a length of 70 mm, including the hind legs (Fig. 2G).

On 24 March 2024 at 07:32h during a tour at Tour Cacao Ancestros, San Francisco, Antioquia, Colombia (5.971944° N, 75.108889° W; 1,032 m a.s.l.), an adult individual of *L. ashmeadii* (TL 781 mm) was photographed preying on an adult toad (*Rhinella* sp., 110 mm SVL). The event lasted approximately 25 minutes on rocks at ground level. In this way, the snake grabbed the anuran from the anterior area and ingested it head first (Fig. 2I).

On 25 March 2024 at 19:00h during herpetofauna monitoring in the Piedra River, Santa Marta, Magdalena, Colombia (11.275661° N, 73.904118° W; 50 m a.s.l.), an adult *L. ashmeadii* (TL500 mm), was found within a stream while feeding on an adult Root lizard (*Loxopholis rugiceps*, 40 mm SVL). The event lasted approximately 10 minutes on some Caracolí (*Anacardium excelsum*) leaves fallen on the rocks of the body of water. In this case, the snake managed to bite the lizard through the upper part of the neck (Fig. 2H) and ingested it from head.

Among the new prey recorded, we found representation of both amphibians (Anura) and reptiles (Sauria), which were identified based on diagnostic morphological characters. The warty toad (*Rhinella humboldti*), characterized by being a small toad with marked bony crests on the head, an olive-gray color, small elongated poison glands on the back of the eardrum, very granular skin and ocher-yellow gluttony in males. (Galvis-Peñuela et al., 2011; Pereyra et al., 2021). The iridescent-eyed banana frog (*Boana pugnax*) can be differentiated from other Hylids present in the area by the presence of pronounced, double bars of a dark color on the abdominal flanks, black bars on the anterior surface of the thighs and extensive palmaeatures on the back, hands and feet (Lynch & Suárez-Mayorga, 2001). The red-eyed monkey frog (*Phyllomedusa venusta*) is easily distinguished by having practically smooth skin with small pustules, a bright green back, white lips, yellowish cream flanks with whitish spots, and a grayish belly with white spots (Barrio-Amorós, 2006). The striped tree frog (*Scinax ruber*) is characterized as a small greenish-brown frog, with the groin and the back of the thighs yellowish with irregular dark brown spots. It also has a dark supratympanic band, light flanks with small dark brown spots and a yellowish belly (Renjifo & Lundberg, 1999). The four-eyed toad (*Pleurodema brachyops*) is easy to recognize by its large and showy blue-black lumbar spots, on a reddish background, which simulate a pair of eyes. The hidden surface of the thighs and inguinal region are also reddish. It has thin fingers without webbing (Galvis-Peñuela et al., 2011; Hernández-Palma et al., 2023).

As for reptiles, the yellow-headed gecko (*Gonatodes albogularis*) is distinguishable for being a dichromatic species, where the females are a brown hue with scattered spots on the back and the males have a coppery-orange hood on their heads and the rest of the body is blackish in color. Also thin, cylindrical fingers with small, narrow scales, with a narrow but divided terminal lamella

above the claws (Barrio-Amorós, 2010; Galvis-Peñuela et al., 2011; Uetz et al., 2023). The common house gecko (*Hemidactylus frenatus*) is a small lizard with a coloration that can vary from light gray to medium brown, with dark stripes from the nostril to the eye and dark stripes on the sides of the body at variable distances. On the upper part of the head and body, it has small granular scales and scattered flat tubercles in the parietal and temporal areas, ventrally it has larger overlapping flat scales. It has well-developed fingers, each with an oblong digital pad, rectangular lamellae of the pads, divided medially except for the terminal one (Galvis-Peñuela et al., 2011; Uetz et al., 2023). The root lizard (*Loxopholis rugiceps*) is also a small lizard (does not exceed 450mm LRC) that is characterized by having both the forelimbs and hindlimbs covered with strongly keeled scales and a small head. The color of the back is dark brown with the sides of a more reddish tone. The labial scales are whitish with vertically elongated black spots (Renjifo & Lundberg, 1999; Uetz et al., 2023).

During the review we did not find information on the diet of *L. approximans*, *L. frenata*, *L. larcorum*, *L. misinawui*, *L. pulchriceps* and *L. tarairiu*. The majority of prey reported for *Leptodeira* species are anurans, accounting for 81.5% of the total, with 75 individuals from 65 species across 9 families, mainly Hylidae, Phyllomedusidae, and Leptodactylidae. Additionally, 6.5% of the prey are lizards, 7.6% are snakes, and 4.3% are fish. Only one species of salamander (*Bolitoglossa*) was recorded as prey of *L. ornata* (Ali & Ali 2022). Following the anurans, lizards and snakes

Tabla 1. Lista de presas registradas para *Leptodeira* spp., en este estudio y en la literatura. / **Table 1.** List of prey items recorded for *Leptodeira* spp., in literature and this study.

Species	Prey	References
Leptodeira splendida	**Amphibians**	
	Lithobates psilonota	Huerta-García et al., 2015
Leptodeira maculata	**Amphibians**	
	Hypopachus oxyrrhinus	Cruz-Sáenz et al., 2010
	Incilius mazatlanensis	Cruz-Sáenz et al., 2010
	Leptodactylus fragilis	Mata-Silva et al., 2012
	Lithobates neovolcanica	Cruz-Sáenz et al., 2010
	Rhinella horribilis	García-Mata et al., 2017
	Smilisca baudinii	Cruz-Sáenz et al., 2010
	Snakes	
	Salvadora mexicana	Palacios-Aguilar et al., 2020
	Leptodeira maculata	Montalbán et al., 2010
	Lizards	
	Sceloporus pyrocephalus	Palacios-Aguilar et al., 2020
Leptodeira septentrionalis	**Amphibians**	
	Agalychnis callidryas	Brown, 2020
	Agalychnis moreletii	Kaiser, 2010
	Agalychnis spurrelli	Ortega-Andrade et al., 2011
	Craugastor cf. *loki*	Cabrera-Guzmán et al., 2009
	Dendropsophus ebraccatus	Savage, 2002
	Dendropsophus microcephalus	Oliva et al., 2010
	Incilius valliceps	Engerman & Engerman, 2015
	Leptodactylus fragilis	Dehling, 2009

Tabla 1 (cont.). Lista de presas registradas para *Leptodeira* spp., en este estudio y en la literatura.

Table 1 (cont.). List of prey items recorded for *Leptodeira* spp., in literature and this study.

Species	Prey	References
Leptodeira septentrionalis (cont.)	*Leptodactylus melanonotus*	McKelvy et al., 2013
	Lithobates vaillanti	Mora, 1999
	Scinax elanochroa	Russell et al., 1999
	Smilisca baudini	Savage, 2002
	Smilisca cyanosticta	Bello-Sánchez et al., 2018
	Smilisca phaeota	Arroyo-Trejos & Mora, 2016
	Rhaebo haematiticus	Arias et al., 2015
	Rhinella humbolti	Bello-Sánchez et al., 2018
	Snakes	
	Ninia sebae	McKelvy et al., 2013
Leptodeira annulata	**Amphibians**	
	Elaichistocleis surinamensis	Graham & Kelehear, 2017
	Elaichistocleis panamensis	Crawford, 2007
	Synapturanus sp.	Martins & Oliveira, 1998
	Rhaebo guttatus	Dueñas & Báez, 2003
	Rhinella granulosa	Morais & Ávila, 2007
	Rhinella marina	Dueñas & Báez, 2003
	Rhinella mirandariveroi	Ferraz et al., 2018
	Rhinella crucifer	Vrcibradic et al., 2007
	Osteocephalus taurinus	Campos et al., 2011; Hangman & Schulte, 2007
	Boana crepitans	Lantyer-Silva et al., 2012; Hudson et al., 2019
	Boana lanciformis	Duellman, 1978; Duellman, 2005; Dueñas & Báez, 2003
	Cruziohyla craspedopus	Campbell & Lamar 2007
	Dendropsophus bokermanni	Duellman, 1978; Duellman, 2005
	Dendropsophus marmoratus	Duellman, 1978; Duellman, 2005
	Dendropsophus parviceps	Duellman, 1978; Duellman, 2005
	Phyllomedusa sp.	Martins & Oliveira, 1998; Duellman, 2005
	Phyllomedusa vaillanti	Nascmiento et al., 2013
	Phyllomedusa tetraploidea	Nascmiento et al., 2013
	Phyllomedusa tomopterna	Nascmiento et al., 2013

Tabla 1 (cont.). Lista de presas registradas para *Leptodeira* spp., en este estudio y en la literatura.

Table 1 (cont.). List of prey items recorded for *Leptodeira* spp., in literature and this study.

Species	Prey	References
Leptodeira annulata (cont.)	*Phyllomedusa nordestina*	Falkenberg et al., 2013
	Scinax ruberv	Beebe, 1946; Dueñas & Báez, 2003
	Crossodactylus bokermanni	Thomassen et al., 2013
	Leptodactylus cf. *macrosternum*	Sales et al., 2013
	Leptodactylus mystaceus	Carvalho et al., 2007
	Leptodactylus rhodonotus	Arrivillaga et al., 2019
	Adenomera sp.	Martins & Oliveira, 1998
	Pristimantis ramagii	Dos Santos et al., 2018
	Pristimantis altamazonicus	Duellman, 1978
	Pristimantis brevicrus	Duellman, 2005
	Physalaemus cuvieri	Costa & Andrade, 2020
	Lizards	
	Hemidactylus mabouia	Cantor & Pizzatto, 2008; Hudson et al., 2019
	Snakes	
	Atractus zebrinus	Cantor & Pizzatto, 2008
	Oxyrhopus guibei	Cantor & Pizzatto, 2008
	Erythrolamprus poecilogyrus	Entiauspe-Neto, et al. 2016
Leptodeira rhombiferas	**Amphibians**	
	Rhinophrynus dorsalis	Céspedes et al., 2018
	Engystomops pustulosus	Dougherty & Lisondro, 2023
	Boana rosenbergi	Dougherty & Lisondro, 2023
	Hylidae	Knight, 2016
	Rhamdia sp.	Cespedes & Abarca, 2014
	Rhamdia guatemalensis	Rojas-Carranza & Anderson, 2023
	Rhamdia laticauda	Solís & Guerrero, 2016
	Snakes	
	Chironius flavopictus	Nuñez et al., 2021
Leptodeira rubricata	**Fishes**	
	Poeciliidae	Savage, 2002; Solórzano, 2004.
Leptodeira ornata	**Amphibians**	
	Hyalinobatrachium colymbiphyllum	Nuñez-Escalante & Garro, 2020
	Agalychnis callidryas	Dougherty & Lisondro, 2023
	Boana rosenbergi	Dougherty & Lisondro, 2023

Tabla 1 (cont.). Lista de presas registradas para *Leptodeira* spp., en este estudio y en la literatura.

Table 1 (cont.). List of prey items recorded for *Leptodeira* spp., in literature and this study.

Species	Prey	References
Leptodeira ornata (cont.)	*Duellmanohyla legleri*	Abarca et al., 2021
	Rhinella humbolti	Vargas-Salinas & Aponte-Gutierrez, 2013
	Bolitoglossa lignicolor	Ali & Ali 2022
Leptodeira punctata	**Amphibians**	
	Smilisca fodiens	Rodríguez et al., 2011
Leptodeira nigrofasciata	**Amphibians**	
	Phyllodactylus tuberculosus	Mora et al., 2020
Leptodeira polysticta	**Amphibians**	
	Smilisca baudinii	Mendoza-Henao, 2011
Leptodeira ashmeadii	**Amphibians**	
	Rhinella humbolti	This study
	Boana pugnax	This study
	Phyllomedusa venusta	This study
	Trachycephalus typhonius	Manzanilla et al., 1998
	Pleurodema brachyops	This study
	Lizards	
	Gonatodes albogularis	This study
	Phyllodactylus ventralis	Ugueto & Rivas. 2006
	Hemidactylus frenatus	This study
Leptodeira uribei	**Amphibians**	
	Triprion spatulatus	Torres-Pérez-Coeto et al., 2018
	Incilius marmoreus	Torres-Pérez-Coeto et al., 2018
	Lizards	
	Anolis nebulosus	Nieto-Toscano & Martinez-Coronel, 2021

are the second most diverse dietary items (represented by four and two families, respectively), both with six species reported in the diet of four *Leptodeira* species. Finally, as the least recorded items are fish, represented by four prey belonging to the family (Heptapteridae), one of them remaining unidentified (Table 1).

Most species of the genus *Leptodeira* are not strictly batracophagous. However, the high proportion and diversity of anuran prey reported in their diet, added to the fact that several anuran species can produce toxic skin secretions (Almeida et al., 2019; Duport, 2020), suggests that there may be a high level of dietary specialization among several species within the genus, but they are mainly generalist snakes. On the other hand, *Leptodeira* species likely consume more species of fish, salamanders, and snakes than have been reported. But the low number of studies on the trophic ecology of these snakes makes it difficult to precisely determine the true extent of prey diversity within the genus. In some cases, prey was only identified to genus level due to the status of preservation of the specimen.

Some studies suggest that snakes may change their dietary preferences depending on food availability, which could result

in them feeding more on anurans during the rainy season and switching to lizards or other more common groups during the dry season (Roberto & Ramos, 2020). However, this hypothesis has not been tested. This requires more natural history data to assess the total diversity of prey consumed by snakes of the genus *Leptodeira* and to test whether dietary preference could be related to developmental stages, or restricted by environmental variables such as seasonality and changes in food availability, and/or behavioral factors such as hours of activity.

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APPENDICES

Apéndice 1. Depredación de *Gonatodes albogularis* por *Leptodeira ashmeadii*.
Appendix 1. Predation on *Gonatodes albogularis* by *Leptodeira ashmeadii*.

https://youtube.com/shorts/aqWSPwQ6xeI?feature=share

Apéndice 2. Depredación de *Boana pugnax* por *Leptodeira ashmeadii*.
Appendix 2. Predation on Banana frog *Boana pugnax* by *Leptodeira ashmeadii*.

https://youtube.com/shorts/RENzrhCcVkY

CONTRACTING BEHAVIOR IN THE GIANT GLADIATOR FROG *BOANA BOANS* (HYLIDAE) AND THE EMERALD CRYSTAL FROG *ESPADARANA PROSOBLEPON* (CENTROLENIDAE)

COMPORTAMIENTO DE CONTRACCIÓN EN LA RANA GLADIADORA GIGANTE *BOANA BOANS* (HYLIDAE) Y LA RANA DE CRISTAL ESMERALDA *ESPADARANA PROSOBLEPON* (CENTROLENIDAE)

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Resumen.– Los anuros presentan diversos comportamientos anti depredadores, tanatosis (también conocida como inmovilidad tónica), donde los anuros fingen estar muertos, y contracción (o encogimiento). A diferencia de la tanatosis, durante el encogimiento los anuros suelen permanecer con los ojos cerrados, las extremidades contraídas cercanas al cuerpo. Al tratar de estirar alguna de sus patas, el animal la regresa hacia su cuerpo, generalmente cubriendo algún órgano vital. En este trabajo reportamos el comportamiento de encogimiento observado por primera vez en la rana gladiadora gigante (*Boana boans*), y la rana de cristal esmeralda (*Espadarana prosoblepon*). Estos reportes son importantes, ya que contribuyen en el entendimiento de la ecología y comportamiento de estas especies y de los anuros en general.

Palabras clave.– Antidepredador, defensa, depredador, evitación, protección, toxinas.

Abstract.– Anurans exhibit several anti-predator behaviors, including thanatosis (also known as tonic immobility) where anurans pretend to be dead, and contracting (or shrinking). In contrast to thanatosis, contracting anurans usually remain with their eyes closed and their limbs contracted close to the body covering vital organs. If one attempts to stretch a limb from a contracted position , it pulls it back to the body after release. Here, we report for the first time, observations of contracting behavior in the Giant gladiator frog (*Boana boans*), and the Emerald glass frog (*Espadarana prosoblepon*). These records are important since they contribute towards the understanding of ecology and behavior of these species and anurans generally.

Keywords.– Antipredator, avoidance, defense, predator, protection, toxins.

Different groups of post-metamorphic anuran have evolved a variety of creative ways to avoid predators, which have been grouped into numerous categories by different authors. These include the use of visual systems, such as aposematic coloration to warn potential predators of danger; cryptic coloration that provides camouflage to go unnoticed by predators; and behavioral systems, such as adopting postures that make them appear larger and more intimidating, feigning death, or contracting to avoid suffering more damage than they would receive in a fight (Toledo et al., 2011; Ferreira et al., 2019). These last two behaviors can be confused by a human observer due to the immobility of the specimen, but they have been well defined by Toledo et al., (2010). When anurans pretend to be dead, a behavior called thanatosis or tonic immobility, they show no movement even when touched, usually keeping their eyes open and their limbs loose. In contrast to thanatosis, when anurans engage in contracting or shrinking behavior, they usually keep their eyes closed and their front and hind limbs bent and close to the body. If an observer attempts to stretch any of the animal's legs, the animal will immediately force it back close to the body,

usually covering its vital organs with its hind legs and its head with its hands. Formal recording of these mechanisms helps to improve knowledge of the natural history of the species and the behavioral mechanisms involved (Guerra et al., 2018). In this paper we report defensive contracting behavior in both the Giant Gladiator Frog *Boana boans* (Linnaeus, 1758), which, although previously reported for the genus *Boana* (Ferreira et al., 2019; Toledo et al., 2010), had not been previously reported in *B. boans*, and the Emerald Glass Frog *Espadarana prosoblepon* (Boettger, 1892), making this the second record of this behavior in the family Centrolenidae. *Boana boans* is a large tree frog belonging to the family Hylidae. Males can measure between 80 and 118 mm in cloacal length, and females between 84 and 110 mm (Rodriguez & Duellman, 1994). They have a wide distribution in South America, mainly in the Amazon basin, and in Central America where they are only found in the central and eastern areas of Panama, with an altitudinal distribution ranging from 0 to approximately 1,000 m a.s.l. (La Marca et al., 2010).

Espadarana prosoblepon, of the family Centrolenidae, is a small frog, with a snout-cloaca length between 26.7 and 29.6 mm in males and females 29.5–31.8 mm in females. Its distribution extends in Central America from eastern Honduras, Nicaragua, Costa Rica, Panama, and in South America along the Pacific slope of the Andes in Colombia and Ecuador, from sea level to 1,900 m a.s.l. (Guayasamin et al., 2020).

Ferreira et al., (2019) reported on defense behaviors of many species throughout different regions of the world, classifying the most representative species in each of them, with the *Boana* genus being among the most representative for charge, contraction, mouth gape, death feigning, production of slippery secretions, kick, puncture, and distress calls. Some of these behaviors have been documented for *B. boans*, among wish distress calls (Hödl & Gollmann, 1986; Rocha & López-Baucells, 2014; Arrivillaga & Levac, 2019), mouth gape (Lima et al., 2005), limb stretching and leaping (Rocha and López-Baucells, 2014), body inflation and jump away (Arrivillaga & Levac, 2019), have previously been reported.

For the Centrolenidae family, reported defensive behaviors are very rare, but include cloacal discharge (Vockenhuber, 2008; Escobar-Lasso & Rojas-Morales, 2012), crouching down and body-raising (Escobar-Lasso & Rojas-Morales, 2012; Pedroso-Santos, 2021), body inflation (Escobar-Lasso & Rojas-Morales, 2012), odour secretion (Escobar-Lasso & Rojas-Morales, 2012), noxious secretion (Rueda-Almonacid, 1994), thanatosis or feigning death (Toledo et al., 2011; López-Molina et al., 2023), distress call (Souza et al., 2016), contraction or shrinking (López-Molina et al., 2023), bite (Toledo et al., 2011) and kick (Vockenhuber et al., 2008), these last two are exclusive to individuals of this group during parental care. *E. prosoblepon* is known to produce acrid or pungent odors as a defense against predators when captured (Guayasamin et al., 2020).

During two field trips to the Cocobolo Nature Reserve, Province of Panama, Republic of Panama (Fig. 1), a general survey was carried out and two males of *B. boans* were captured for identification. The first individual (Fig. 2A) was found on 5 August 2022, at 21:00 h., in the highest part of the reserve (9.32° N, 79.205167° W), at about 721 m a.s.l., perched about two meters high on a sapling. The second individual (Figure 2B) was found on 7 January 2023, at about 22:40 h. on the banks of the Mamoní River (9.289517° N, 79.206517° W), at about 235 m a.s.l., calling on the trunk of a small bush at about one meter above the ground. When both individuals were captured, they adopted a contracting posture, which was very similar in both individuals: bringing their hind legs close to the body, apparently protecting the abdominal area, placing their hands next to the head with the palms facing outwards and the head bent forward, and the eyes closed until they returned to their normal posture (Fig. 2). When the animals' legs were stretched out both individuals immediately pulled them back into the contracting position, close to the body. The first individual found was placed on the ground after adopting the contracting posture, where it remained for approximately four minutes. The second individual was held by hand and, unlike the first individual, it had inflated its lungs, looking more rounded with its legs slightly apart than what was observed in individual 1. It remained in this position for about a minute and a half.

In addition to these reports for *B. boans*, during field sampling on 23 November 2022, carried out in the Pixbae creek (8.8151° N, 80.469467° W), near the community of Cutevilla, province of Coclé, Panama (Fig. 1), at about 64 m a.s.l., a male *E. prosoblepon* was found at approximately 1730 h. When captured for identification, it immediately adopted a contracting posture, bringing its hind legs close to its body. However, unlike *B. boans*, it did not bring its hands to the sides of its head, but placed them close to the gular and thoracic regions, with the palms facing outwards. The head was not tilted forward and the eyes remained open, in addition to not appearing to have inflated the lungs (Fig. 3), this individual produced a pungent or plant-like odor when captured, similar to that described previously for *E. prosoblepon* (Guayasamin et al., 2020) and other species in the family Centrolenidae, wich have been reported at the date *Centrolene quindianum*, *C. savagei*, *Nymphargus grandisonae* (Escobar-Lasso & Rojas-Morales, 2012) and *N. pijao* (López-

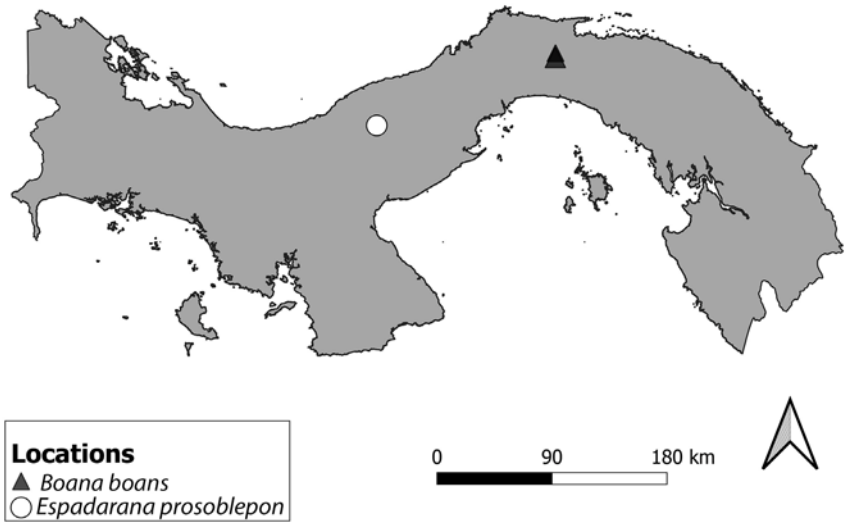

Figura 1. El Istmo de Panamá con las localizaciones donde los animales fueron observados. Los triángulos negros muestran la localidad de la Reserva Natural Cocobolo, provincia de Panamá, donde los individuos de *B. boans* fueron observados. El circulo blanco muestra la localidad donde el individuo de *E. prosoblepon* fue encontrado. Elaboración: Erick Barría.

Figure 1. The Isthmus of Panama with the locations where the animals were observed. The black triangles show the locality of the Cocobolo Nature Reserve, province of Panama, where the individuals of *B. boans* were observed. The white circle shows the locality where the *E. prosoblepon* individual was found. Made by: Erick Barría.

Figura 2. Individuos de *Boana boans* encontrados en la Reserva Natural Cocobolo mostrando el comportamiento de contracción, acompañado por la protección de los ojos, bajando la barbilla (A y B) e inflando el cuerpo (B). Foto: Erick Barría.

Figure 2. Individuals of *Boana boans* found in the Cocobolo Nature Reserve showing contracting behavior, accompanied by eye protection, chin-tucking (A and B) and puffing up the body (B). Photo: Erick Barría.

Figura 3. Individuo de *Esparadana prosoblepon* mostrando el comportamiento de contracción, colocando las piernas cerca del estómago y las manos cubriendo la región gular y torácica. Foto: Erick Barría

Figure 3. Individual of *Esparadana prosoblepon* showing contracting behavior, placing the legs close to the belly and the hands covering the gular and thoracic region. Photo: Erick Barría.

Molina et al., 2023). This behavior in *E. prosoblepon* was very brief, lasting approximately 30 seconds.

The contracting behavior of *B. boans* reported in this study was accompanied by other behaviors as described by Toledo et al., (2011). Some of these are also behaviors that have not been previously reported for this species, such as eye protection, usually with the chin bent towards the abdomen or other similar positions, covering the head, eyes, and eardrum with the forearms and hands – behaviors that usually occurs when the frogs are in a motionless position (observed in the two individuals of *B. boans*). Another behavior previously reported for *B. boans* is "chin-tucking", which is characterized by bending the chin towards the pectoral region; and body inflation (Arrivillaga & Levac, 2019), also known as "lung inflation" (Ferrante et al., 2014), which consists of filling the lungs with air and thus increasing the size of the frog. The main possible function of contracting and eye protection is to prevent damage during subjugation and to prevent ingestion. Likewise, the main possible function for "body inflation" and "chin-tucking" is to prevent underplaying, modifying their appearance to make themselves look larger than they are, fooling predators into deciding that the prey is too big to eat. This behavior is very likely to help intimidate predators (Toledo et al., 2011; Caro, 2014; Ferreira et al., 2019) and may have been carried out to make it more difficult for a possible predator to ingest the individual (Arrivillaga & Levac, 2019). The sequence of all these behaviors may represent a more complex behavior (Guerra et al., 2018), and the simultaneous use of several defense strategies appear to increase the probability that a frog will be able to escape from a predator (Toledo et al., 2011). In addition, anurans may respond differently to several types of predators, using different predator avoidance strategies within the same species, or a combination of these strategies (Ferrante et al., 2014). This could be seen in the differences observed between two individuals of *B. boans*, in which only one of them performed "body inflation" when held in the hand by the researcher.

In contrast to the combination of different physical defensive strategies observed in *B. boans*, we assume that *E. prosoblepon* only performed contracting to protect the vital organs with the legs, since no other postural elements were observed. Toledo et al., (2010) suggested that contracting behavior is characteristic of frogs with the ability to produce toxins in the skin or release secretions, reporting that 80 % of contracting anurans released skin secretions. Ferreira et al., (2019) classify these secretions into four types: adhesive, odoriferous, slippery, and noxious. According to this classification, the secretions produced by *B. boans*, for instance, can be classified as noxious, since they are known to produce certain skin peptides with a dual function. They can also serve as a first line of immunity against bacterial, protozoan and fungal infections, but the cytotoxic activity of these peptides may have an anti-predator function, as they can cause irritation and pain in the oral mucosa of predators (Raaymakers et al., 2017; Conlon et al., 2023). These peptides may be acting alongside other toxins that weaken the cell membranes of predators, facilitating the permeability of the toxins and allowing them to act more quickly (König et al., 2015; Raaymakers et al., 2017).

No such studies of toxin secretion have been conducted for the family Centrolenidae, but the skin secretions that produce pungent or plant-like odors when trapped can be categorized as odoriferous-type secretions (Ferreira et al., 2019), which can function as a kind of chemical camouflage (Toledo et al., 2011), or to cause irritation to the mucous membranes of potential predators. It has also been speculated that if predators learn that unpalatable prey is associated with some odor, they may avoid prey with that odor in the future. (Williams et al., 2000; Ferreira et al., 2019).

As suggested by López-Molina et al., (2023), these behaviors may not be rare in the species of our study. However, there is a need for an effort to publish each particular behavior, as they help us better understand the ecological species strategies when faced to the danger posed by predators.

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ECOLOGICAL DETERMINANTS OF AMPHIBIAN AND REPTILE DIVERSITY: PATTERNS ACROSS SPATIAL SCALES

DETERMINANTES ECOLÓGICOS DE LA DIVERSIDAD DE ANFIBIOS Y REPTILES. PATRONES A TRAVÉS DE ESCALAS ESPACIALES

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Resumen.— Los patrones de biodiversidad son el resultado de procesos evolutivos y ecológicos que actúan por separado o en conjunto a diferentes escalas espacio-temporales. Los procesos específicos que afectan estos patrones de diversidad no serán los mismos para cada grupo taxonómico, ya que puede depender de las características específicas de cada grupo. En este trabajo, describimos los principales determinantes ecológicos que afectan los patrones de diversidad taxonómica y funcional de anfibios y reptiles en tres escalas espaciales: regional, paisaje y local. Además de las tendencias generales mencionadas en este documento, se destacan algunos vacíos de conocimiento que podrían servir para guiar futuros estudios que analicen la complejidad de los patrones de diversidad de anfibios y reptiles en todo el mundo.

Palabras clave.— Clima, composición del paisaje, estructura de la comunidad, interacciones bióticas, rasgos funcionales.

Abstract.— Biodiversity patterns result from evolutionary and ecological processes acting separately or in concert at different spatial and temporal scales. Since the importance of these processes may depend on taxon-specific characteristics, the ecological and evolutionary processes affecting diversity patterns will not be the same across distinct taxonomic groups. Here, we describe the major ecological determinants affecting both amphibian and reptile taxonomic and functional diversity patterns at three scales: regional, landscape, and local. In addition to the general trends presented herein, some knowledge gaps are highlighted to guide future studies that investigate the complexity of amphibian and reptile diversity patterns worldwide.

Keywords.— Biotic interactions, climate, community structure, functional traits, landscape composition.

Community diversity and its underlying ecological and evolutionary determinants have been a widely explored topic in community ecology (Weiher et al., 2011). Biological diversity is a complex phenomenon that comprises taxonomic, phylogenetic, and functional dimensions that are often used to measure distinct but complementary aspects (Magurran & McGill, 2011). Taxonomic diversity concerns the composition and relative abundance of species in a community (Whittaker, 1972), while phylogenetic diversity measures how many phylogenetically distinct lineages are present (Faith, 1992). Functional diversity focuses on the breadth of functional traits (i.e., measurable traits that impact fitness through their effects on growth, reproduction, and survival; Tilman, 2001; Violle et al., 2007). By exploring how these diversity dimensions change at different spatial and temporal scales and which ecological and evolutionary determinants might explain these patterns,

we can take appropriate measures to conserve biodiversity in a changing world.

Biodiversity patterns are the result of key evolutionary and ecological processes acting separately or in concert at different spatial and temporal scales (Holt, 2003; Weiher et al., 2011; Pilowsky et al., 2022; Fig. 1). At broader scales, geological (e.g., plate tectonics) and evolutionary processes (e.g., speciation, adaptation, range expansion, evolutionary time; Mittelbach et al., 2007; Mittelbach & Schemske, 2015) promote the formation of regional species pools across the globe (Ricklefs, 1987; Ricklefs & Schluter, 1993). At finer scales, species' dispersal abilities (Holt, 2003), stochastic processes (e.g., ecological drift; Caswell, 1976; Hubbell, 2001), environmental filters and ecological interactions (Diamond, 1975; Abrams, 1983; Keddy, 1992; Weiher & Keddy, 1999) mainly determine which species from these pools may be present in local communities, although some studies have shown that allopatric speciation, colonization and local extinction may also play an important role on local diversity patterns (e.g., Pigot & Etienne, 2015). Differences in competitive ability, habitat and resource use determine species coexistence within local communities, and these interactions feedback to influence the biotic and abiotic environment (Chesson, 2000; HilleRisLambers et al., 2012; Mittelbach & Schemske, 2015). The importance of these processes is likely to depend on attributes, such as life history, physiology, trophic relationships, or behavior

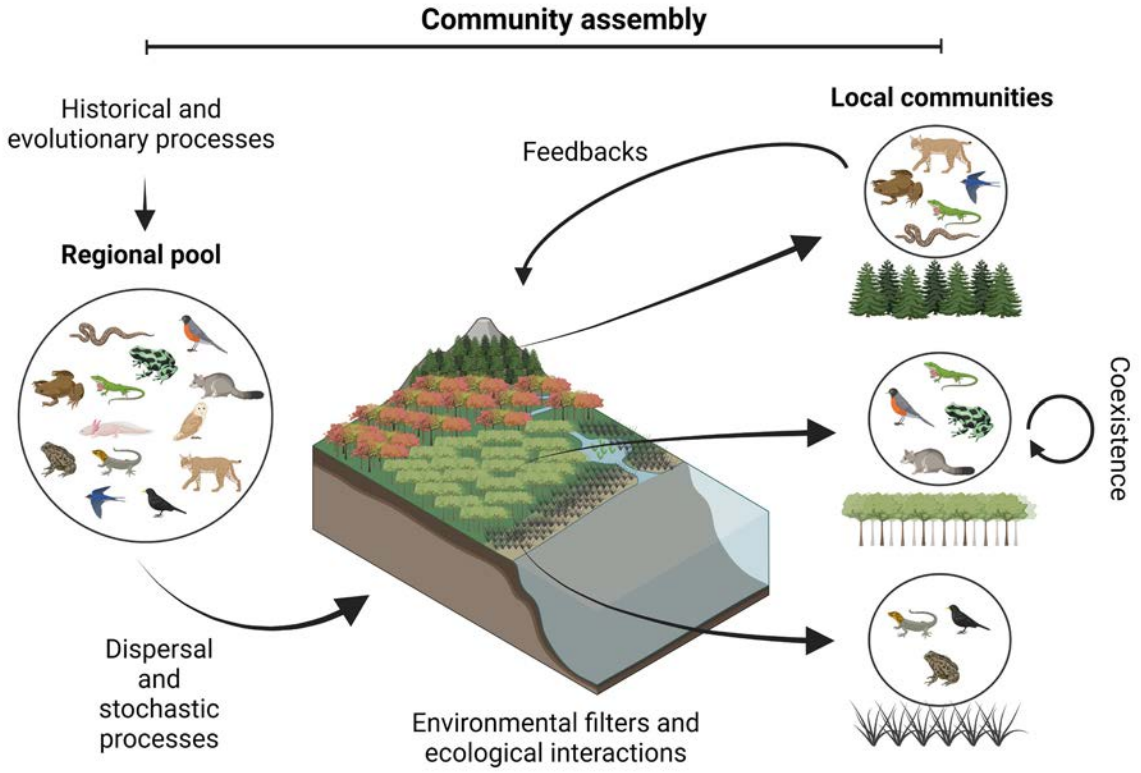

Figura 1. Diagrama que muestra los principales procesos ecológicos y evolutivos que determinan los patrones de diversidad y ensamblaje de comunidades a diferentes escalas espacio-temporales. A escalas gruesas, los procesos históricos y evolutivos promueven la formación de fuentes (*pools*) de especies particulares. A escalas más finas, la capacidad de dispersión de las especies, los procesos estocásticos, los filtros ambientales y las interacciones ecológicas determinan cuáles especies de estas fuentes pueden estar presentes en las comunidades locales. Las diferencias en la capacidad competitiva, utilización del hábitat y obtención de recursos de cada especie determina la coexistencia de las mismas dentro de las comunidades locales y estas interacciones, a su vez, pueden causar retroalimentaciones en el ambiente biótico y abiótico. Creado con BioRender.com.

Figure 1. Diagram showing the main ecological and evolutionary processes determining diversity patterns and community assemblies at different spatio-temporal scales. At broad scales, historical and evolutionary processes promote the formation of particular regional species pools. At finer scales, species' dispersal abilities, stochastic processes, environmental filters and ecological interactions determine which species from these pools may be present in local communities. Differences in competitive ability, habitat utilization and resource uptake determine the coexistence of species within local communities, and these interactions, in turn, may cause feedbacks in the biotic and abiotic environment. Created with BioRender.com.

that are shared by species of a specific taxonomic group. Thus, the specific ecological and evolutionary processes that affect diversity patterns are expected to vary across distinct taxonomic groups.

Evolutionary and ecological determinants of amphibian and reptile diversity patterns have been studied for a long time, and several important contributions have attempted to compile some of this vast amount of information. For instance, researchers have synthesized the major determinants affecting community structure of tropical tadpoles (Texeira-Borges & Duarte-Rocha, 2013), resource distribution in salamanders and newts (Vignoli et al., 2016), anthropic factors affecting amphibian and reptile communities (Cushman, 2006; Gardner et al., 2007; Hamer & McDonell, 2008; Thompson et al., 2015; Cordier et al., 2021), and determinants causing changes in diversity patterns along altitudinal gradients (McCain, 2010; Willig & Presley, 2016; Antonelli et al., 2018). Although important, these contributions mainly addressed specific determinants across a small number of scales, for a few taxonomic groups, or at restricted geographical ranges (Cushman, 2006; Gardner et al., 2017; Hamer & McDonell, 2008; Texeira-Borges & Duarte-Rocha, 2013; Thompson et al., 2015; Vignoli et al., 2016; Cordier et al., 2021). A more general synthesis of the major determinants affecting amphibian and reptile communities is needed to discern better the main processes acting at different spatial scales (or at least the most studied), and to identify knowledge gaps that need to be addressed to understand the community assembly of these groups better. Additionally, as each taxonomic group may be affected differently by these determinants and ecological processes, the synthesis described herein may be different from others performed with groups such as mammals or plants (e.g., Eiserhardt et al., 2011; Peixoto et al., 2018), and can be useful to either herpetologist starting their careers as well as experts who may use this information for future analyses.

In this perspective, we examine and describe the major ecological determinants affecting amphibian and reptile diversity patterns at regional, landscape, and local scales, according to what has been found in the literature (see Appendix 1: Methods; Appendix 2). Although scale boundaries may be subjective, most studies regard regional, landscape, and local scales as study areas spanning distances of > 200 km, 2 km – 200 km and < 2 km, respectively, with decreasing grain sizes (e.g., Pineda & Halffter, 2004; Urbina-Cardona et al., 2006; Hamer & Parris, 2011; di Virgilio et al., 2014; Iop et al., 2020; Barnagaud et al., 2021; Fonte et al., 2021). We delimited our perspective to the determinants of taxonomic and functional diversity patterns. Our aim is not to quantify the importance of each determinant at each scale, but rather to provide an overview of the main determinants having a positive or negative effect on amphibian and reptile diversity patterns. This is the first comprehensive synthesis of the main ecological factors affecting amphibian and reptile taxonomic and functional diversity patterns at multiple scales. We hope this perspective will prove useful as a guide for conservation, resource management and decision making, as well as a basis for ecologists aiming to investigate amphibian and reptile communities further.

REGIONAL SCALE: THE KEY ROLES OF HISTORY, CLIMATE, AND TOPOGRAPHY

Amphibian and reptile diversity patterns in a particular region are influenced primarily by the size and composition of regional pools, which differ from one region to another depending on their evolutionary histories and the interplay between speciation, extinction and dispersal events (e.g., Wiens, 2007; Pyron & Burbrink, 2011; Belmaker & Jetz, 2012; Pyron, 2014; Llorente-Culebras et al., 2021; Zamora-Marín et al., 2021; Fig. 1). For example, greater amphibian diversification in tropical regions seems to be explained by a higher speciation rate or evolutionary time in the tropics, higher extinction in temperate regions and limited dispersal out of the tropics, compared with temperate regions (e.g., Wiens, 2007; Pyron & Wiens, 2013; García-Rodríguez et al., 2020). Locations under similar conditions, but in separate regions, may exhibit highly discrepant local species richness and composition if, for example, dispersal between regions is limited or the formation history of both regions are different (Höfer & Bersier, 2001; Harrison & Cornell, 2008; Pyron & Burbrink, 2014; He et al., 2017; Valente-Debien et al., 2019; Rivas et al., 2021). Local richness sometimes tends to be greater as regional pool richness increases (Ricklefs, 1987; Ricklefs & Schluter, 1993; Harrison & Cornell, 2008; Rabosky et al., 2019), nevertheless, this relationship is not always clear as both regional and local processes may interactively influence each other (e.g., trade-offs between ecological specialization and dispersal at local scales could influence regional diversity patterns; Gonçalves-Souza et al., 2013).

Species distributions and dispersal across regions are affected by biogeographical barriers, such as mountain ranges, oceans, and rivers. This has been observed in *Anolis* species from the Antilles, where changes in species composition and morphological characteristics across different islands are due, in part, to the history of the geologic formation of the archipelago (Losos, 1992; Harmon et al., 2005; Langerhans et al., 2006; Stuart et al., 2012). This has also been seen in snakes assemblages, where species richness on islands is explained by colonization of new

lineages from mainland, which ultimately depends on island isolation (Pyron & Burbrink, 2014). More recent examples have shown that distinct anuran and reptile communities exist on either sides of the Madeira River in the Amazon region and the São Francisco River in eastern Brazil (Dias-Terceiro et al., 2015; Marques-Peixoto et al., 2020; Gonçalves-Sousa et al., 2022), which attest the effects of smaller barriers on diversity patterns. Thus, these barriers may represent important determinants of diversity changes across regions that will depend on amphibians and reptiles limited dispersal capacities (e.g., Vitt & Caldwell, 2014; Arreortúa-Martínez, 2020; Brocka, 2020) and random events (e.g., ecological drift; Caswell, 1976; Hubbell, 2001).

Regional amphibian and reptile diversity patterns are mostly influenced by climatic factors and water-energy dynamics. Most studies agree that, in general, regions with higher average annual temperatures and precipitation tend to host greater taxonomic richness (Barnosky et al., 2001; Soares & Brito, 2006; Aragón et al., 2009; Laurencio & Fitzgerald, 2010; Qian & Kissling, 2010; di Virgilio et al., 2014; Kafash et al., 2020; Pinkert et al., 2020; Fonte et al., 2021; Liang et al., 2022; Raz et al., 2023) and functional diversity (Jiménez-Robles et al., 2017; García-Llamas et al., 2019; Ochoa-Ochoa et al., 2019; Barnagaud et al., 2021; Fonte et al., 2021; Castaño-Quintero et al., 2022) in both groups, although some exceptions are observed in salamanders, which tend to be more diverse in temperate regions with lower temperatures and higher precipitation rates (e.g., Kozak & Wiens, 2012; Gould et al., 2017). Both groups are highly dependent of water and energy inputs (Qian et al., 2007; Whittaker et al., 2007; Veetas et al., 2019), nevertheless, reptiles seem to be mostly affected by the amount of solar energy, usually measured as potential evapotranspiration, hours of sunshine, or minimum temperature (Barnosky et al., 2001; Hawkins et al., 2003; Rodríguez et al., 2005; Qian et al., 2007; Whittaker et al., 2007; Qian, 2010; Liang et al., 2022), while amphibians are affected by solar energy, water availability and productivity, measured as actual evapotranspiration, annual rainfall or the normalized difference vegetation index (Barnosky et al., 2001; Hawkins et al., 2003; Rodríguez et al., 2005; Qian et al., 2007; Whittaker et al., 2007; Qian, 2010; Gouveia et al., 2013; Zhang et al., 2017). Therefore, reptile diversity seems to be more constrained by energy inputs, while amphibian diversity by both water and energy inputs (Qian et al., 2007; Whittaker et al., 2007; Veetas et al., 2019).

Some of the patterns described above may be explained by amphibians' and reptiles' physiological and reproductive requirements (Vitt & Caldwell, 2014). For reptiles, temperature and the amount of solar energy are important factors for physiological functions such as locomotion, growth, and reproduction (Wang et al., 2016), and some species with specific thermal preferences may not prevail in regions with colder or extremely high temperatures (e.g., García-Llamas et al., 2019; García-Porta et al., 2019). For amphibians, precipitation and water availability are key for reproduction, as reflected by a greater diversity of reproductive modes in regions with higher precipitation rates (da Silva et al., 2012; Ochoa-Ochoa et al., 2019), especially of species that depend on lentic and lotic water bodies, or phytotelmata, for reproduction (e.g., Jiménez-Robles et al., 2017; Fonte et al., 2021). These patterns are also explained by a greater diversity of feeding guilds and habits, as well as smaller body sizes, in warmer regions for amphibians (e.g., García-Llamas et al., 2019; Rubalcaba et al., 2019; Fonte et al., 2021) or by changes in body sizes and activity patterns along climatic gradients for reptiles (e.g., species with bigger body sizes and diurnal activity in colder regions; Barnagaud et al., 2021; Rubalcaba et al., 2019, 2023).

Since climatic factors are important determinants of amphibian and reptile diversity, regions with higher aridity levels may harbor both amphibian and reptile communities with poorer functional diversity, due to ecological filters, or less functional redundancy, due to higher competition between functionally similar species (e.g., Ochoa-Ochoa et al., 2019; Gonçalves-Sousa et al., 2022). Nevertheless this may not be necessarily true for squamates, as some arid regions may have hyper-diverse communities with functionally-similar species (Wiens et al., 2012; Vidan et al., 2019). This is the case for Australian desert lizard communities which are outstandingly rich in comparison to other arid regions (e.g., North American, Kalahari, or Atacama deserts; Pianka, 1969; Pianka, 1971; Pianka, 1972, Pianka, 1973; Roll et al., 2017; Vidan et al., 2019; Tejero-Cicuéndez et al., 2022), where different ecological and evolutionary mechanisms have been proposed (e.g., greater diversification in larger geographic areas, higher evolutionary time and rate, effects of deep time environmental dynamics; James & Shine, 2000; Tejero-Cicuéndez et al., 2022).

Topographic factors in most regions are also related with amphibian and reptile taxonomic and functional diversity patterns. Regions with greater topographic heterogeneity tend to harbor higher taxonomic and functional diversity (Laurencio & Fitzgerald, 2010; McCain, 2010; Kozak & Wiens, 2012; Gould et al., 2017; Antonelli et al., 2018; Barnagaud et al., 2021; Liang et al., 2022; Rivera-Reyes, 2022), since they promote a higher number of vegetation types and land use covers (Nogués-Bravo & Martínez-Rica, 2004; Soares & Brito, 2006; Qian & Kissling, 2010; Muñoz et al., 2016; García-Llamas et al., 2018; Barnagaud et al., 2021), more complex hydrographic networks (Soares &

Brito, 2006; Vera et al., 2011; Muñoz et al., 2016), and diverse microclimatic conditions (Qian & Kissling, 2010), providing a broader ecological space for more species and promoting higher diversification rates (e.g., García-Rodríguez et al., 2020; García-Rodríguez et al., 2021). For example, amphibians dependent on lentic water bodies for reproduction may be more abundant in lower elevations, while species with direct development and terrestrial reproductive stages, in higher elevations (Jiménez-Robles et al., 2017). Slope variability can favor the presence of amphibian and reptile species with different dispersal or movement abilities that may use complementary resources (García-Llamas et al., 2019), while a higher number of vegetation types in more topographical heterogeneous regions may allow the prevalence of reptile species with different habits (Barnagaud et al., 2021), increasing functional diversity.

At the regional scale, land use change seems to be a relevant driver, as found by some authors (Ribeiro et al., 2009; Torres et al., 2014; Marsh et al., 2016; de Solan et al., 2018; García-Llamas et al., 2019; Gherghel et al., 2019; Barnagaud et al., 2021; Dehling & Dehling, 2023), nevertheless, it seems that the effects of climatic conditions and topography tend to be stronger (e.g., Keil et al., 2012; Lin et al., 2020; Barnagaud et al., 2021). Despite of this, few studies have still found a significant effect of land use change on amphibian and reptile diversity patterns at the regional scale (e.g., Ribeiro et al., 2009; Marsh et al., 2016; de Solan et al., 2018; García-Llamas et al., 2019; Barnagaud et al., 2021). For instance, a lower taxonomic and functional diversity have been observed in regions with a higher urbanization (de Solan et al., 2018; Barnagaud et al., 2021) and agricultural intensification (Ribeiro et al., 2009; Marsh et al., 2016; García-Llamas et al., 2019; Barnagaud et al., 2021). Land use change transforms heterogeneous and structurally complex land covers (e.g., forests) into more homogeneous ones (e.g., crops), reducing the ecological available space that can be used by functionally distinct species (e.g., Berriozabal-Islas et al., 2017; *see Local scale*). Species that tend to be more affected include those characterized as low fecundity, large-bodied (Barnagaud et al., 2021), omnivorous, tree-dwelling and diurnal (García-Llamas et al., 2019), while other species traits show a more complex pattern (e.g., García-Llamas et al., 2019). As most of these changes occur at smaller scales (e.g., *see Landscape and Local scales*) it is possible that the effect of land use change on diversity patterns at smaller scales are reflected at broader scales.

Biotic interactions affecting diversity patterns at a local scale are also reflected at the regional scale, specifically as non-random co-occurrence patterns. For example, *Plethodon* salamanders in eastern United States, and Pelomedusidae turtle communities in sub-Saharan Africa, are non-randomly structured according to body size, suggesting underlying mechanisms of competition or emergent neutrality that creates clusters of functionally redundant species (Adams, 2007; Luiselli et al., 2021). Snake communities seem to also be structured by competition, and species coexistence can be explained by food resources in tropical regions, and by available micro-habitat partitioning in temperate regions (Luiselli, 2006a). Nevertheless, other studies have found that the effects of biotic interactions on diversity are only detectable at much smaller scales (Rabosky et al., 2007; Aloise et al., 2015), or that some taxonomic groups may be unaffected by competitive mechanisms (e.g., most turtles communities; Luiselli, 2006b), suggesting that the relevance of climate, biotic interactions and other processes (e.g., stochastic processes) may vary between regions or taxa, depending on the context.

LANDSCAPE SCALE: THE IMPORTANCE OF HABITAT COMPOSITION AND CONFIGURATION

Although climatic and topographic gradients tend to be less pronounced as the spatial scale is reduced, they still shape amphibian and reptile diversity patterns in most landscapes. For example, small elevational changes can produce variations in Amazonian lizard taxonomic diversity (e.g., ranges from 24 to 128 m a.s.l.; Marques-Peixoto et al., 2020) and in anuran taxonomic and functional diversity in Mexico and Ecuador (e.g., Pineda & Halffter, 2004; Jiménez-Robles et al., 2017). This may be explained by changes in temperature, relative humidity, and habitat structure along these gradients, which represent important determinants for many amphibians and reptiles at the local scale (e.g., Cabrera-Guzmán & Reynoso, 2012; *see Local scale*). These micro-climatic and topographic variations produce species composition turnover across landscapes (e.g., Jiménez-Robles et al., 2017; Fig. 2), for which more ecologically different species (e.g., different habits, feeding guilds; García-Llamas et al., 2019) may be expected in landscapes with more heterogeneous topographic and micro-climatic conditions.

Landscape composition and configuration (i.e., types of land cover or uses and their spatial arrangement across a landscape; Turner & Gardner, 2015) is one of the most important and best studied determinants of amphibian and reptile diversity patterns at the landscape scale (Cushman, 2006; Gardner et al., 2007; Hamer & McDonell, 2008; Thompson et al., 2015; Cordier et al., 2021). Highly heterogeneous landscapes that include a mix of different vegetation types tend to harbor a greater taxonomic and functional diversity (e.g., Atauri & Lucio, 2001; García-Llamas et al., 2018; García-Llamas et al., 2019), as more ecologically distinct

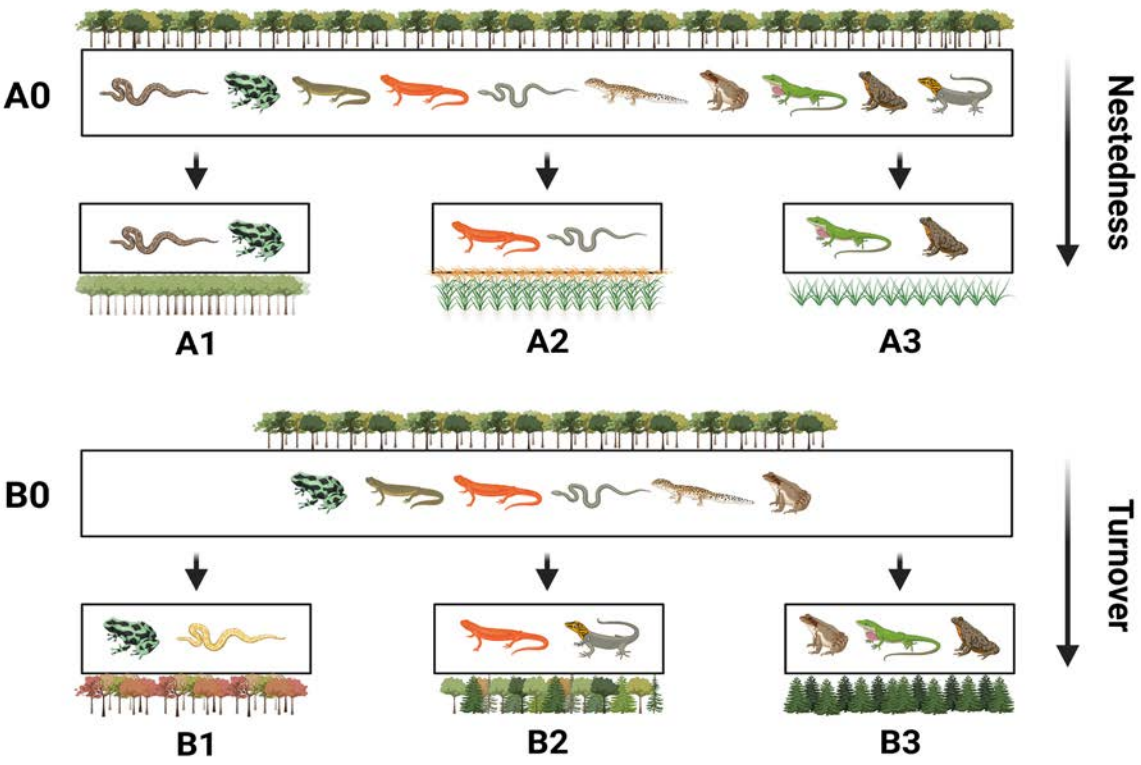

Figura 2. Ejemplo hipotético que describe patrones de recambio y anidamiento (Baselga, 2009) en dos paisajes diferentes (A y B). En el paisaje A se produce anidamiento, esto debido a que las comunidades A1-A3 son subconjuntos de la comunidad A0, la cual es más diversa. En este escenario, A0 representa un fragmento de bosque maduro grande, A1 un fragmento de bosque secundario, A2 un cultivo y A3 un pastizal. Por lo tanto, varias especies del fragmento de bosque maduro grande (A0) se pierden, y sólo algunas prevalecen en hábitats más perturbados (A1-A3). En el paisaje B se produce un recambio ya que todos los sitios tienen especies únicas, mientras que algunas son compartidas. En este escenario, cada sitio representa un tipo de bosque diferente que alberga principalmente especies únicas. Creado con BioRender.com.

Figure 2. Hypothetical example describing turnover and nestedness patterns (Baselga, 2009) in two different landscapes (A and B). In landscape A, nestedness occurs in which communities in A1-A3 are subsets of the broader community in A0. In this scenario, A0 represents a large mature forest fragment, A1 a secondary forest fragment, A2 a cropland and A3 a pasture. Therefore, species are lost from the large mature forest fragment (A0), and only some species prevail in more perturbed habitats (A1-A3). In landscape B, turnover occurs in which all sites have unique species while only some are shared. In this scenario, each site represents different forest types that harbor mainly unique species. Created with BioRender.com.

species may be present. In some cases, a mixture of natural and anthropic land uses increases amphibian and reptile diversity, as it favors both generalist and specialist species (e.g., Urbina-Cardona et al., 2006; Guerra & Aráoz, 2015; Berriozabal-Islas et al., 2017; Ferrante et al., 2017; Branoff & Campos-Cerqueira, 2021). Nevertheless, most studies coincide that the increase of anthropic land uses diminishes taxonomic (Pillsbury & Miller, 2008; Canessa & Parris, 2013; Leavitt & Fitzgerald, 2013; Michael et al., 2016; Sawatzky et al., 2019; Iop et al., 2020; Albero et al., 2021) and functional diversity (Almeida-Gomes et al., 2019), as it leads to the loss of some specialist species (e.g., Berriozabal-Islas et al., 2017; *see Local scale*). It is yet unclear what factors give rise to these contrasting patterns, although it may reflect the specific micro-climatic and micro-habitat characteristics of the anthropic land uses (*see Local scale*). For example, landscapes that have a greater diversity of anthropic land uses (e.g., different types of crops; Carpio et al., 2016; Collins & Fahrig, 2017) with greater structural complexity (Pineda & Halffter, 2004; Mendenhall et al., 2014; Guerra & Aráoz, 2015; Ferrante et al., 2017) and less contrast with the natural landscape composition (Deans & Chalcraft, 2016; Ryberg & Fitzgerald, 2016) may have a greater amphibian and reptile diversity.

The configuration of natural and modified land uses throughout human dominated landscapes help maintain amphibian and reptile diversity. For example, large, regular-shaped natural vegetation remnants (i.e., fragments) host a high taxonomic (Bell & Donnelly, 2006; Cabrera-Guzmán &

Reynoso, 2012; Leavitt & Fitzgerald, 2013; Russildi et al., 2016; Suárez et al., 2021; Schivo et al., 2023) and functional diversity (Almeida-Gomes et al., 2019; Palmeirim et al., 2021) in both groups. This is mainly attributed to a greater environmental and structural heterogeneity (Inger & Colwell, 1977; Almeida-Gomes et al., 2019), which allows ecologically different species to persist, especially those with specific arboreal or rheophilic (i.e., that preferred to live in lotic water bodies) habits, heliophobic thermoregulation modes (i.e., species that avoid direct exposure to solar radiation), specific reproductive modes (e.g., anurans depositing eggs on vegetation over standing water bodies) or species not-resistant to desiccation (Watling & Braga, 2015; Almeida-Gomes et al., 2019; Palmeirim et al., 2021). Also, large fragments are colonized more easily, allowing species to have larger population sizes and lower extinction rates (Arrhenius, 1921; Almeida-Gomes et al., 2022). However, small fragments with a combined area equivalent to a large fragment may host greater species diversity, as both generalist and specialist species may use them (Fahrig, 2020). As such, several authors have emphasized the importance of conserving small fragments throughout landscapes affected by land use change (Lomolino, 2000; Lindenmayer, 2019; Wintle et al., 2019; Hamer, 2021).

A higher density and connectivity of small natural vegetation remnants are also correlated with a higher amphibian and reptile taxonomic and functional diversity (e.g., Mazerolle & Villard, 1999; da Silva et al., 2011; Almeida-Gomes & Rocha, 2014; Mendenhall et al., 2014; Ghosh & Basu, 2020; Ramírez-Arce et al., 2022), since they may facilitate dispersal to and occupation in degraded landscapes. The same is true for water bodies, in which greater density and connectivity permit higher amphibian taxonomic (Lemckert & Mahony, 2010; Hamer & Parris, 2011; Vera et al., 2011; le Viol et al., 2012; Bounas et al., 2020; Ghosh & Basu, 2020) and functional diversity (Ribeiro et al., 2017), as well as a higher aquatic snake taxonomic diversity (Vogrinc et al., 2018). For instance, the diversity of amphibian activity patterns, habits, and reproductive modes reduces the further the distance to water bodies (Ribeiro et al., 2017), reflecting their importance for rich amphibian communities to persist. These landscape elements may be important for metapopulation and metacommunity dynamics, serving as sources for sink habitats, such as anthropic land uses (Richter-Boix et al., 2007; Ryberg & Fitzgerald, 2016; Rosas-Espinoza et al., 2022), or as biological corridors between large vegetation remnants. In this sense, anthropic land uses with greater structural complexity and less contrast with respect to natural land covers is also beneficial to metapopulation and metacommunity dynamics by being more permeable matrices for dispersal (Deans & Chalcraft, 2016; Ryberg & Fitzgerald, 2016; Hernández-Ordóñez et al., 2019).

Biotic interactions that affect diversity patterns at local scale are also reflected at the landscape scale, as species occurrences throughout the landscape can be influenced by interactions, such as competition. For instance, in the United States the rattlesnake species *Crotalus horridus* is less likely to use large, forested areas that also contain *Crotalus adamanteus* snakes (Steen et al., 2014). This is due to trophic niche overlap between the two species and probably a higher competitive hierarchy of *Crotalus adamanteus*. When other land uses are present, both co-occur more often (Steen et al., 2014), implying that landscape characteristics also influence species interactions. Competition can also structure communities of amphibians in low-productivity habitats in Brazil (Huckembeck et al., 2020) and of snakes in degraded land uses in Nigeria (Luiselli, 2006c), which are presumed to have lower resource availability. Nevertheless, some studies have found that amphibians communities in the Chihuahuan desert are mainly structured by environmental differences between land covers, and not by competition (Schalk et al., 2015). This suggests that the relevance of landscape characteristics, environmental filters and biotic interactions may change depending on the biogeographical context of each landscape.

LOCAL SCALE: THE IMPACT OF MICRO-HABITAT CHARACTERISTICS AND BIOTIC INTERACTIONS

Most anthropic land uses have a negative impact on amphibian and reptile communities (Newbold et al., 2015, 2018, 2020). A lower taxonomic and functional diversity is observed in such land uses in comparison with natural land covers (Cushman, 2006; Cagle, 2008; Canessa & Parris, 2013; Trimble & van Aarde, 2014; Carpio et al., 2016; Hölting et al., 2016; Russildi et al., 2016; Berriozabal-Islas et al., 2017; Hernández-Ordóñez et al., 2019; Ghosh & Basu, 2020; Cordier et al., 2021; Rosas-Espinoza et al., 2022; Schivo et al., 2023), although similar values have been recorded in some instances (e.g., shade-grown coffee, cacao crops or agricultural *marais*; Heinen, 1992; Pineda & Halffter, 2004; Wanger et al., 2009; Brüning et al., 2018; Dehling & Dehling, 2023). Even though a clear pattern is not always observed for how different traits may change (e.g., Ribeiro et al., 2017; Rosas-Espinoza et al., 2022), some studies suggest that species lost from anthropic land uses tend to be large-sized anuran species (Ribeiro et al., 2017) with arboreal habits, specific reproductive modes (e.g., reproduction in streams; Almeida-Gomes et al., 2019; Baffa-Trasci et al., 2020) and smaller clutch sizes (Jiménez-Robles et al., 2017), as well as heliophobic reptiles species with larger body sizes, that depend on water bodies (Palmeirim et al., 2021) and specialized diets (Berriozabal-Islas et al., 2017). A select few generalist species may prevail in these perturbed habitats, however, producing a nested pattern where

species are gradually lost from highly-rich natural environments to poorer, anthropic ones (e.g., Berriozabal-Islas et al., 2017; Almeida-Gomes et al., 2019; Branoff & Campos-Cerqueira, 2021; Dehling & Dehling, 2023; Fig. 2), although species turnover may also be observed due to some unique species occurring only in degraded habitats (e.g., Jiménez-Robles et al., 2017; Rosas-Espinoza et al., 2022; Fig. 2).

The fact that some anthropic land uses have similar amphibian and reptile diversity values as do natural land covers (Pineda & Halffter, 2004; Mendenhall et al., 2014; Guerra & Aráoz, 2015; Ferrante et al., 2017; Branoff & Campos-Cerqueira, 2021; Rosas-Espinoza et al., 2022) may be explained by their structural heterogeneity. For example, shade coffee, cacao and palm heart plantations have a more complex vegetation structure and leaf litter depth than other anthropic land uses, such as intensive croplands and pastures, creating more available ecological space that can be used by ecologically different species (Heinen, 1992; Pineda & Halffter, 2004; Kurz et al., 2014). Moreover, changes in vegetation structure caused by wood extraction (Patrick et al., 2006; MacNeil & Williams, 2014; Eyre et al., 2015; Hölting et al., 2016; Muñoz et al., 2021), fire regimes (Rochester et al., 2010; Santos & Cheylan, 2013) or cattle (Kutt et al., 2012; Ferrante et al., 2017), presence of pollution (Taylor & Fox, 2001; Suárez et al., 2021) or introduced grasses (Schlesinger et al., 2020), and direct mortality by humans may cause the local extinction of some reptile species in natural land covers, reducing taxonomic and functional diversity.

Micro-climatic and micro-habitat characteristics, thus, seems to explain much of the diversity patterns observed at broader scales and within localities (e.g., Bars-Closel et al., 2017; Zamora-Marín et al., 2020). For example, greater taxonomic diversity is usually observed in sites and seasons of the year with higher relative humidity and intermediate temperatures (e.g., Cabrera-Guzmán & Reynoso, 2012; da Silva et al., 2012; Villa et al., 2019), since low humidity and extreme temperatures can cause desiccation and create habitats that exceed reptile and amphibian thermal tolerances. Elevation and slope are also important factors, and a greater taxonomic (Laurencio & Fitzgerald, 2010; Qian & Kissling, 2010; Cabrera-Guzmán & Reynoso, 2012; Dias-Terceiro et al., 2015; Muñoz et al., 2016; de Solan et al., 2018) and functional diversity (Jiménez-Robles et al., 2017; de Solan et al., 2018; García-Llamas et al., 2019; Marques-Peixoto et al., 2020) are observed at lower elevations and in terrains with lower slopes (although intermediate and high elevations may also have high species richness depending on the region and context; McCain, 2010; Kutt et al., 2011). This may be explained by the correlation between elevation and some important micro-climatic conditions for amphibians and reptiles as explained above (e.g., temperature, relative humidity), as well as a greater prevalence of lentic water bodies in lowlands, which are important for amphibian reproductive modes that rely on water bodies for egg deposition, or habitat-specific reptiles dependent of high humidity levels (e.g., Jiménez-Robles et al., 2017; Ribeiro et al., 2017; Marques-Peixoto et al., 2020). Also, lower slopes may represent a less energetic cost for most species' movements (e.g., those with smaller body sizes), and may have a complex vegetation structure (e.g., more large trees and woody elements; Martínez-Ramos et al., 1988; Cabrera-Guzmán & Reynoso, 2012) and more stable daily temperature patterns (Pianka, 2000). For semiaquatic environments, higher levels of oxygenation (Weaver & Barret, 2017; Bounas et al., 2020), variable values of conductivity (de Oliveira & Eterovick, 2009; Hamer & Parris, 2011), longer hydroperiods (da Silva et al., 2012; Vogrinc et al., 2018; Atkinson et al., 2021), the presence of sandstone, stony or clay substrates (Lemckert & Mahony, 2010; Kret et al., 2015) and a higher proportion of natural vegetation (Sanchez et al., 2009; Lemckert & Mahony, 2010; Hamer & Parris, 2011; da Silva et al., 2012; Provete et al., 2014; Kret et al., 2015; Albero et al., 2021; Schivo et al., 2023; but see Skelly et al., 2014) have all been shown to promote greater taxonomic and functional diversity for amphibians and aquatic snakes. Water-body size may be also important (Sanchez et al., 2009; Lemckert & Mahony, 2010; da Silva et al., 2012; Provete et al., 2014; Baffa-Trasci et al., 2020; Albero et al., 2021; Schivo et al., 2023), as larger ponds usually provide more refuges and breeding sites for amphibians (although they may, in turn, harbor a greater number of predators, making some species more abundant in small, ephemeral water bodies; Wellborn et al., 1996; Richter-Boix et al., 2007; Sanchez et al., 2009). For terrestrial environments, sites with greater leaf-litter depths (Cabrera-Guzmán & Reynoso, 2012; Ochoa-Ochoa et al., 2014; Eyre et al., 2015), canopy cover (Pineda & Halffter, 2004; Urbina-Cardona et al., 2006; Behangana et al., 2009; Cabrera-Guzmán & Reynoso, 2012; Garda et al., 2012), herb, shrub, rocks or woody debris cover (Cabrera-Guzmán & Reynoso, 2012; Eyre et al., 2015; Rotem et al., 2020; Evans et al., 2019; Ramírez-Arce et al., 2021) and presence of large trees and structurally complex vegetation (Garda et al., 2012; Dias-Terceiro et al., 2015; Doherty et al., 2015; Michael et al., 2016; Goutte et al., 2017; Neilly et al., 2017; Marques-Peixoto et al., 2020) harbor greater amphibian and reptile taxonomic and functional diversity.

Biotic interactions are, perhaps, one of the most important determinants of species occurrence at the local scale (Diamond, 1975; Schoener, 1977; Bruno et al., 2003). Negative interactions, such as competition and predation, are important determinants

of amphibian and reptile diversity patterns. For instance, the presence of predators, such as fish (Bounas et al., 2020), aquatic invertebrates (Richter-Boix et al., 2007) and salamanders (Sredl & Collins, 1991), in large-sized ponds can lead to a decrease in tadpole density in some species, affecting diversity patterns observed. Also, the presence of invasive species can decrease the abundance of native species through competition for similar food resources, as has been observed for anurans in aquatic ecosystems of the United States (Pilliod et al., 2010) and Spain (Richter-Boix et al., 2013). Differences in the competitive ability of species with overlapping niches may lead to competitive exclusion, but some mechanisms, such as niche partitioning, allow species to coexist (Winemiller & Pianka, 1990; Chesson, 2000; HilleRisLambers et al., 2012; Vignoli et al., 2016).

The capacity of amphibians and reptiles to partition multiple niche dimensions may allow species to coexist in many localities. For example, *Sceloporus* species in Mexico consume similar food resources, but substrate use between species tends to differ (Barbault et al., 1985). *Anolis* ecomorphs in the Antilles mainly differ from each other in the food resources they consume and the micro-habitats they use (Losos, 1994), while species within the same ecomorph group may differ in thermal preferences (i.e., substrates used for thermoregulation; Ingram et al., 2022). Lizard species in Australia have been observed to partition temporal (i.e., hours of activity), spatial (i.e., micro-habitats used), and trophic (i.e., food) niche dimensions, allowing a greater number of species to comprise a community (Pianka, 1973). Interestingly, temporal niche partitioning of acoustic activity may allow amphibians with similar micro-habitat and food preferences to reduce potential competition (Boquimpani-Freitas et al., 2007; Sanchez et al., 2009; but see Ochoa-Ochoa et al., 2021; Sugai et al., 2021). The same happens in space: stream noise promotes micro-habitat partitioning among anurans, where different species occupy sites at different distances from the stream (Carvajal-Castro & Vargas-Salinas, 2016). Niche partitioning among species is also possible due to differences in life history traits, such as reproductive activity, sexual maturity, and body size (López-Juri et al., 2015). Thus, the diversity of ecological preferences in amphibian and reptile communities plays an important role in species coexistence.

Although relatively less studied, facilitation (Bruno et al., 2003) seems to be an important diversity determinant that arise from modifications of the microhabitat. Ecological engineers (i.e., organisms that directly or indirectly control the resource availability for other species by modifying the physical environment; Pringle, 2008) can create appropriate environments for some amphibian and reptile species. For example, dam construction by beavers in the United States results in permanent aquatic habitats with a high diversity of breeding sites for several amphibian species (Cunningham et al., 2007; Romansic et al., 2020). Likewise, African elephants modify the vertical structure of the vegetation they feed on, creating a greater number of refuges for *Lygodactylus keniensis* lizards (Pringle, 2008). Other examples of facilitation include the use of bromeliads and leaf-cutter ant nests as refuges or oviposition sites in several anuran species (e.g., *Chiasmocleis antenori, Lithodytes lineatus, Oophaga pumilio, Osteocephalus fuscifacies, Smilisca baudinii*; Savage, 2002; Schlüter et al., 2009; Jiménez-Robles et al., 2017; Aguilar-Cruz et al., 2021; Fig. 3). Therefore, facilitation represents and important, but underrated, aspect that must be further explored.

The effects of interactions depend on micro-habitat characteristics and neutral processes. For example, higher resource availability, such as prey density, allows snake species in South Carolina, United States, to have a broader niche overlap without negative competition effects (Durso et al., 2013), while lower resource availability promotes higher trophic and spatial partitioning in chameleons in Nigeria and western Cameroon (Luiselli, 2006d). Variation in precipitation rates throughout the year modify temporal niche partitioning among anuran species in the Atlantic Forest of Brazil (Boquimpani-Freitas et al., 2007), with different acoustic activity patterns at each season of the year (but see Ochoa-Ochoa et al., 2021). At small scales, random events such as small disturbances, resource pulses or the arrival of a pregnant female to a given pond may have profound effects of the local diversity. Also, because small areas can only support relatively few individuals, demographic stochasticity is expected to determine population dynamics (Melbourne, 2012). Thus, random colonization, extinction and ecological drift are likely to regulate communities at small scales, allowing for coexistence and determining diversity (Martins et al., 2015). Therefore, biotic interactions, micro-habitat conditions, and stochastic processes seem to synergistically influence the structure of many amphibian and reptile communities.

CONCLUSIONS AND FUTURE PERSPECTIVES

In this perspective, we have described important ecological determinants explaining amphibian and reptile diversity patterns at distinct spatial scales (Table 1). Regional species pools and biogeographical barriers, in combination with climate, water-energy inputs and topographical gradients (e.g., temperature, precipitation, potential evapotranspiration, hours of sunshine, minimum temperature, actual evapotranspiration, annual rainfall, normalized difference vegetation index,

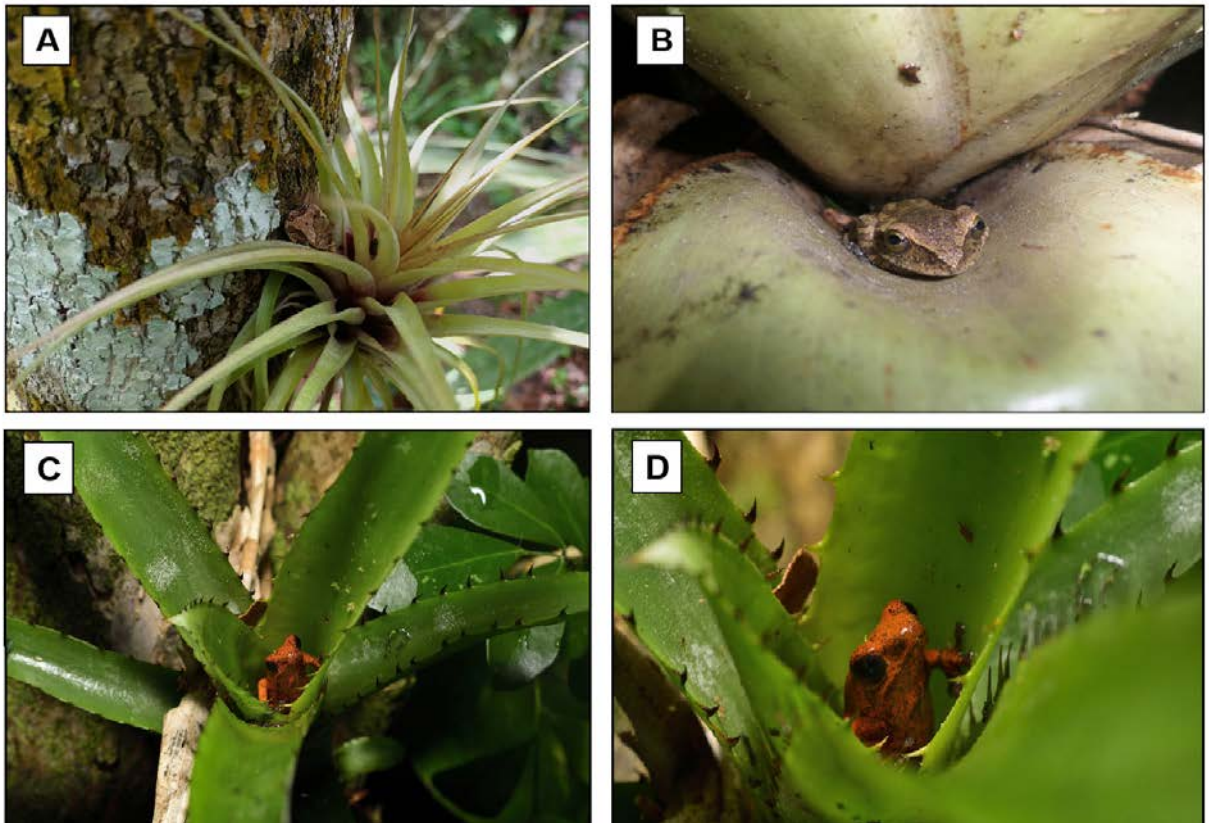

Figura 3. Ejemplos de interacciones positivas, como la facilitación. En A y B, mostramos imágenes del anuro *Smilisca baudinii* usando bromelias como refugio, mientras que en C y D, mostramos al anuro *Oophaga pumilio* usando bromelias como sitios de oviposición (es decir, sitios para el desarrollo de sus renacuajos). Fotos: A y B por Victor Hugo Colín Martínez y Yonatan Aguilar Cruz. Fotos: C y D por Leonardo Daniel Ponce Rosales.

Figure 3. Examples of positive interactions, such as facilitation. In A and B, we show images of the anuran *Smilisca baudinii* using bromeliads as a refuge, while in C and D, we show the anuran *Oophaga pumilio* using bromeliads as oviposition sites (i.e., sites for tadpole development). Photos: A and B by Victor Hugo Colín Martínez and Yonatan Aguilar Cruz. Photos: C and D by Leonardo Daniel Ponce Rosales.

topographic heterogeneity and slope variability), are important factors determining diversity patterns at the regional scale. At the landscape scale, micro-climatic and topographic variations in temperature, relative humidity or elevation, and landscape composition and configuration (e.g., land use change, landscape heterogeneity, density and connectivity of natural vegetation remnants and ponds), represent some of the main determinants of diversity patterns, although the effects of landscape composition (i.e., land use change) are often reflected at the regional scale. Finally, land use-change, micro-climatic conditions (i.e., temperature, relative humidity), micro-habitat characteristics (i.e., elevation, slope, water body characteristics, vegetation composition and structure), biotic interactions (e.g., competition) and facilitation are important determinants at the local scale, although the effects of interactions have also been observed at landscape and regional scales. The discussed determinants could be acting separately or in concert, and observed taxonomic and functional diversity patterns reflect the specific functional traits and niche requirements of amphibians and reptiles. Besides the general trends that we discussed throughout this perspective, we also identified several knowledge gaps that could be important to consider in order to guide future studies. These gaps are discussed in the rest of this section, along with the final conclusions.

Gaps at each spatial scale. At the regional scale, we observed that the effects of biogeographical barriers are important historical determinants of amphibian and reptile diversity patterns. Nevertheless, relatively few studies seems to have directly evaluated their effects (e.g., Dias-Terceiro et al., 2015; Marques-Peixoto et al., 2020; Gonçalves-Sousa et al., 2022), with most of them focusing on climatic and topographical influences (e.g., Soares & Brito, 2006; Laurencio & Fitzgerald, 2010; Qian & Kissling, 2010; di Virgilio et al., 2014; Jiménez-Robles et al., 2017;

Tabla 1. Síntesis de los principales determinantes de los patrones de diversidad de anfibios y reptiles en cada escala espacial. Los signos de más (+) y menos (-) reflejan la dirección del efecto de cada determinante en los patrones de diversidad taxonómica y funcional. La configuración del paisaje, las características del microhábitat de ambientes terrestres o semiacuáticos y las interacciones bióticas pueden tener efectos positivos o negativos en los patrones de diversidad, dependiendo de las condiciones específicas del paisaje/microhábitat o las interacciones examinadas. Para más detalles, consultar el texto.

Table 1. Synthesis of the main determinants of amphibian and reptile diversity patterns at each spatial scale. Plus (+) and minus (-) signs reflect the direction of the effect of each determinant on taxonomic and functional diversity patterns. Landscape configuration, semiaquatic and terrestrial environments' micro-habitat characteristics and biotic interactions may have positive or negative effects on diversity patterns, depending on the specific landscape/micro-habitat conditions or interactions examined. For more details, see the text.

Ecological determinants	Spatial scale		
	Regional	Landscape	Local
Historical factors			
Regional pools and evolutionary dynamics (+)	■		
Historical barriers: rivers, oceans, mountains (+)	■		
Climate and water-energy dynamics			
Macro-climatic conditions: Annual temperature and precipitation (+)	■		
Water-energy inputs: Potential and actual evapotranspiration, hours of sunshine, minimum temperature, normalized difference vegetation index, productivity (+)	■		
Micro-climatic conditions: Temperature and relative humidity (+)		■	■
Aridity levels (-)	■		
Topography			
Topographic heterogeneity: Variation in elevation, slope and topography (+)	■	■	
Elevation (-)			■
Slope (-)			■
Habitat structure			
Landscape compositional heterogeneity (+)	■	■	
Landscape configuration: Large vegetation remnants, density and connectivity of small vegetation remnants and ponds (+/-)		■	
Land use change: Perturbed land uses (-)	■	■	■
Semiaquatic environment's micro-habitat characteristics: Water bodies' morphology, level of oxygenation, conductivity, hydroperiod, and presence of sandstone/stony/clay substrates or natural vegetation (+/-)			■
Terrestrial environment's micro-habitat characteristics: Leaf-litter depth, canopy cover, herb/shrub/rocks/woody debris cover, and presence of large trees and structurally complex vegetation (+/-)			■
Small perturbations			
Wood extraction (-)			■
Fire regimes (-)			■
Grazing (-)			■
Pollution (-)			■
Introduced species (-)			■
Biotic interactions			
Competition (+/-)	■	■	■
Facilitation (+)			■

García-Llamas et al., 2019; Ochoa-Ochoa et al., 2019; Barnagaud et al., 2021; Fonte et al., 2021). Additionally, biotic interactions and land use change are mainly studied at the local scale, but their effects can be seen at the regional scale as well (e.g., Luiselli, 2006a, b; Adams, 2007; García-Llamas et al., 2019; Barnagaud et al., 2021; Luiselli et al., 2021). Therefore, more efforts are needed to address the effects of different kinds of biogeographic barriers and evolutionary processes, as well as land use change and biotic interactions, on amphibian and reptile diversity patterns at broader scales, particularly in topographically complex regions affected by anthropic activities.

At the landscape scale, we observed a predominant focus on investigating the impacts of landscape composition and configuration on amphibian and reptile diversity patterns, with a particular interest in the amount of habitat and its spatial arrangement in the landscape (e.g., Cushman, 2006; Gardner et al., 2007; Hamer & McDonell, 2008; Canessa & Parris, 2013; Leavitt & Fitzgerald, 2013; Thompson et al., 2015; Michael et al., 2016; Sawatzky et al., 2019; Iop et al., 2020; Albero et al., 2021; Cordier et al., 2021). Nevertheless, we believe that in the face of the ongoing land use change across the globe, more studies must also focus on evaluating which anthropic land uses (e.g., which kind of crops) could be less harsh for amphibian and reptile communities at different natural environments, as those with greater structural complexity or less contrast with the natural landscape composition may allow the presence of many different species (Pineda & Halffter, 2004; Mendenhall et al., 2014; Guerra & Aráoz, 2015; Deans & Chalcraft, 2016; Ryberg & Fitzgerald, 2016; Ferrante et al., 2017). This approach holds promise for devising innovative strategies that reconcile human economic development with biodiversity preservation, by selecting those anthropic land uses that produce less impact in particular landscapes. Additionally, while biotic interactions remain under-explored at this scale, they likely play a pivotal role in shaping species presence within the landscape. Thus, we advocate for the incorporation of biotic interactions, such as co-occurrence patterns, in landscape-level studies to provide a more comprehensive understanding of the ecological dynamics at play.

At the local scale, we observed that most studies evaluating biotic interactions seems to focus on competition, niche overlap and niche partitioning between species (e.g., Pianka, 1973; Boquimpani-Freitas et al., 2007; Richter-Boix et al., 2007; Pilliod et al., 2010; Durso et al., 2013; Richter-Boix et al., 2013; Ingram et al., 2022). Few studies, nevertheless, seems to have focused on facilitation, despite this likely being equally important in explaining species occurrences and diversity patterns (e.g., Cunningham et al., 2007; Pringle, 2008; Romansic et al., 2020), and virtually no study seems to concern on positive interactions such as mutualism or commensalism, at least from what was revised in this perspective. We suggest that more studies explore the role of these interactions at local and broader scales, with particular attention to facilitation and positive interactions.

The need for multi-scale studies. Processes across different scales are likely acting in concert. For example, specific micro-habitat characteristics, generally measured at the local scale, may explain diversity changes at the landscape scale (e.g., Mendenhall et al., 2014; Kurz et al., 2014; Rosas-Espinoza et al., 2022). Biotic interactions determine species occurrences at the landscape scale, while at the same time being influenced by changes in landscape and micro-habitat characteristics (e.g., Luiselli, 2006c; Boquimpani-Freitas et al., 2007; Durso et al., 2013; Steen et al., 2014). Exploring processes at a single scale may not be informative by itself, and could even produce unclear patterns. Thus, studies assessing patterns of amphibian and reptile diversity should be performed at multiple hierarchical scales in order to better understand the patterns observed. This could be done by measuring the same set of ecological determinants (and its relationships with taxonomic and functional diversity) at different extents and grains of analysis in order to identify the "scale of effect" of each determinant (i.e, the appropriate scale at which the ecological response is best predicted by a particular determinant; Wiens, 1989; Jackson & Fahrig, 2012; Jackson & Fahrig, 2015).

The importance of selecting appropriate functional traits. Taxonomic and functional diversity are usually correlated (de Bello et al., 2021), and therefore, most studies showed that both dimensions responded similarly to certain ecological determinants. Nevertheless, some authors observed that they responded in opposite or unexpected ways (e.g., de Solan et al., 2018; Rosas-Espinoza et al., 2022), which could be due to the specific functional traits selected by the authors. Each functional trait usually explain an species' specific response to a particular environmental condition (e.g., Ribeiro et al., 2017; García-Llamas et al., 2019). For example, amphibians reproductive traits (e.g., reproductive mode, development time) may explain species responses to pond characteristics (e.g., Lemckert & Mahony, 2010; Ribeiro et al., 2017; Baffa-Trasci et al., 2020; Atkinson et al., 2021), while habits (e.g., terrestrial, arboreal) and body size may explain responses to vegetation characteristics and land use change (e.g., Ribeiro et al., 2017). When calculating functional diversity metrics using a combination of traits, the resulting patterns heavily rely on the selection of these traits (Tsianou & Kallimanis, 2016, 2017), and a careful consideration of which

traits are pertinent to the specific ecological determinant under investigation can elucidate observed patterns more effectively. Therefore, it is crucial to first explore how each trait (or combination of traits) responds to each determinant, as this knowledge essentially guides the selection of appropriate traits for a specific ecological determinant, enhancing the accuracy and relevance of subsequent analyses.

On the other hand, most studies tended to measure similar morphological, behavioral and life history traits (e.g., body size, reproductive mode, diet, habits) at different scales and contexts, which may help us discern which traits may be relevant at a particular scale. Nevertheless, this may also limit our understanding by choosing traits that may be not important at a particular scale or that are proxies of relevant functional traits, which may contribute to the opposite or unexpected patterns observed in some studies. For example, physiological traits such as thermal tolerances may be relevant at the local, landscape and regional scale where macro- and micro-climate is an important determinant, whereas defensive behaviors may be relevant particularly at the local scale, where biotic interactions are prevalent. Measuring other functional traits, such as body temperature, coloration or defensive behavior (Pianka et al., 2017), which seems to be rarely measured in most studies, may help further our understanding of species responses to environmental gradients at different scales.

FINAL CONCLUSIONS

Our perspective described the intricate interplay of ecological determinants shaping amphibian and reptile diversity across various spatial scales, as well as some important knowledge gaps that would be interesting to explore. We advocate for multi-scale studies to decipher the complex dynamics underlying species diversity, identifying the scale at which ecological determinants exert the strongest influence. Additionally, the careful selection of functional traits is crucial, with traditional traits being complemented by lesser-explored ones, like thermal tolerances and defensive behaviors, which may be more relevant under specific conditions. Additionally, and probably more innovative, would be to incorporate analyses of species movements and population dynamics, as well as stochastic processes, which can also explain part of the patterns observed at the community level (e.g., Martins et al., 2015; Vásquez-Restrepo et al., 2022). Addressing these gaps and adopting a comprehensive, multi-scale and multi-disciplinary approach, will not only deepen our understanding of species responses to environmental change but also inform effective conservation strategies in the face of ongoing anthropic impacts and climate change.

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APPENDIX

Appendix 1. Methods

We compiled scientific papers from Web of Science and Scopus database on June 2nd 2022, and updated again in July 5th 2023 for additional papers. We used the following search terms: (amphibian* OR reptile* OR herpetofauna* OR anuran* OR caecilian* OR salamander* OR lizard* OR snake* OR crocodile* OR turtle*) AND ("community structure" OR diversity OR assemblage* OR "functional group*" OR "functional trait*" OR trait*) AND (environmental* OR climatic* OR abiotic* OR biotic* OR anthropic* OR ecological) AND (determinant* OR driver* OR factor* OR variable* OR effect*) AND ("across scale*" OR "multiple scale*" OR "regional scale*" OR "landscape scale*" OR "local scale*" OR "scaling issue*" OR scale*). We also used the following algorithm in order to find additional articles related to biotic interactions: (amphibian* OR reptile* OR herpetofauna* OR anuran* OR caecilian* OR salamander* OR lizard* OR snake* OR crocodile* OR turtle*) AND ("assembly rules" OR "checkerbording" OR "niche overlap" OR "co-ocurrence*") AND ("community structure" OR diversity OR assemblage* OR "functional group*" OR "functional trait*" OR trait*). The above search terms were searched in 'Title', 'Abstract' and 'Keywords' fields. We tried to use a great variety of search terms combinations in order to find most scientific manuscripts that analyzed amphibian and reptile taxonomic and functional diversity patterns at regional, landscape and local scales, and their relationships with different ecological drivers.

We only considered studies that used the concept of scale explicitly in their analyses and worked at local, landscape or regional scales (although some not mentioning it explicitly or performed at global or continental scales are mentioned for further examples or explanations). Furthermore, only studies that dealt with amphibians or reptiles communities, but not individual species, were taken into account (although some examples of studies dealing with individual species are mentioned particularly for biotic interactions). We also only considered studies dealing with taxonomic and functional diversity, not phylogenetic diversity, as we were particularly interested in how different traits or functional groups were affected by different ecological determinants. Finally, only studies that measured and correlated ecological drivers (e.g., biotic, abiotic or anthropic determinants) with the structure of amphibian and reptile communities were taken into account (studies that only described amphibian and reptile diversity in a particular location were not taking into account).

The initial search resulted in 1,034 studies from Web of Science and 770 from Scopus, but only 207 were ultimately considered relevant and cited in this perspective, since this initial search revealed numerous studies that: 1) were unrelated to the topic (e.g., assessments of species extinction risk), 2) addressed phylogenetic diversity, 3) focused on other taxonomic groups (e.g., plants, parasites of amphibians and reptiles), 4) examined the relationship of an ecological determinant with a single species, 5) described amphibian and reptile diversity in a particular location without measuring any ecological determinant, or 6) did not mentioned the scale of analysis explicitly. Therefore, those studies were not considered.

Appendix 2. Bibliographic references used for the examination of the major ecological determinants affecting amphibian and reptile diversity patterns at regional, landscape, and local scales. For each reference, we described at which spatial scale the study was performed, which taxonomic group was evaluated (amphibians, reptiles or both), the diversity dimension studied, the functional traits (in case the author performed any functional diversity analysis) and the functional diversity measure or index used, and the main determinants evaluated according to the classification in Table 1. For reference codes see the footnote at the end.

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
1	Continental and Regional	Amphibians (Salamanders)	Taxonomic and functional	Size guild	Functional guilds	Biotic interactions (competition)
2	Local	Amphibians	None. Species occupancy	-	-	Biotic interactions (facilitation)
3	Landscape and Local	Amphibians	Taxonomic	-	-	Landscape configuration and semiaquatic environment's micro-habitat characteristics
4	Landscape	Amphibians	Taxonomic	-	-	Landscape configuration
5	Landscape	Amphibians	Taxonomic and functional	Body size, micro-habitat preference, reproduction type	Rao's quadratic entropy, functional dissimilarity and nestedness	Landscape configuration
6	Landscape	Amphibians	Taxonomic and functional	Micro-habitat preference	Mean values, functional dissimilarity	Landscape configuration
7	Regional	Reptiles (Lizards)	Taxonomic	-	-	Biotic interactions (competition)
8	Global and Regional	Amphibians	Taxonomic	-	-	Macro-climatic conditions, topographic heterogeneity
9	Regional	Amphibians and Reptiles	Taxonomic	-	-	Macro-climatic conditions, topographic heterogeneity, water-energy inputs
10	Landscape	Amphibians and Reptiles	Taxonomic	-	-	Landscape configuration
11	Local	Amphibians	Taxonomic and functional	Body size, development time, reproduction season	Mean values	Semiaquatic environment's micro-habitat characteristics
12	Landscape and Local	Amphibians	Taxonomic and functional	Reproductive mode and phenology, ecomorphological guild, micro-habitat preference, body size	Functional diversity index	Semiaquatic environment's micro-habitat characteristics, landscape composition and configuration
13	Local	Reptiles (Lizards)	Taxonomic and functional	Diet breadth	Mean values	Biotic interactions

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
14	Regional	Reptiles	Taxonomic and functional	Diurnal activity, reproductive mode, body size, annual fecundity, age at sexual maturity, habits, perturbance resistance, diet	Functional richness, dispersion and evenness	Macro-climatic conditions, land use change
15	Regional	Amphibians and Reptiles	Taxonomic	-	-	Landscape compositional heterogeneity, water-energy inputs, evolutionary dynamics
16	Local	Reptiles	Taxonomic and phylogenetic (diversification rates)	-	-	Terrestrial environment's micro-habitat characteristics
17	Landscape and Local	Amphibians	Taxonomic	-	-	Terrestrial environment's micro-habitat characteristics, micro-climatic conditions, landscape configuration
18	Landscape	Amphibians and Reptiles	Taxonomic	-	-	Landscape configuration
19	Regional and Local	Amphibians	Taxonomic	-	-	Water-energy inputs, landscape compositional heterogeneity, regional pools
20	Landscape	Reptiles	Taxonomic and functional	Diet, foraging behavior, micro-habitat preference, activity pattern, body size, biomass	Functional richness, dispersion and evenness	Land use change
21	Local	Amphibians	Functional	Number of calling males per time period	Temporal acoustic niche breadth and overlap	Micro-climatic conditions
22	Landscape and Local	Amphibians	Taxonomic	-	-	Semiaquatic environment's micro-habitat characteristics, landscape composition and configuration, biotic interactions (competition)
23	Landscape and Local	Amphibians	Taxonomic	-	-	Terrestrial and Semiaquatic environment's micro-habitat characteristics, landscape configuration
24	Landscape and Local	Amphibians	Taxonomic	-	-	Land use change

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
25	Local	General theory for various taxonomic groups	Taxonomic	-	-	Biotic interactions (facilitation)
26	Landscape and Local	Amphibians and Reptiles	Taxonomic	-	-	Terrestrial environment's micro-habitat characteristics, landscape configuration
27	Landscape and Local	Reptiles (Snakes)	Taxonomic	-	-	Macro-climatic conditions, landscape configuration, terrestrial environment's micro-habitat characteristics
28	Landscape and Local	Amphibians	Taxonomic	-	-	Semiaquatic environment's micro-habitat characteristics, landscape configuration
29	Regional and Landscape	Amphibians and Reptiles	Taxonomic	-	-	Land use change
30	Local	Amphibians	Taxonomic and functional	Body size, call frequency, breeding habitat	Mean pairwise phenotypic distance	Semiaquatic and Terrestrial environment's micro-habitat characteristics
31	Regional	Amphibians	Taxonomic and functional	Body size, micro-habitat preference, reproduction type, presence of larva, spawn site, site of larva development, parental care	Rao's quadratic entropy	Macro-climatic conditions
32	Local	General theory for various taxonomic groups	Taxonomic	-	-	Biotic interactions
33	Landscape	Amphibians	Taxonomic	-	-	Landscape compositional heterogeneity, landscape configuration
34	Landscape and Local	Amphibians and Reptiles	Taxonomic	-	-	Land use change
35	Landscape and Local	Amphibians	Taxonomic	-	-	Landscape configuration, semiaquatic environment's micro-habitat characteristics, biotic interactions (facilitation)
36	Landscape	Amphibians	Taxonomic	-	-	Land use change, landscape configuration

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
37	Landscape and Local	Amphibians	Taxonomic	-	-	Landscape configuration, semiaquatic environment's micro-habitat characteristics
38	Local	Amphibians	Taxonomic and functional	Reproductive mode	Functional groups	Micro-climatic conditions
39	Regional and Local	Amphibians	Taxonomic	-	-	Geographical distance, micro-climatic conditions, semiaquatic and terrestrial environment's micro-habitat characteristics
40	Regional and Local	Reptiles	Taxonomic and functional	Body size, diet, daily activity pattern, yearly activity pattern, locomotion type, micro-habitat preference, clutch size, age at sexual maturity, reproduction mode	Pairwise functional distances	Landscape composition and configuration
41	Landscape	Amphibians	Taxonomic	-	-	Landscape configuration, semiaquatic environment's micro-habitat characteristics
42	Regional and Local	Amphibians	Taxonomic, functional and phylogenetic	Micro-habitat preference, calling site, breeding seasonality, egg deposition site and type, tadpole type, body size, head width, hind-limb length, hand and foot webbing, terminal disks	Functional richness	Land use change
43	Regional	Reptiles	Taxonomic	-	-	Macro-climatic conditions, land use change
44	Regional and Local	Amphibians	Taxonomic	-	-	Historical barriers, terrestrial environment's micro-habitat characteristics
45	Local	Reptiles	Taxonomic	-	-	Small perturbations (fire regimes), terrestrial environment's micro-habitat characteristics
46	Local	Reptiles (Snakes)	Functional	Diet	Trophic niche overlap	Terrestrial environment's micro-habitat characteristics

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
47	Local	Reptiles (Lizards)	Taxonomic	-	-	Small perturbations (fire regimes), terrestrial environment's micro-habitat characteristics
48	Local	Reptiles	Taxonomic	-	-	Small perturbations (wood extraction), terrestrial environment's micro-habitat characteristics
49	Landscape	General theory for various taxonomic groups	Taxonomic	-	-	Landscape configuration
50	Landscape	Amphibians	Taxonomic	-	-	Landscape composition and configuration
51	Regional	Amphibians	Taxonomic and functional	Predominant lifestyle, reproductive strategy	Functional groups	Macro-climatic conditions
52	Regional and landscape	Amphibians and Reptiles	Taxonomic	-	-	Landscape compositional heterogeneity
53	Regional	Amphibians and Reptiles	Taxonomic and functional	Feeding guild, habitat use type, daily activity	Functional diversity index, functional redundancy	Macro-climatic conditions, topographic heterogeneity, land use change, water-energy inputs, landscape compositional heterogeneity
54	Regional	Amphibians	Taxonomic and phylogenetic (diversification rates)	-	-	Macro-climatic conditions, topographic heterogeneity, evolutionary dynamics
55	Global and Regional	Amphibians	Taxonomic and phylogenetic (diversification rates)	-	-	Topographic heterogeneity
56	Local	Reptiles (Lizards)	Taxonomic	-	-	Terrestrial environment's micro-habitat characteristics
57	Landscape and Local	Amphibians and Reptiles	Taxonomic	-	-	Land use change
58	Regional	Amphibians and Reptiles	Taxonomic	-	-	Macro-climatic conditions, topographic heterogeneity, land use change

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
59	Landscape and Local	Amphibians and Reptiles	Taxonomic	-	-	Landscape composition heterogeneity, landscape configuration
60	Regional and Landscape	Reptiles (Lizards)	Taxonomic, functional and phylogenetic	Body size, clutch size, sexual dimorphism, foraging mode, preferred microhabitat, activity period, reproductive mode	Pairwise functional distances	Historical barriers, micro-climatic conditions, terrestrial environment's micro-habitat characteristics
61	Regional and Local	Amphibians and Reptiles	Taxonomic	-	-	Regional pools
62	Regional, Landscape and Local	Amphibians (Salamanders)	Taxonomic	-	-	Macro-climatic conditions, geographical distance, landscape configuration, terrestrial environment's micro-habitat characteristics, elevation, slope
63	Regional and Local	Amphibians	Taxonomic	-	-	Geographical distance, terrestrial and semiaquatic environment's micro-habitat characteristics, slope
64	Global	Amphibians	Taxonomic	-	-	Historical and actual macro-climatic conditions, water-energy inputs
65	Landscape and Local	Amphibians	Taxonomic	-	-	Land use change
66	Landscape and Local	Amphibians	Taxonomic	-	-	Semiaquatic environment's micro-habitat characteristics, biotic interactions (predation), landscape configuration
67	Landscape and Local	Amphibians	Taxonomic	-	-	Land use change, landscape configuration
68	Landscape and Local	Amphibians	Taxonomic	-	-	Landscape configuration, semiaquatic environment's micro-habitat characteristics, biotic interactions (predation)

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
69	Regional	Reptiles (Lizards)	Taxonomic and functional	Body size, body shape, three-dimensional landmark coordinates from the head, lamella number, sexual size dimorphism	Mean values	Historical barriers, macro-habitat type
70	Regional and Local	General theory for various taxonomic groups	Taxonomic	-	-	Regional pools
71	Global and Regional	Amphibians and Reptiles	Taxonomic	-	-	Water-energy inputs
72	Regional	Amphibians and Reptiles	Taxonomic	-	-	Historical and actual macro-climatic conditions, land use change, macro-habitat type, geological processes
73	Local	Amphibians and Reptiles	Taxonomic	-	-	Land use change, terrestrial environment's micro-habitat characteristics
74	Landscape and Local	Amphibians	Taxonomic, functional and phylogenetic	Body size, toe webbing, mouth width, leg length, dorsum skin thickness/ type, respiration type, fecundation type, male reproductive display for female response, male reproductive display site, fecundation site, egg laying site, parental care of clutches, daily activity, habitat during nonbreeding season, number of habitats used in nonbreeding season	Functional groups	Micro-climatic conditions, terrestrial environment's micro-habitat characteristics, land use change
75	Regional and Local	General theory for various taxonomic groups	Taxonomic	-	-	Biotic interactions
76	Regional and Local	Amphibians and Reptiles	Taxonomic	-	-	Regional pools
77	Landscape and Local	Amphibians	Taxonomic	-	-	Macro-climatic conditions, landscape configuration, land use change, terrestrial environment's micro-habitat characteristics

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
78	Landscape and Local	Amphibians	Taxonomic and functional	Diet, biomass	Trophic niche breadth	Land use change, macro-habitat type
79	Landscape and Local	Amphibians and Reptiles	Taxonomic and functional	Micro-habitat preference	Spatial niche breadth and overlap	Land use change, macro-habitat type
80	Local	Reptiles (Lizards)	Taxonomic and functional	Micro-habitat preference, body temperature, diet	Mean values	Biotic interactions (competition)
81	Landscape and Local	Amphibians	Taxonomic	-	-	Terrestrial and Semiaquatic environment's micro-habitat characteristics, landscape configuration
82	Regional	Reptiles (Lizards)	Taxonomic	-	-	Macro-climatic conditions, land use change, macro-habitat type
83	Regional and Local	Amphibians	Taxonomic and functional	Reproductive mode, clutch size	Functional groups	Macro-climatic conditions, land use change
84	Regional	Reptiles (Lizards)	Taxonomic	-	-	Macro-climatic conditions, topographic heterogeneity, water-energy inputs, geological processes
85	Continental and Regional	Amphibians and Reptiles	Taxonomic	-	-	Macro-climatic conditions, land use change, geographical distance
86	Regional	Amphibians (Salamanders)	Taxonomic	-	-	Macro-climatic conditions, evolutionary dynamics
87	Landscape and Local	Amphibians	Taxonomic	-	-	Semiaquatic environment's micro-habitat characteristics, biotic interactions (predation), landscape configuration, elevation, slope
88	Local	Amphibians and Reptiles	Taxonomic	-	-	Terrestrial environment's micro-habitat characteristics, land use change, macro-habitat type

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
89	Local	Reptiles (Lizards)	Taxonomic	-	-	Terrestrial environment's micro-habitat characteristics, elevation, land use change, macro-habitat type
90	Landscape and Local	Amphibians and Reptiles	Taxonomic	-	-	Macro-climatic conditions, terrestrial environment's micro-habitat characteristics, land use change, macro-habitat type, small perturbations (grazing)
91	Regional and Local	Reptiles (Lizards)	Taxonomic and functional	Snout-vent length, forelimb length, hindlimb length, pectoral girdle width, pelvic girdle width, toe-pad width, head depth, jaw length, jaw width	Mean values	Historical barriers, macro-habitat type
92	Regional	Amphibians and Reptiles	Taxonomic	-	-	Macro-climatic conditions, water-energy inputs, elevation
93	Landscape and Local	Amphibians	Taxonomic	-	-	Semiaquatic environment's micro-habitat characteristics, landscape configuration, biotic interactions (predation)
94	Landscape and Local	Reptiles (Lizards)	Taxonomic	-	-	Terrestrial environment's micro-habitat characteristics, landscape configuration
95	Landscape and Local	Amphibians	Taxonomic	-	-	Semiaquatic environment's micro-habitat characteristics, landscape composition and configuration
96	Regional	Reptiles (Lizards)	Taxonomic	-	-	Macro-climatic conditions, water-energy inputs, topographic heterogeneity
97	Regional and Landscape	Amphibians	Taxonomic	-	-	Macro-climatic conditions, landscape configuration, land use change

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
98	Landscape	General theory for various taxonomic groups	Taxonomic	-	-	Landscape configuration
99	Regional	Amphibians and Reptiles	Taxonomic, functional and phylogenetic	Trophic behaviour, microhabitat preference, body size, daily activity, reproduction, longevity, displacement mode	Functional diversity index	Regional pools, macro-climatic conditions, land use change, macro-habitat type
100	Regional	Reptiles (Lizards)	Taxonomic	-	-	Island's area
101	Local	Reptiles (Lizards)	Functional	Diet	Trophic niche segregation	Life history traits
102	Regional	Reptiles (Lizards)	Taxonomic and functional	Body size and shape, hindlimb length, tail length, color, number of subdigital lamellae	Functional groups	Historical barriers
103	Regional and Local	Reptiles (Lizards)	Taxonomic and functional	Diet, body size, micro-habitat preference	Mean values	Biotic interactions (competition)
104	Regional	Reptiles (Snakes)	Functional	Diet, habitat type	Spatial and trophic niche partitioning	Biotic interactions (competition)
105	Regional	Reptiles (Turtles)	Taxonomic	-	-	Biotic interactions (competition)
106	Landscape and Local	Reptiles	Functional	Diet	Food niche overlap	Land use change
107	Regional	Reptiles (Lizards)	Taxonomic and functional	Diet, habitat type	Mean values	Biotic interactions (competition)
108	Continental and Local	Reptiles (Turtles)	Taxonomic	-	-	Biotic interactions (competition)
109	Landscape and Local	Amphibians (Salamanders)	Taxonomic	-	-	Terrestrial environment's micro-habitat characteristics, micro-climatic conditions, land use change, landscape configuration, small perturbations (wood extraction)
110	Regional and Local	Reptiles (Lizards)	Taxonomic	-	-	Historical barriers, landscape configuration, terrestrial environment's micro-habitat characteristics
111	Regional and Landscape	Amphibians	Taxonomic	-	-	Land use change, landscape configuration

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
112	Regional and Local	Amphibians	Taxonomic and phylogenetic	-	-	Evolutionary dynamics, stochastic processes
113	Landscape and Local	Amphibians and Reptiles	Taxonomic	-	-	Land use change, landscape configuration
114	Regional	Reptiles	Taxonomic	-	-	Region's area, topographic heterogeneity, macro-climatic conditions, water-energy inputs
115	Local	General theory for various taxonomic groups	None. Population dynamics	-	-	Stochastic processes
116	Landscape and Local	Amphibians and Reptiles	Taxonomic and functional	Snout-vent length, general habitat stratum, oviposition habitat, average number of offspring	Community-weighted mean	Land use change, landscape configuration, terrestrial environment's micro-habitat characteristics
117	Landscape and Local	Reptiles	Taxonomic	-	-	Land use change, landscape configuration, slope, elevation, aspect, terrestrial environment's micro-habitat characteristics
118	Local	Reptiles	Taxonomic	-	-	Land use change, macro-habitat type, small perturbations (fire regime)
119	Regional	Amphibians and Reptiles	Taxonomic and species distributions	-	-	Macro-climatic conditions, topographic heterogeneity, water-energy inputs, macro-habitat type, distance to hydrological networks
120	Landscape and Local	Reptiles	Taxonomic and functional	Micro-habitat preference	Functional groups	Small perturbations (grazing), terrestrial environment's micro-habitat characteristics
121	Global and Regional	Amphibians and Reptiles	Taxonomic and functional	Thermal strategy, body mass, trophic level	Functional groups	Land use change
122	Global and Regional	Amphibians and Reptiles	Taxonomic	-	-	Land use change
123	Global, Regional and Local	Amphibians and Reptiles	Taxonomic	-	-	Land use change

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
124	Regional	Amphibians and Reptiles	Taxonomic	-	-	Macro-climatic conditions, land use change
125	Landscape and Local	Amphibians	Taxonomic	-	-	Macro-climatic conditions, land use change, landscape configuration, terrestrial environment's micro-habitat characteristics
126	Local	Amphibians	Functional	Vocalization duration, structure and frequency	Spatial and temporal acoustic niche breadth and overlap	None
127	Continental and Regional	Amphibians	Taxonomic and functional	body size, primary habitat type, fertilization type, reproductive cycle, reproductive type, spawn site, presence/absence of larvae, site of development of larvae, presence/absence of parental care	Functional Hill's numbers	Water-energy inputs, macro-climatic conditions, aridity levels
128	Landscape and Local	Reptiles (Lizards)	Taxonomic, functional and phylogenetic	Body length, thermoregulation mode, type of habitat used, range of prey size	Rao's quadratic entropy, community-weighted mean, functional uniqueness	Landscape configuration
129	Local	Amphibians	Taxonomic	-	-	Land use change, small perturbations (wood extraction), terrestrial environment's micro-habitat characteristics
130	Regional and Local	Reptiles (Lizards)	Taxonomic	-	-	Macro-habitat type, evolutionary dynamics
131	Regional and Local	Reptiles (Lizards)	Taxonomic	-	-	Terrestrial environment's micro-habitat characteristics
132	Regional	Reptiles (Lizards)	Taxonomic and species distributions	-	-	Macro-habitat type
133	Local	Reptiles (Lizards)	Taxonomic and Functional	Diet, micro-habitat preference, activity pattern	Temporal, spatial and trophic niche partitioning	Biotic interactions (competition)
134	Landscape and Local	Amphibians (Salamanders)	None. Species occupancy	-	-	Semiaquatic environment's micro-habitat characteristics, landscape configuration, biotic interactions (predation)

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
135	Landscape and Local	Amphibians	Taxonomic	-	-	Semiaquatic environment's micro-habitat characteristics, landscape configuration, land use change
136	Landscape and Local	Amphibians	Taxonomic and functional	Body size, micro-habitat preference, reproductive mode	Functional guilds	Terrestrial environment's micro-habitat characteristics, landscape configuration
137	Regional	Amphibians	Taxonomic	-	-	Historical and actual macro-climatic conditions
138	Local	Reptiles (Lizards)	Taxonomic	-	-	Biotic interactions (facilitation)
139	Landscape and Local	Amphibians	Taxonomic	-	-	Semiaquatic and terrestrial environment's micro-habitat characteristics, landscape configuration
140	Global	Reptiles (Snakes)	Taxonomic	-	-	Evolutionary dynamics
141	Global and Regional	Reptiles (Snakes)	Taxonomic and phylogenetic	-	-	Macro-climatic conditions, water-energy inputs, island's area and isolation
142	Regional	Amphibians	Taxonomic and phylogenetic	-	-	Macro-climatic conditions, water-energy inputs, evolutionary dynamics
143	Global and Regional	Amphibians	Taxonomic and phylogenetic	-	-	Evolutionary dynamics
144	Regional and Local	Amphibians and Reptiles	Taxonomic	-	-	Water-energy inputs, topographic heterogeneity, plant richness
145	Global and Regional	Amphibians and Reptiles	Taxonomic	-	-	Macro-climatic conditions, water-energy inputs, topographic heterogeneity
146	Regional	Amphibians and Reptiles	Taxonomic	-	-	Macro-climatic conditions, water-energy inputs, topographic heterogeneity
147	Regional and Local	Reptiles (Lizards)	Functional	Body size	Community-weighted mean	Macro-habitat type, biotic interactions (competition)

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
148	Regional and Local	Reptiles	Taxonomic	-	-	Regional pools
149	Local	Reptiles (Snakes)	None. Species occupancy	-	-	Terrestrial environment's micro-habitat characteristics
150	Landscape	Amphibians	Taxonomic	-	-	Land use change, landscape configuration
151	Global and Regional	Amphibians and Reptiles	Taxonomic	-	-	Historical and actual macro-climatic conditions, topographic heterogeneity, water-energy inputs, island's isolation
152	Landscape and Local	Amphibians	Taxonomic, functional and phylogenetic	Activity pattern, micro-habitat preference, habitat type, fossorial behavior, adult snout-vent length, breeding site, breeding strategy, clutch size, parental care, breeding season, breeding pattern, geographic range size	Rao's quadratic entropy, community-weighted mean	Terrestrial and Semiaquatic environment's micro-habitat characteristics, landscape configuration
153	Regional	Reptiles	Taxonomic	-	-	Macro-climatic conditions, topographic heterogeneity, land use change
154	Landscape and Local	Amphibians	Taxonomic	-	-	Semiaquatic environment's micro-habitat characteristics, landscape configuration, biotic interactions (predation)
155	Local	Amphibians	Functional	Micro-habitat used, body size, time to metamorphosis	Mean values	Biotic interaction (competition)
156	Regional	General theory for various taxonomic groups	Taxonomic	-	-	Historical barriers, evolutionary dynamics
157	Regional and Local	General theory for various taxonomic groups	Taxonomic	-	-	Historical barriers, evolutionary dynamics, semiaquatic and terrestrial environment's micro-habitat characteristics, biotic interactions

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
158	Regional	Amphibians and Reptiles	Taxonomic	-	-	Region's area, topographic heterogeneity, elevation
159	Regional	Amphibians	Taxonomic	-	-	Macro-climatic conditions, water-energy inputs, elevation
160	Landscape and Local	Amphibians and Reptiles	Taxonomic	-	-	Land use change, macro-habitat type, small perturbations (fire regime), terrestrial environment's micro-habitat characteristics
161	Regional	Amphibians and Reptiles	Taxonomic	-	-	Macro-climatic conditions, water-energy inputs, landscape compositional heterogeneity, topographic heterogeneity
162	Global and Regional	Amphibians and Reptiles	Taxonomic	-	-	Macro-climatic conditions
163	Local	Amphibians	Taxonomic	-	-	Semiaquatic environment's micro-habitat characteristics, biotic interactions (facilitation)
164	Landscape and Local	Amphibians	Taxonomic and functional	Reproductive mode, diet, period of activity, micro-habitat preference, body size, type of skin, dorsal pattern, toxicity	Functional richness, evenness and divergence	Land use change, terrestrial environment's micro-habitat characteristics, small perturbations (grazing)
165	Landscape and Local	Reptiles	Taxonomic	-	-	Macro-climatic conditions, terrestrial environment's micro-habitat characteristics, slope, land use change, small perturbations (grazing), landscape configuration
166	Regional	Amphibians and Reptiles	None. Multivariate relationships between traits	Body size, body temperature, cutaneous evaporative water loss	Mean values	Macro- and micro-climatic conditions, water-energy inputs

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
167	Global and Regional	Reptiles (Lizards)	None. Multivariate relationships between traits	Body size, skin colour, thermal tolerance limits, preferred body temperature, thermoregulatory capacity	Community-weighted mean	Macro-climatic conditions, species' thermal performance
168	Landscape and Local	Amphibians and Reptiles	Taxonomic	-	-	Landscape configuration, land use change, terrestrial environment's micro-habitat characteristics
169	Landscape	Reptiles (Lizards)	Taxonomic	-	-	Landscape configuration
170	Landscape and Local	Amphibians	Taxonomic and functional	Breeding period, habitat use, reproductive modes	Functional groups	Semiaquatic and terrestrial environment's micro-habitat characteristics, macro-climatic conditions, biotic interactions (predation)
171	Local	Reptiles	Taxonomic and functional	Micro-habitat preference, altitudinal range, diet, age of sexual maturity	Mean values	Small perturbations (fire regime), terrestrial environment's micro-habitat characteristics
172	Landscape and Local	Amphibians	Taxonomic	-	-	Terrestrial environment's micro-habitat characteristics, landscape configuration
173	Landscape and Local	Amphibians	Functional	Snout-to-vent length, Mouth width, Head length, Head width, Head height, Forelimb length, Thigh length, Tarsus-and-foot length, Shank length, Inter-orbital width, Eye diameter, Inter-narial distance, Narial-to-mouth distance	Average and standard deviation of nearest neighbor distance, average distance to centroid	Land use change, macro-habitat type, biotic interactions (competition)
174	Landscape and Local	Amphibians and Reptiles	Taxonomic	-	-	Terrestrial environment's micro-habitat characteristics, landscape configuration, land use change
175	Local	Reptiles	Taxonomic	-	-	Terrestrial environment's micro-habitat characteristics, biotic interactions (competition)

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
176	Local	Amphibians	None. Species occupancy	-	-	Biotic interactions (facilitation)
177	Landscape and Local	Amphibians	Taxonomic and species occupancy	-	-	Semiaquatic environment's micro-habitat characteristics
178	Regional	Amphibians and Reptiles	Taxonomic	-	-	Macro-climatic conditions, topographic heterogeneity, hydrological networks characteristics, vegetation heterogeneity
179	Local	Amphibians	Functional	Length of larval period, mass at metamorphosis, growth rate	Mean values	Biotic interactions (predation)
180	Local	Reptiles (Snakes)	None. Species occupancy	-	-	Landscape configuration, biotic interactions (competition)
181	Regional	Reptiles (Lizards)	Taxonomic	-	-	Macro-climatic conditions, geographical distance
182	Landscape and Local	Amphibians	Taxonomic and species occupancy	-	-	Landscape configuration, small perturbations (pollution)
183	Landscape and Local	Amphibians	Taxonomic and functional	Vocalization duration, structure and frequency, body size	Mean values	Landscape compositional heterogeneity, terrestrial and semiaquatic environment's micro-habitat characteristics
184	Local	Reptiles (Lizards)	Taxonomic	-	-	Small perturbations (pollution), terrestrial environment's micro-habitat characteristics
185	Global and Regional	Reptiles (Lizards)	Taxonomic	-	-	Macro-climatic conditions, water-energy inputs, topographic heterogeneity, evolutionary dynamics
186	Landscape and Local	Amphibians and Reptiles	Taxonomic	-	-	Land use change
187	Regional	Amphibians	Taxonomic	-	-	Macro-climatic conditions, topographic heterogeneity, land use change

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
188	Local	Amphibians and Reptiles	Taxonomic and functional	Snout–ventral length, mean clutch size, active stratum, reproductive strategy, locomotion, feeding style	Functional groups	Terrestrial environment's micro-habitat characteristics, land use change
189	Landscape and Local	Amphibians and Reptiles	Taxonomic	-	-	Macro- and micro-climatic conditions, terrestrial environment's micro-habitat characteristics, elevation, slope
190	Local	Reptiles	Taxonomic	-	-	Land use change, macro-habitat type
191	Landscape and Local	Amphibians and Reptiles	Taxonomic	-	-	Landscape configuration, landscape compositional heterogeneity
192	Regional	Amphibians and Reptiles	Taxonomic	-	-	Macro-climatic conditions, water-energy inputs
193	Global	Reptiles (Lizards)	Functional	Activity time, diet, micro-habitat preference	Functional groups	None
194	Local	Amphibians	Taxonomic	-	-	Biotic interactions (competition), macro-habitat type
195	Local	Amphibians	Taxonomic	-	-	Micro-climatic conditions
196	Landscape and Local	Reptiles (Snakes)	Taxonomic and species occupancy	-	-	Macro-climatic conditions, landscape configuration, biotic interactions (competition)
197	Landscape and Local	Amphibians and Reptiles	Taxonomic	-	-	Terrestrial environment's micro-habitat characteristics, landscape configuration
198	Landscape and Local	Amphibians	Taxonomic and functional	Body mass, dessication resistance	Mean values	Land use change, landscape configuration
199	Landscape and Local	Amphibians (Salamanders)	Taxonomic and species occupancy	-	-	Terrestrial and Semiaquatic environment's micro-habitat characteristics, landscape configuration
200	Local	Amphibians	Taxonomic and species distributions	-	-	Semiaquatic environment's micro-habitat characteristics, biotic interactions (predation)

Reference number	Spatial scale	Taxonomic group	Diversity dimension studied	Functional traits used	Functional diversity measure or index	Ecological determinants evaluated
201	Regional	Amphibians and Reptiles	Taxonomic	-	-	Macro-climatic conditions, water-energy inputs
202	Global and Regional	Amphibians	Taxonomic	-	-	Evolutionary dynamics
203	Regional	Reptiles (Lizards)	Taxonomic	-	-	Macro-climatic conditions, evolutionary dynamics
204	Local	Reptiles (Lizards)	Functional	Diet	Trophic niche overlap	Biotic interactions (competition)
205	Landscape	General theory for various taxonomic groups	Taxonomic	-	-	Landscape configuration
206	Regional and Local	Amphibians	Taxonomic	-	-	Semiaquatic environment's micro-habitat characteristics, land use change
207	Regional	Amphibians	Taxonomic	-	-	Water-energy inputs

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PRIMEROS REGISTROS DE PISCIVORÍA Y DERMATOFAGIA EN *TELMATOBIUS PHILIPPII* (TELMATOBIIDAE) DESDE EL SALAR DE ASCOTÁN, NORTE DE CHILE

FIRST RECORDS OF PISCIVORY AND DERMATOPHAGIA IN *TELMATOBIUS PHILIPPII* (TELMATOBIIDAE) FROM THE SALAR DE ASCOTÁN, NORTHERN CHILE

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Abstract.– We report the consumption of fish of the species *Orestias ascotanensis* and nuptial pads remains in a population of *Telmatobius philippii* in the Salar de Ascotán, Antofagasta Region, Chile. These are the first reports of this type for a species of the genus *Telmatobius* in Chile.

Keywords.– Anura, conducta, dieta, depredación.

Resumen.– Reportamos el consumo de peces de la especie *Orestias ascotanensis* y de restos de callos nupciales en una población de *Telmatobius philippii* en el Salar de Ascotán, Región de Antofagasta, Chile. Estos son los primeros reportes de este tipo para una especie del género *Telmatobius* en Chile.

Palabras clave.– Anura, behavior, diet, predation.

El género *Telmatobius* Wiegmann, 1834, agrupa a ranas endémicas de los Andes del sur de América, donde su distribución se extiende desde Ecuador hasta el norte de Chile y Argentina (Lavilla, 2005). En Chile, se reconocen actualmente siete especies (Frost, 2024), todas ellas de vida completamente acuática, que habitan en ecosistemas lóticos (arroyos y ríos) y lénticos (vertientes y lagos), asociados a ambientes de altura, en un rango que va desde los 2,200 hasta los 4,500 m s.n.m aproximadamente (Capurro, 1954; Veloso et al., 2005; Veloso, 2006; Méndez & Correa, 2008; Sáez et al., 2014; von Tschirnhaus & Correa, 2021). El género, se caracteriza por ser uno de los más amenazados a nivel global (IUCN, 2023). Todas las especies que habitan en Chile se encuentran fuertemente amenazadas por la extracción de aguas para la industria minera y la agricultura (Soto-Azat et al., 2015).

En el Salar de Ascotán a 3,700 m s.n.m. (Comuna de Ollagüe, Región de Antofagasta, Chile) (Fig. 1) habita una población de *Telmatobius philippii* Cuevas & Formas, 2002 (Sáez et al., 2014), que corresponde a una rana de talla media (47.3 a 80 mm de longitud hocico-cloaca). Estos anuros han sido descritos como depredadores selectivos, con un consumo restringido principalmente a invertebrados acuáticos bentónicos, con una marcada preferencia de anfípodos de la familia Hyalellidae y gasterópodos de la familia Hydrobiidae, aunque su dieta también incluye dípteros, coleópteros y hemípteros en menor proporción (Lobos et al., 2018). Estos hábitos son similares a los descritos en otras especies del país, como *T. dankoi* (ahora conocida como *T. halli*) (Lobos et al., 2016) y *T. chusmisensis* (Lobos et al., 2021).

En general, en las comunidades de sistemas acuáticos continentales, son frecuentes los eventos de depredación de anfibios en sus primeras fases ontogenéticas (huevos y larvas) por peces (Snodgrass et al., 2000; Davis et al., 2017; Hammer, 2021); sin embargo, es escasa la información con respecto al consumo de peces por parte de anuros adultos. En este contexto,

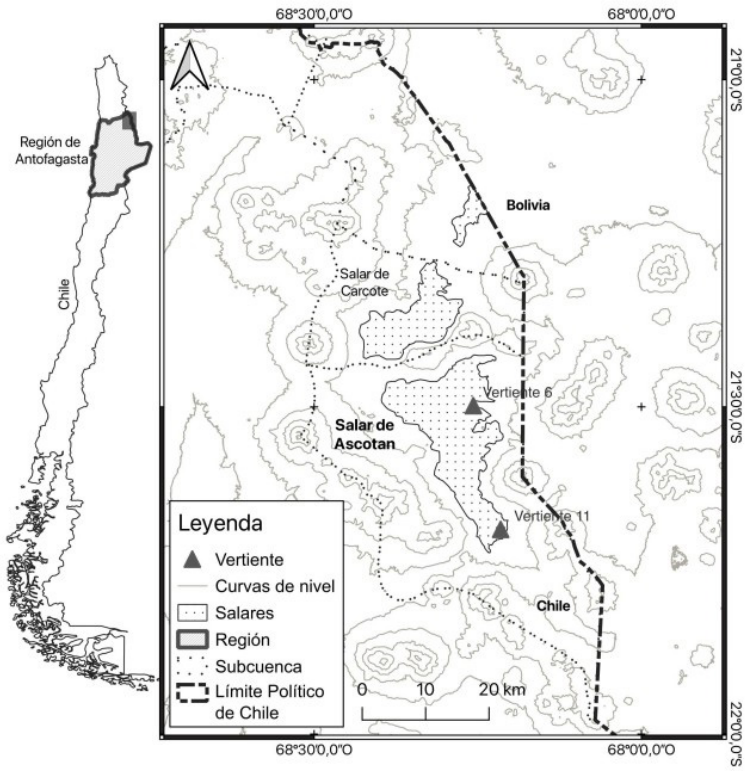

Figure 1. Study area and location of findings.
Figura 1. Área de estudio y ubicación de los hallazgos.

en las vertientes del Salar de Ascotán, los anuros cohabitan con *Orestias ascotanensis* Parenti, 1984, una especie de pez endémica y en peligro de extinción (Vila et al., 2007), la cual no ha sido reportada como presa de *T. philippii* (Lobos et al., 2018). No obstante, el consumo de peces se ha descrito en *Telmatobius* de mayor tamaño, en otros países, como *T. macrostomus* (Peters, 1873) (endémica de los Andes centrales de Perú), depredador de peces de los géneros *Orestias* y *Trichomycterus* (Watson et al., 2017); y *T. culeus* (Garman, 1876) (nativa de Perú y Bolivia) con registro de depredación de peces del género *Orestias* en el lago Titicaca (Muñoz, 2018).

Por otro lado, la dermatofagia es una conducta que ha sido reportada en anfibios, los cuales consumen generalmente la piel desprendida en el proceso de muda (Noble, 1931; Weldon et al., 1993; Kovacs et al., 2007; Sabagh et al., 2008; Fontenot, 2016). Sin embargo, aún se desconocen las causas específicas que motivan el consumo de piel. Se ha sugerido que podría actuar como un mecanismo de recuperación de nutrientes (Bustard & Maderson, 1965) y también para la eliminación de patógenos (Cramp et al., 2014). Por otra parte, se desconoce si esta es una conducta activa o incidental, y si es más frecuente el consumo del tejido del mismo individuo o sus congéneres (Fontenot, 2016).

Como parte de un estudio sobre la ecología de las especies del género *Telmatobius* de la Región de Antofagasta, el día 5 de mayo del año 2022 a las 12:00 h, realizamos un estudio dietario por medio de la técnica del "*stomach flushing*" (Solé et al., 2005). En la vertiente 11 del Salar de Ascotán (21.67850° S, 68.21492° W; datum WGS84) (Fig. 1). Obtuvimos contenidos estomacales de 7 individuos, los cuales fueron almacenados individualmente en tubos de polipropileno con etanol al 50 % para su análisis posterior en laboratorio (Fernández & Domínguez, 2001). Identificamos las presas por medio de una lupa estereoscópica, hasta el máximo nivel de resolución taxonómica posible.

En uno de los individuos (macho, LHC: 49 mm, peso: 17 g) registramos la presencia de restos de tejido epitelial queratinizado (Fig. 2), los cuales asignamos como restos de callos nupciales por medio de una comparación morfológica

con anfibios de la misma especie depositados en la colección del Laboratorio de Genética y Evolución de la Universidad de Chile (Fig. 3); en este animal no registramos presencia de otro tipo de presas.

En otros dos ejemplares (hembra, LHC: 61 mm, peso: 25 g; hembra, LHC: 56 mm, peso: 22.5 g), encontramos restos digeridos de individuos de la especie *O. ascotanensis* (Fig. 4). Sólo uno de los individuos presentó otras presas dentro del contenido gástrico, las cuales correspondieron a un hemíptero de la familia Corixidae y tres gasterópodos de la familia Physidae.

Posteriormente, durante el día 5 de enero del año 2023 a las 10:54 h, registramos en la vertiente 6 (21.48969° S, 68.25701° W; Datum WGS84) (Fig. 1), a un individuo (hembra, LHC: 75 mm, peso: 40 g) depredando a un ejemplar adulto de *O. ascotanensis* (LT: 97 mm, peso: 12 g) (Fig. 5).

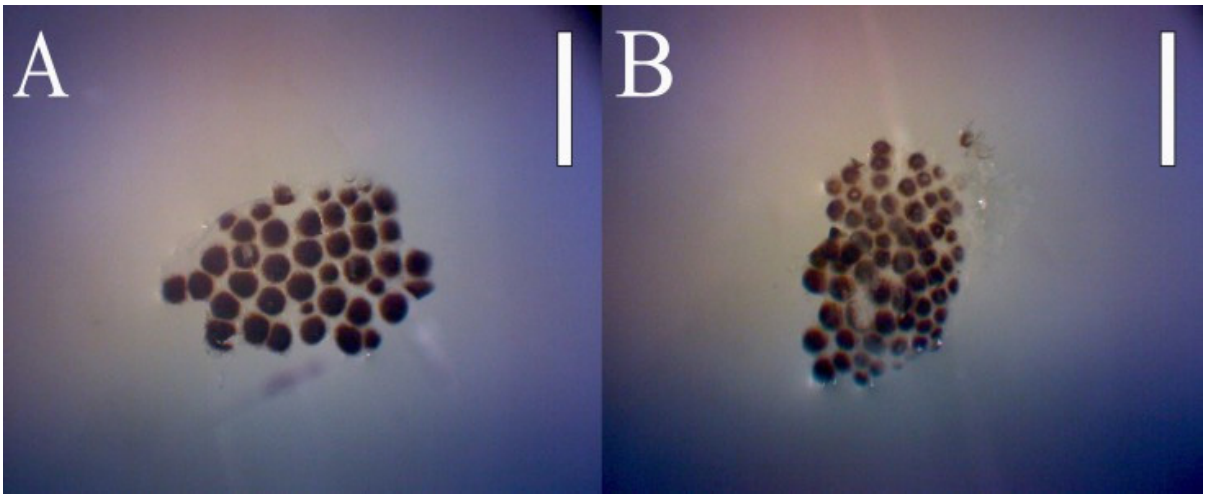

Figure 2. Recording of nuptial pads in the stomach contents of an individual *Telmatobius philippii*. Scale = 1 mm. Photos: Jesús Cornejo Campos.

Figura 2. Registro de callos nupciales en el contenido estomacal de un individuo de *Telmatobius philippii*. Escala = 1 mm. Fotos: Jesús Cornejo Campos.

Figure 3. View of the nuptial pads in an individual of *Telmatobius philippii* from the locality of Amincha (1501025, Universidad de Chile). Scale = 5 mm. Photo: Paola A. Sáez.

Figura 3. Vista del callo nupcial en un individuo de *Telmatobius philippii* de la localidad de Amincha (1501025, Universidad de Chile). Escala = 5 mm. Foto: Paola A. Sáez.

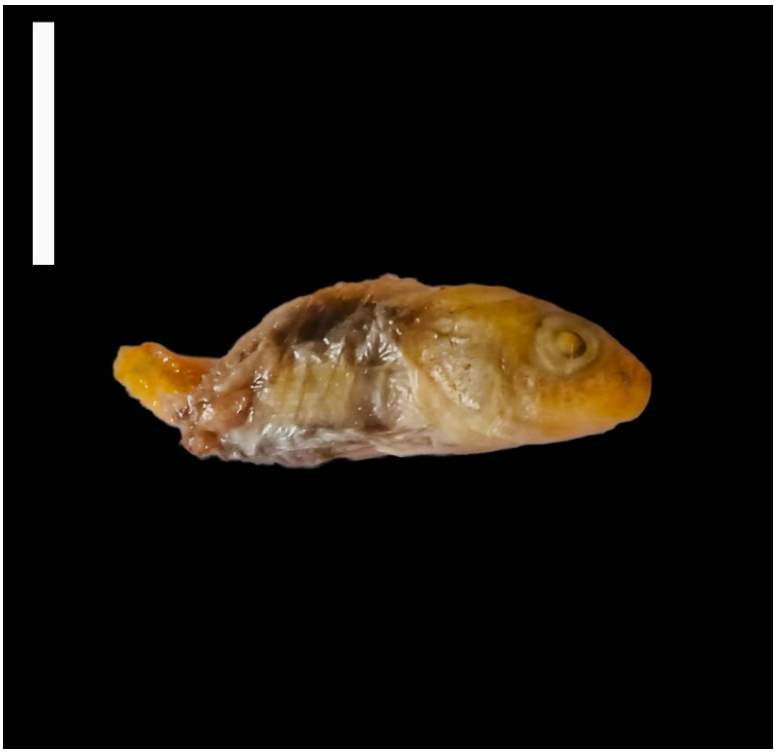

Figure 4. Digested remains of *Orestias ascotanensis* collected from an individual of *Telmatobius philippii*. Scale = 10 mm. Photo: Jesús Cornejo Campos.

Figura 4. Restos digeridos de *Orestias ascotanensis* colectado en un individuo de T*elmatobius philippii*. Escala = 10 mm. Foto: Jesús Cornejo Campos.

Figure 5. Female of *Telmatobius philippii* preying on an individual of *Orestias ascotanensis* on spring 6 of the Salar de Ascotán, Chile. Photo: Gabriel Lobos.

Figura 5. Hembra de *Telmatobius philippii* depredando a un individuo de *Orestias ascotanensis* en la vertiente 6 del Salar de Ascotán, Chile. Foto: Gabriel Lobos.

Los antecedentes aquí reportados, son los primeros para el género en Chile y para *Telmatobius* de talla mediana. Estudios futuros, deberían esclarecer si estos hallazgos son únicamente incidentales o más comunes de lo observado hasta ahora. Por otra parte, las condiciones extremas de estos ambientes de altura pueden forzar a los anuros a estrategias tales como la dermatofagia o la captura de presas más nutritivas como los peces, al menos de manera oportunista.

Por otra parte, las interacciones tróficas descritas son importantes en el contexto del alto grado de amenaza de los anuros y peces del salar. Para el caso de *O. ascotanensis*, se ha reportado que la población de la vertiente 11 corresponde a un grupo diferenciado desde el punto de vista genético, que se caracteriza por presentar la tasa de migración más baja dentro de las poblaciones que habitan las vertientes del salar (Morales et al., 2011; Cruz-Jofré et al., 2016). A nivel de los anfibios, Lobos et al. (2018) reportaron que la vertiente 11 presentó la menor densidad de individuos, y que estos mostraron un índice de condición corporal bajo, lo cual se correlaciona con el mayor grado de perturbación antrópica de este sistema acuático.

El conocimiento de la ecología de estos anuros es de gran relevancia, en especial, cuando en Chile, la nueva Estrategia Nacional del Litio ha considerado al Salar de Ascotán como uno de los salares destinados a la explotación de sales, sin considerar la presencia de anfibios y peces endémicos, gravemente amenazados.

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EFFICIENCY OF DEATH FEIGNING: ANTIPREDATOR MECHANISMS IN *PRISTIMANTIS RAMAGII* (ANURA: STRABOMANTIDAE) DURING A PREDATION ATTEMPT BY *CHIRONIUS FLAVOLINEATUS* (SERPENTES: COLUBRIDAE)

EFICIÊNCIA DA TANATOSE: MECANISMO ANTIPREDATÓRIO EM *PRISTIMANTIS RAMAGII* (ANURA: STRABOMANTIDAE) DURANTE UMA TENTATIVA DE PREDAÇÃO POR *CHIRONIUS FLAVOLINEATUS* (SERPENTES: COLUBRIDAE)

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Resumo.– Este estudo documenta o comportamento de tanatose do sapinho-de-folhiço-da-Paraíba (*Pristimantis ramagii*) em condições *ex-situ*, quando confrontado com uma tentativa de predação pela cobra-cipó não venenosa (*Chironius flavolineatus*). Apesar de predado pela serpente, o mecanismo antipredação do anuro foi eficiente para evitar a predação enquanto realizado. Nossas descobertas comprovam a ocorrência desse comportamento em *P. ramagii* e ressaltam o significado adaptativo da tanatose no aumento da sobrevivência das presas durante encontros predatórios em condições naturais.

Palavras-chave.– Cobra-cipó, dieta, herpetofauna, presa, tática de defesa.

Abstract.– This study documents the death feigning behavior in the Paraíba Robber Frog (*Pristimantis ramagii*) in *ex-situ* conditions when confronted with a predation attempt by the non-venomous snake Boettger's Sipo (*Chironius flavolineatus*). Despite being preyed on by the snake, the amphibian's antipredator mechanism was efficient in avoiding predation while executed. Our findings state the ocurrence of this behaviour in *P. ramagii* and underscore the adaptive significance of death feigning in enhancing prey survival during predatory encounters in natural conditions.

Keywords.– Boettger's sipo, defensive tactics, diet, herpetofauna, prey.

Death feigning, commonly referred to as thanatosis or tonic immobility, is a well-documented antipredator strategy observed across various vertebrate species (Whitman et al., 1986; Giannico, 2014; Muscat et al., 2016; Motte et al., 2018; Pochron & Thompson, 2019; Ferreira et al., 2019). This behavior is evolutionarily advantageous as it can increase an individual's chances of evading predators by inhibiting attacks or preventing subsequent predatory attempts (Miyatake et al., 2004). Death feigning does not occur spontaneously but is typically triggered by specific stimuli associated with predation threats (Greene, 1988; Miyatake et al., 2004).

Death feigning is characterized a mechanism of posture symplesiomorphic in Anura (Ferreira et al., 2019). During this behavior the individual may fully opening their eyes, partially opening their mouths, and relaxing their limbs to simulate

death more convincingly (Toledo et al., 2010). This behavior serves as an effective secondary defense strategy for many species (Sazima, 1974; Toledo et al., 2011; Lourenço-de-Moraes et al., 2016; Ferreira et al., 2019). The interaction between predator and prey during death feigning typically follows an escalated sequence of approach, detection, identification, and a reduction in interaction through the prey's antipredator mechanism (Lourenço-de-Moraes et al., 2016). The interaction concludes with either the prey's escape and survival or the predator's subjugation and consumption of the prey (Humphreys & Ruxton, 2018).

During a study on the predation behavior and diet of the non-venomous snake *Chironius flavolineatus* Boettger, 1885, we offered amphibians of the species *Pristimantis ramagii* (Boulenger, 1888) as prey and observed the thanatosis (death-feigning) behavior of the frog during a predation attempt by the snake *C. flavolineatus*. The snake was captured on November 30, 2018, at 17:30, and the frog on December 11, 2018, at 15:50, both from the same urban forest patch in Jacaraú municipality (6° 39' 36.90" S, 35° 15' 04.40" W), in the state of Paraíba, northeast Brazil. The specimens were collected by hand and housed in a glass terrarium (50 cm x 50 cm x 40 cm) in the animal ecology laboratory at Universidade Federal da Paraíba, Campus IV, under permits SISBIO N°65652-1 and CEUA-UFPB 2485280119. The death feigning behavior and predation attempt were recorded using a Xiaomi® Mijia 1080p smart IP wireless camera.

During an experiment on the feeding behavior of *Chironius flavolineatus* in captivity, an individual of *Pristimantis ramagii* was introduced to the terrarium. The frog is a common species in the northeast Atlantic Forest (Pereira-Filho et al., 2023). It is listed as least concern in The IUCN Red List of Threatened Species (IUCN, 2023) and does not appear on the National List of Threatened Species of Extinction of Brazil (Portaria MMA nº 148, 7 June 2022). There are reports in the literature of *Pristimantis ramagii* in the diet of *Chironius flavolineatus* (Arruda et al., 2024) and being preyed upon by other snake species, such as *Dendrophidion atlantica* and *Leptodeira annulata* (Santos et al., 2018; Lima et al., 2019).

Upon introduction to the terrarium, the frog exhibited escape behavior, including jumping and colliding with the terrarium walls. At the first sign of movement from the snake, the frog immediately adopted death feigning behavior, turning onto its back with its belly facing up and remaining completely immobile with eyes opened (Fig. 1B). This state lasted for 3 min 20 s. During this period, the snake foraged throughout the terrarium and encountered the frog three times without detecting it (Fig. 2 A-F). After the last encounter, the frog made slight movements with its forelimbs and cranial region, preparing for a potential escape (see Ferreira et al., 2019). These movements triggered a predatory response from the snake, leading to the frog's capture and ingestion immediate (Fig. 2 G-H).

Macdonald (1973) noted that active prey is more likely to be targeted by snakes compared to inactive prey. Anurans can maintain the death feigning posture with their bellies facing upwards for up to 5 min before resuming normal behavior and attempting to escape (Toledo et al., 2011; Lourenço-de-Moraes et al., 2016; Ferreira et al., 2019). In this study, the frog remained immobile for over 3 min in a controlled environment, demonstrating the efficacy of death feigning as a survival strategy in *ex-situ* conditions. The snake only detected the prey after it began to move, underscoring the importance of immobility in evading predators. It is important to make it clear that the

Figura 1. Indivíduos recolhidos na área de estudo. A) *Chironius flavolineatus*; B) *Pristimantis ramagii* em posição natural; C) *P. ramagii* durante a simulação de morte. Fotos: A) Vanessa do Nascimento Barbosa, B) e C) Ricardo Lourenço-de-Moraes.

Figure 1. Individuals collected in the study area. A) *Chironius flavolineatus*; B) *Pristimantis ramagii* in natural position; C) *P. ramagii* during death feigning. Photos: A) Vanessa do Nascimento Barbosa, B) and C) Ricardo Lourenço-de-Moraes.

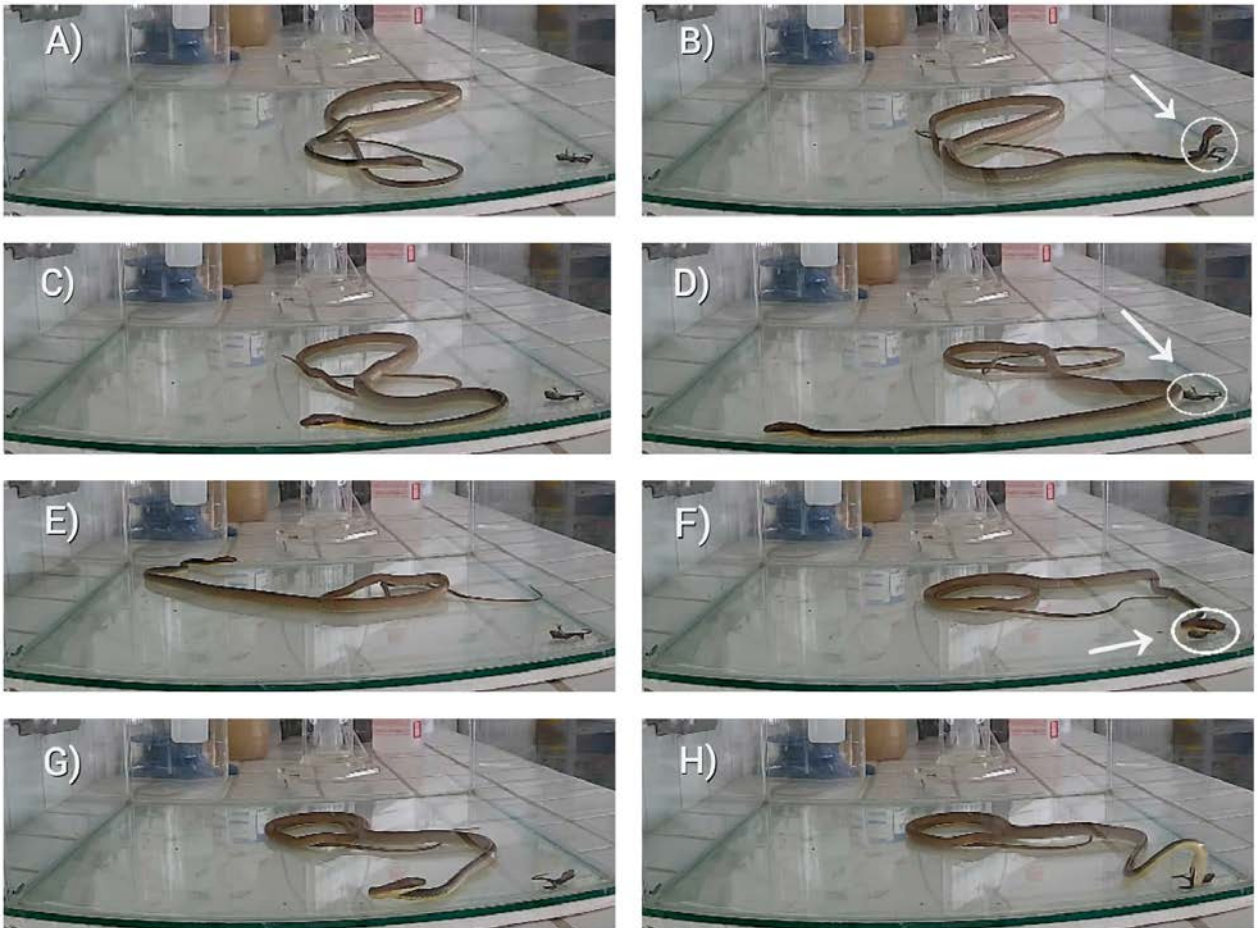

Figura 2. Comportamento de tanatose de *Pristimantis ramagii* e tentativa de predação por *Chironius flavolineatus* registrado em condições de cativeiro em 12 de dezembro de 2018, às 11:00 . A) Início da simulação de morte exibida pelo sapo; B) Primeiro contato da serpente com o sapo; C) Serpente forrageando na parte frontal do terrário; D) Segundo contato entre os espécimes; E) Serpente forrageando na parte de posterior do terrário; F) Terceiro contato entre os espécimes; G) O sapo movimenta cuidadosamente suas patas traseiras; H) Ataque predatório e ingestão da presa pela serpente.

Figure 2. Death feigning behavior of *Pristimantis ramagii* and predation attempt by *Chironius flavolineatus* recorded in captivity conditions on December 12, 2018, at 11:00. A) initial death feigning displayed by the frog; B) Snake's first contact with the frog; C) Snake foraging in the front part of the terrarium; D) Second contact between the specimens; E) Snake foraging in the rear part of the terrarium; F) Third contact between the specimens; G) Frog slightly moving its hindlimbs; H) Predatory strike and prey ingestion by the snake.

behavior of death feigning normally occurs in synergy with the mechanisms of camouflage and release of odoriferous secretion that blends in with the environment (Lourenço-de-Moraes et al., 2016; Ferreira et al., 2019). Thus, the effectiveness of this behavior in a natural environment should be higher when compared to the experiment in the present study. Our observations highlight the effectiveness of death feigning in natural predation scenarios and emphasize its role as an evolutionary survival mechanism for less protected species (Humphreys & Ruxton, 2018).

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NUEVOS REGISTROS DE DISTRIBUCIÓN DE *OEDIPINA ELONGATA* (CAUDATA: PLETHODONTIDAE) EN EL NORTE DE GUATEMALA

NEW DISTRIBUTION RECORDS OF *OEDIPINA ELONGATA* (CAUDATA: PLETHODONTIDAE) IN THE NORTH OF GUATEMALA

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La salamandra tropical centroamericana, *Oedipina elongata* (Schmidt, 1936), es una especie perteneciente a la familia Plethodontidae, siendo la única familia de salamandras que se distribuye en América Central (Köhler, 2011). La especie se distribuye de manera disyunta, teniendo presencia en el estado de Chiapas, México, Guatemala, Belice y Honduras (Fig. 1). (Lee, 1996; Campbell, 1998; Köhler, 2011; Hernández-Ordoñez, et al., 2015). En Guatemala esta especie se ha reportado para los departamentos de Alta Verapaz e Izabal, teniendo pocos registros de colecta. Estos registros escasos pueden deberse a sus hábitos secretivos y fosoriales, ya que la especie suele habitar en lo profundo de troncos podridos, debajo de rocas grandes o bien entre la hojarasca del suelo del bosque, saliendo esporádicamente luego de una intensa lluvia (Lee, 1996). En esta nota reportamos tres registros de distribución para la especie, dos de los cuales son nuevos para el departamento de Petén y uno para el norte de Alta Verapaz, Guatemala.

Guatemala, Petén, Poptún. Reserva de la Biosfera Montañas Mayas (16.42625° N, 89.23486° W; WGS84; 716 m s.n.m.). El 2 de junio de 2022 encontramos un individuo adulto de *Oedipina elongata* (62 mm de longitud hocico-cloaca (LHC); 145 mm de longitud total (LT)); activa en las orillas del Río Machaquilá, en el área de bosque riparo (Fig. 2A y B). El individuo se encontraba entre madera podrida de un gran árbol caído. Este registro representa el primero para la especie en el departamento de Petén, así como el primero en el área de las Montañas Mayas en Guatemala. Lee (1996); Campbell (1998), mencionan que la especie no se conoce en el departamento de Petén; este es el primer registro de la especie colectado para el área. Esto confirma la unicidad de las poblaciones de las Montañas Mayas en Belice y Guatemala, que fueron continuas en el pasado. La especie amplia su rango de distribución hacia el noreste 69 kilómetros (km), desde el sitio de recolecta en Double Falls, Stan Creek, Belice (16.68078° N, 88.63056° W; datum WGS84; 393 m s.n.m.) (Lee, 1996).

Guatemala, Petén, San Luis. Refugio de Vida Silvestre Xutilhá, Comunidad Nacimiento El Cangrejal (16.16578° N, 89.72504° W; WGS84; 265 m s.n.m.). El 31 de octubre de 2023 encontramos un individuo adulto de *Oedipina elongata* (60 mm LHC; 157 mm, LT) (Fig. 2C). Se encontraba caminando encima de un termitero cercano al borde del bosque, a una altura no mayor a 1 m sobre el suelo. Presumiblemente podría estar buscando alimentarse de las termitas. Este registro ocurre al sur desde las Montañas Mayas en la región fisiográfica perteneciente al cinturón plegado de Petén, el cual posee una fisiografía única ya que consta de diversos cerros de origen kárstico (Marshall, 2007). El área se encuentra rodeada por cultivos de milpa y la presencia de la comunidad Nacimiento El Cangrejal; se puede encontrar basura dentro del área del bosque, lo que podría afectar a la fauna local. Debido a la perdida de los bosques, las poblaciones de esta área han quedado aisladas de las poblaciones que se encuentran al norte en el área de Montañas Mayas. Este registro extiende la distribución de la especie en 79 km al noreste, desde el punto ubicado en Finca El Volcán, Senahú, Alta Verapaz (15.4833° N, 89.8666°W; datum WGS84; 875 m s.n.m.) (GBIF, 2024).

Guatemala, Alta Verapaz, Cobán. Parque Nacional Laguna Lachuá (15.94266 N, 90.65800° W; WGS84; 190 m s.n.m.). El 3 de octubre de 2011 se encontró (EML015) un espécimen de *Oedipina elongata* (55 mm LHC; 127 LT); sobre la fronda de un helecho a 30 cm del suelo, por el sendero principal en los primeros 2 km, desde la entrada principal del parque (Fig. 2D). Este es el primer registro de la especie al norte de Alta Verapaz, ya que de este departamento se conoce únicamente su distribución en el área

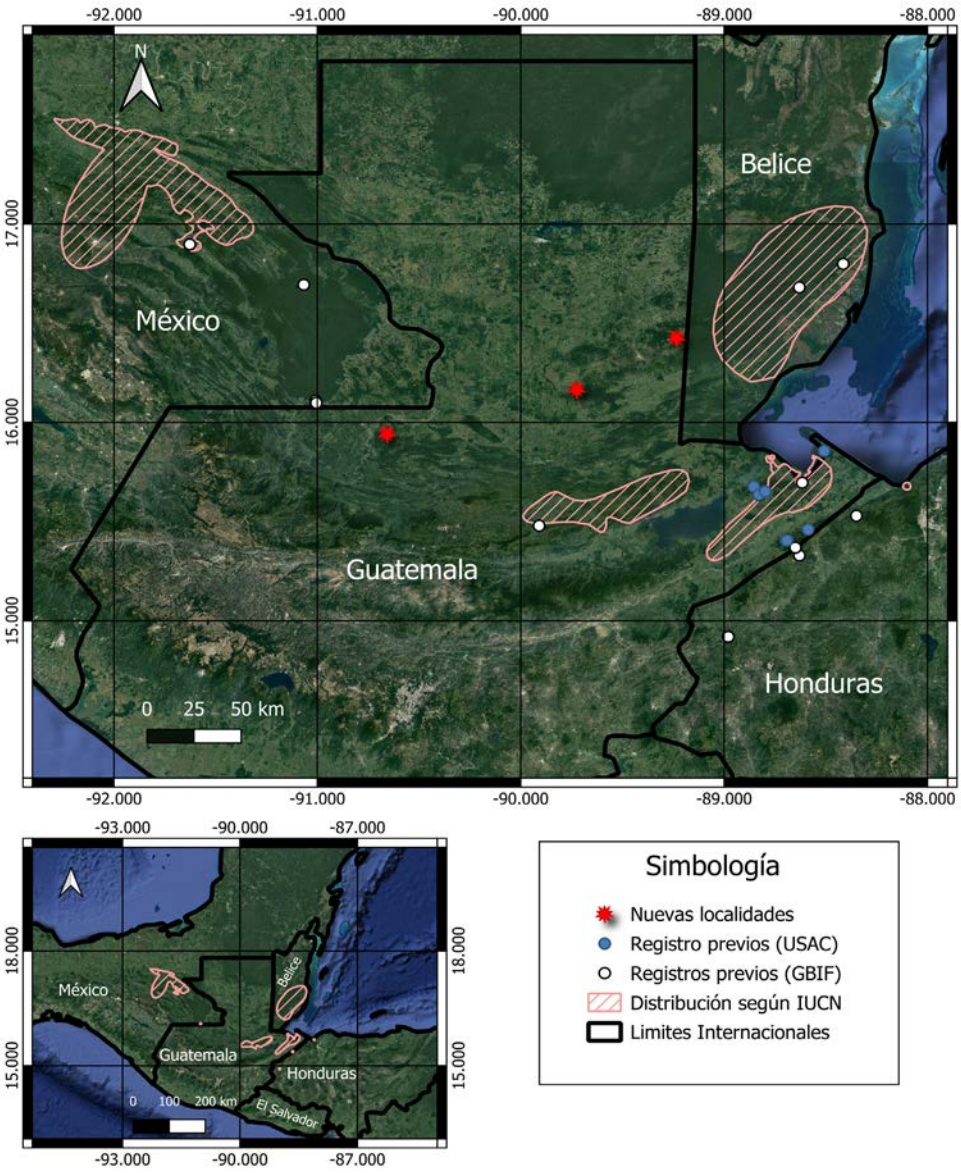

Figure 1. Geographic distribution of *Oedipina elongata* in Guatemala, Mexico, Belize and Honduras. Red stars indicate new distribution records resulting from the present study. Blue (USAC) and White (GBIF) dots indicate previous records, areas with diagonal stripes correspond to the distribution according to the IUCN (IUCN SSC Amphibian Specialist Group, 2020).

Figura 1. Distribución geográfica de *Oedipina elongata* en Guatemala, México, Belice y Honduras. Las estrellas rojas indican los nuevos registros de distribución resultado del presente estudio. Los puntos azules (USAC) y blancos (GBIF) indican registros previos, las áreas con rayas diagonales corresponden a la distribución según la IUCN (IUCN SSC Amphibian Specialist Group, 2020).

de Senahú específicamente de Finca el Volcán. Este registro extiende la distribución 37 km, al sureste de la localidad limítrofe a la Reserva de la Biosfera en Montes Azules, Chiapas, México (16.09° N, 90.98° W, 170 m s.n.m.) (GBIF, 2024; Hernández-Ordoñez et al., 2015). Todos los especímenes fueron identificados utilizando las guías de campo de Lee (1996), Campbell (1998) y Köhler (2011). Los especímenes encontrados en el departamento de Petén fueron fotografiados en vida; mientras que el individuo de Laguna Lachuá fue fotografiado ya preservado. Todos los especímenes fueron colectados de forma manual; sacrificados utilizando la anestesia Cloretone; los ejemplares fueron fijados con formol al 10 % y posteriormente preservados en alcohol al 70 %. Estos fueron depositados en la colección de referencia de anfibios y reptiles de la Universidad de San Carlos de Guatemala (USAC), Ciudad de Guatemala (Tabla 1). Solo se tomaron los datos de GBIF pertenecientes a colectas de especímenes depositados en colecciones de distintas universidades y/o museos.

Estos registros extienden la distribución de *O. elongata* 37 km hacia el sureste de Alta Verapaz desde el punto en Chiapas, México, y 69 km en dirección oeste hacia Petén desde el punto en Stann Creek, Belice y 79 km hacia el noreste desde Finca

Figure 2. Specimens of *Oedipina elongata* in different localities: A y B) Poptún, Petén; C) San Luis, Petén; D) Cobán, Alta Verapaz. Photos: José E. Cifuentes-Flores (A and B), Mario R. Rivera-Yurrita (C and D).

Figura 2. Especímenes de *Oedipina elongata* de diferentes localidades: A y B) Poptún, Petén; C) San Luis, Petén; D) Cobán, Alta Verapaz. Fotos: José E. Cifuentes-Flores (A y B), Mario R. Rivera-Yurrita (C y D).

Table 1. Localities of the new records of *Oedipina elongata* in Guatemala. / **Tabla 1.** Localidades de los nuevos registros de *Oedipina elongata* en Guatemala.

Número USAC	Departamento	Localidad	Latitud	Longitud	msnm
USAC 5297	Petén	Poptún, Reserva de la Biosfera Montañas Mayas, Río Machaquilá	16.42625°	89.23486°	716
USAC 6063	Petén	San Luis, Refugio de Vida Silvestre Xutilhá,	16.16578°	89.72504°	265
USAC 3380	Alta Verapaz	Cobán, Parque Nacional Laguna Lachuá	15.94266°	90.65800°	190

El Volcán, Alta Verapaz hacia el departamento de Petén. Esta especie ocurre desde el nivel del mar hasta los 770 m s.n.m., por lo que los nuevos registros se encuentran en el rango altitudinal conocido de la especie (Köhler, 2011). Esta especie de salamandra se encuentra en la categoría de "Preocupación menor", según la lista roja de IUCN (IUCN SSC, 2020). Según el LEA-CONAP de Guatemala, la especie se encuentra en la Categoría 3, como Vulnerable para el país (Consejo Nacional de Áreas Protegidas, 2022).

La Reserva de la Biosfera Montañas Mayas, Refugio de Vida Silvestre Xutilhá y el Parque Nacional Laguna Lachuá, son tres áreas protegidas que presentan amenazas fuertes debido al incremento de la frontera agrícola, ganadera, el monocultivo de Palma Africana y la deforestación (IUCN, 2020). Estas tres áreas protegidas han perdido una gran cantidad de hectáreas de bosque, quedando parches de bosques sin conectividad entre sí. La especie habita en sitios bastante húmedos, es posible que ocurra más al norte de Petén en la Reserva de la Biosfera Maya (RBM), pero hasta la fecha no se cuentan con registros ni fotográficos ni de colecta.

Agradecimientos.– Para el personal de guardarecursos del CONAP, Poptún, y al personal de la Asociación BALAM ONG por el acompañamiento a las áreas protegidas del sureste de Petén; al Ing. Oscar Zuñiga y el Ing. Ronaldo Chacón por la coordinación para el ingreso a las áreas. Un agradecimiento especial para Muhammad Mayén y Dulce Herrera por haber encontrado el primer registro de la salamandra para el área de Montañas Mayas del lado de Guatemala; así como para Billy Hernández y Muhammad Mayén por acompañar durante el encuentro del segundo registro de la salamandra para el departamento de Petén. Un agradecimiento a CONAP, Petén por proporcionar las licencias de colecta No. 0719-B y No.0753-B y la licencia de investigación No.0010-C, con la que se colectaron los datos que acá presentamos.

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NEW PREY ITEM IN THE DIET OF THE CALIFORNIA RED-LEGGED FROG (*RANA DRAYTONII*) FROM BAJA CALIFORNIA, MEXICO

NUEVA PRESA EN LA DIETA DE LA RANA DE PATAS ROJAS DE CALIFORNIA (*RANA DRAYTONII*) DE BAJA CALIFORNIA, MÉXICO

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Resumen.– Para proteger especies amenazadas como la rana de patas rojas de California (*Rana draytonii*), es importante conocer su historia natural, incluyendo las relaciones de la red alimenticia. Reportamos las primeras observaciones de *R. draytonii* comiendo e intentando comer avispas caza tarántulas (*Pepsis* sp.) en los matorrales montanos xerofíticos de Baja California.

Palabras clave.– Avispa caza tarántulas, depredación, dieta, rana.

Abstract.– To protect threatened species such as the California red-legged frog (*Rana draytonii*) it is important to understand their natural history, including food web relationships. We report the first observations of *R. draytonii* eating and attempting to eat tarantula hawk wasps (*Pepsis* sp.), based on observations from the xerophytic montane shrublands of Baja California.

Keywords.– Diet, frog, predation, tarantula hawk wasp.

The California red-legged frog (*Rana draytonii*) is distributed from central California, USA, to northwestern Baja California, Mexico, and is the largest native frog in western North America (Linsdale, 1940; Reaser, 2003; Backlin et al., 2017). It is an endangered species in Mexico (Peralta-García et al., 2016), and its habitat (Reis, 1999; Fellers & Kleeman, 2007; Halstead et al., 2018) and reasons for population decline (Kiesecker & Blaustein, 1997; Gilliland, 2010; Alcala et al., 2019) have been comparatively well documented. The species is known to have a broad and variable diet (Bishop, 2011), with adults largely feeding on invertebrates but also taking other amphibians and small mammals (Hayes & Tennant, 1985; Ford et al., 2013; Bishop et al., 2014). Nonetheless, knowledge gaps still exist concerning the feeding habits of *R. draytonii*. Here we report the first observation of *Rana draytonii* as a predator of tarantula hawk wasps (*Pepsis* sp.).

On October 29, 2023 at 10:42 h, at Rancho Meling, Sierra San Pedro Mártir, Municipality of Ensenada, Baja California, Mexico (30.9756° N, 115.7444° W; datum WGS 84; 640 m a.s.l.), while doing pond maintenance focused on improving habitat for *R. draytonii*, we observed a tarantula hawk wasp (*Pepsis* sp.) active on leaf litter at the pond edge. An adult *R. draytonii* resting in shallow water moved toward the wasp, grasped it by its anterior end, and then returned to the pond edge whereupon it swallowed the wasp (Fig. 1). A couple of minutes later, another tarantula hawk wasp appeared, and a different adult *R. draytonii* repeatedly struck this second wasp. In its second strike, the frog caught the wasp from the posterior end but the wasp immediately stung the frog on the tongue, causing the frog to expel it (Fig. 2). The frog scratched its mouth with its front legs before returning to the water. We suspect that the successful predation of the first *Pepsis* individual was due to it being a male, which lack stingers (Salman, 1930; Schmidt, 2016). The second predation attempt was clearly unsuccessful due to the wasp being a female.

Among frogs, only the American bullfrog (*Rana catesbeiana*) has been verified to eat members of the genus *Pepsis* (Krupa, 2002; Akmentins et al., 2009). A single record does exist of remains of an unidentified wasp from the Pompilidae family (to which *Pepsis* belongs) being recovered from the stomach of

Figura 1. An adult *Rana draytonii* successfully eating a tarantula hawk wasp (*Pepsis* sp.), with the wasp's abdomen and hindlegs still visible in the frog's mouth. Photo: David Mora Giles.

Figure 1. Ejemplar adulto de *Rana draytonii* comiendo exitosamente a una avispa caza tarántulas (*Pepsis* sp.), con el abdomen y las patas traseras de la avispa aún visibles en la boca de la rana. Foto: David Mora Giles.

a *R. draytonii* (Bishop et al., 2014). However, the observations reported in this contribution are the first confirmed records of predation or attempted predation of *Pepsis* by *R. draytonii*.

Insects have developed various strategies to deter predation (Feldhaar, 2011; Lindstedt, et al., 2019), but *Pepsis* sp. wasps largely rely on aposematism (metallic blue bodies and orange wings) to alert potential predators to the venomous sting possessed by females (Schmidt, 2004; Schmidt, 2016). Our observations confirm that aposematism can fail to deter predation by *R. draytonii*. This might be related to frogs' feeding response being generally stimulated by the presence of any potential prey entering their field of vision (Schulte, 2012), and aposematism has been shown to delay but not necessarily prevent attacks on solitary prey in another frog species (Hatle & Salazar, 2001).

Figura 2. Photo sequence (A–D) of a second adult *Rana draytonii* unsuccessfully attempting to eat a tarantula hawk wasp (*Pepsis* sp.). Photo: David Mora Giles.

Figure 2. Secuencia de fotos (A–D) de segundo adulto de *Rana draytonii* intentado comerse sin éxito una avispa caza tarántulas (*Pepsis* sp.) (A–D). Foto: David Mora Giles.

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https://www.youtube.com/watch?v=I98NIfVh-RQ

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ÁCAROS (ACARIFORMES: PROSTIGMATA) PARÁSITOS DE *SCELOPORUS VARIABILIS* (REPTILIA: PHRYNOSOMATIDAE) EN LA ZONA DE LAS ALTAS MONTAÑAS, VERACRUZ, MÉXICO

PARASITIC MITES (ACARIFORMES: PROSTIGMATA) ON *SCELOPORUS VARIABILIS* (REPTILIA: PHRYNOSOMATIDAE) IN THE HIGH MOUNTAIN AREA OF VERACRUZ, MEXICO

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Abstract.— In reptiles, ectoparasitism is recurrent and is caused by ticks or other mites, causing dermatitis and other skin diseases. The objective of the study was to describe the characteristics of mite infestations (abundance, interval, intensity and prevalence) in the pink-bellied spiny lizard (*Sceloporus variabilis* Wiegmann, 1834; Squamata: Phrynosomatidae) in the municipality of Córdoba, Omealca and Amatlán de Los Reyes belonging to the area of the Altas Montañas, Veracruz, Mexico, as well as to relate if there exists a relationship between lizard body characteristics and mite abundance. Fourteen specimens of *S. variabilis* were collected and classified by sex and age, and mites were removed from different parts of the body. A total of 145 mites were extracted and identified as *Eutrombicula alfreddugesi* (Trombiculidae) (prevalence was 92.9 %; abundance: 10.4 mites and range: 1-46 mites); *Geckobiela variabilis* (Pterygosomatidae), 42 (prevalence: 64.2 %; abundance: 3 mites and range: 1-13 mites) and only 20 unidentified individuals. The largest number of mites was present under the scales in the axillary and lateral areas. The evaluation analysis showed that the lizards had a greater number of *E. alfreddugesi* on the head; while *G. variabilis* was located on the arms and tail; regarding the sex of the lizards, it was not an important factor affecting the parameters of mite infestation, so other behavioral and environmental factors influence its high prevalence.

Keywords.— Mite, ectoparasitism, lizard, Phrynosomatidae, Trombiculidae.

Resumen.— En reptiles, el ectoparásitismo es recurrente y es causado por garrapatas u otros ácaros, produciéndoles dermatitis y otras enfermedades de la piel. El objetivo de este estudio fue describir las características de las infestaciones por ácaros (abundancia, intervalo, intensidad y prevalencia) en la lagartija espinosa de vientre rosado (*Sceloporus variabilis* Wiegmann, 1834; Squamata: Phrynosomatidae) en el municipio de Córdoba, Omealca y Amatlán de Los Reyes pertenecientes a la zona de las Altas Montañas, Veracruz, México, así como relacionar sus características corporales con la abundancia de ácaros. Se recolectaron 14 ejemplares de *S.*

variabilis, fueron clasificados por sexo y edad y se les extrajeron los ácaros de las diferentes partes del cuerpo. Se extrajeron 145 ácaros que fueron identificados como *Eutrombicula alfreddugesi* (Trombiculidae) (prevalencia fue 92.9 %; abundancia: 10.4 ácaros e intervalo: 1-46 ácaros); *Geckobiela variabilis* (Pterygosomatidae) 42 (prevalencia: 64.2 %; abundancia: 3 ácaros y el intervalo: 1-13 ácaros) y solo 20 individuos no identificados. La mayor cantidad de ácaros se presentó por debajo de las escamas de la zona axilar y lateral. El análisis de correlación mostró que las lagartijas tenían mayor cantidad de *E. alfreddugesi* en la cabeza; mientras que *G. variabilis* se ubicaba en los brazos y cola; con respecto al sexo de las lagartijas no fue un factor importante que afecte los parámetros de infestación por ácaros, por lo que otros factores de comportamiento y ambientales influyen en su alta prevalencia.

Palabras clave.— Ácaro, ectoparasitismo, lagartijas, Phrynosomatidae, Trombiculidae.

INTRODUCCIÓN

El parasitismo es un tipo de asociación biológica entre organismos de diferentes especies, en la que uno de ellos (parásito), obtiene beneficio de esta relación y vive a expensas del otro (hospedero). Por ejemplo, las células del tejido epitelial y lifático sirven de reserva nutricional para las larvas y en otras ocasiones pueden causar daño a diversos grupos de vertebrados como aves, mamíferos y reptiles (Olalla-Herbosa & Tercero-Gutiérrez, 2011). De acuerdo con su ubicación en el hospedero, el parásito se clasifica en endoparásito (interno o endoparásito) y ectoparásito (externo o ectoparásitos) que se encuentran en la capa superficial de la piel (Levinson, 2012). En reptiles, el ectoparasitismo es frecuente y por lo regular es causado por garrapatas y otros ácaros (García-De la Peña et al., 2004).

Los ácaros ectoparásitos se ubican debajo de las escamas del hospedero, en zonas como los conductos auditivos, en las articulaciones del codo, cuello, axilas y costados, donde no son alcanzados por los reptiles; son vectores de microorganismos patógenos y pueden causar diversas enfermedades como anemia, dermatitis, debilitamiento y/o actividad reducida (Fajfer, 2012). Para reptiles, de acuerdo con la propuesta de Fajfer (2012) se conocen 15 familias de los subórdenes Mesostigmata e Ixodida (órden Parasitiformes) y subórden Prostigmata (Orden Acariformes). Ya que es una clasificación diferente Lindquist et al. (2009), destaca la familia Trombiculidae, cuyas especies y parasitosis son comunes en los países tropicales y templados del mundo, sin embargo, en los trombicúlidos únicamente la etapa larval es parásita (Roberts et al., 2013).

Los trombicúlidos son ectoparásitos de una gran cantidad de vertebrados terrestres (Hoffmann, 1990; Paredes-León et al., 2008) y es conocido que las larvas de estos ácaros pueden atacar animales domésticos y producirles dermatitis (Hoffmann, 1990). Existen más de 165 especies de trombicúlidos y todos son ectoparásitos, con un mayor número de registros de hospederos para la especie *Eutrombicula alfreddugesi* y para *E. batatas* (Hoffmann, 1990). *E. alfredugesi* se ha registrado en al menos 34 especies de reptiles (Paredes-León et al., 2008), se encuentra con mayor frecuencia en varias familias del orden Squamata (Baak-Baak et al., 2020), particularmente en lagartijas con distribución geográfica en el estado de Veracruz como *Ameiva undulata undulata*, *Basiliscus vittatus* y *Sceloporus variabilis variabilis* (Paredes-León et al., 2008); recientemente se descubrió una nueva especie de ácaro, *Geckobiela variabilis* (Pterygosomatidae), que coexiste con *E. alfredduguesi*, reportada en individuos de *S. variabilis* en Catemaco, Veracruz y de la cual, se cuenta con escaso conocimiento acerca de su parasitismo (Paredes-León & Guzmán-Cornejo, 2015).

En los últimos años se publicó una cantidad importante de reseñas monográficas sobre las relaciones parásito-hospedero de ácaros asociados con mamíferos y aves, pero estudios de este tipo de relación inter-específica entre ácaros y reptiles o anfibios, han recibido una atención limitada (Fajfer, 2012). En México, los artrópodos más estudiados son aquellos que afectan directamente a la salud pública, como los mosquitos y las garrapatas (Baak-Baak et al., 2020) y a pesar de los esfuerzos por documentar la diversidad de estos artrópodos, algunos han pasado desapercibidos (Torres-Chable et al., 2017). Aunque México posee una gran cantidad de estos reptiles, los estudios sobre ectoparásitos aún son limitados (García-De la Peña et al., 2010).

El conocimiento de la relación entre ácaros y lagartijas es relevante desde el punto de vista ecológico y de la salud del hospedero (García-De la Peña et al., 2010). Además, la documentación de la diversidad de artrópodos de importancia médica y veterinaria sigue siendo un aspecto relevante para la salud humana y veterinaria, pues al conocer la distribución regional de los artrópodos y sus hospederos, permite el diseño

e implementación de estrategias de prevención y control de enfermedades, para aquellos organismos que tienen roles potenciales como reservorios o vectores (Baak-Baak et al., 2020). Con base en lo anterior, el presente trabajo tiene como objetivo describir las características de las infestaciones por ácaros (abundancia, intervalo de intensidad y prevalencia) en la lagartija espinosa de vientre rosado, *Sceloporus variabilis*, del municipio de Córdoba, Omealca y Amatlán de Los Reyes, perteneciente a la zona de las Altas Montañas, Veracruz, México, así como relacionar sus características corporales con la abundancia de ácaros. *S. variabilis* es una especie que se considera un modelo biológico para estudiar la interacción parásito-hospedero (Mora-Collado et al., 2020) debido su amplia distribución y adaptación a áreas fragmentadas, por lo que es posible colectar ejemplares para su estudio sin afectar a sus poblaciones, además de que no se encuentra en riesgo (Chaves et al., 2013; Montiel et al., 2023) y es recomendable realizar estudios de las nuevas especies de ácaros ectoparásitos reportadas para esta lagartija en su rango de distribución geográfica (Paredes-León & Guzmán-Cornejo, 2015).

MATERIALES Y MÉTODOS

El presente estudio se realizó en diferentes localidades de los municipios de Córdoba, Omealca y Amatlán de los Reyes, los cuales pertenecen a la región denominada Las Altas Montañas, ubicada en la zona centro del estado de Veracruz, México, basado en un muestreo por conveniencia (Fig. 1); estos municipios cuentan con bosques tropicales, en esta región estos ecosistemas están dominados por una mezcla de especies representativas de vegetación de selva mediana y alta perennifolia (Miranda & Hernández-X, 1963). Considerando un gradiente de altitud, los ejemplares de S. variabilis fueron recolectados en las siguientes localidades con base en el criterio altitudinal: localidad de Omealca, municipio de Omealca a 420 m s.n.m; localidades Cerro de Lourdes y Peñuela del municipio de Amatlán de los Reyes a 742 m s.n.m; y en el municipio de Córdoba a 861 m s.n.m.

En campo, se realizó una recolecta de ejemplares de *S. variabilis* de tipo incidental, los organismos fueron colocados en

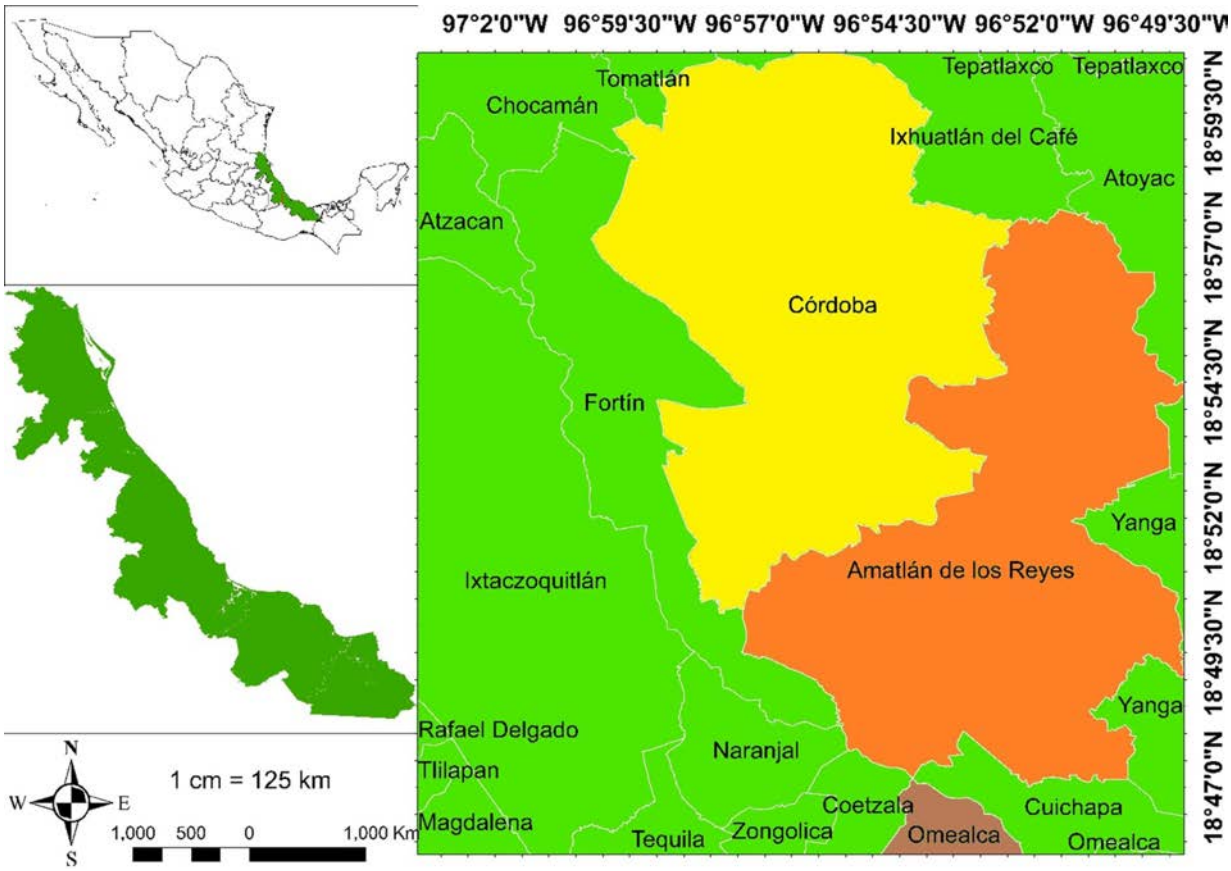

Figure 1. Omealca, Amatlán de los Reyes and Cordoba municipalities in Veracruz state where *Sceloporus variabilis* collections were carried out.

Figura 1. Municipios Omealca, Amatlán de los Reyes y Córdoba del estado de Veracruz donde se realizaron las recolectas de *Sceloporus variabilis*.

bolsas de manta y posteriormente se trasladaron al Laboratorio de Microscopia Óptica de la Facultad de Ciencias Biológicas y Agropecuarias de la Universidad Veracruzana, donde se recabaron las características morfométricas (longitud total-LT, longitud hocico cloaca-LHC, ancho de la cabeza-AC, largo de la cabeza-LC y el largo del brazo izquierdo-LB), se registró el sexo (macho y hembra) con base en su dimorfismo sexual y se determinó la categoría de edad de cada individuo, con base en la reportada para la especie (3.5 cm de LHC; Montiel et al., 2023). Las lagartijas fueron sacrificadas por hipotermia, se colocaron en cajas Petri y los ectoparásitos fueron removidos con una pinza de punta fina con ayuda de un microscopio de disección binocular (marca Carl Zeiss®, modelo Axiostar con cámara para microscopio Industrial Digital Camera 10 MP, ½ 3" Color, Aptina Cmos Sensor) y un microscopio de disección marca Velab® con pantalla digital integrada (Digital LCD Stereo Microscope G Series). Los ácaros fueron depositados en viales de polietileno con alcohol al 70 % y fueron contabilizados y clasificados con base en el sexo y categoría de edad de las lagartijas; asimismo, se anotaron las zonas corporales (cuello, axilas, laterales) y la cantidad de ácaros encontrados. Las lagartijas fueron recolectadas bajo la Licencia de Colecta Científica con Propósitos de Enseñanza en Materia de Vida Silvestre (SGPA/DGVS/001894/18) emitida por la Subsecretaria de Gestión para la Protección Ambiental, de la Dirección General de Vida Silvestre, Secretaria de Medio Ambiente y Recursos Naturales y fueron depositados para su resguardo en el Laboratorio de Microscopia de la Facultad de Ciencias Biológicas y Agropecuarias.

Para la identificación taxonómica de los ácaros se recurrió a la técnica de microscopia óptica o de campo claro (Sánchez, 2011), que consiste en aclarar a los ácaros con lactofenol para la distinción de los caracteres morfológicos y aunque fueron montados en laminillas no se conservaron adecuadamente, y se compararon con las claves taxonómicas y literatura para identificar a nivel familia, género y especie a la que pertenecen (Hoffmann, 1990; Paredes-León & Guzmán-Cornejo, 2015). Los ácaros fueron fotografiados con Microscopía Electrónica de Barrido Ambiental (ESEM), en la Central de Instrumentación y Microscopia Electrónica Ambiental/Confocal/Fuerza Atómica del Departamento de Biotecnología del Instituto Politécnico Nacional, siguiendo la metodología de Delgado-Núñez et al. (2020). Para ello, las muestras se montaron en soportes de aluminio, adheridos sobre cinta conductora de carbono de doble cara y un detector de electrones retro-dispersos en 20 kV y 20 Pa de presión. Las muestras se observaron directamente y las imágenes se capturaron a una ampliación 200 X y 1000 X en formato TIFF (2048 × 1536 píxeles) en un Microscopio Carl Zeiss (modelo EVO LS10; Múnich, Alemania). Además, se implementó la técnica de microscopia Confocal láser de barrido (CLSM), donde las muestras se montaron en portaobjetos de vidrio para ser observadas en modo lambda en paralelo, se obtuvo una secuencia de imágenes a longitudes de onda láser de 405 nm, 488 nm, 561 nm y 640 nm (4 % de capacidad) en un microscopio Carl Zeiss A modelo LSM 800 (Múnich, Alemania). Las imágenes fueron tomadas a 20 X y 40 X con el Plan Apocromático, 1.3 apertura numérica y 1 Unidad Airy (AU) de una abertura estenopeica. Se obtuvieron las imágenes a una resolución de 2048 x 2048 píxeles en formato TIFF. Para las fotografías a color de las muestras montadas en el portaobjetos de vidrio y observadas mediante microscopía confocal, se tomaron utilizando una cámara HD acoplada (AxioCam, Carl Zeiss, Modelo 305, color, Göttingen, Alemania). Las imágenes fueron manejadas utilizando el software de edición Zeiss ZEN 2.6 (Blue edition).

Con la cantidad de ácaros contabilizados, se evaluaron las características de la infestación de *S. variabilis* tomando en cuenta la estimación de la abundancia, intervalo y la prevalencia, que son indicadores para cuantificar a los parásitos a partir de hospederos (Rózsa et al., 2000); también se estimó la proporción de ácaros por sexo y categoría de edad de las lagartijas. Para probar la hipótesis de la relación tamaño-cantidad de ácaros, se aplicó un análisis de correlación con los datos morfológicos de las lagartijas y la cantidad de ácaros en el software PAST (Hammer et al., 2001).

RESULTADOS

Se recolectaron 14 individuos de la especie *S. variabilis* en los tres municipios de la zona centro en las Altas Montañas, Veracruz, de los cuales, 2 correspondían a hembras adultas (14 %) y 12 a machos (86 %). Los ejemplares mostraron variación en las distintas medidas corporales que se les tomaron (Tabla 1), después de determinar la talla mínima a la madurez sexual (3.5 cm de LHC) para clasificar la categoría de edad de las lagartijas, resultaron 13 adultos y 1 juvenil. En la observación microscópica de ectoparásitos en la superficie de las lagartijas estudiadas (Fig. 2), se encontró un total de 207 ácaros (145 *E. alfreddugesi*, 42 *G. variabilis* y 20 sin identificar) (Fig. 3).

El análisis de correlación entre las especies mostró que *E. alfreddugesi* se encuentra mayormente en cabeza, mientras que *G. variabilis* se localizaba en la cola y brazos de las lagartijas (Fig. 4); sin embargo, para la variable de sexo la mayor cantidad de ácaros se presentó en machos con 58 ácaros (46 ejemplares de *E. alfreddugesi* y 7 ejemplares de *G. variabilis* y 5 sin identificar) por ejemplo en un individuo macho, los adultos de mayor tamaño

Table 1. Measures of the *Sceloporus variabilis* specimens captured by municipality and classified by sex and number of mites reported.

Tabla 1. Medidas de los ejemplares de *Sceloporus variabilis* recapturados por municipio y clasificados por sexo y cantidad de ácaros reportados.

No.	Sexo	LT	LHC	AC	LC	LB	*Eutrombicula alfreddugesi*	*Geckobiella variabilis*	S/I	Total	Municipio
1	M	13.2	5	1.2	2	0.5	5	0	0	5	Omealca
2	M	13	4.5	1.5	3	2	15	13	0	28	Omealca
3	M	9.1	8.1	1.2	1.4	1.1	2	2	0	4	Córdoba
4	M	12.5	5	1	1.5	1.5	1	5	0	6	Omealca
5	M	14.3	6.1	1.3	1.2	2.5	2	0	0	2	Córdoba
6	M	9	4.5	0.5	1.5	3	25	6	0	31	Amatlán de los Reyes
7	M	15.5	7	1.7	1.5	3.5	46	7	5	58	Amatlán de los Reyes
8	M	4.5	2.5	0.5	0.8	1	2	0	1	3	Amatlán de los Reyes
9	M	13.5	6	1	2.1	1.7	1	0	1	1	Amatlán de los Reyes
10	M	11.3	5.3	1.1	1.2	2.6	1	3	0	4	Córdoba
11	M	5.7	4.5	0.9	1.3	1.9	4	0	0	4	Córdoba
12	H	11	5.5	1	1.5	2	2	3	0	5	Omealca
13	M	9	4.5	1.5	2	0.5	39	2	13	54	Amatlán de los Reyes
14	H	10	7	1.5	2	1.5	0	1	0	1	Amatlán de los Reyes
Promedio		**10.8**	**5.3**	**1.1**	**1.6**	**1.8**	**145**	**42**	**20**	**206**	

Figure 2. a) Specimen of *Sceloporus variabilis*. b) Ectoparasites located in the neck of the specimen.

Figura 2. a) Ejemplar de *Sceloporus variabilis*. b) Ectoparásitos ubicados en el cuello del ejemplar.

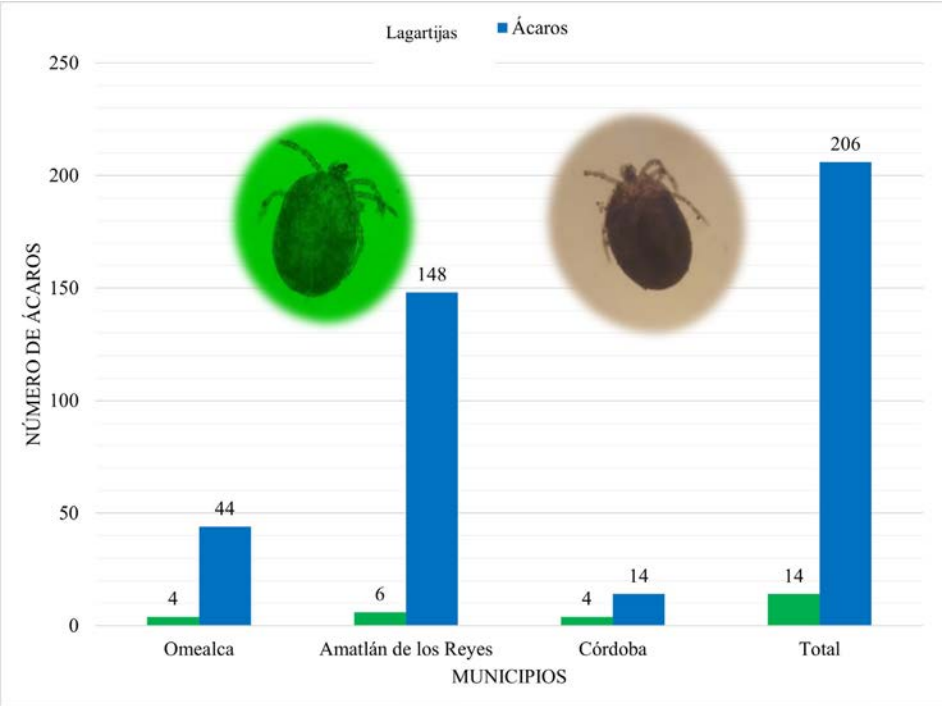

Figure 3. Number of *E. alfreddugesi* mites found on *S. variabilis* by municipality of collection.

Figura 3. Cantidad de ácaros de *E. alfreddugesi* encontrados en *S. variabilis* por municipio de colecta.

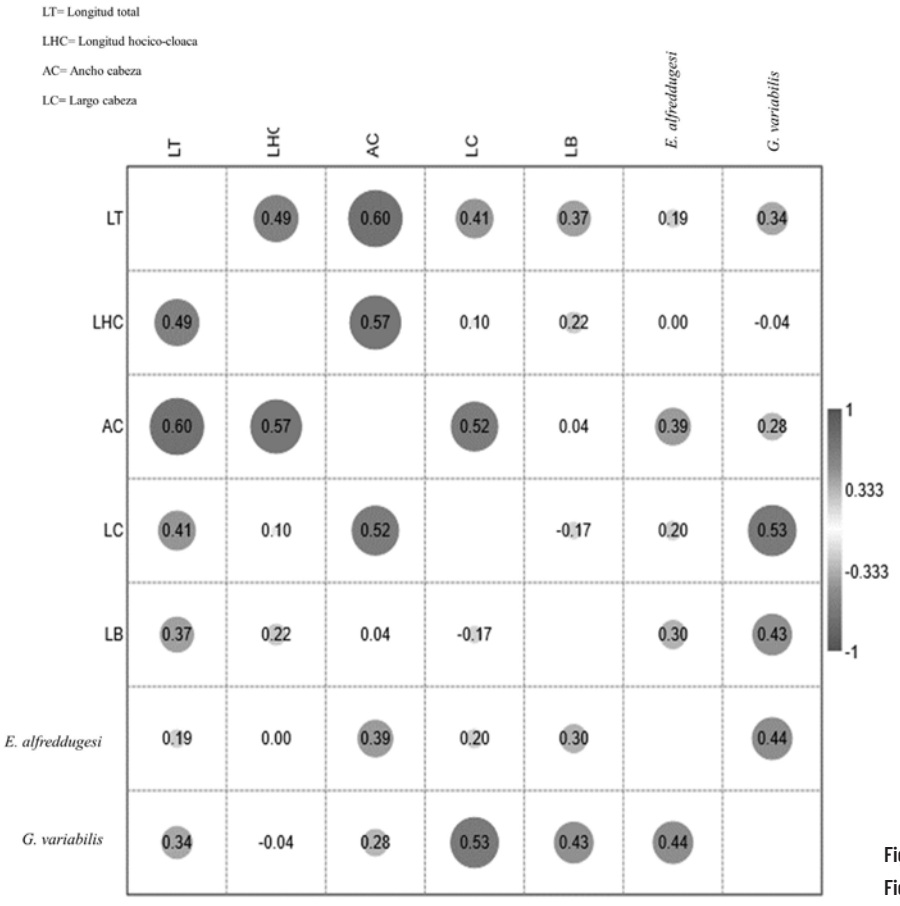

Figure 4. Correlation analysis between mite species

Figura 4. Análisis de correlación entre las especies de ácaros.

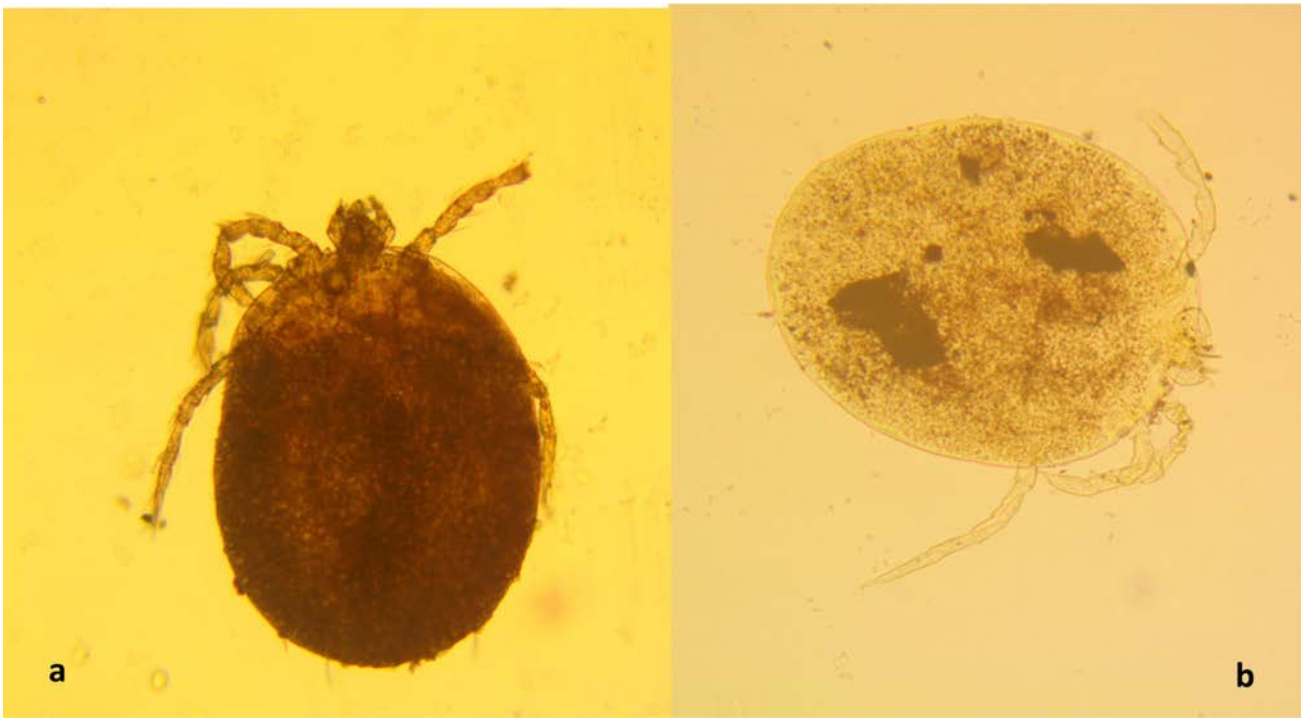

Figure 5. *Eutrombicula alfreddugesi* larva a) dorsal view b) ventral view. / **Figura 5.** Larva de *Eutrombicula alfreddugesi* a) vista ventral b) vista dorsal.

fueron a los que se les contabilizó la mayor cantidad de ácaros (15.5 cm de LHC con 58 ácaros). Las zonas corporales con mayor abundancia de ácaros en las lagartijas fueron la zona axilar (lados izquierdo y derecho) y la zona lateral (ambos lados), los cuales, se localizaron por debajo de las escamas de los hospederos.

Los ectoparásitos encontrados en las lagartijas fueron identificados 145 larvas de la especie *Eutrombicula alfreddugesi* (Trombiculidae) (Figs. 6 y 8), que se caracterizó por presentar un idiosoma que en su vista dorsal consta de un escudo más o menos rectangular con cinco sedas y un par de sedas humerales dorsales; con sensilias flageliformes lisas o con ramas, con un par de ojos de cada lado en una placa ocular. El gnatosoma (también llamado capitulo o falsa cabeza) se compone de las partes bucales que están representadas por un par de quelíceros y un par de pedipalpos y algunas estructuras que sirven de protección y sostén a estos ácaros, con aproximadamente 22 setas dorsales dentro del escudo. En la vista ventral del idiosoma, los órganos de Claparede se encuentran entre las coxas del primer y segundo par de patas, coxas unisetosas. El ano está cerca del extremo posterior del idiosoma en la vista ventral. La larva presenta tres pares de patas divididas en siete segmentos (coxa, trocánter, basifemur, telefémur, genua, tibia y tarso) cada pata termina en uñas pareadas y el empodio en forma de garra sin onicotriquias.

También, se encontraron 42 ejemplares adultos de la familia Pterygosomatidae, especie *Geckobiela variabilis* que ya ha sido reportada en esta especie de lagartija en Catemaco, Veracruz, ya que en la imagen presentada (Figs. 7 y 8) se nota el cuerpo más largo que ancho y la unión de las coxas que están parcialmente fusionadas en lugar de estar completamente, escudo prodorsal ausente y con numerosas sedas idiosomales en la superficie dorsal y lateral, el gnatosoma relativamente corto en hembras, una parte del largo del idiosoma. El subcapítulo con un par de sedas delgadas y lisas insertadas detrás de los palpos que son relativamente cortos, fémur-tarso de los palpos son ligeramente más largos que la base del gnatosoma, con seta dorsalmente ancha y pectinada y tan larga como el fémur. Los quelíceros ligeramente más largos que los palpos, globosos en la base y muy delgados distalmente; dedo queliceral fijo reducido, membranoso y con margen finamente aserrado, además móvil apuntando hacia afuera lateralmente, robusto, curvado y con dos dientes diminutos en la punta. Las patas son más cortas que el lago del idiosoma, la pata I es más larga y gruesa que las demás.

Todas las lagartijas fueron parasitadas por ambas especies de ácaros, independientemente del municipio en donde fueron recolectados y del sexo de las lagartijas; para *Eutrombicula alfreddugesi* se obtuvieron los siguientes datos la prevalencia fue 92.9 %; la abundancia fue de 10.4 ácaros promedio; además

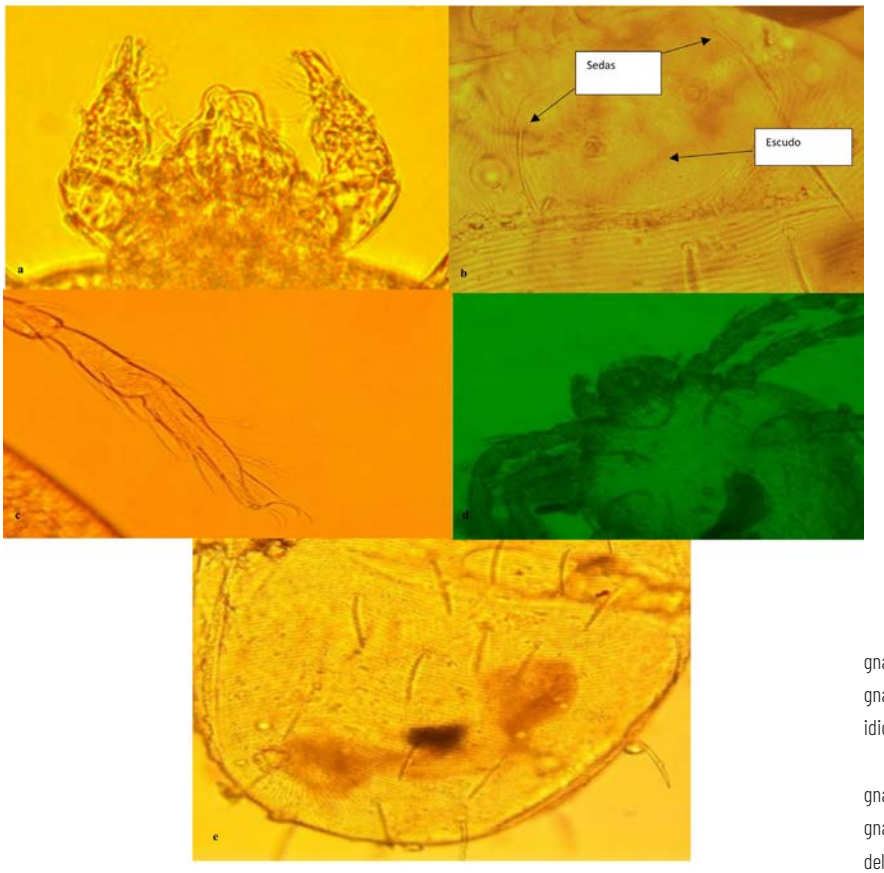

Figure 6. Morphological details of *Eutrombicula alfreddugesi* a) gnathosoma (ventral view); b) dorsal sclerite; c) tarsus of leg III; d) gnathosome in Phase contrast (ventral view); e) Anterior end of the idiosoma (dorsal view).

Figura 6. Detalles morfológicos de *Eutrombicula alfreddugesi* a) gnatosoma (vista ventral); b) escudo dorsal; c) tarso de la pata III; d) gnatosoma en Contraste de fases (vista ventral); e) Extremo anterior del idiosoma (vista dorsal).

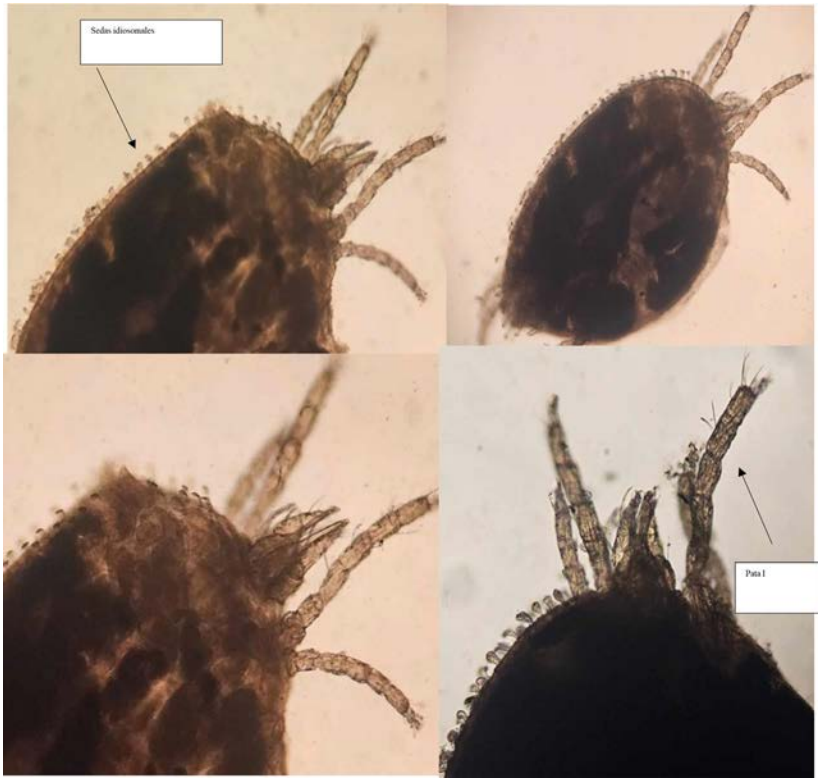

Figure 7. Morphological details of *Geckobiella variabilis* a) dorsal setae; b) leg I (ventral view); c) leg II; d) leg I.

Figura 7. Detalles morfológicos de *Geckobiella variabilis* a) sedas dorsales; b) pata I (vista ventral); c) pata II; d) pata I.

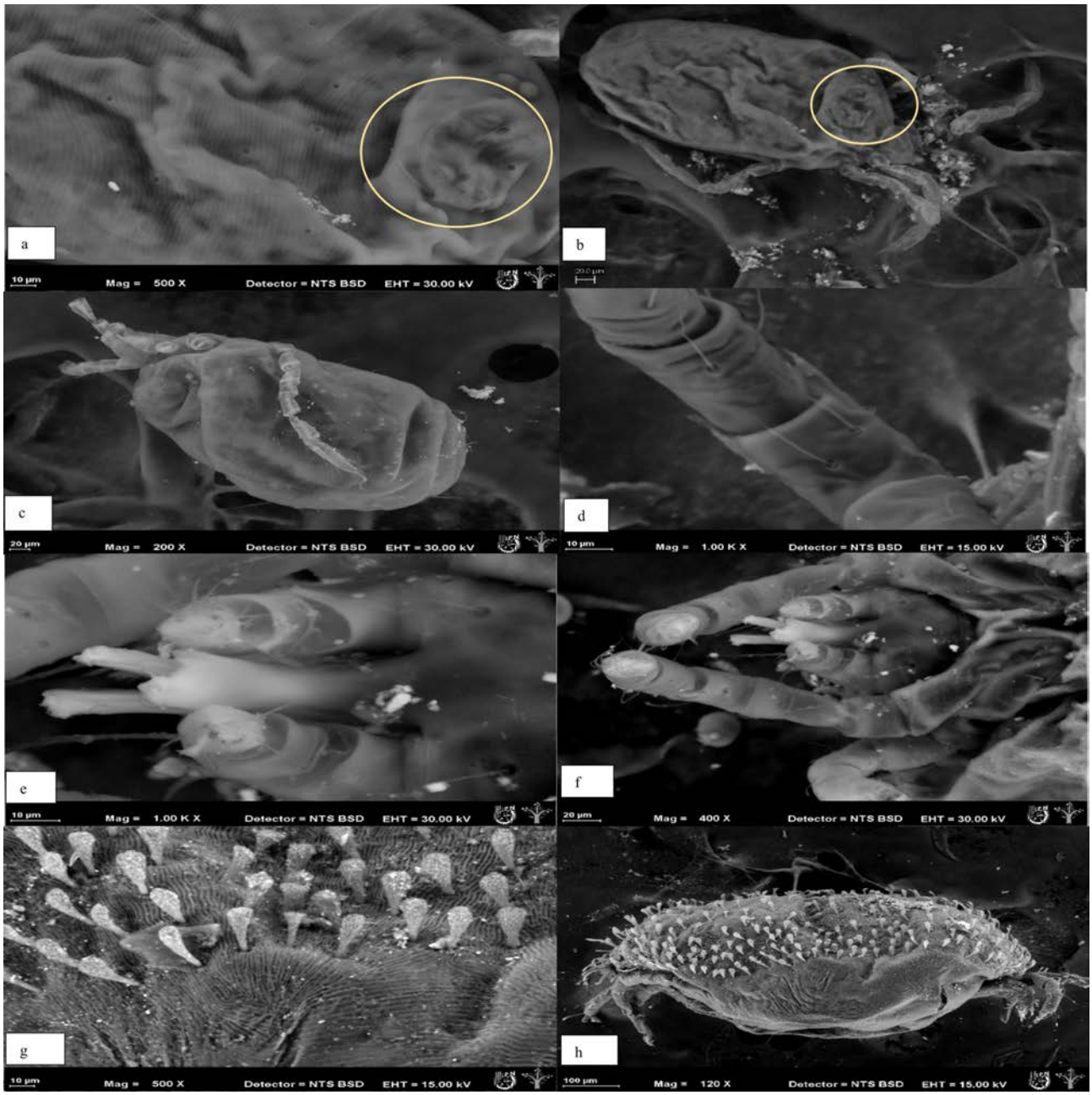

Figure 8. *Eutrombicula alfreddugesi* a-b) Shield, c-d) leg and e-f)) gnathostoma ventral view; *Geckobiella variabilis*, g) dorsal setae and h) lateral view of the idiosome.
Figura 8. *Eutrombicula alfreddugesi* a-b) Escudo, c-d) pata y e-f)) gnatostoma vista ventral; *Geckobiella variabilis*, g) sedas dorsales y h) vista lateral del idiosoma.

Table 2. Características de las infestaciones por ácaros en *S. variabilis*. / **Tabla 2.** Parameters of the infestations for mites in *S. variabilis*.

N	**Sexo**		**Indicadores de infestación**			
Ejemplares infestados	M	H	Total de ácaros	Abundancia	Intervalo	Prevalencia (%)
14	12	2	206	14.71	1-58	100

las lagartijas presentaron un intervalo desde 1 hasta 46 ácaros (Tabla 2). Con *Geckobiela variabilis*, la prevalencia fue de 64.2 %; la abundancia de 3 ácaros promedio y el intervalo de 1-13 ácaros presentes. El municipio de Amatlán de los Reyes, Ver., fue el sitio donde *S. variabilis* tuvo mayor carga parasitaria con 148 ácaros, posteriormente Omealca con 44 y finalmente Córdoba con 14.

DISCUSIÓN

En especies como *Sceloporus couchii* (García-De la Peña et al., 2004) y *Tropidurus hispidus* (de Carvalho et al., 2006), ya se había reportado la presencia de infestaciones por ácaros de la familia Trombiculidae y Hoffmann (1990) reporta la presencia de esta familia varias especies de lagartijas; incluyendo *S. variables* y recientemente para Catemaco, Veracruz, se sabe que coexisten con *Geckobiela variabilis* (Pterygosomatidae) (Paredes-León & Guzmán-Cornejo, 2015); por lo que este estudio abona al conocimiento de la relación ectoparasitaria de *E. alfreddugesi* y *G. variabilis* sobre *S. variabilis* en la región centro de Veracruz, México, pues solo se habían reportado nemátodos endoparásitos en la especie en esta región (Mora-Collado et al., 2020) y los ectoparásitos en ejemplares del sur de Veracruz (Paredes-León & Guzmán-Cornejo, 2015).

Al comparar los resultados con un estudio realizado por García-De la Peña et al. (2010) donde estudiaron la carga ectoparasitaria de la lagartija espinosa de Yarrow (*S. jarrovii*), se encontró el ácaro *E. alfreddugesi* que coincide con las características morfológicas identificadas en este estudio y las reportadas por otros autores (Hoffmann, 1990; Cunha-Barros et al., 2003; Janovy & Roberts, 2009; Bassini-Silva, 2021), sin embargo, *E. alfreddugesi* se encontraba coexistiendo con otro ácaro de la familia Leeuwenhoekiidae y reportaron que el 100% de las lagartijas portaban ambas especies de ácaros, en su mayoría concentrados en los pliegues del cuello. Este tipo de coexistencia entre los ácaros de *E. alfreduguesi* y de *G. variabilis* es interesante como aporte al conocimiento de la parasitosis en *S. variabilis* (Paredes-León & Guzmán-Cornejo, 2015). En este mismo estudio, los autores no observaron una relación significativa entre la LHC y el número total de ácaros, esto indica que aparentemente el tamaño del cuerpo del hospedador parece no ser un factor importante que afecte los niveles de infestación por ácaros, y que pueden ser otros factores como cambios hormonales y de comportamiento o debido a factores ambientales podrían estar afectando la infestación (Espinoza-Carniglia et al., 2016).

Otro estudio realizado por García-De la Peña et al. (2011) mencionan que tres especies de lagartijas del género *Sceloporus* portaban ácaros de *E. alfreddugesi* y la región corporal del cuello, fue la zona de mayor infestación. En el presente estudio se observó la mayor abundancia corporal de ácaros en la zona axilar y la zona dorso lateral, lo que puede deberse a que los ácaros tienen una especificidad orgánica al seleccionar sitios específicos en el cuerpo del hospedero como son las axilas, ingles y oídos (Hoffmann, 1990). Algunos autores también mencionan que los ácaros suelen concentrarse en estas zonas debido a los llamados "bolsillos de ácaros" que son invaginaciones que se observan alrededor del cuello y en las axilas de las lagartijas (Arnold, 1986) y, por lo general, se interpretan como la respuesta evolutiva del hospedero para limitar el daño causado por los parásitos (Bertrand & Modrý, 2004). Estos "bolsillos" proporcionan protección contra golpes mecánicos, deshidratación y permiten que los ácaros no se puedan eliminar fácilmente; además, las escamas que presentan las lagartijas facilitan la alimentación y resguardo de los ectoparásitos (Delfino et al., 2011).

Guzmán-Cornejo et al. (2018) en la Ciudad de México colectaron 24 lagartijas de *S. torquatus*, resultando *E. alfreddugesi* como uno de los parásitos asociados con una prevalencia relativamente alta (> 70 %), lo que concuerda con este estudio, en donde encontramos una prevalencia del 92.9 % de ácaros de *E. alfreddugesi* en la lagartija *S. variabilis*. Recientemente se ha reportado a *E. alfreddugesi* parasitando al gecko común (*Hemidactylus frenatus*) con una prevalencia del 62.5 % (Baak-Baak et al., 2020); en dicho trabajo, los autores destacan el riesgo potencial que ejercen los geckos en humanos al albergar ácaros, pues son vectores de agentes infecciosos como las bacterias de los géneros *Borrelia* y *Rickettsia*, además de provocar dermatitis en sus hospederos (Baak-Baak et al., 2020). La trombiculiasis es la irritación provocada por larvas de estos ácaros, pero está poco documentada debido a que muchas veces no se informa, ya que en muchos casos suele confundirse con una alergia causada por plantas u otros insectos, y que suele tratarse con remedios caseros (Baak-Baak et al., 2020).

No se encontraron lesiones en la piel o debilitamiento en ninguna de las lagartijas de *S. variabilis* estudiadas; sin embargo, al habitar zonas de contacto con animales domésticos, seres humanos y con *Hemidactylus frenatus* (reptil que prácticamente vive dentro de las casas), puede jugar el rol como reservorio o vector potencial de ácaros. En México, ya se ha reportado un caso de trombiculiasis en un niño de 3 años, residente de Veracruz (Bada-del Moral et al., 2015). Dos años después en Brasil, se reportó a *E. alfreddugesi* y *E. batatas* como causantes de una infestación en cabras y humanos en granjas en el estado de Maranhão, causando una picazón severa y dermatitis (Faccini et al., 2017). De ahí la importancia de conocer la distribución

regional de los artrópodos de importancia médica y veterinaria que permitan el monitoreo y la implementación de estrategias de prevención de estas enfermedades a través del monitoreo de sus hospederos.

CONCLUSIÓN

El análisis de ectoparásitos realizado a los 14 individuos de *S. variabilis*, confirmó la presencia de 206 ácaros identificados como *Eutrombicula alfreddugesi* (Trombiculidae) y *Geckobiela variabilis* (Pterygosomatidae). Los ácaros observados en *S. variabilis* mostraron una mayor abundancia en zona axilar y lateral.

Independientemente del municipio en donde se colectaron las lagartijas, todas estuvieron parasitadas, presentando una alta prevalencia de ácaros (100 %). Sin embargo, en el municipio de Amatlán de los Reyes, Ver., se notó una abundancia mayor.

El análisis de regresión lineal mostró que existe una relación entre caracteres del cuerpo con el número de ácaros encontrados. En cuanto al sexo de las lagartijas, no fue un factor importante que influye los niveles de infestación por ácaros. No se observaron lesiones en la piel en ninguno de los especímenes infestados, ni ningún indicio de que las lagartijas estuvieran debilitadas.

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PRIMER REGISTRO DE LA RANA CARIBEÑA *LEPTODACTYLUS INSULARUM* (BARBOUR, 1906) (ANURA: LEPTODACTYLIDAE) EN EL DEPARTAMENTO DEL QUINDÍO, COLOMBIA

FIRST RECORD OF THE CARIBBEAN DITCHFROG *LEPTODACTYLUS INSULARUM* (BARBOUR, 1906) (ANURA: LEPTODACTYLIDAE) IN THE DEPARTMENT OF QUINDIO, COLOMBIA

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La familia Leptodactylidae está constituida por anuros de hábitos terrestres que habitan principalmente bosques y zonas abiertas como pastizales y potreros (Ibanez et al., 1999; Savage, 2002). Actualmente, está compuesta por 237 especies agrupadas en 13 géneros (Frost, 2024). Esta familia se distribuye desde el sur de Norteamérica hasta el sur de Suramérica en rangos altitudinales menores a los 2,000 m s.n.m (Hedges & Heinicke, 2007; Da Silva et al., 2020; Cáffaro et al., 2022; Carvalho et al., 2022; Frost, 2024). En Colombia, habitan nueve géneros y ~40 especies distribuidas en gran parte de las ecorregiones del país (Lynch, 1996; Acosta-Ortiz, 2022; Acosta-Galvis, 2023; Frost, 2024).

En Colombia, el género *Leptodactylus* es el más diverso con 27 de las 40 especies que representan la familia (Acosta-Galvis, 2023; Frost, 2024). *Leptodactylus insularum* (Barbour, 1906) es una especie de tamaño moderado (LRC = 94 - 170 mm, x = 131.4 mm; *n* = 216 en machos y 103 - 154 mm, $\bar{x}$ = 132.0 mm; *n* = 224 en hembras) (Heyer & Heyer, 2013); su cabeza es tan larga como ancha; tímpano prominente con un anillo timpánico liso; ausencia de saco vocal externo; presencia de dos pliegues dorsolaterales marrones que van desde la parte posterior del ojo hasta la ingle; dorso con pequeños tubérculos color canela y presenta un patrón de coloración, en la porción media, canela/marrón; crestas laterales con rayas marrones/canela; sus extremidades posteriores tienden a ser largas, con pequeños tubérculos en la parte externa del tarso (Heyer & Heyer, 2013). *L. insularum* exhibe dimorfismo sexual: en machos, los antebrazos varían de ligeramente a muy hipertrofiados, presentan dos espinas negras en los dedos I de las extremidades anteriores y en épocas reproductivas, una mancha central con pequeños tubérculos color canela en el pecho, ambas características ausentes en hembras (Heyer & Heyer, 2013). Además, la planta de la extremidad posterior es lisa en hembras (en algunos machos con pequeños tubérculos) y su tímpano no está rodeado de tubérculos (presentes en machos) (Heyer & Heyer, 2013).

Esta especie se encuentra distribuida en Colombia, Costa Rica, Panamá, Trinidad y Tobago y Venezuela (Frost, 2024). En Colombia, se ha registrado en las tierras bajas de la Orinoquia, Caribe y Valle del Magdalena entre los 0 y 1,400 m s.n.m (Cochran & Goin, 1970; Acosta, 2010; Heyer & De Sá, 2011; Angarita-Sierra, 2014; Pedroza-Banda et al., 2014). *L. insularum* se ha reportado en 23 de los 32 departamentos de Colombia (Acosta-Galvis, 2023) (Fig. 1). En particular, Gómez-Hoyos et al. (2017) reportan su presencia en el departamento del Quindío, pero no proveen evidencia que sustente su reporte (i.e., localidad y coordenadas geográficas del ejemplar depositado en colecciones biológicas, o referencia bibliográfica que soporte el reporte). Además, en la lista más reciente de la herpetofauna del departamento del Quindío elaborada por Román-Palacios et al. (2017), esta especie no está incluida. En consecuencia, la presencia de esta rana en el departamento es incierta. La presente nota tiene como objetivo reportar el primer registro formal de *L. insularum* en el departamento del Quindío.

El 02 de diciembre de 2023, se llevaron a cabo recorridos nocturnos realizando búsquedas libres de anfibios y reptiles en la vereda Pisamal, municipio de La Tebaida, departamento del Quindío (4.411339° N, 75.813361° W, 1,045 m s.n.m) (Fig. 1). Esta localidad, se caracteriza por la presencia de microhábitats tales como pastizales, guaduales y humedales. En una de las orillas

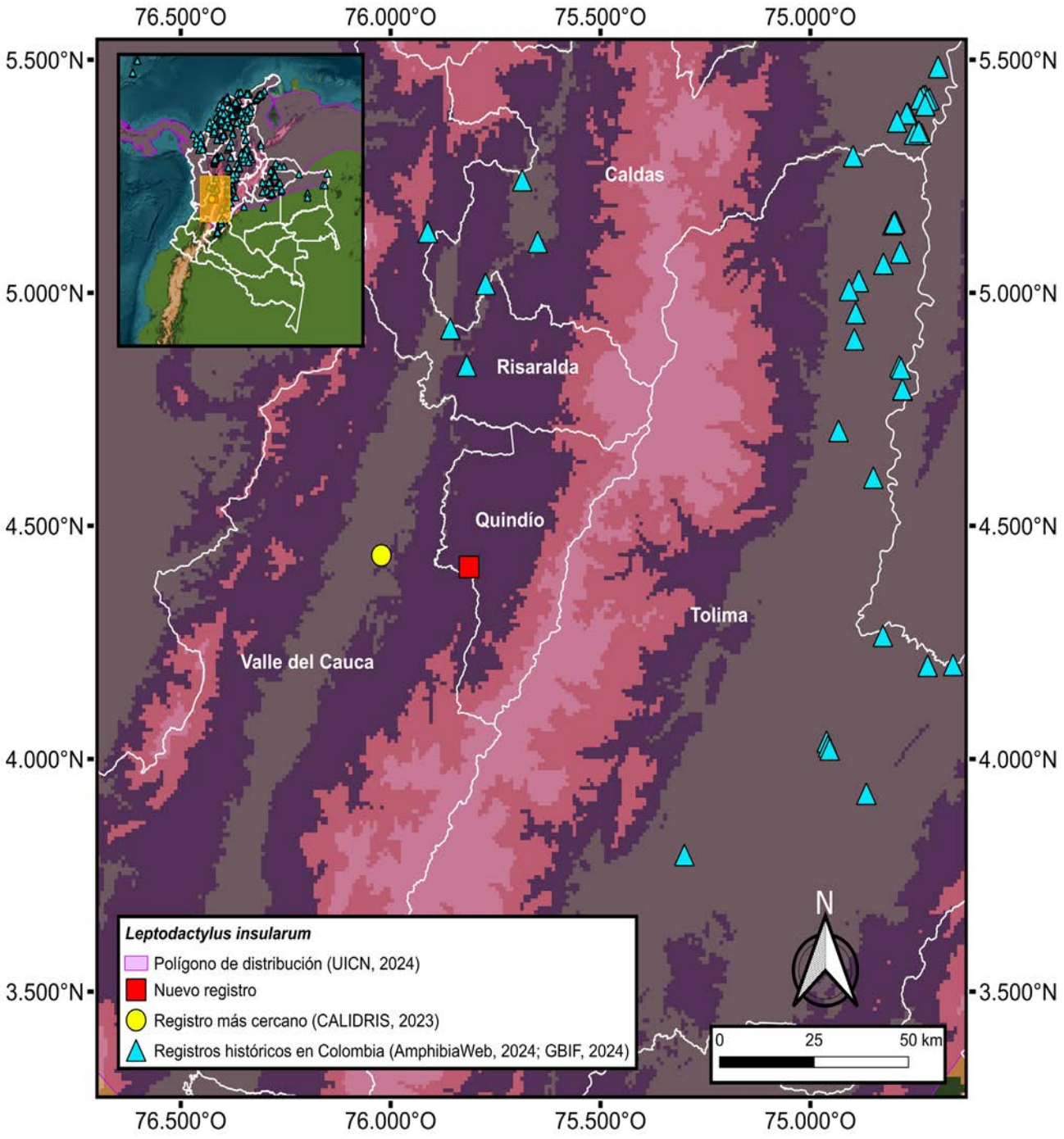

Figure 1. Distribution of *Leptodactylus insularum* in Colombia. Map prepared in QGIS from the occurrence records of AmphibiaWeb (2024), CALIDRIS (2023), GBIF (2024). Distribution polygon of *L. insularum* according to IUCN (2024).

Figura 1. Distribución de *Leptodactylus insularum* en Colombia. Mapa elaborado en QGIS a partir de los registros de ocurrencia de AmphibiaWeb (2024), CALIDRIS (2023), GBIF (2024). Polígono de distribución de *L. insularum* según UICN (2024).

Figure 2. A) Wetland located in the Pisamal – La Tebaida village (Quindío, Colombia) where the registration was carried out and B) Male of *Leptodactylus insularum*. Photos: A: Santiago Angel Soto, B: Brandon Brand Buitrago-Marulanda.

Figura 2. A) Humedal ubicado en la vereda Pisamal – La Tebaida (Quindío, Colombia) en donde se realizó el registro y B) Macho de *Leptodactylus insularum*. Fotos: A: Santiago Angel Soto, B: Brandon Brand Buitrago-Marulanda.

de un humedal, rodeado de un guadual y un pastizal (Fig. 2A), se encontraron dos machos adultos de *L. insularum*, inmóviles fuera del agua, los cuales intentaron huir hacia el humedal al ser detectados (Fig. 2B). Cabe resaltar que ninguno de los individuos fue recolectado.

Esta especie se diferencia de otros congéneres por la presencia de dos espinas negras en el dedo I de las extremidades posteriores (una espina negra en *L. bolivianus* y *L. guianensis*) (de Sá et al., 2014), pliegues dorsolaterales completos y bordes en los dedos de las extremidades anteriores (ausentes en *L. fragilis*), parche con espinas en el pecho (ausentes en *L. colombiensis*) (de Sá et al., 2014). En particular, con *L. fragilis* y *L. colombiensis*, especies reportadas en el Quindío (Román-Palacios et al., 2017), también se diferencia por su tamaño corporal, siendo los individuos adultos de *L. insularum* más grandes: *L. fragilis* (LRC = 27 - 43 mm, $\overline{x}$ = 34.8 mm en machos; 30.1 - 43.6 mm, $\overline{x}$ = 36.3 mm en hembras) y *L. colombiensis* (LRC = 36 - 55.9 mm, $\overline{x}$ = 44.4 mm en machos; 39.9 - 62.5 mm, $\overline{x}$ = 53.3 mm en hembras) (de Sá et al., 2014).

A partir de los registros de ocurrencia de *L. insularum* depositados en AmphibiaWeb (2024), CALIDRIS (2023; https://calidris.org.co/quienes-somos/) y GBIF (2024; https://www.gbif.org/), los cuales fueron filtrados con coordenadas geográficas asociadas a un espécimen preservado de una colección biológica, se encontró que los registros más cercanos al nuevo registro de *L. insularum* corresponden a localidades ubicadas en el Valle del Cauca (4.436395° N, 76.022161° W, 982 m s.n.m) y Risaralda (4.843859° N, 75.818724° W, 1,123 m s.n.m a 23.6 Km y 48.3 Km, respectivamente. Estas medidas fueron tomadas mediante Google Earth Pro® teniendo en cuenta el perfil de elevación, es decir, no son distancias lineales. Basados en el polígono formado por la distribución de *L. insularum* en Colombia (Fig. 1, *sensu* UICN, 2024), su presencia en el Quindío era esperada, por tanto, este registro aporta información valiosa sobre su área de distribución en un nuevo departamento. A pesar de que esta especie presenta una amplia distribución y esté catalogada en Preocupación Menor (LC) (UICN, 2020), en esta localidad también se registró la presencia de la especie invasora rana toro *Aquarana catesbeiana* (Shaw 1802), por tanto, es necesario realizar estudios enfocados en las interacciones interespecíficas (p.ej., competencia por recursos) de esta especie con *L. insularum* al igual que con las otras especies nativas que se encuentren en dicha zona.

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CONTRIBUCIÓN AL CONOCIMIENTO DE LA OFIDIOFAUNA DEL DEPARTAMENTO DE CAAZAPÁ, PARAGUAY

CONTRIBUTION TO THE KNOWLEDGE OF THE OPHIDIOFAUNA OF THE DEPARTMENT OF CAAZAPÁ, PARAGUAY

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Abstract.— Paraguay has a richness of 120 species of snakes. There are still areas with few studies. Active searches for snakes were carried out opportunistically at different times, covering a period between July 2015 and October 2022. Work was done with the Caazapá Volunteer Firefighters, who collected snakes corpses that were killed en route or by the locals. Finally, through education campaigns on snakes and snakes (both virtual and face-to-face), a network of contacts was developed that collaborate by sending photographs. The records comprise 121 total specimens that correspond to 37 species, divided into 5 families: Boidae 1 specimen, Colubridae 5 specimens, Dipsadidae with the largest number of species, 23 in total, 2 species of the Elapidae family and 6 species of the Viperidae family. Twenty-nine species represent new records for the department of Caazapá. The work provides very important data for the knowledge of snake species in the Department of Caazapá, including photographic records, dates and georeferences of the different species.

Keywords.— Georeferences, new records, photographic records, snakes.

Resumen.— Paraguay posee una riqueza de 120 especies de ofidios. Aún tiene zonas con pocos estudios. Se realizaron búsquedas activas de serpientes, de manera oportunista, en diferentes horarios, entre julio del 2015 a octubre del 2022. Se trabajó con los Bomberos Voluntarios de Caazapá, se recogieron cadáveres de serpientes muertas en ruta o matadas por lugareños. Con campañas de educación sobre ofidios y ofidismo (tanto virtuales como presenciales), se desarrolló una red de contactos que colaboran con los registros. Se registraron 121 ejemplares. Correspondiente a 37 especies, divididos en 5 familias, Boidae 1 ejemplar, Colubridae 5 ejemplares, Dipsadidae con la mayor cantidad de especies, 23 en total, 2 especies de la familia Elapidae y 6 especies de la familia Viperidae. 29 especies de ofidios son nuevos registros para el departamento de Caazapá. El trabajo aporta datos muy importantes para el conocimiento de las especies de ofidios del Departamento de Caazapá. Contando con registros fotográficos, fechas y georreferencias de las distintas especies.

Palabras clave.— Georreferencias, nuevos registros, ofidios, registros fotográficos.

INTRODUCCIÓN

Paraguay es un país mediterráneo, ubicado en el centro de Sudamérica, entre los meridianos 54° 19' y 62° 38' W, y los paralelos 18° 18' y 27° 30' S. Se encuentra en una zona principalmente subtropical del reino zoogeográfico Neotropical cercano al límite zoogeográfico Panameño (Holt et al., 2013). Una de las principales cualidades biogeográficas del área, es la confluencia

de diferentes ecorregiones (Spichiger et al., 1995; Avila Torres et al., 2018), lo que le brinda al país una flora y fauna muy diversa, pero con escasa riqueza de endemismos (Hayes, 1995; del Castillo & Clay, 2005; Brusquetti & Lavilla, 2006; Weiler et al., 2013; Cacciali et al., 2016; De la Sancha et al., 2017; Koerber et al., 2017). Respecto específicamente a la fauna de ofidios, Paraguay posee una riqueza de 120 especies (Cacciali, 2024) de las cuales tres son endémicas: *Phalotris nigrilatus*, *Phalotris normanscotti* y *Phalotris shawnella* (Ferrarezzi, 1993; Cabral & Cacciali, 2015; Cacciali et al., 2020; Smith et al., 2022).

Paraguay cuenta aún con gran cantidad de vacíos en cuanto al conocimiento de su fauna de ofidios, existiendo áreas que son pobre o incluso nulamente muestreadas (Cacciali & Ubilla 2016). Las zonas mejor muestreadas en Paraguay se circunscriben a áreas protegidas en donde los esfuerzos de muestreo cuentan con un prolongado trabajo de recopilación de datos (McDiarmind & Foster, 1987; Aquino et al., 1996; Cacciali, 2013; Cacciali et al., 2015; Martínez et al., 2016). Un caso particular, es el área previamente denominada Reserva Natural Laguna Blanca, la cual tuvo un periodo de muestreo intensivo gracias a una institución de investigación que se basó en el área, generando una gran cantidad de información, y designándola como la primera área de importancia para la conservación de anfibios y reptiles por la alta concentración de especies endémicas del Cerrado y especies que en Paraguay sólo se las ha registrado en esa área hasta el momento (Smith et al., 2016). Lamentablemente, esta área salió del sistema nacional de áreas silvestres protegidas.

Sin embargo, a pesar de la importancia que los listados de especies brindan para generar información de base para el conocimiento, protección y posterior planificación estratégica destinada a la conservación (Ferrer Pérez et al., 2009; Martínez-Camilo et al., 2012); Paraguay no cuenta con iniciativas destinadas a conocer la fauna de ofidios de regiones o áreas administrativas locales. Esto perjudica al momento de planificar la zonificación de áreas destinadas a desarrollo urbano y rural, y sectores prioritarios para conservación del patrimonio biológico. Respecto a esto, el Departamento de Caazapá cuenta con seis áreas silvestres protegidas: Monumento Natural Isla Susú, Paisaje Protegido Ycuá Bolaños, Reserva Natural Ypetí, Parque Nacional Caazapá, Reserva Natural Tapytá, y el extremo norte de la Reserva para Parque Nacional San Rafael.

Los trabajos publicados orientados al conocimiento de la fauna de ofidios de Caazapá o localidades internas, son prácticamente nulos. Cacciali (2013) brinda información sobre serpientes presentes en la Reserva para Parque Nacional San Rafael, la cual se localiza en el límite de los Departamentos de Caazapá e Itapúa, y la mayor parte de la superficie del área se encuentra en este último departamento. Por otra parte, existe información sobre la fauna de ofidios del Departamento de Caazapá en una recopilación sobre la distribución de los reptiles en Paraguay (Cacciali et al., 2016) en donde se proponen los registros para ese departamento, los cuales se restringen a únicamente nueve especies.

MATERIALES Y MÉTODOS

El área de estudio es el departamento de Caazapá se encuentra ubicado en el centro sur de la región oriental de Paraguay. Donde confluyen dos ecorregiones diferentes la ecorregión del Chaco húmedo y el Bosque Atlántico del Alto Paraná. En la figura 1 se observa el mapa de Paraguay con sus ecorregiones según Dinerstein et al. (1995) y la ubicación del VI Departamento Caazapá. El chaco húmedo es una extensa región cuyo paisaje predominante es un mosaico de tierras altas, con bosques, cursos de ríos, esteros, pajonales y pastizales. Con lluvias estacionales, con desborde de ríos (Williams & Vera, 2023). El Bosque Atlántico del Alto Paraná es una selva tropical húmeda que cubre la cuenta alta del Río Paraná, cubre el este de Paraguay (Williams & Vera, 2023).

Se realizaron búsquedas activas de serpientes, de manera oportunista, en diferentes horarios del día, abarcando un lapso comprendido entre julio del 2015 y octubre del 2022. Se muestrearon distintos hábitats (campos, bosques, chacras, arroyos, humedales) de todo el departamento de Caazapá, teniendo como epicentro el Distrito de Caazapá. Además de la búsqueda activa, se trabajó con los Bomberos Voluntarios de Caazapá a quienes la ciudadanía solicita ayuda por el ingreso de serpientes a los domicilios. También se recogieron cadáveres de serpientes muertas en ruta o matadas por los lugareños. Finalmente, mediante campañas de educación sobre ofidios y ofidismo que llevé a cabo (tanto virtuales como presenciales), se desarrolló una red de contactos que colaboran con el envío de fotografías, las cuales también son incluidas como modo de registro.

Se tomaron registros fotográficos de todos los ejemplares observados. Las fotografías pueden obtenerse a través de los enlaces de Figshare. Cada especie fue georreferenciada, con la fecha del registro, ambiente del registro.

RESULTADOS

Los registros se observan en la Tabla 1. Se citan las especies, y los distintos distritos con los registros de la especie. Se encontraron

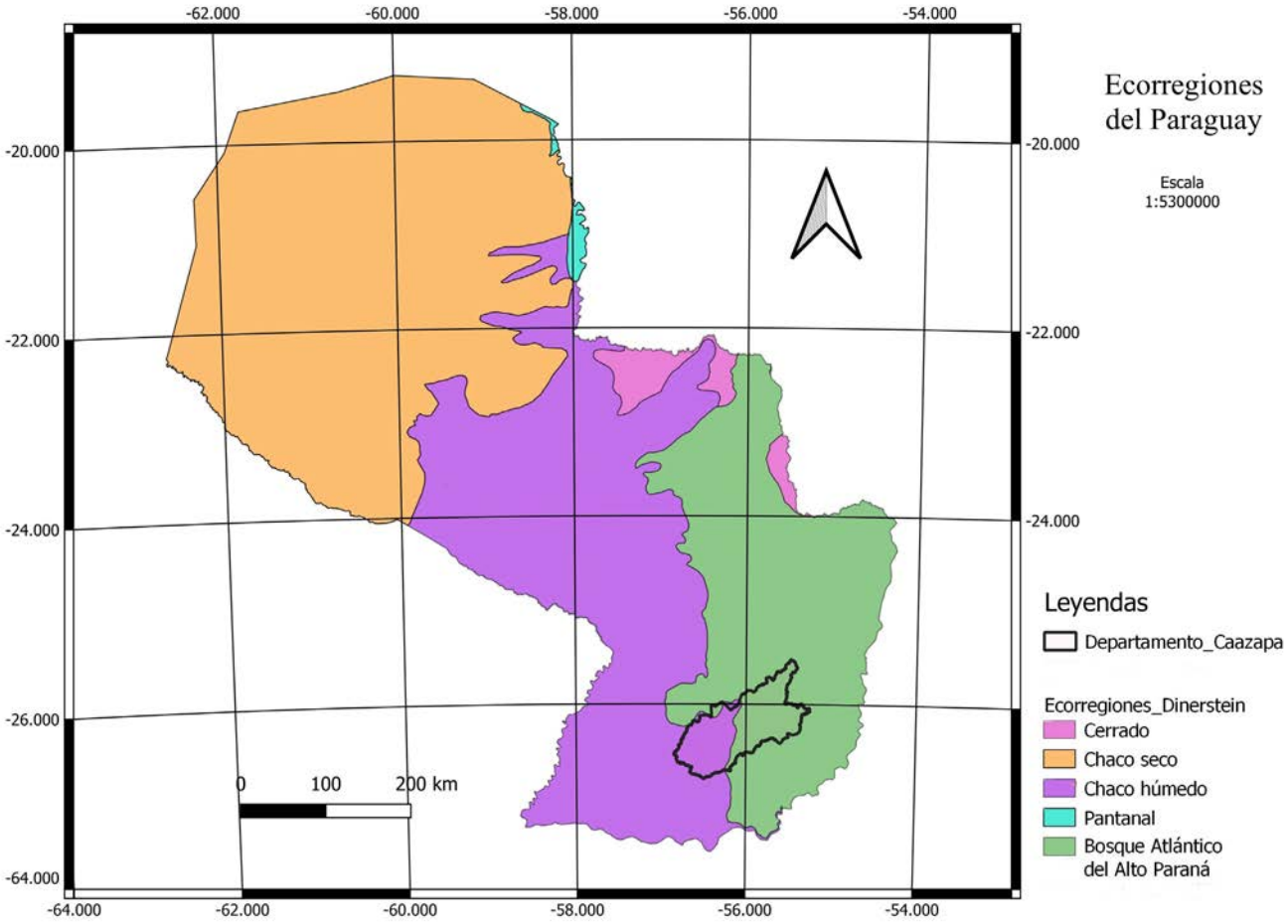

Figure 1. Map of Paraguay with its ecoregions and the geographical location of the department of Caazapá.

Figura 1. Mapa del Paraguay con sus ecorregiones y la ubicación geográfica del departamento de Caazapá.

121 especímenes que corresponden a 37 especies, divididos en cinco familias, Boidae un ejemplar, Colubridae cinco ejemplares, Dipsadidae con la mayor cantidad de especies, 23 en total, dos especies de la familia Elapidae y seis especies de la familia Viperidae. Los registros de las especies se muestran por distritos en la Tabla 1. La especie con mayor cantidad de registros fue *Bothrops alternatus* con 13 registros en seis distritos. El distrito con mayor cantidad de registros fue Caazapá con 25 especies, que representa el 67.6 %, en segundo lugar, Coronel Maciel con 11 registros.

Las fotos y videos están divididos en carpetas en Figshare, se anexan los enlaces de los distintos archivos en la Tabla 2. La cantidad de registros se muestra en la figura 2, las figuras 3, 4 y 5 muestran los puntos de registro de especies, eligiendo una coordenada por especie y distrito para no superponer. Los registros se distribuyen de la siguiente manera: rescate 27.3 %, animales matados por lugareños 26.4 %, fotografiados, filmados por lugareños 13.2 %, búsqueda activa diurna 8.3 %, búsqueda activa nocturna 2.5 %, incendios forestales 2.5 %. (Tabla 3). El hábitat con mayor cantidad de registros fue el de los pastizales con un 31.4 %, posteriormente las zonas urbanas con el 30.5 %, chacra 16.6 %, bosques 11.6 %, zonas semiacuáticas 9.9 %. Se agregaron 29 especies al departamento Caazapá- Las especies registradas por primera vez fueron marcadas en la Tabla 1 con (*).

Registramos especies como la *Atractus paraguayensis* que está catalogada como en peligro de extinción, *Bothrops jararaca*, *Micrurus corallinus* especies vulnerables, *Apostolepis dimidiata*, con datos insuficientes según Martínez et al. (2020). Las figuras del 6 a la 14, muestran las fotografías de las especies registradas, a excepción de la *Bothrops diporus* que se obtuvo una filmación del ejemplar.

Table 1. List of species and districts where they were recorded. Abbreviations: Cz. (Caazapá), Ma. (Coronel Maciel), Ye. (Fulgencio Yegros), Yu. (Yuty), 3M. (3 de Mayo), SJ. (San Juan Nepomuceno), Ab. (Abai) Ta. (Tavai), GM. (General Higinio Morínigo), BV. (Buena Vista) Mo. (Moisés Santiago Bertoni). Species that are new records are indicated with an asterisk (*). The numbers indicate the number of registrations in the district.

Tabla 1. Lista de especies y distritos dónde se registraron. Abreviaturas: Cz. (Caazapá), Ma. (Coronel Maciel), Ye. (Fulgencio Yegros), Yu. (Yuty), 3M. (3 de Mayo), SJ. (San Juan Nepomuceno), Ab. (Abai) Ta. (Tavai), GM. (General Higinio Morínigo), BV. (Buena Vista) Mo. (Moisés Santiago Bertoni). Las especies que son registros nuevos se indican con un asterisco (*). Los números indican la cantidad de registros en el distrito.

Especies	Cz.	Ma.	Ye.	Yu.	3M.	Sa.	Ab.	Ta.	Ge.	Bu.	Mo.
Adelphostigma occipitalis *	1										
Apostolepis dimidiata *	9										
Atractus paraguayensis *		2									
Bothrops alternatus *	7	2			1	1			1		1
Bothrops diporus						1					
Bothrops jararaca *							1				
Bothrops jararacussu *	3				1						
Bothrops matogrossensis	2	3									
Clelia clelia	3										
Crotalus durissus *				2			1	1			
Dipsas turgida *	2	1		1							
Drymarchon corais *											1
Dryophylax hypoconia *	1										
Erythrolamprus aesculapii *	3					1					
Erythrolamprus almadensis *	1										
Erythrolamprus frenatus *	2										
Erythrolamprus macrosomus *	2										
Erythrolamprus miliaris *	3										
Erythrolamprus poecilogyrus	3										
Eunectes notaeus *	1		1	1							
Helicops infrataeniatus *	1										
Helicops leopardinus *	1										
Hydrodynastes gigas *	1	1	1								
Leptophis marginatus *	2										
Lygophis flavifrenatus *	2										
Mesotes strigatus *		1									
Micrurus altirostris *	6	1									
Micrurus corallinus				1			1				
Oxyrhopus guibei *	3										
Oxyrhopus rhombifer *		1									
Palusophis bifossatus *	6	1		1							1

Table 1 (cont.). List of species and districts where they were recorded. Abbreviations: Cz. (Caazapá), Ma. (Coronel Maciel), Ye. (Fulgencio Yegros), Yu. (Yuty), 3M. (3 de Mayo), SJ. (San Juan Nepomuceno), Ab. (Abai) Ta. (Tavai), GM. (General Higinio Morínigo), BV. (Buena Vista) Mo. (Moisés Santiago Bertoni). Species that are new records are indicated with an asterisk (*). The numbers indicate the number of registrations in the district.

Tabla 1 (cont.). Lista de especies y distritos dónde se registraron. Abreviaturas: Cz. (Caazapá), Ma. (Coronel Maciel), Ye. (Fulgencio Yegros), Yu. (Yuty), 3M. (3 de Mayo), SJ. (San Juan Nepomuceno), Ab. (Abai) Ta. (Tavai), GM. (General Higinio Morínigo), BV. (Buena Vista) Mo. (Moisés Santiago Bertoni). Las especies que son registros nuevos se indican con un asterisco (*). Los números indican la cantidad de registros en el distrito.

Especies	Cz.	Ma.	Ye.	Yu.	3M.	Sa.	Ab.	Ta.	Ge.	Bu.	Mo.
Philodryas olfersii	1										1
Pseudablabes patagoniensis *	6										
Spilotes pullatus							1				
Tantilla melanocephala *					1						
Xenodon dorbignyi *	2	1									
Xenodon merremi	7										

Table 2. Figshare links to folders by species of snakes in the Department of Caazapá, Paraguay. /

Tabla 2. Enlaces de Figshare de las carpetas por especies de serpientes en el Departmento de Caazapá, Paraguay.

Especies	Enlaces
Adelphostigma occipitalis *	https://figshare.com/account/projects/130445/articles/ 18516131
Apostolepis dimidiata *	https://figshare.com/account/projects/130445/articles/18515696
Atractus paraguayensis *	https://figshare.com/account/projects/130445/articles/18516230
Bothrops alternatus *	https://figshare.com/account/projects/130445/articles/18515702
Bothrops diporus	https://figshare.com/account/projects/130445/articles/20469180
Bothrops jararaca *	https://figshare.com/account/projects/130445/articles/18515744
Bothrops jararacussu *	https://figshare.com/account/projects/130445/articles/18515738
Bothrops matogrossensis	https://figshare.com/account/projects/130445/articles/18515735
Clelia clelia	https://figshare.com/account/projects/130445/articles/18515699
Crotalus durissus *	https://figshare.com/account/projects/130445/articles/18515747
Dipsas turgida *	https://figshare.com/account/projects/130445/articles/18515753
Drymarchon corais *	https://figshare.com/account/projects/130445/articles/18515756
Dryophylax hypoconia *	https://figshare.com/account/projects/130445/articles/18516170
Erythrolamprus aesculapii *	https://figshare.com/account/projects/130445/articles/18515759
Erythrolamprus almadensis *	https://figshare.com/account/projects/130445/articles/18515771
Erythrolamprus frenatus *	https://figshare.com/account/projects/130445/articles/18515774
Erythrolamprus macrosomus *	https://figshare.com/account/projects/130445/articles/18515768
Erythrolamprus miliaris *	https://figshare.com/account/projects/130445/articles/18515783
Erythrolamprus poecilogyrus	https://figshare.com/account/projects/130445/articles/18515789
Eunectes notaeus *	https://figshare.com/account/projects/130445/articles/18515792
Helicops infrataeniatus *	https://figshare.com/account/projects/130445/articles/22336078
Helicops leopardinus *	https://figshare.com/account/projects/130445/articles/19329146
Hydrodynastes gigas *	https://figshare.com/account/projects/130445/articles/18515795
Leptophis marginatus *	https://figshare.com/account/projects/130445/articles/18515798
Lygophis flavifrenatus *	https://figshare.com/account/projects/130445/articles/19608972

Table 2 (cont.). Figshare links to folders by species of snakes in the Department of Caazapá, Paraguay.

Tabla 2 (cont.). Enlaces de Figshare de las carpetas por especies de serpientes en el Departmento de Caazapá, Paraguay.

Especies	Enlaces
Mesotes strigatus *	https://figshare.com/account/projects/130445/articles/18516173
Micrurus altirostris *	https://figshare.com/account/projects/130445/articles/18515822
Micrurus corallinus	https://figshare.com/account/projects/130445/articles/18515831
Oxyrhopus guibei *	https://figshare.com/account/projects/130445/articles/18515834
Oxyrhopus rhombifer *	https://figshare.com/account/projects/130445/articles/18515837
Palusophis bifossatus *	https://figshare.com/account/projects/130445/articles/18515840
Philodryas olfersii	https://figshare.com/account/projects/130445/articles/18515843
Pseudablabes patagoniensis *	https://figshare.com/account/projects/130445/articles/18515846
Spilotes pullatus	https://figshare.com/account/projects/130445/articles/18577073
Tantilla melanocephala *	https://figshare.com/account/projects/130445/articles/18516149
Xenodon dorbignyi *	https://figshare.com/account/projects/130445/articles/18516179
Xenodon merremi	https://figshare.com/account/projects/130445/articles/18516185

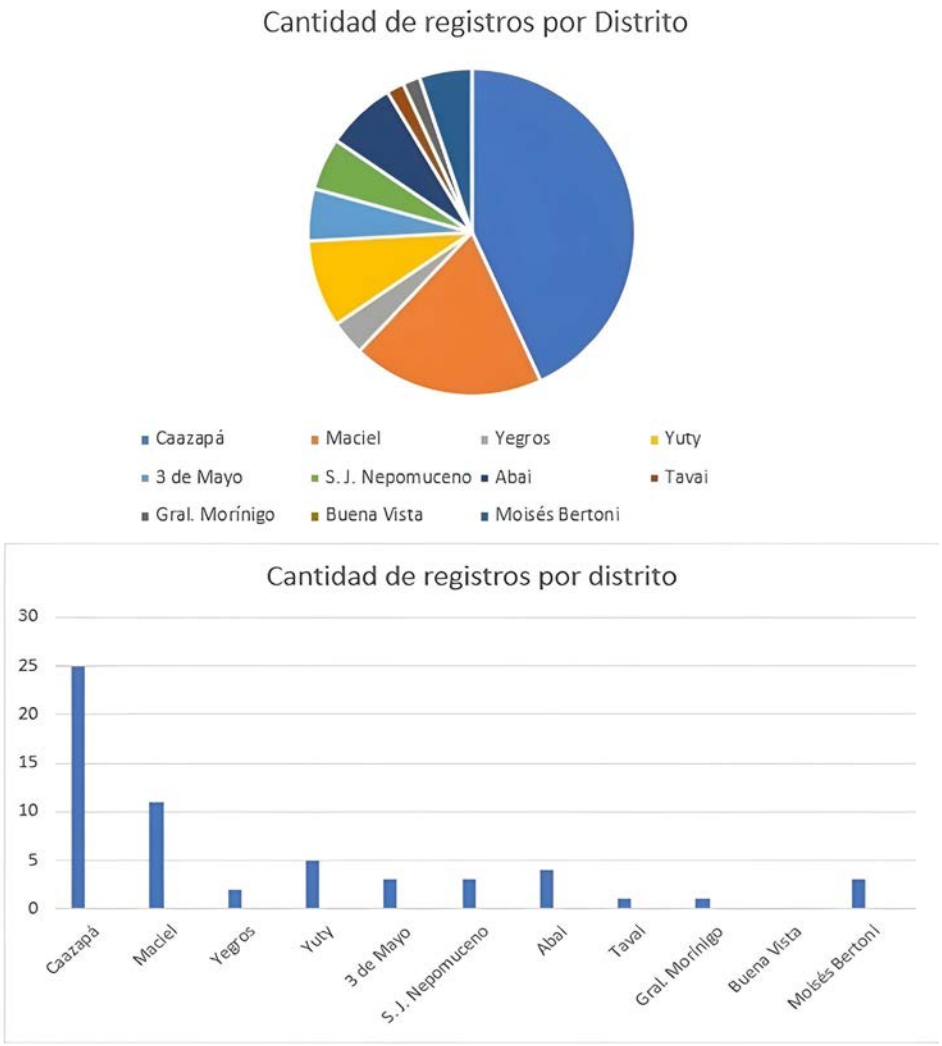

Figure 2. Number of records by districts of snakes in the Department of Caazapá, Paraguay.

Figura 2. Cantidad de registros por distritos por especies de serpientes en el Departmento de Caazapá, Paraguay.

Table 3. Percentages of records of snakes in the Department of Caazapá, Paraguay according to the different ways of obtaining data.

Tabla 3. Porcentajes de los registros por especies de serpientes en el Departmento de Caazapá, Paraguay según las distintas formas de obtención de datos.

Obtención de datos	Cantidad de Registros	Porcentajes
Rescates	33	27.3 %
Atropellados	24	19.8 %
Fotografiados, filmados por lugareños	16	13.2 %
Matados por lugareños	32	26.4 %
Búsqueda activa diurna	10	8.3 %
Búsqueda activa nocturna	3	2.5 %
Incendios	3	2.5 %
Total de registros	**121**	**100 %**

Figure 3. Map of the Department of Caazapá with its districts and georeferences of the ophidian species.

Figura 3. Mapa del Departamento de Caazapá con sus distritos y las georreferencias de las especies de ofidios.

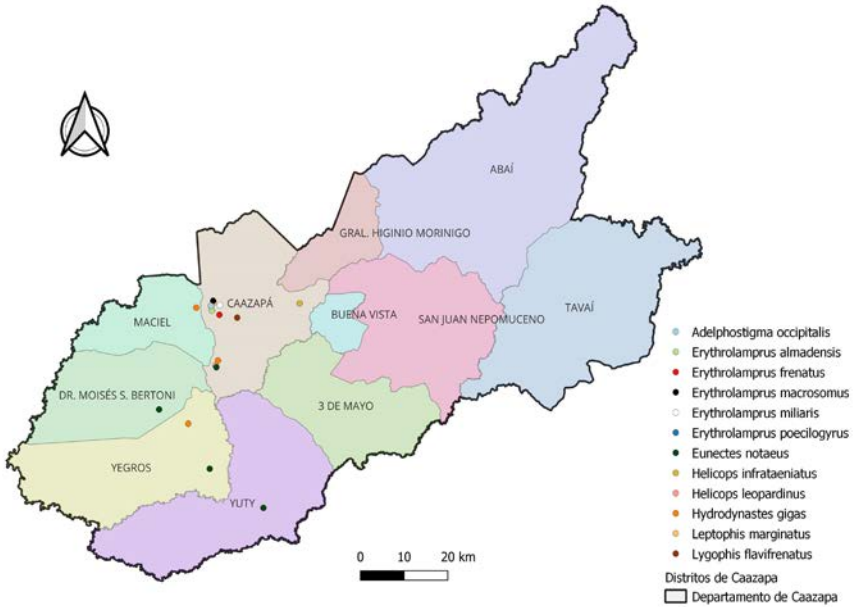

Figure 4. Map of the Department of Caazapá with its districts and georeferences of the ophidian species.

Figura 4. Mapa del Departamento de Caazapá con sus distritos y las georreferencias de las especies de ofidios.

Figure 6. A) *Apostolepis dimidiata*. B) *Atractus paraguayensis*. C) *Bothrops alternatus*. D) *Bothrops jararaca*. Photos: A, B, C: J. F. Maciel Méndez; D: E. Rojas.

Figura 6. A) *Apostolepis dimidiata*. B) *Atractus paraguayensis*. C) *Bothrops alternatus*. D) *Bothrops jararaca*. Fotos: A, B, C: J. F. Maciel Méndez; D: E. Rojas.

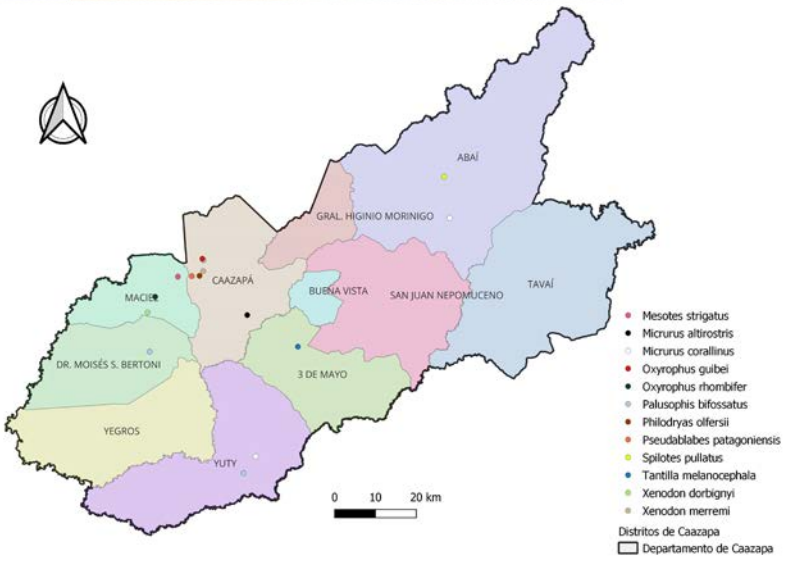

Figure 5. Map of the Department of Caazapá with its districts and georeferences of the ophidian species.

Figura 5. Mapa del Departamento de Caazapá con sus distritos y las georreferencias de las especies de ofidios.

Figure 7. *A) Bothrops jararacussu.* B) *Bothrops matogrossensis.* C) *Clelia clelia.* D) *Crotalus durissus.* Photos: A: C. Monges; B, C: J. F. Maciel Méndez; D: P. Gorostiaga.
Figura 7. *A) Bothrops jararacussu.* B) *Bothrops matogrossensis.* C) *Clelia clelia.* D) *Crotalus durissus.* Fotos: A: C. Monges; B, C: J. F. Maciel Méndez; D: P. Gorostiaga.

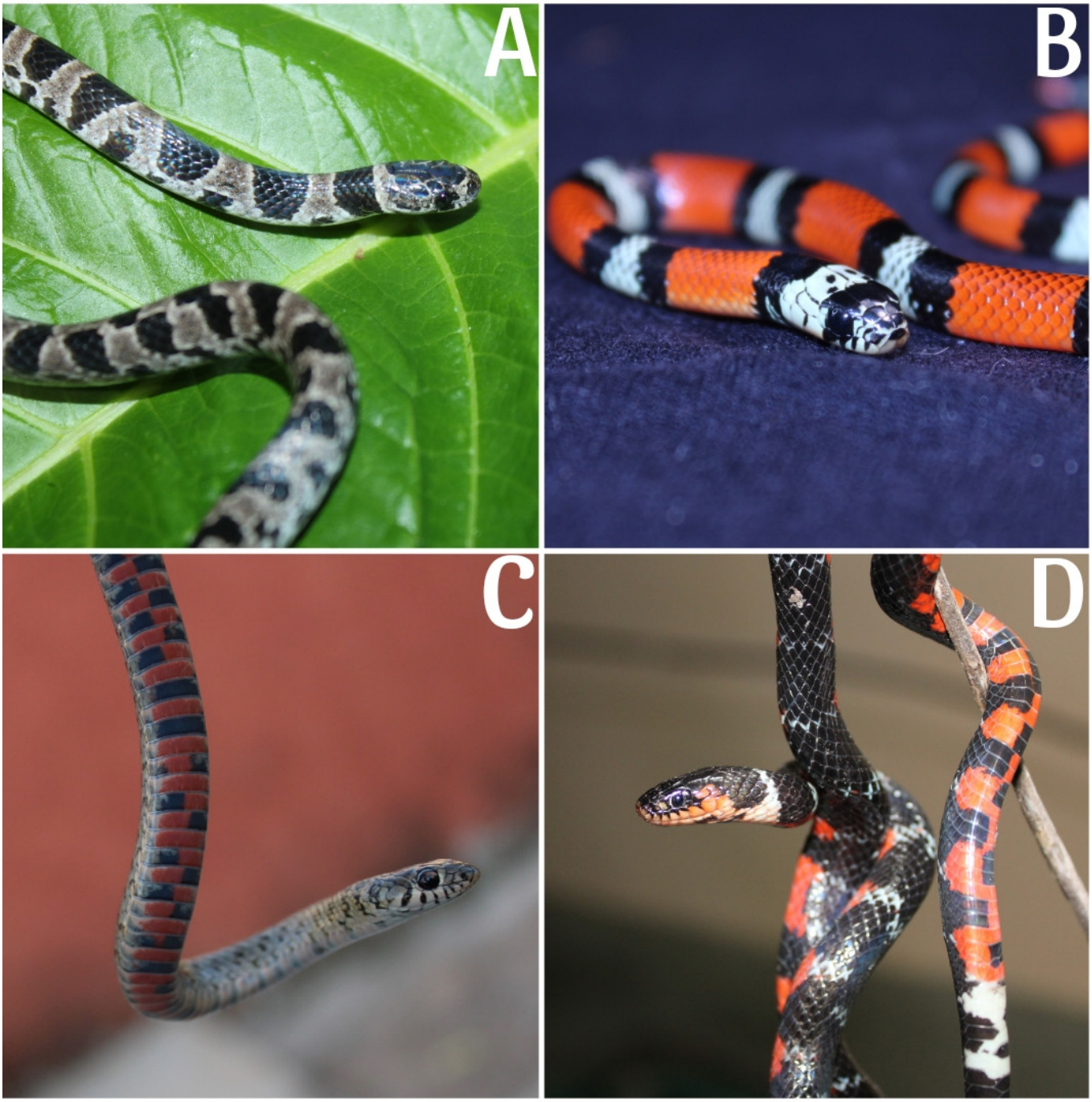

Figure 8. A) *Dipsas turgida.* B) *Erythrolamprus aesculapii.* C) *Erythrolamprus almadensis.* D) *Erythrolamprus frenatus.* Photos: J. F. Maciel Méndez.
Figura 8. A) *Dipsas turgida.* B) *Erythrolamprus aesculapii.* C) *Erythrolamprus almadensis.* D) *Erythrolamprus frenatus.* Fotos: J. F. Maciel Méndez.

Figure 9. A) *Erythrolamprus macrosomus*. B) *Erythrolamprus miliaris*. C) *Erythrolamprus poecilogyrus*. D) *Eunectes notaeus*. Photos: A, B, C: J. F. Maciel Méndez; D: J. Villalba.

Figura 9. A) *Erythrolamprus macrosomus*. B) *Erythrolamprus miliaris*. C) *Erythrolamprus poecilogyrus*. D) *Eunectes notaeus*. Fotos: A, B, C: J. F. Maciel Méndez; D: J. Villalba.

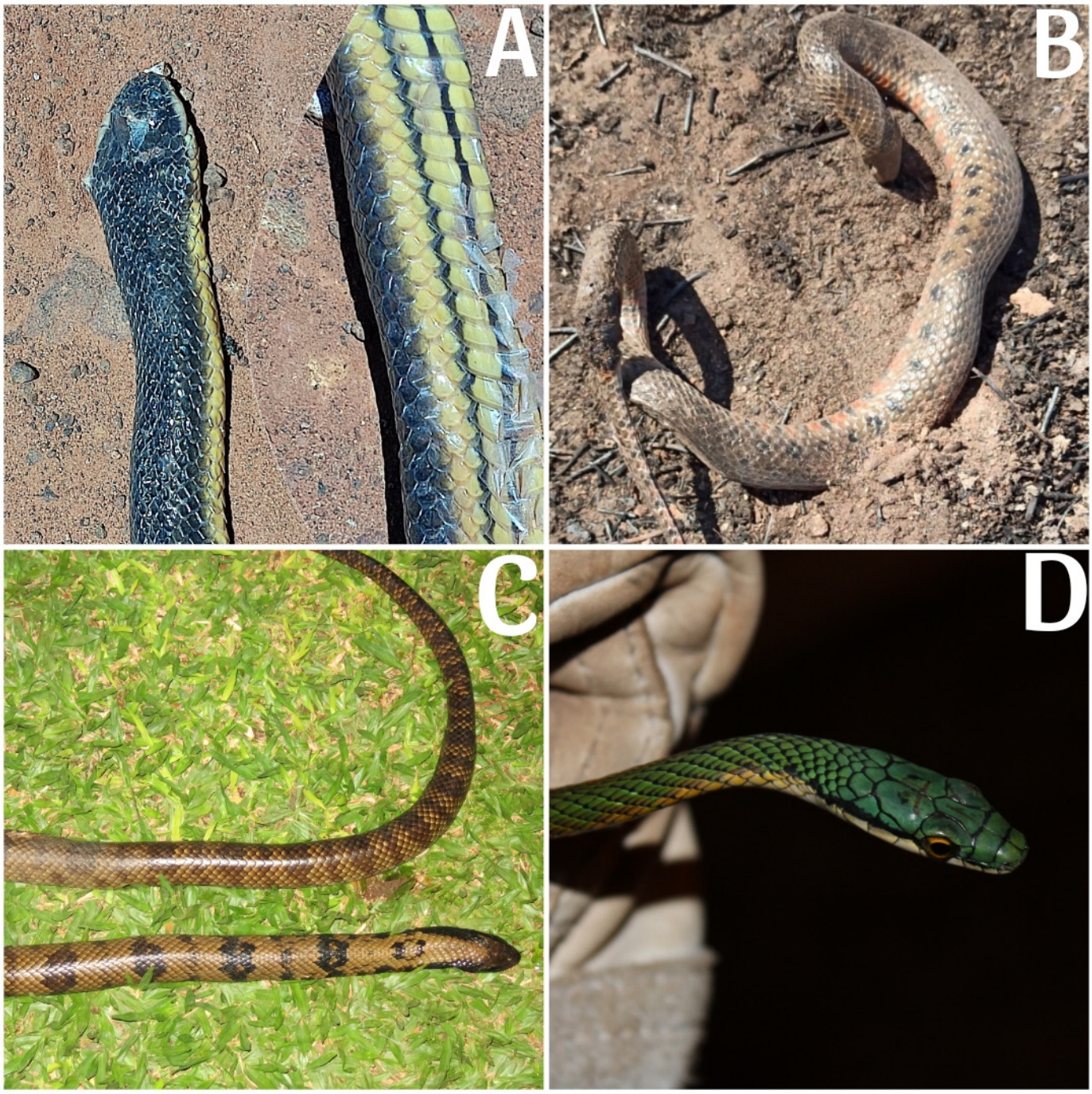

Figure 10. A) *Helicops infrataeniatus*. B) *Helicops leopardinus*. C) *Hydrodynastes gigas*. D) *Leptophis marginatus*. Photos: J. F. Maciel Méndez.
Figura 10. A) *Helicops infrataeniatus*. B) *Helicops leopardinus*. C) *Hydrodynastes gigas*. D) *Leptophis marginatus*. Fotos: J. F. Maciel Méndez.

Figure 11. A) *Lygophis flavifrenatus.* B) *Micrurus altirostris.* C) *Micrurus corallinus.* D) *Oxyrhopus guibei.* Photos: J. F. Maciel Méndez.
Figura 11. A) *Lygophis flavifrenatus.* B) *Micrurus altirostris.* C) *Micrurus corallinus.* D) *Oxyrhopus guibei.* Fotos: J. F. Maciel Méndez.

Figure 12. A) *Oxyrhopus rhombifer*. B) *Palusophis bifossatus*. C) *Philodryas olfersii*. D) *Pseudablabes patagoniensis*. Photos: A: C. Benítez; B, C, D: J. F. Maciel Méndez.
Figura 12. A) *Oxyrhopus rhombifer*. B) *Palusophis bifossatus*. C) *Philodryas olfersii*. D) *Pseudablabes patagoniensis*. Fotos: A: C. Benítez; B, C, D: J. F. Maciel Méndez.

Figure 13. A) *Spilotes pullatus.* B) *Adelphostigma occipitalis.* C) *Tantilla melanocephala.* D) *Dryophylax hypoconia.* Photos: A: E. Rojas; B: J. F. Maciel Méndez; C: B. Butlod; D: G. Gómez.
Figura 13. A) *Spilotes pullatus.* B) *Adelphostigma occipitalis.* C) *Tantilla melanocephala.* D) *Dryophylax hypoconia.* Fotos: A: E. Rojas; B: J. F. Maciel Méndez; C: B. Butlod; D: G. Gómez.

Figure 14. A) *Mesotes strigatus*. B) *Xenodon dorbignyi*. C) *Xenodon merremi*. D) *Drymarchon corais*. Photos: J. F. Maciel Méndez.

Figura 14. A) *Mesotes strigatus*. B) *Xenodon dorbignyi*. C) *Xenodon merremi*. D) *Drymarchon corais*. Fotos: J. F. Maciel Méndez.

DISCUSIÓN

El Departamento de Caazapá, Paraguay, ha revelado una mayor diversidad de ofidios de lo que se conocía previamente que eran de nueve ofidios según Cacciali et al. (2016), El presente trabajo presenta una serie de nuevos registros de especies de ofidios para el Departamento de Caazapá, con 29 nuevas especies. La *Bothrops alternatus* serpiente de importancia médica fue la más registrada, de hábitos terrestres, en ambientes deteriorados por el hombre (Cacciali, 2024). La *Apostolepis dimidiata* serpiente con datos insuficientes (Martínez et al., 2020) tuvo nueve registros en el interior de las casas y zonas de escombros en el distrito de Caazapá. Esta expansión en el conocimiento de la herpetofauna local es relevante por varias razones.

En primer lugar, permite comprender mejor la distribución geográfica de las serpientes en la región y evaluar su estado de conservación fuera de las áreas protegidas. Además, la capacitación de los habitantes locales en el reconocimiento de estas especies ha generado un cambio de actitud positivo hacia los ofidios, reduciendo significativamente las muertes de estos animales debido al desconocimiento. Esto se refleja en las constantes fotografías enviadas y al pedido constante de rescates de serpientes que ingresa en los domicilios, que anteriormente eran matados, esto se afianza con los relatos de los lugareños que mencionan que, sin la capacitación, lo más probable es que los mate.

Queda mucho por hacer en la educación ambiental, las cifras de matanzas siguen siendo altas. Es evidente que la educación ambiental y la participación ciudadana son herramientas poderosas para la conservación de la biodiversidad. Mitigar este conflicto humano - serpientes es necesario llevar a cabo estudios a escala local que evalúen los factores ambientales, humanos y aquellos relacionados con las serpientes que determinan la probabilidad de que ocurra una mordedura (Chippaux et al., 2015). Se registraron dos familias de importancia médica, tres géneros y ocho especies. Las distribuciones geográficas de la mayoría de las especies son poco entendidas y generalmente contienen muchas lagunas, el déficit de Wallaceano (Bini et al., 2006). La ciencia ciudadana a través de las redes sociales se ha utilizado con éxito tanto en programas de monitoreo (Dickinson et al., 2010; Menacho-Odio, 2015; Zuñiga et al., 2023). Los resultados obtenidos en Caazapá demuestran que es posible cambiar la percepción negativa hacia los ofidios y fomentar su protección.

En conclusión, los nuevos registros de ofidios en Caazapá resaltan la importancia de continuar investigando y monitoreando la diversidad herpetológica de la región. Al involucrar a la sociedad en estos esfuerzos, se contribuye no solo a la conservación de las serpientes, sino también a la construcción de una cultura de respeto y valoración por la naturaleza. La participación ciudadana ha sido fundamental en este proceso. Gracias a la accesibilidad de la tecnología, los habitantes han podido registrar fotográficamente diversas especies de serpientes, enriqueciendo considerablemente la base de datos. De hecho, algunas especies solo han sido registradas a través de estas fotografías, demostrando la importancia de involucrar a la comunidad en la investigación científica.

Si la investigación se centraba solamente en obtener registros por búsqueda activa, el resultado sería mucho más sucinto y se perdería la gran riqueza de ofidios del Departamento. Sin dejar de lado la necesidad de los monitoreos en el tiempo que son piezas fundamentales para conocer la biodiversidad.

CONCLUSIÓN

El trabajo aporta datos muy importantes para el conocimiento de las especies de ofidios del Departamento de Caazapá, información fundamental para lograr listas completas de especies, que son la base de estudios biogeográficos y permiten generar estrategias de conservación con criterios científicos, además se obtuvieron registros fotográficos, fechas y georreferencias de las distintas especies, incluso de taxones amenazados que existe escasa información. Se pretende seguir logrando una mayor comprensión de la distribución de las especies, de los distritos con mayor presencia y por sobre todo la educación de los lugareños.

La matanza de las serpientes está muy asociado al miedo de sufrir un accidente ofídico. Con educación debemos de mitigar el miedo de las personas, lo que se traduce a una menor matanza de animales por temor y desconocimiento. Como lo hecho por Nieto-Ariza et al. (2022) con el Proyecto Pucarara en Bolivia. Vimos resultados muy alentadores en la mayoría de los lugareños que deseaban aprender más sobre las serpientes, con gran aceptación de los jóvenes, revirtiendo el comportamiento de eliminación y persecución de serpientes que permite mantener y conservar la biodiversidad.

Agradecimientos.– Al Cuerpo de Bomberos Voluntarios de Caazapá K141, a los participantes de los cursos sobre identificación de serpientes, cuyos aportes son de mucha importancia, a la Facultad de Ciencias Veterinarias Filial Caazapá, al Consejo Directivo de la Facultad de Ciencias Veterinarias de la Universidad Nacional de Asunción.

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PRIMERA CONTRIBUCIÓN A LA DIVERSIDAD HERPETOLÓGICA DE LA RESERVA ECOLÓGICA PANAMAES, LOS SANTOS, PANAMÁ

FIRST CONTRIBUTION TO THE HERPETOLOGICAL DIVERSITY OF THE PANAMAES ECOLOGICAL RESERVE, LOS SANTOS, PANAMA

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Abstract.– Monitoring was carried out in transects within the Panamaes Ecological Reserve, which is located in the province of Los Santos, District of Pedasí. From November 2021 to June 2022, covering the dry and rainy seasons, we looked for amphibians and reptiles. The sampling effort took a total of 252.5 hours and covered 54.32 km in transects and general search areas with the aim of determining whether the conservation and reforestation efforts within the reserve have been successful. As a result of this work, we found a total of 808 individuals belonging to 43 species, of which 29 belong to the class Reptilia and 14 to the class Amphibia. These results show a positive outcome for the conservation and reforestation effects within the reserve. The most abundant species of amphibians were *Dendropsophus microcephalus* and *Boana platanera,* and the most abundant reptiles were *Basiliscus basiliscus* and *Anolis gaigei*.

Keywords.– Amphibians, Arco seco, Azuero, conservation, reptiles.

Resumen.– Se realizaron monitoreos en transectos dentro de la Reserva Ecológica Panamaes, ubicada en la provincia de Los Santos, Distrito de Pedasí. Los monitoreos se llevaron a cabo de noviembre de 2021 a junio de 2022, abarcando las estaciones seca y lluviosa. Se buscaron anfibios y reptiles durante un total de 252.5 horas de esfuerzo de muestreo, recorriendo 54.32 km entre transectos y áreas de búsqueda generales con el objetivo de determinar si los esfuerzos de conservación y reforestación dentro de la reserva han funcionado. Se obtuvo como resultado de este trabajo un total de 808 individuos reportados pertenecientes a 43 especies, de las cuales 29 corresponden a la clase Reptilia y 14 a la clase Amphibia. Esto representa un resultado positivo para los efectos de conservación y reforestación dentro de la REP. Las especies más abundantes fueron *Dendropsophus microcephalus* y *Boana platanera* por parte de los anfibios y *Basiliscus basiliscus* y *Anolis gaigei* por parte de los reptiles.

Palabras clave.– Anfibios, Arco seco, Azuero, conservación, reptiles.

INTRODUCCIÓN

Los bosques en Panamá contribuyen al sostenimiento y la conservación de la diversidad biológica (Tokarz & Condit, 2021). Estos bosques han sufrido la presión antropogénica por la búsqueda de beneficios, como la madera, tierra para cultivos y ganadería, sin considerar las consecuencias (Cedeño et al., 2006). Este impacto negativo es más facil observarlo en los bosques del Arco Seco en la península de Azuero, los cuales representan cerca del 7 % de los bosques de Panamá (MiAmbiente, 2009). Esta península es la región más seca del país, y en ella se encuentra la mayor parte de los bosques estacionalmente secos

remanentes de Panamá (Griscom & Ashton, 2011; Garibaldi et al., 2018). Los bosques secos tropicales son considerados uno de los ecosistemas tropicales más amenazados (Janzen, 1988; Bawa & Seidler, 1998), con una precipitación anual menor a 1,000 mm y una temperatura inferior a 18 °C (MiAmbiente, 2009), lo que limita esta región a un clima tropical de sabana (CATHALAC, 2016). Debido al clima y la distribución geográfica, existen especies de flora y fauna que son endémicas de los bosques secos tropicales (Hasnat & Hossain, 2020). Los bosques secos tropicales de Panamá están pasando por una transición en el uso del suelo; esto debido a cambios en factores que van desde el abandono de zonas de pastoreo a la reforestación activa de algunos lugares (Sánchez-Azofeifa et al., 2005; Vieiria & Scariot, 2006; Griscom et al., 2009).

La Reserva Ecológica Panamaes (REP), ubicada en la península de Azuero, se decretó en el año 2003 con la finalidad de proteger el bosque seco tropical, ya que este bosque enfrenta severas amenazas, como la tala, la ganadería intensiva y extensiva, y el mal manejo de los suelos, siendo la región con más pérdida boscosa del país (MiAmbiente, 2020). La REP tiene como principal objetivo la recuperación de los bosques secos tropicales dentro de la reserva para que lleguen a ser florecientes y que poco a poco proporcionen recursos naturales, principalmente a los pobladores de la zona (Morales et al., 2016). Algunas de las técnicas de reforestación que se han usado en la REP son la regeneración pasiva de bosques así como la instalación de plantaciones (Sloan, 2008). La reforestación puede ser necesaria para restaurar la salud del ecosistema y, monitoreando la presencia de fauna sensible a cambios en el entorno, como los anfibios y reptiles, se podrían evaluar las prácticas exitosas y la restauración dentro de la reserva (Kovacs, 2019).

Debido a la gran presión antropogénica que ha sufrido esta región (Cedeño et al., 2006), se tienen como consecuencias un alto grado de deforestación, menos agua, menos bosques y menos sitios en donde se puedan realizar investigaciones sobre la herpetofauna propia de la región. Las zonas áridas son menos estudiadas en cuanto a la herpetofauna (Fernandez-Badillo et al., 2016) y aún menos con respecto a los anfibios por sus características fisiológicas. Esto se debe a que ellos se asocian a ambientes acuáticos, puesto que la mayoría de las especies de este grupo pasan las primeras etapas de su desarrollo en el agua (Aguillon-Gutiérrez, 2018). En consecuencia, los estudios de anfibios en esta zona han sido muy escasos. No obstante, aunque gran parte de la biodiversidad de anfibios anuros se encuentra en zonas caracterizadas por alta humedad relativa (Abad et al., 2017), existen también anuros en zonas semiáridas y áridas (Canseco-Márquez & Gutierrez-Mayén, 2010). Para contrarrestar la escasez de agua característica de dichos ecosistemas, estos animales han desarrollado evolutivamente mecanismos ecofisiológicos y comportamientos muy diversos, como la formación de madrigueras y capullos, la reflectancia, la coloración, la postura corporal, la disminución del metabolismo, la retención de líquidos y la permeabilidad cutánea, entre otros (Aguillon-Gutiérrez, 2018).

En cuanto a los reptiles, estos representan una parte significativa de la biodiversidad de ambientes donde el agua es un recurso escaso (González et al., 2004). Este grupo es el que se presenta con mayor diversidad en aquellas zonas (Perlaza-Berrío & Peláez-Plazas, 2018). En el bosque seco tropical donde las temperaturas son en promedio más altas que en el resto de país, la capacidad de termorregular la temperatura interna con el ambiente es una ventaja que los reptiles poseen (Lara-Resendiz, 2020). Además, la capacidad de poner huevos recubiertos de una cascara que los protege de la desecación supone una ventaja en estos ambientes en donde la disponibilidad de agua es un factor determinante (Zug et al., 2001).

La revisión de las publicaciones de los grupos faunísticos aquí presentados deja al descubierto la escasez de estudios sobre anfibios y reptiles en el bosque seco de Panamá. Por esta razón, los objetivos del presente estudio son comprobar si los planes de conservación de los bosques secundarios dentro de la reserva están funcionando como hábitat de los anfibios y reptiles; determinar cuál de los grupos, anfibios o reptiles, presenta una mayor abundancia y diversidad; y especificar el estado de conservación en el que se encuentra cada especie en la Reserva Ecológica Los Panamaes.

MATERIAL Y MÉTODOS

Descripción del área de estudio

El área de estudio se ubicó en la provincia de Los Santos, distrito de Pedasí en la región central de la República de Panamá. Esta área es caracterizada por las actividades agrícolas y ganaderas que constituyen el uso principal del suelo en el Arco Seco (MiAmbiente, 2009). Este lugar presenta un tipo de bosque húmedo tropical que a su vez colinda con el bosque pluvial montano bajo (Holdridge, 1971), específicamente para la REP, y presenta una precipitación anual en ocasiones por debajo de los 1,000 mm (MiAmbiente, 2009). También cabe mencionar que, según Köppen (1900), la región del Arco Seco entra en la zona A con un clima tropical de sabana en la cual hay una estación seca bien definida de entre tres a cinco meses. Los lugares específicos para los muestreos fueron seleccionados por su fácil accesibilidad y por reunir las condiciones adecuadas para el desarrollo de este

proyecto. Es importante remarcar que no existe información debidamente publicada relacionada a anfibios y reptiles de la REP (Fig. 1).

Reserva Ecológica Panamaes

La REP es una parcela de terreno de aproximadamente 560 ha en Puerto Escondido, Pedasí, provincia de Los Santos en la península de Azuero (coordenadas: 7° 26' 44.4" N, 80° 4' 14.3" W). La propiedad está compuesta por varias fincas cuyo principal dueño, el príncipe Maximiliano de Liechtenstein, comparte su visión para regenerar y conservar los ecosistemas terrestres, costeros y oceánicos a través del manejo sostenible de la tierra (Fig. 2).

Metodología de campo

Los muestreos fueron realizados entre noviembre de 2021 y junio de 2022 divididos en cuatro visitas a la reserva. La primera visita preliminar fue para delimitar el área en la que se realizarían los transectos y las tres visitas posteriores, para realizar el monitoreo biológico. Cada visita duró de tres a cuatro días para muestrear. Se utilizó la metodología de transecto para tratar de cubrir la mayor cantidad de superficie (Lips et al., 1999; Heyer et al., 2014) en la reserva. En total, se colocaron cinco transectos: sendero Los Panamaes, Río La Miel, Laguna, Quebrada #2 y Laguna-Tecal con una longitud aproximada de 1.5 km. Los transectos fueron monitoreados hasta un máximo de 2 m de cada lado y hasta los 2 m de altura (Fig. 3).

Todos los transectos fueron georreferenciados y luego se generó un mapa con ayuda del programa de uso libre QGIS (QGIS, 2023) en donde se ubicaron los transectos delimitados para los monitoreos utilizando la aplicación de uso libre Wikiloc (Ramot et al., 2022) y haciendo uso también de un GPS Garmin GPSMAP 62s y Garmin GPSMAP 64sx. En este estudio, se realizaron muestreos diurnos y nocturnos utilizando búsquedas aleatorias por encuentro visual (Lips et al., 1999) las cuales

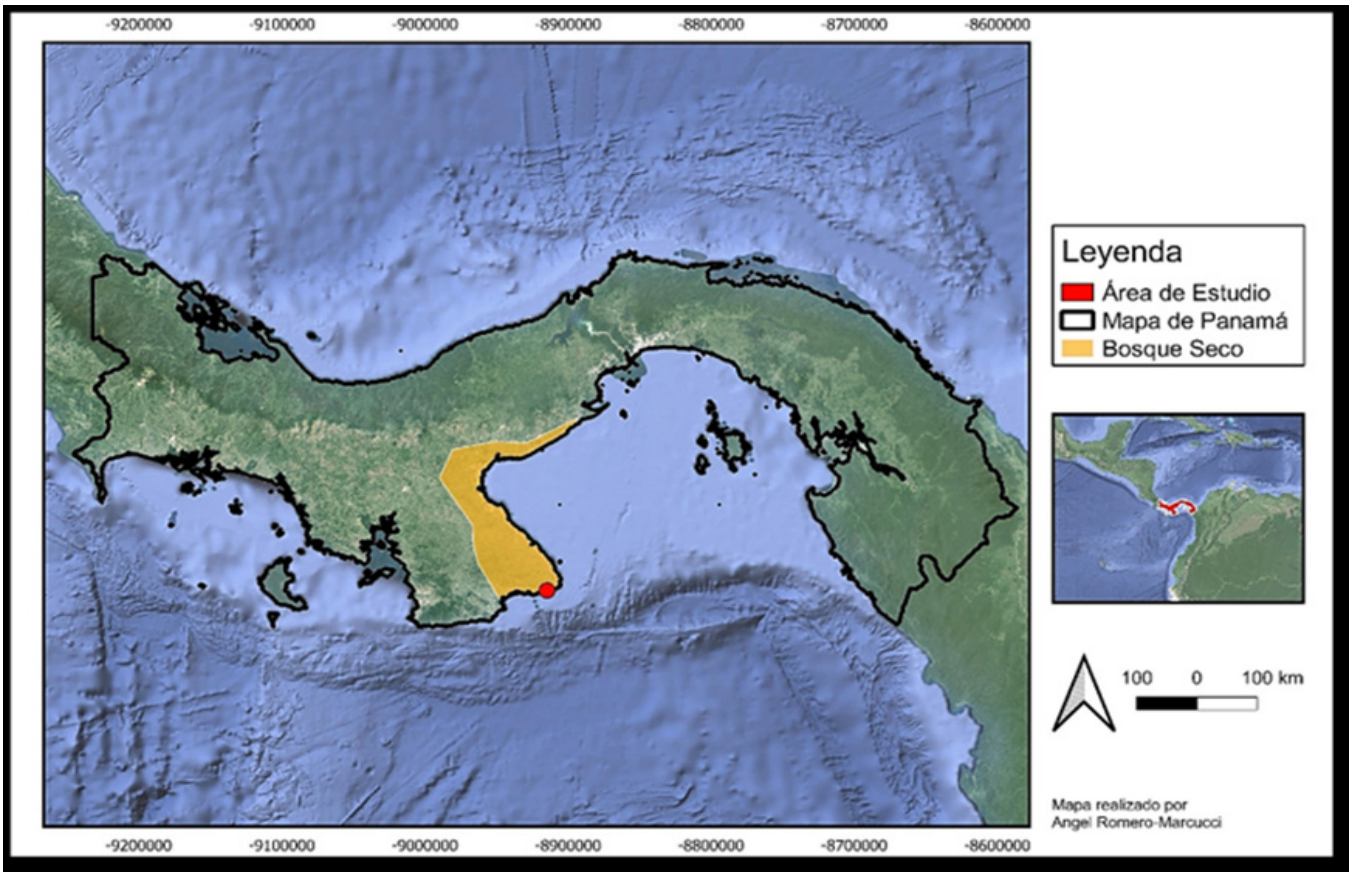


Figure 1. Location of the study area in the Azuero peninsula, Los Santos Province, Panama. The yellow area indicates the extent of the tropical dry forests in Panama and the red dot indicates the location where the study was done.

Figura 1. La ubicación del área de estudio en la península de Azuero, provincia de Los Santos, Panamá. El área en amarillo indica la extensión de los bosques tropicales secos en Panamá y el punto rojo indica el lugar donde se realizó este estudio.

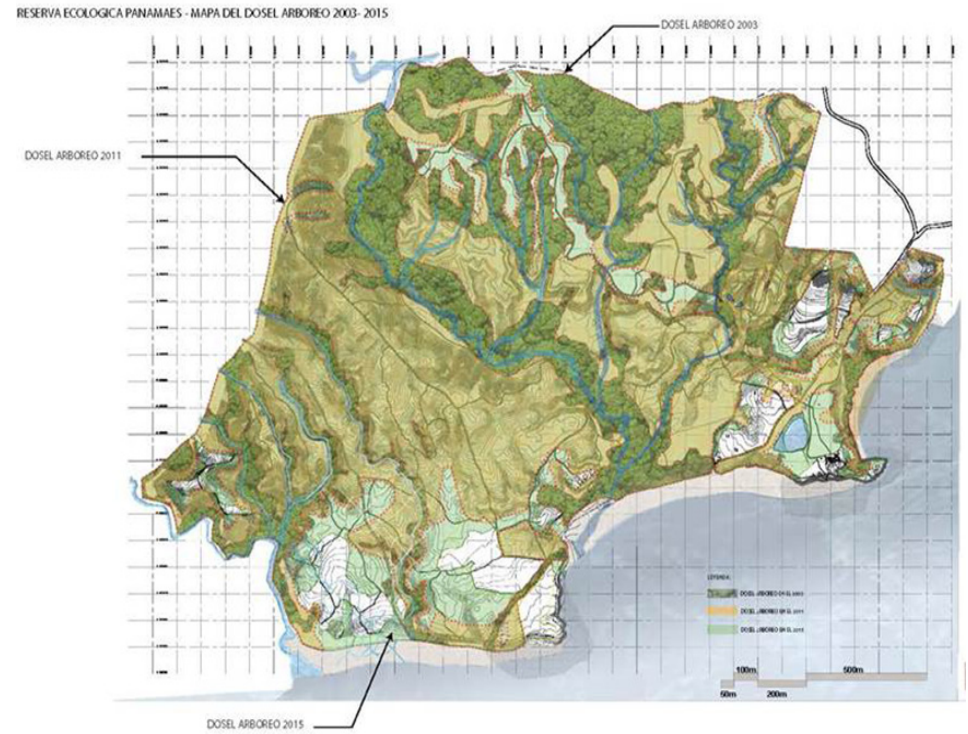


Figure 2. General map of the Panamaes ranch and time of reforestation. Green = tree canopy in 2003. Light green = regenerating forest in 2011. Mint green = regenerating forest in 2015 (Morales et al., 2016).

Figura 2. Mapa general de la finca Panamaes y el tiempo de reforestación. Verde = dosel arbóreo en 2003. Verde claro = bosque en regeneración en 2011. Verde menta = bosque en regeneración en 2015 (Morales et al., 2016).

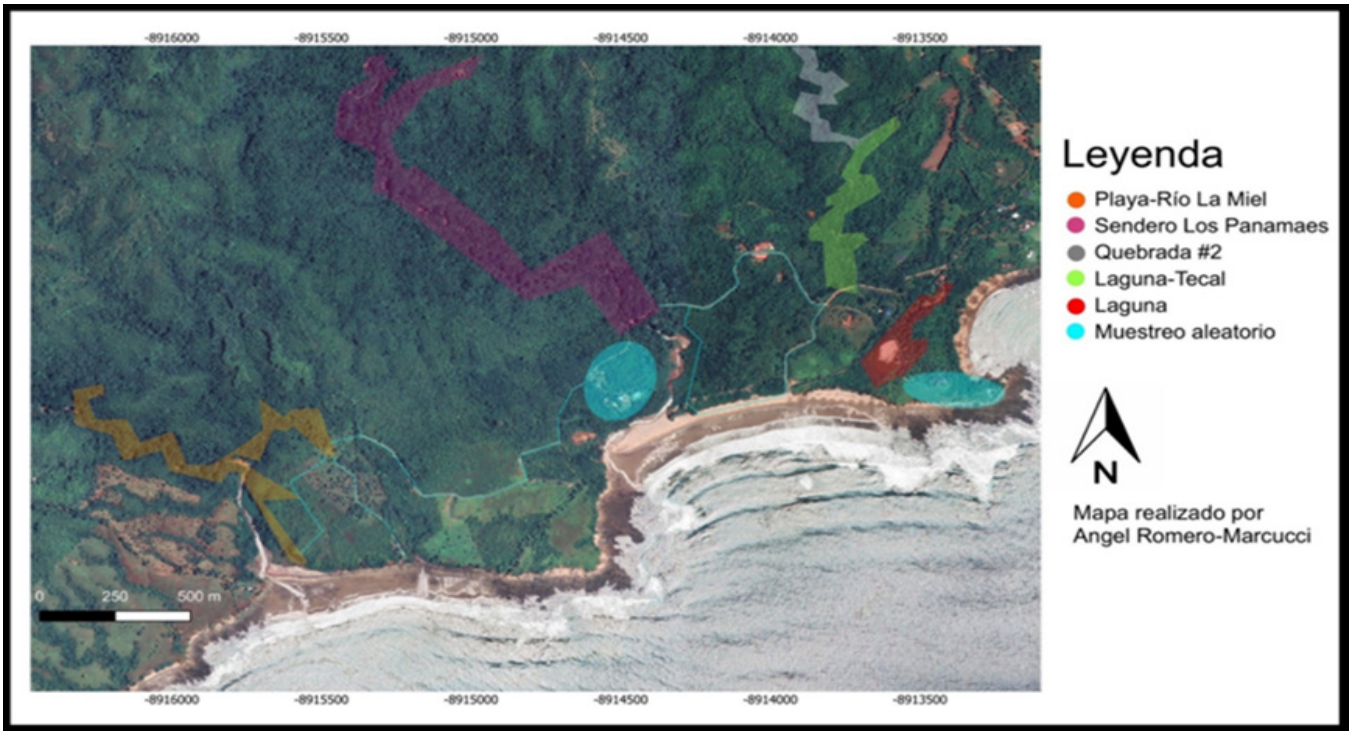


Figure 3. Location of transects within the Panamaes Ecological Reserve. Transects: orange = Playa-Rio La Miel; pink = Sendero Los Panamaes; gray = Quebrada #2; reed green = Laguna-Tecal; red = Laguna; light blue = random sampling.

Figura 3. Localización de los transectos dentro de la Reserva Ecológica Panamaes. Transectos: naranja = Playa-Rio La Miel; rosado = Sendero Los Panamaes; gris = Quebrada #2; verde caña = Laguna-Tecal; rojo = Laguna; celeste = muestreo aleatorio.

abarcaron áreas de suelo, como madrigueras, huecos, troncos, hojarasca, cerca de cuerpos de agua y en arbustos y árboles. En el caso de las serpientes, se utilizaron ganchos herpetológicos y pinzas herpetológicas; mientras que, para los sapos, ranas, lagartijas y anolis, la captura fue manual. Las observaciones se iniciaron a la misma hora del día, durante todos los días de la gira (Puerta et al., 2014).

Identificación de especies

Identificación de especies. Para la identificación de las especies, se utilizaron las claves de identificación *Amphibians of Costa Rica* (Leenders, 2016), *Reptiles of Costa Rica* (Leenders, 2019), *Amphibians of Central America* (Köhler, 2011), y *Reptiles of Central America* (Köhler, 2008). A los individuos que no se lograron identificar en el momento, se les tomaron fotografías de los muslos, ingle, cabeza, manos y patas, parte ventral y dorsal, al igual que una fotografía panorámica de todo el cuerpo para su posterior determinación.

Estado de conservación

Para conocer el estado de conservación de las especies registradas en este estudio, se utilizó como referencia el listado de especies amenazadas de fauna y flora de Panamá (MiAmbiente, 2016), la lista roja de especies amenazadas de la Unión Internacional para la Conservación de la Naturaleza (IUCN SSC Amphibian Specialist Group, 2023) y el listado de la Convención sobre el Comercio Internacional de Especies Amenazadas de Fauna y Flora Silvestres (CITES, 2020).

Esfuerzo de muestreo

Se recorrió un total de 54.32 km entre el día y la noche. El esfuerzo total de muestreo para esta investigación fue de 252.5 horas/persona, dividido en 126.25 horas/persona de esfuerzo diurno y 126.25 horas/persona de esfuerzo nocturno.

Análisis estadísticos

Riqueza y diversidad. Para este trabajo, se calculó la diversidad utilizando los números de diversidad de Hill (q0 = riqueza, q1= índice exponencial de Shannon y q2 = índice inverso de Simpson), los cuales tienen como unidades los números de especies y miden lo que se denomina el número efectivo de especies presentes en una muestra. Estos números son una medida del grado de distribución de las abundancias relativas entre las especies y permiten las comparaciones entre índices de diversidad debido a las transformaciones matemáticas que usan de los índices originales de Simpson y Shannon (Hill, 1973; Jost, 2006, 2007; Moreno et al., 2011; Tuomisto, 2011). Adicional a esto, se calcularon los índices de entropía (H), probabilidad (1-D) y equidad (J).

Curva de rarefacción. Se generaron curvas de rarefacción mediante el programa en línea "iNext" que permiten evidenciar diferencias en la diversidad de especies, representada por los números de diversidad de Hill (Chao et al., 2016). Adicionalmente, se evaluó la completitud de la muestra y la representatividad de los grupos (anfibios y reptiles) utilizando la cobertura de la muestra (Cn) y el déficit de cobertura para determinar la eficacia del inventario (Chao & Shen, 2010; Chao & Jost, 2012) con una fórmula planteada por Pineda & Moreno (2015) en el programa Excel.

Abundancia. Se calculó la abundancia relativa multiplicando el número total de individuos de una especie por el total de especies encontradas en la REP. La densidad poblacional se calculó como el número de individuos por unidad de área; para ello se aplicó el método sugerido por Ojasti & Dallmeier (2000).

RESULTADOS

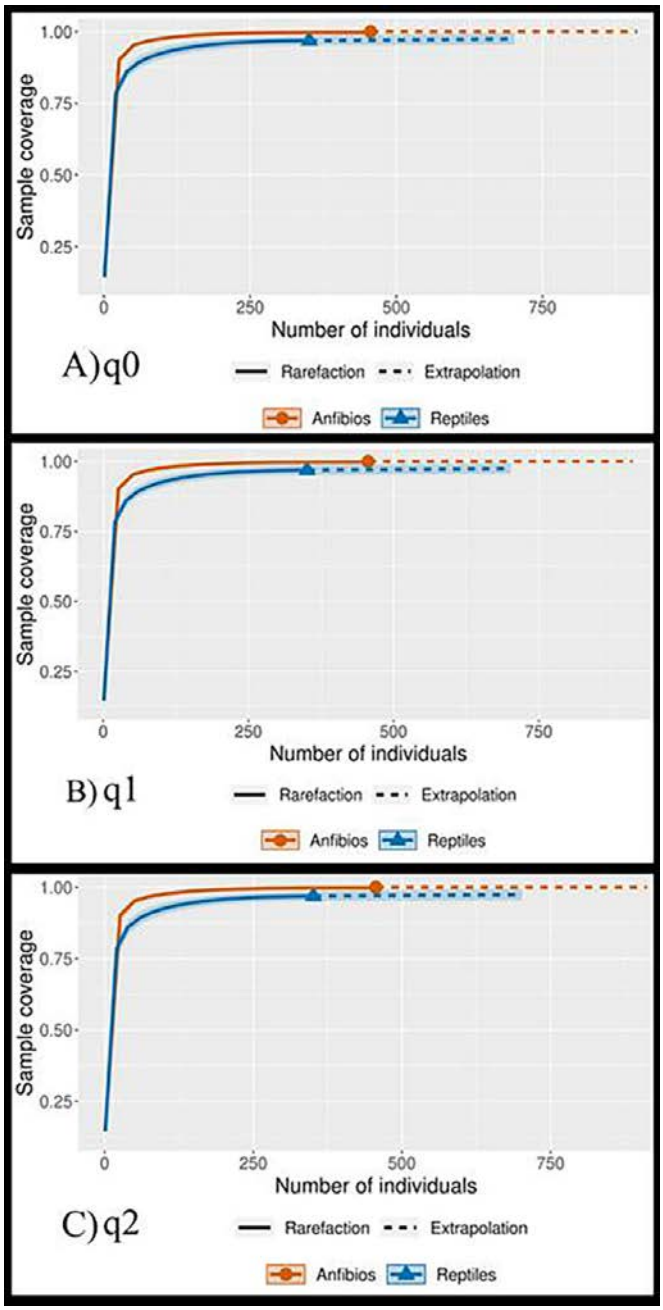
Para la herpetofauna de la REP, se encontró un total de 808 individuos pertenecientes a 43 especies, 14 especies de anfibios y 29 especies de reptiles. La cobertura de la muestra fue mayor en anfibios que en reptiles con un valor de Cn = 0.99 y 0.96 respectivamente (Fig. 4). El esfuerzo de muestreo se midió utilizando el estimador de Chao 2 y el resultado para los anfibios fue de un 83 % y para los reptiles, 73 %, es decir, en ambos casos existe la probabilidad de encontrar más especies (Fig. 5).

Anfibios

De las 14 especies reportadas, solo una especie (*Dendrobates auratus*) se encuentra en un estatus vulnerable (VU) de acuerdo con la Unión Internacional para la Conservación de la Naturaleza (IUCN, 2023) para Panamá y en el apéndice II de CITES (Tabla 1).

Riqueza y diversidad. Al realizar las curvas de rarefacción de este estudio, encontramos que la riqueza de especies (q0) se comporta de manera diferente al índice exponencial de Shannon (q1) y al índice inverso de Simpson (q2), los cuales presentan una tendencia a la estabilización de la asíntota. Por esta razón, se asume que estos índices no aumentarían por más especies y/o individuos nuevos que se agreguen a la muestra. Esto indica que el número de especies abundantes y dominantes muestreadas sí fue adecuado (Fig. 5).

Índice de entropía, probabilidad y equidad. El cálculo del índice de Shannon fue de H = 2.1. El índice de dominancia de Simpson (1-D) fue del 84 % y al estimar el índice de equidad de Pielou, se obtuvo J = 0.55 (Fig. 6).



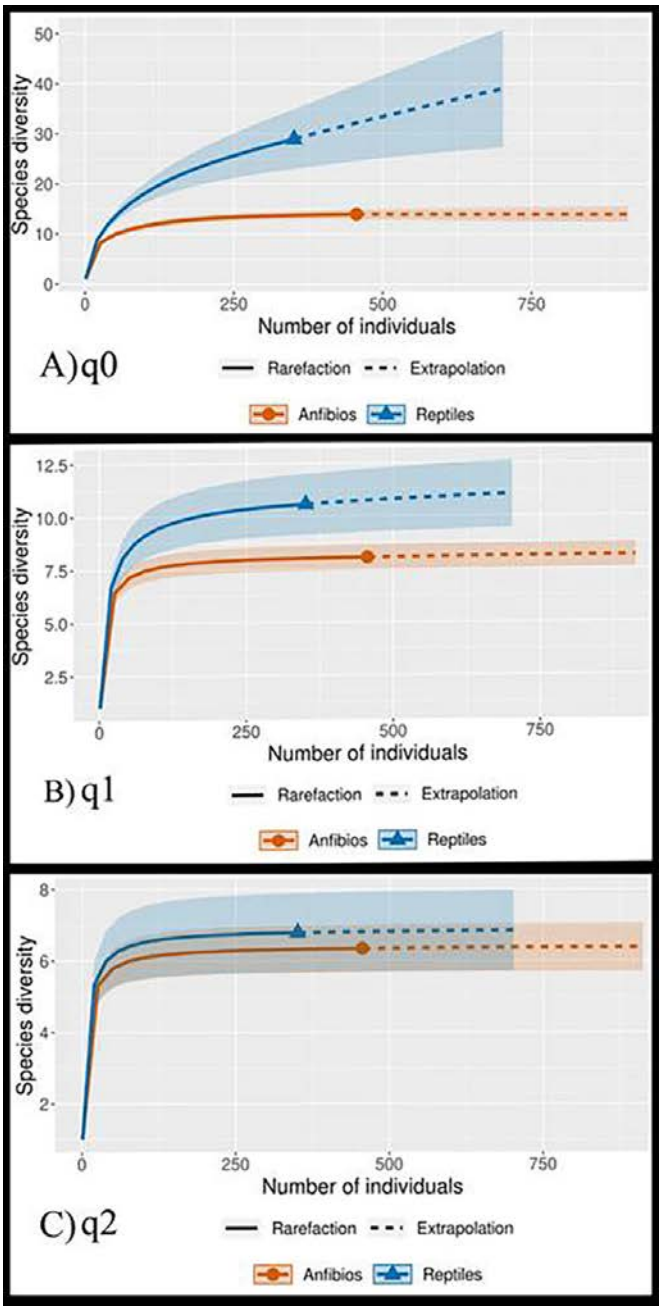


Figure 4. Sample coverage of the orders A) Richness (q0), B) Shannon's ntropy (q1) and C) Simpson's Reciprocal (q2). The continuous line is the rarefaction curve; the dotted line, the extrapolation; orange is for amphibians; blue is for reptiles; and the triangles and circles are for the observations de la finca Panamaes en el área Azuero, provincia de Los Santos, Panamá.

Figura 4. Cobertura de la muestra de los órdenes A) Riqueza (q0), B) Exponencial de Shannon (q1) y C) Inverso de Simpson (q2). La línea continua indica la rarefracción; la línea punteada, la extrapolación; el color naranja, anfibios; color azul, reptiles; y los triángulos y círculos indican las observaciones de la finca Panamaes en el área Azuero, provincia de Los Santos, Panamá.

Figure 5. A) Richness rarefaction curve (q0), B) Shannon's Entropy (q1) and C) Simpson's Reciprocal (q2). The continuous line indicates the rarefaction curve; the dotted line, extrapolation; orange is for amphibians; blue is for reptiles; and the triangles and circles are for the observations from the finca Panamaes in Azuero, provincia de Los Santos, Panamá.

Figura 5. A) Curva de rarefracción de Riqueza (q0), B) Exponecial de Shannon (q1) y C) Inverso de Simpson (q2). La línea continua indica la rarefracción; la línea punteada, la extrapolación; el color naranja, anfibios, el color azul, reptiles; y los triángulos y círculos indican las observaciones de la finca Panamaes en el área Azuero, provincia de Los Santos, Panamá.

Table 1. List of species by amphibian family of the Panamaes Ecological Reserve with common name and conservation status.

Tabla 1. Listado de especies por familia de anfibios de la Reserva Ecológica Panamaes con el nombre común y el estado de conservación.

Listado de los anfibios registrados en la Reserva Ecológica Panamaes, Pedasí, Los Santos								
Familia	**Especie**	**Nombre común**	**Cantidad de individuos**	**Estado de conservación**			**Fuente**	**Tipo de vegetación**
				MA	**CITES**	**UICN**		
Bufonidae	*Incilius signifer*	Sapo de bosque seco	1			LC	O	BS
	Rhinella horribilis	Sapo común	5			LC	O	BS
Dendrobatidae	*Dendrobates auratus*	Rana dardo verdinegra	6	VU	II	LC	O	BP
Hylidae	*Boana platanera*	Rana platanera	109			LC	O	BP, BS
	Dendropsophus microcephalus	Rana grillo	111			LC	O	BS, BG
	Scinax altae	Rana de árbol	27			LC	O	BS, BG
	Smilisca phaeotha	Rana enmascarda	10			LC	O	BP, BS
	Smilisca sila	Rana arborícola Ñata	39			LC	O	BP, BS
	Trachycephallus vermiculatus	Rana lechosa	4			LC	O	BP, BS
Leptodactylidae	*Engystomops pustulosus*	Tungara	37			LC	O	BS, BG
	Leptodactylus fragilis	Rana de espuma frágil	45			LC	O	BG
	Leptodactylus insularum	Rana de espuma insular	52			LC	O	BG
	Leptodactylus savagei	Rana toro	3			LC	O	BP, BG
Microhylidae	*Elachlistocleis pearsei*	Rana pingüina	7			LC	O	BG

Note. MA (Ministry of Environment of Panama): VU = Vulnerable (MiAmbiente, 2016); IUCN (International Union for Conservation of Nature): LC = Least Concern (IUCN, 2023); CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora): I = cited in Appendix 1, II = cited in Appendix 2 and III = cited in Appendix 3 (CITES, 2020). Source: O = direct observation in the field. Vegetation type: BG = gallery forest, BP = primary or little intervened forest, BS = secondary or intervened forest (Young, 1999), L = lagoon, CP = near the beach.

Nota. Estado de conservación: MA (Ministerio de Ambiente de Panamá): VU = vulnerable (MiAmbiente, 2016); UICN (Unión Internacional para la Conservación de la Naturaleza): LC = preocupación menor (IUCN SSC Amphibian Specialist Group, 2023); CITES (Convención sobre el Tráfico Internacional de Especies Amenazadas de Flora y Fauna Silvestre): I = citadas en el apéndice 1, II = citadas en el apéndice 2 y III = citadas en el apéndice 3 (CITES, 2020). Fuente: O = observación directa en el campo. Tipo de vegetación: BG = bosque de galería, BP = bosque primario o poco intervenido, BS = bosque secundario o intervenido (Young, 1999), L = laguna, CP = cerca de playa.

Abundancia. Para las 14 especies de anfibios, se registró un total de 457 individuos. Las especies más abundantes fueron *Dendrosophus microcephalus* con 24.6 % (111 individuos), *Boana platanera* con 24.1 % (109 individuos), *Leptodactylus insularum* con 11.5 % (52 individuos), *Leptodactylus fragilis* con 10.0 % (45 individuos) y *Smilisca sila* con 8.6 % (39 individuos). *Incilius signifer*, *Leptodactylus savagei*, *Trachycephalus vermiculatum*, *Rhinella horribilis*, *Dendrobates auratus*, *Elachiostecleis pearsei*, *Smilisca phaeota*, *Scinax altae* y *Engiostomops pustulosus* presentaron porcentajes menores a 8 % (Fig. 7).

Reptiles

Se registraron un total de 29 especies de reptiles divididas en 13 familias. De las especies registradas, solo cinco se encuentran en condición vulnerable para Panamá de acuerdo con la IUCN (2023) y en el apéndice II de CITES (Tabla 2).

Riqueza y diversidad. Al realizar las curvas de rarefacción de este estudio, encontramos que q0 no se estabiliza a medida que el esfuerzo de muestreo se duplica y por tanto es posible que aún falten especies de reptiles por agregar. Por otro lado, si se tiene en cuenta la abundancia relativa de las especies, q1 presenta

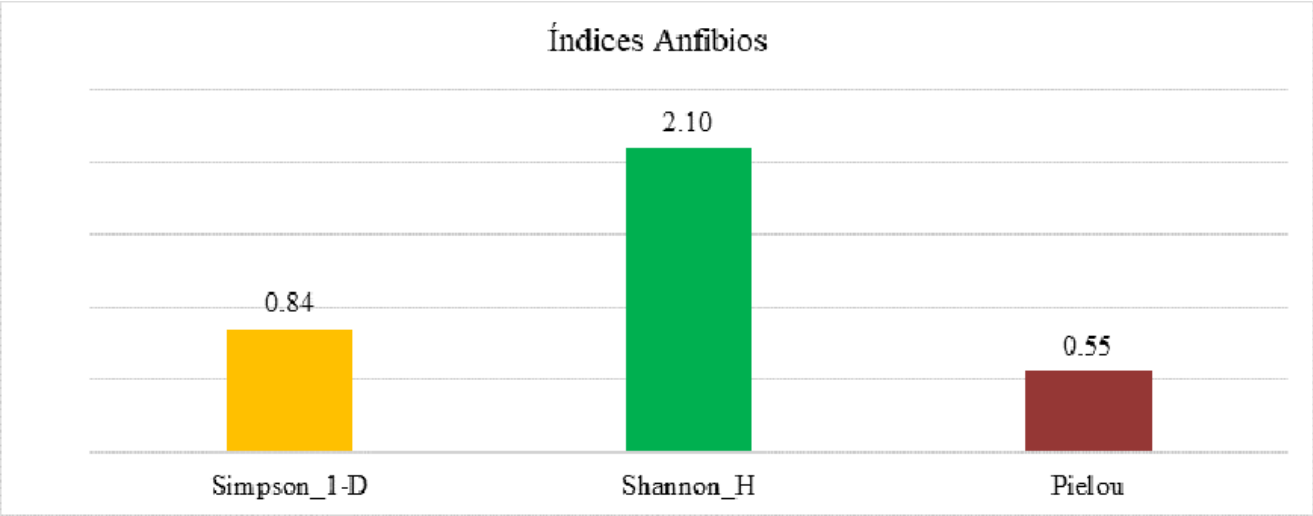


Figure 6. Simpson's dominance index, Shannon's diversity index and Pielou's evenness index for amphibians from the finca Panamaes in Azuero, provincia de Los Santos, Panamá.

Figura 6. Índice de dominancia de Simpson, índice de diversidad de Shannon e índice de equidad de Pielou en anfibios de la finca Panamaes en el área Azuero, provincia de Los Santos, Panamá.

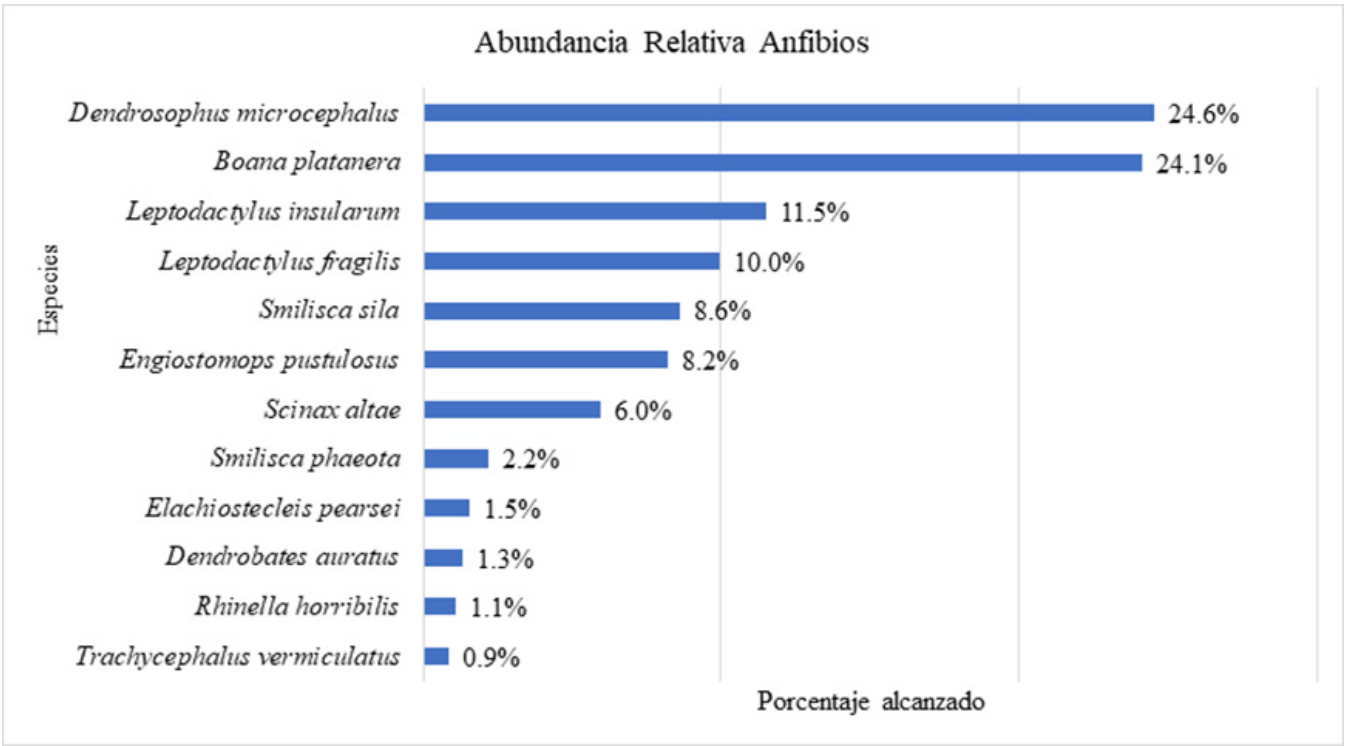


Figure 7. Relative abundance of amphibians from the finca Panamaes in Azuero, provincia de Los Santos, Panamá.

Figura 7. Abundancia relativa de anfibios del área Azuero, provincia de Los Santos, Panamá.

Table 2. List of species by family of reptiles from the Panamaes Ecological Reserve with the common name and contributions to the conservation status

Tabla 2. Listado de especies por familia de reptiles de la Reserva Ecológica Panamaes con el nombre común y aportes al estado de conservación.

Listado de los anfibios registrados en la Reserva Ecológica Panamaes, Pedasí, Los Santos								
Familia	**Especie**	**Nombre común**	**Cantidad de individuos**	**Estado de conservación**			**Fuente**	**Tipo de vegetación**
				MA	**CITES**	**UICN**		
Alligatoridae	*Caiman crocodilus*	Caiman o Babillo	1	VU	II	LC	O	L, BS
Corytophanidae	*Basiliscus basiliscus*	Basilisco común	6			LC	O	BG, BS, BP
Dactyloidae	*Anolis auratus*	Rana platanera	9			LC	O	BG
	Anolis biporcatus	Rana grillo	16			LC	O	BP, BS, BG
	Anolis gaigei	Rana de árbol	65			LC	O	BP, BS, BG
Gekkonidae	*Hemicatylus frenatus*	Gecko común	5			LC	O	BP, BS, BP
Gymnophthalmidae	*Elachlistocleis pearsei*	Limpia casa	5			LC	O	BP
Kinosternidae	*Kinosternon scorpioides*	Tortuga escorpión de lodo	3			LC	O	BP
Iguanidae	*Ctenosaura similis*	Iguana negra	27			LC	O	CP
	Iguana iguana	Iguana verde	31	VU	II	LC	O	BP, BS, BP
Teiidae	*Holcosus festibus*	Borriguero de montaña	4			LC	O	BP, BS, BP
Sphaerodactylidae	*Gonatodes albogularis*	Gecko cabeciamarillo	9			LC	O	BP, BS, BP
Boidae	*Boa imperator*	Boa constrictora	1	VU	I-II	LC	O	BP
	Corallus ruschembergerii	Boa arborícola	4	VU	II	LC	O	BP, BS
	Epicrates maurus	Boa arcoiris	1	VU	II	LC	O	BP
Colubridae	*Chironius flavopictus*	Ranera azul, cazadora	1			LC	O	BS
	Dendrophidion percarinatum	Corredora	1			LC	O	BP
	Drymobius margaritiferus	Culebra borriguera	1			LC	O	BP
	Enulius flavitorques	Culebra cienpiecera	3			LC	O	BP, BS
	Imantodes cenchoa	Bejuquilla cabezona común	1			LC	O	BP
	Marisora unimarginata	Mabuya	1			LC	O	BP
	Leptodeira rhombifera	Culebra ojos de gato	8			LC	O	BP, BS, BG
	Leptophis depressirostris	Bejuquilla verde	3			LC	O	BG, BS, BP
	Mastigo dryas alternatus	Boriguera	2			LC	O	BS, BP
	Oxybelis aeneus	Bejuquilla chocolate	1			LC	O	BP
	Oxybelis fulgidus	Bejuquilla verde o falsa Lora	4			LC	O	BP, BG
	Pseudoboa neuwiedii	Candel o víbora de sangre	1			LC	O	BP
	Stenorrhina degenhardtii	Culebra alacranera	1			LC	O	BG
Elapidae	*Micrurus nigrocinctus*	Coral centroamericana	1		III	LC	O	BP

Table 2 Note. Conservation status: MA (Ministry of Environment of Panama):VU = Vulnerable (MiAmbiente, 2016); IUCN (International Union for Conservation of Nature): LC = Least Concern (IUCN, 2023); CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora): I = cited in Appendix 1, II = cited in Appendix 2 and III = cited in Appendix 3 (CITES, 2020). Source: O = direct observation in the field. Vegetation yype: BG = gallery forest, BP = primary or little intervened forest, BS = secondary or intervened forest (Young, 1999), L = lagoon, CP = near the beach.

Tabla 2 Nota. Estado de conservación: MA (Ministerio de Ambiente de Panamá): VU = Vulnerable (MiAmbiente, 2016); UICN (Unión Internacional para la Conservación de la Naturaleza): LC = preocupación menor (IUCN SSC Amphibian Specialist Group, 2023); CITES (Convención sobre el Tráfico Internacional de Especies Amenazadas de Flora y Fauna Silvestre): I = citadas en el apéndice 1, II = citadas en el apéndice 2 y III = citadas en el apéndice 3 (CITES, 2020). Fuente: O = Observación directa en el campo. Tipo de vegetación: BG = bosque de galería, BP = bosque primario o poco intervenido, BS = bosque secundario o intervenido (Young, 1999), L = laguna, CP = cerca de playa.

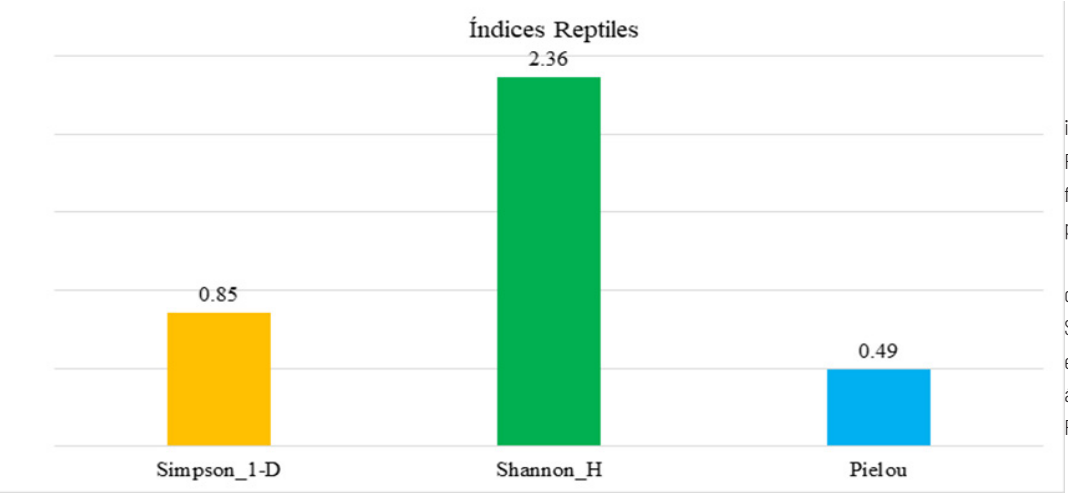


Figure 8. Simpson's dominance index, Shannon's diversity index and Pielou's evenness index for reptiles from the finca Panamaes in Azuero, provincia de Los Santos, Panamá.

Figura 8. Índice de dominancia de Simpson, índice de diversidad de Shannon e índice de equidad de Pielou en reptiles de la finca Panamaes en el área Azuero, provincia de Los Santos, Panamá.

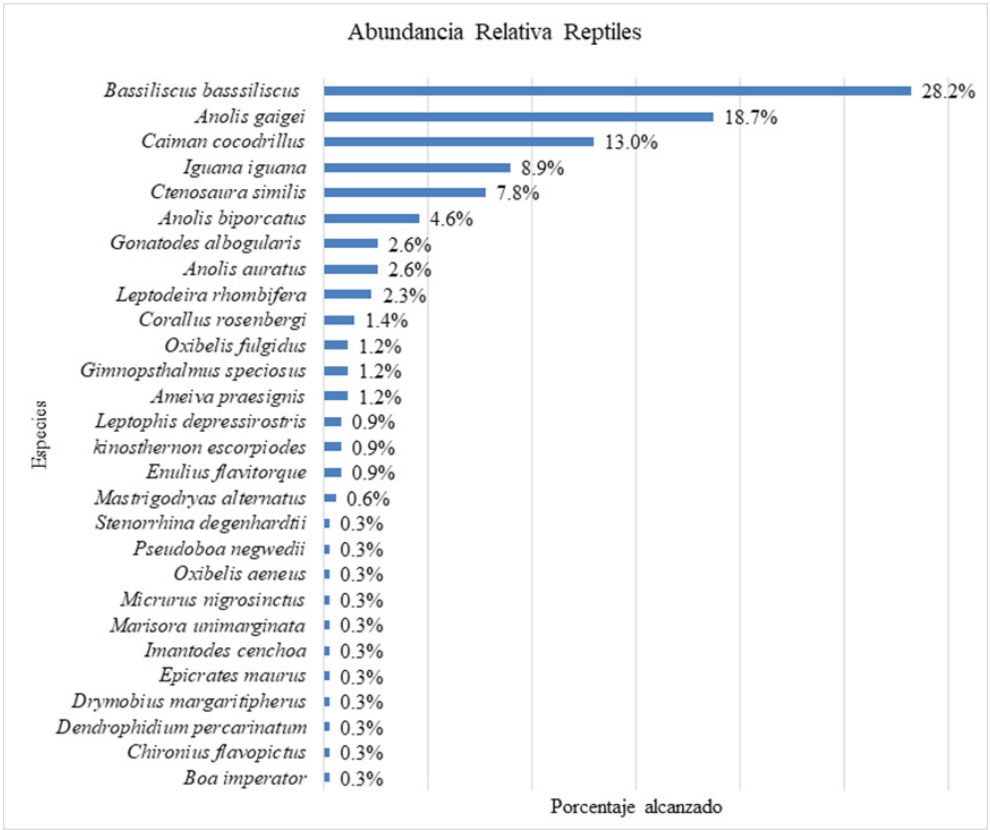


Figure 9. Relative abundance of reptiles from the finca Panamaes in Azuero, provincia de Los Santos, Panamá.

Figura 9. Abundancia relativa de reptiles del área Azuero, provincia de Los Santos, Panamá.

una tendencia exponencial y q2 presenta una asíntota estable, por lo cual se asume que no aumentarían por más individuos nuevos que se agreguen a la muestra. Esto indica que el número de especies abundantes y dominantes que se muestrearon sí fue adecuado (Fig. 5).

Índice de entropía, probabilidad y equidad. La diversidad de Shannon fue de H = 2.36y el 1-D fue de 85 %. Al estimar el índice de homogeneidad de Pielou, se obtuvo J = 0.49 (Fig. 8).

Abundancia. Para las 29 especies identificadas, se registró un total de 347 individuos. Las especies más abundantes fueron *Basiliscus basiliscus* 28 % (98 individuos), *Anolis gaigei* 18.7 % (65 individuos), *Caiman cocodrilus* 13 % (45 individuos), *Iguana iguana* 8.9 % (31 individuos) y *Ctenosaura similis* 7.8 % (27 individuos). Las demás especies tuvieron con un porcentaje inferior al 5 % (Fig. 9).

DISCUSIÓN

Para este estudio, se reportaron 14 especies de anfibios y 29 de reptiles. Las 43 especies de este estudio son más del doble de las especies reportadas por Kovacs (2019), con cinco especies de anfibios y 13 de reptiles, tan solo a 13 km al oeste de la REP en playa Venao. Esta diferencia puede deberse a que se calcula que un promedio de un tercio de las especies de anfibios y reptiles disminuyen una vez que se eliminan los bosques primarios en las regiones de los ecosistemas neotropicales (Palmeirim et al., 2017).

Los anfibios reportados (Tabla 1) para la REP representan el 6.1 % de los anfibios listados para el territorio panameño, el cual cuenta con 227 especies hasta abril de 2023 (Frost, 2023). Mientras que, para el caso de los reptiles, se reportaron 29 especies (Tabla 2) con 13 familias dentro de la REP, las cuales representan el 9.1 % del total de especies dentro del territorio panameño con 320 especies (Uetz et al., 2022).

Todas las especies reportadas en esta investigación, tanto de anfibios como de reptiles, se encuentran en una categoría de preocupación menor (LC) según estándares internacionales (IUCN SSC Amphibian Specialist Group, 2023). Sin embargo, las especies *Boa imperator*, *Epicrates maurus*, *Corallus ruschenbergerii*, *Iguana iguana*, *Caiman cocodrilus* y la rana *Dendrobates auratus* se encuentran en estado vulnerable (VU) para Panamá (MiAmbiente, 2016) y dentro del apéndice II de CITES (CITES, 2020); en esta última se denota que estas especies no están necesariamente amenazadas de extinción, pero que podrían llegar a estarlo si no se hace un control estricto de su comercio.

Dentro de los reptiles, 17 especies son serpientes (Fig. 10), representando el 10.8 % del total de serpientes descritas para Panamá (Ray, 2017). Solo se reportó una especie con importancia médica dentro de la reserva (*Micrurus nigrocinctus*), este tipo de coral es uno de las más abundantes y mejor distribuidos en el país (Köhler, 2008; Wilson et al., 2010). Por otra parte, también se logró reportar una serpiente (*Stenorrhina degenhardtii*) comúnmente llamada serpiente alacranera que, como su nombre común lo indica, es una serpiente que se alimenta de alacranes o escorpiones, los cuales sí son de importancia médica, especialmente para niños y adultos mayores (Köhler, 2008; Leenders, 2019).

Riqueza y diversidad. Según el análisis de la cobertura de muestreo (Cn), la riqueza de anfibios está completa, pero, en el caso de los reptiles, podría aumentar de 29 a 39 especies tomando en cuenta la extrapolación de los datos (Fig. 4). Sin embargo, se debe tener en cuenta que esta riqueza, a pesar de que se considera bastante completa en el caso de los anfibios, es un estimado de la cantidad de especies (Jiménez-Valverde & Hortal, 2003) para la REP, ya que para los análisis de estos datos no se toman en consideración las especies que presentan mayor actividad fosorial, como las cecilias. (Vargas-Salinas & Aponte-Gutiérrez, 2016). La riqueza de especies reportadas de la REP es muy similar para otras zonas de la península de Azuero, como en el caso del Parque Nacional Cerro Hoya (PNCH) (Martínez-Cortes, 1999) y la Reserva Forestal La Tronosa (RFT) (Cedeño et al., 2006). En estas zonas se reportaron 16 especies de anfibios para cada sitio, además de 24 anfibios y 33 reptiles en la Reserva Forestal El Montouso (Rodríguez et al., 2004). Las similitudes reportadas en cuanto a la cantidad de especies de herpetofauna entre estos lugares se atribuye a que presentan hábitats similares y también a que comparten las condiciones climáticas propias del Arco Seco de la península de Azuero (Cedeño et al., 2006).

Adicionalmente, se comparó la riqueza y diversidad de anfibios y reptiles utilizando una Cn = 0.9 (Fig. 10), en donde los reptiles tuvieron una mayor riqueza y diversidad. Este resultado es consistente con la teoría, ya que algunos reptiles pueden tener adaptaciones que les permiten resistir climas cálidos; mientras que, los anfibios son generalmente más vulnerables a los incrementos ligeros de temperatura en su entorno (Griffis-Kyle et al., 2018). Esto es similar a estudios herpetológicos de bosques secos tropicales de Centroamérica (Suazo-Ortuño et al., 2015; Fraga-Ramírez et al., 2017). Debido a que son animales poiquilotermos, la temperatura afecta más directamente a los anfibios que a los reptiles porque es más fácil que se evapore el agua de sus cuerpos.

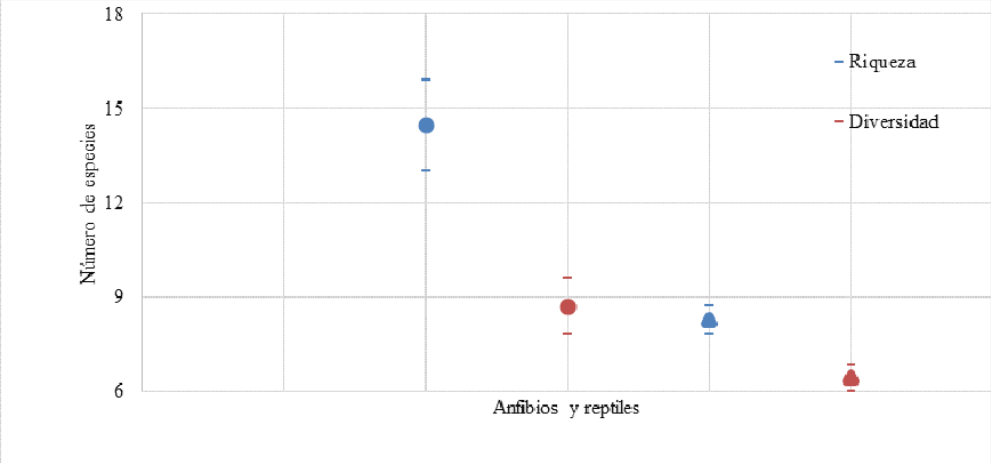


Figure 10. Comparison of the richness and diversity of amphibians and reptiles (x-axis) using the Hill numbers (y-axis) with a Cn = 0.9. Richness in blue; diversity in red; reptiles in circles; and amphibins in triangles from the finca Panamaes in Azuero, provincia de Los Santos, Panamá.

Figura 10. Comparación de la riqueza y diversidad de anfibios y reptiles (eje x) utilizando los números de Hill (eje y) con una Cn = 0.9. Color azul = riqueza; color rojo = diversidad; círculos = reptiles; triángulos = anfibios del área Azuero, provincia de Los Santos, Panamá.

Si bien estos grupos de vertebrados han desarrollado diferentes adaptaciones para hacer frente a los rigores de climas extremos, son pocos los anfibios que pueden vivir en las zonas áridas (McClanahan et al., 1994). Por lo tanto, era de esperarse reportar menor cantidad de especies de anfibios en comparación a los reptiles y, teniendo en cuenta que el neotrópico tiene la mayor diversidad de especies de anfibios del mundo, existen muy pocas especies adaptadas a ambientes secos (Székely et al., 2016).

En comparación con estudios realizados en la región de Azuero, la REP posee una menor cantidad de reptiles; la RFT reportó 32 especies (Elizondo-Lara et al., 2007) y el PNCH posee 34 especies, excluyendo las tortugas marinas (Martínez-Cortes, 1999). Es probable que esta diferencia en la cantidad de especies de la REP en comparación con las otras reservas se deba a que estudiamos un bosque secundario, el cual cuenta con una edad aproximada de entre 10 y 15 años, por lo que es mucho más joven que los bosques de las otras reservas, además de que se desarrollaba actividad agrícola en esta zona y sus alrededores.

Índices de entropía, probabilidad y equidad. Margalef (1972) menciona que el índice de Shannon normalmente oscila entre 1 y 5, e interpreta valores de 2 como entropía baja, de 2 a 3.5 media y superiores a 3.5 como incertidumbre mayor o entropía alta (Medrano Meraz et al., 2017). Para la REP, se obtuvo un índice de Shannon de 2.1 en el caso de los anfibios y de 2.3 para los reptiles. Esto indica que la REP cuenta con una entropía media, por lo que en este caso, el ecosistema está menos diversificado y es más predecible en términos de qué especies se encuentran allí. Adicionalmente, es consistente con el índice de equidad (J = 0.55 anfibios y J = 0.49 reptiles), el cual indica que no todas las especies reportadas en este estudio presentan la misma abundancia. Esto sugiere una baja estabilidad en la diversidad de especies, debido a que los individuos por especie no se distribuyen de manera homogénea (Magurran, 1988). Además, los resultados del índice de Simpson sugieren que si tomamos dos especies al azar dentro de la REP, la probabilidad de que las especies sean iguales es de 84 % y 85 % para anfibios y reptiles respectivamente, y, con base en esa probabilidad, se considera que una comunidad es más compleja mientras mayor sea el número de especies otorgándole así mayor estabilidad con el tiempo (Baca, 2000). Con esta información, se podría inferir que esta comunidad de herpetofauna presenta una diversidad media (Bouza & Covarrubias, 2005); dicho de otra manera, el índice de probabilidad indica que algunas especies son dominantes sobre otras, lo que confiere una menor diversidad a los herpetos de la reserva. Tepetlan et al. (2016), basado en las publicaciones de Clements (1916), Smuts (1926) y Odum & Barrett (1971), dice que una menor diversidad causa una mayor inestabilidad en una comunidad y que la competencia por los recursos (alimento, agua, refugio, etc.) es de los factores que pueden estar determinando esta heterogeneidad en la dominancia de las especies.

A pesar de los índices de entropía, probabilidad y equidad, los anfibios y reptiles establecen una comunidad con diversidad media. Este resultado se podría considerar relativamente bueno dado que hace 15 años esta cantidad de especies hubiese sido poco probable de registrar, ya que en su mayoría los suelos eran de pastoreo y generalmente el recambio de la cantidad de especies de potreros a bosques es diferente (Urbina-Cardona & Rosales, 2005). Además, los resultados en cuanto a la cantidad de especies para este tipo de bosque son similares a los reportados en la Reserva Ecológica Arenillas, Ecuador (Székely et al., 2016); esta reserva cuenta con una altitud y características climáticas parecidas a la región de Los Santos.

No existe un inventario formal en años anteriores sobre los herpetozoos de la REP. Esto se debe a que simplemente no existía un bosque como tal y, en su mayoría, el suelo era para la agricultura y ganadería en los cuales la utilización de agroquímicos era frecuente, lo que a su vez afecta mayormente a los anfibios (Sparling et al., 2001). Sin embargo, es natural asumir que la riqueza y diversidad de herpetos era menor a la del bosque secundario actual (Urbina-Cardona & Rosales, 2005) debido a la gran deforestación y ganadería extensiva características de la REP de hace 15 años (MiAmbiente, 2009) (Fig. 11). El hecho de reportar 43 especies particulares para la reserva y dentro del bosque seco tropical representa un gran aporte para la herpetofauna panameña.

Abundancia. La cantidad de individuos por especie fue muy variable, inclusive en algunos casos se registró un solo individuo por especie. Estos casos fueron considerados como especies raras. Las especies más abundantes de la REP fueron las especies *D. microcephalus* y *B. platanera* porque gran parte de la colecta de datos se dio a principios y mediados de la temporada lluviosa en donde las ranas pertenecientes a la familia Hylidae empiezan la temporada reproductiva (Gorzula & Señaris, 1998; Savage, 2002). Por esta razón, se presentó una convergencia de estos individuos en puntos específicos de la reserva. Por otro lado, los reptiles *A. gaigei* y *B. basiliscus* fueron los más abundantes debido a que estas especies son capaces de vivir en diferentes entornos: desde bosques bien conservados hasta bosques secundarios y

Figure 11. You do not need to set foot in the reserve to understand the tremendous ecological regeneration that has already occurred. Perhaps you can appreciate better the success of our mission from afar. This image shows the before and after of the forest cover of the reserve in 2003 and in 2015 (Morales et al., 2016).

Figura 11. No es necesario poner un pie en la reserva para entender la tremenda regeneración ecológica que ya ha ocurrido, ya que tal vez se observa mejor la realización de nuestra misión de lejos. En esta imagen se muestra el antes de la cubierta forestal de la reserva en 2003 versus el después en 2015 (Morales et al., 2016).

plantaciones cerca de cuerpos de agua (Savage, 2002; Koehler et al., 2012).

No obstante, las bajas abundancias en la mayoría de especies, tanto de anfibios como reptiles, se deben quizás a una combinación de factores entre los que se pueden incluir la fragmentación de los bosques, el aislamiento de individuos y la pérdida de hábitat. También pueden incluirse los hábitos ecológicos de las especies que dificultan la detección y captura de individuos; estos factores pueden variar entre grupos taxonómicos específicos (Schneider-Maunoury et al., 2016). Sin embargo, con base en la cobertura de muestra (Cn) de los órdenes q0, q1 y q2, el cual mide la abundancia promedio de los individuos muestreados dentro de las especies observadas (Moreno et al., 2011), se obtuvo una Cn mayor al 96 %, es decir, una Cn satisfactoria (Chao & Shen, 2003; Beck & Schwanghart, 2010) para tanto anfibios como reptiles. En cambio, utilizando los valor sugeridos por el estimador Chao 2, el cual utiliza datos de presencia o ausencia de una especie dentro de una muestra (Espinoza, 2003), se calculó la eficiencia del muestreo con valores del 84 % para anfibios y 73 % para reptiles, pero Villareal et al. (2004) estima valores superiores a 85 % para un buen inventario. Por esto, se puede asumir que aún faltan especies por registrar dentro de la reserva como el *Anolis lemurinus* (Kovacs, 2019) o *Bothrops asper* para el caso de los reptiles y *Hyalinobatrachium tatayoi* para los anfibios (Cedeño et al., 2006), las cuales han sido registradas en reservas privadas y ecológicas de la región de Azuero.

Los grupos sensibles, que tienen un bajo número relativo de individuos, suelen ser más vulnerables a las intervenciones humanas y a los desastres naturales, llevando así a una extinción local de especies y a la pérdida de variabilidad genética (Elizondo-Lara et al., 2007). Tal es el caso del bufo *I. signifer* que, si bien es una especie que se encuentra bajo preocupación menor, en este estudio casi no se reportaron individuos a pesar de que el bosque seco tropical es su hábitat preferido (Flores De Gracia et al., 2017; Sosa-Bartuano, 2018). Además, es conocido que el aislamiento de individuos y la fragmentación de los bosques (como ocurre dentro de la REP) afectan la distribución local de especies, su desplazamiento, y disminuyen los sitios para reproducción (Schelhas & Greenberg, 1996; Tocher et al., 1996).

Cabe señalar que dentro de las especies observadas no se registraron especies de tortugas marinas ni cocodrilos, los cuales sí se encuentran dentro de la REP (H. Peralta *com. pers.*, 20 abril de 2022). Los resultados del estudio nos permiten resaltar a la REP como zona de diversidad herpetológica y, pese a sus bajos índices de diversidad, aún faltan especies por reportar. Por lo tanto, la reserva es de suma importancia para la preservación de la herpetofauna local a pesar de poseer zonas con bosques secundarios jóvenes y de estar bajo presión de actividades antropogénicas a sus alrededores. Dada su importancia por contener elementos herpetológicos como *C. crocodilus*, *I. iguana*, *B. imperator*, *C. ruschembergerii*, *E. maurus*, y la rana *D. auratus* así como aves migratorias y mamíferos de la zona, se están realizando acciones efectivas para controlar la tasa de deforestación, las quemas y la contaminación con agroquímicos mediante charlas de conservación ecológica con estudiantes y personas de las comunidades cercanas además de la reforestación constante en la REP. Esto permite que los hábitats boscosos, los fragmentados y sus remanentes dejen de estar en condiciones paupérrimas para soportar poblaciones silvestres a largo plazo (Morales et al., 2016).

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CONTRIBUTION TO THE KNOWLEDGE OF HERPETOFAUNA IN AN AREA OF ECOLOGICAL IMPORTANCE: BOSQUE PROTECTOR CERRO BLANCO, GUAYAQUIL, ECUADOR

CONTRIBUCIÓN AL CONOCIMIENTO DE LA HERPETOFAUNA EN UN ÁREA DE IMPORTANCIA ECOLÓGICA: BOSQUE PROTECTOR CERRO BLANCO, GUAYAQUIL, ECUADOR

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Resumen.– El Bosque Protector Cerro Blanco, uno de los últimos relictos de bosque seco tropical y el más extenso en la provincia del Guayas, Ecuador, presenta una biodiversidad que requiere una documentación continua y precisa para comprender su estado actual. Entre los estudios anteriores, el que informó el mayor número de especies identificó 22 especies en total, incluidos siete anfibios y 15 reptiles. Sin embargo, nuestro estudio entre octubre de 2014 y enero de 2024, utilizando tanto métodos de muestreo sistemáticos como no sistemáticos, ha identificado un total de 57 especies, incluyendo 20 especies de anfibios y 37 de reptiles. De estas, nueve especies son endémicas del Ecuador, cinco de las cuales son anfibios y cuatro reptiles. A diferencia de estudios anteriores que se centraron principalmente en áreas de fácil acceso y de alto tránsito turístico, nuestro muestreo abarcó tanto zonas frecuentemente visitadas como áreas menos exploradas y de difícil acceso. Esto permitió superar las limitaciones de investigaciones previas y proporcionó un panorama más completo de la herpetofauna en el BPCB, donde el amplio rango de hábitats presentes facilitó la observación de una notable riqueza de especies, contribuyendo significativamente a la actualización de los registros herpetológicos, que han sido escasos en los últimos 30 años.

Palabras clave.–Anfibios, bosque seco tropical, especies endémicas, Guayaquil, reptiles.

Abstract.– The Bosque Protector Cerro Blanco, one of the last relics of tropical dry forest and the largest in the province of Guayas, Ecuador, presents a biodiversity that requires continuous and precise documentation to understand its current state. Among the previous studies, the one that reported the largest number of species identified 22 species in total, including seven amphibians and 15 reptiles. However, our study between October 2014 and January 2024, using both systematic and non-systematic sampling methods, has identified a total of 57 species, including 20 species of amphibians and 37 reptiles. Of these, nine species are endemic to Ecuador, five amphibians and four reptiles. Unlike previous studies that focused mainly on easily accessible areas with high tourist traffic, our sampling covered both frequently visited areas and less explored and difficult-to-access areas. This allowed us to overcome the limitations of previous research and provided a more complete picture of the herpetofauna in the BPCB, where the wide range of habitats present facilitated the observation of a remarkable richness of species, contributing significantly to the updating of herpetological records, which have been scarce in the last 30 years.

Keywords.– Amphibians, endemic species, Guayaquil, reptiles, tropical dry forest.

INTRODUCTION

Ecuador, a small yet highly biodiverse country, is recognized as one of the world's richest in species diversity (Cuesta et al., 2017). Its continental territory includes a diverse range of ecosystems, from paramos and mangroves to cloud forests and tropical forests, spread across three primary regions: the Coast, the Andes, and the Amazon (Kleemann et al., 2022). However, this remarkable biodiversity is under significant threat, making Ecuador the second country globally with the highest number of threatened species (Mestanza-Ramón et al., 2023). Specifically, 60 reptile species are at risk, 41 of which are endemic (Torres-Carvajal et al., 2024), while 194 amphibians are endangered, including 111 species unique to the country (Ron et al., 2024). The situation is further exacerbated by a 12 % reduction in natural forest cover between 1990 and 2018, driven by land-use change, urbanization, and resource extraction (Guarderas et al., 2022; Kleemann et al., 2022). This loss is particularly severe in the coastal region, where deforestation poses a critical threat (González-Jaramillo et al., 2016; Sierra et al., 2022). In particular, the tropical dry forests of the coast have experienced alarming rates of degradation and deforestation (Rivas et al., 2020).

In terms of conservation, Ecuador categorizes its natural areas into protective forests (PFs) and protected areas (PAs). Covering 2,425,002 hectares or 9.72 % of the national territory, PFs are strategically located in areas difficult for agriculture or inappropriate for land use, protecting water resources, soil, and biodiversity (Ministerio del Ambiente del Ecuador, 2019). However, the protection of tropical dry forests may be inadequate to mitigate deforestation, as it persists within protected areas (Rivas et al., 2020).

The "Bosque Protector Cerro Blanco" (BPCB), one of the main protected tropical dry forests in western Ecuador due to its size and biological diversity, is located in Guayaquil, the largest city in the country. Guayaquil exemplifies the loss of primary forests (Horstman et al., 2017) caused by urban sprawl, agriculture, and mining activities (Murillo et al., 2020). Despite hosting a notable diversity of amphibians and reptiles, awareness of these species remains limited, even among professionals in environmental, biological, or ecological fields (Amador, 2015). Decades of neglect by local administrations have allowed urban expansion to extend beyond set boundaries, notably in 2016 when Guayaquil's growth continued along the South American Pacific coast in the Gulf of Guayaquil, leading to severe environmental and social impacts (Palme et al., 2016; Pérez de Murzi & Orejuela, 2023). Over time, the city has experienced significant environmental degradation (Murillo et al., 2020).

The BPCB encompasses 6,078 hectares and represents one of the best-preserved remnants of the tropical dry forest ecosystem typical of Ecuador's coast (Parker & Carr, 1992). Although this ecosystem is not known for its species richness, it stands out for its high endemism, hosting 54 mammal species, 221 bird species, 8 amphibian species, and 12 reptile species, along with over 700 vascular plant species, 20% of which are endemic to southwestern Ecuador (Cun, 2012). Research on BPCB's herpetofauna is scarce, with only a few focused studies, such as those by Parker & Carr (1992), Salvatierra et al. (2010), Amador & Martínez (2011), and Almendáriz & Carr (2012), which provide valuable insights but also highlight the need for further investigation. Expanding existing knowledge would allow for a more comprehensive understanding of BPCB's herpetofaunal diversity.

The objective of this research is to provide a detailed view of the diversity of amphibians and reptiles in BPCB, Guayaquil, Ecuador. Given the paucity of complete and up-to-date information on this topic, our study seeks to address this gap with the results of our own research. In this way, we aim to offer a vision of the distribution and occurrences of amphibians and reptiles throughout the BPCB area.

MATERIALS AND METHODS

Herpetological sampling was carried out in the Bosque Protector Cerro Blanco. This forest is located in the southwestern extension of the Chongón-Colonche Mountain range. This protective forest contains five types of ecosystems, the most significant being the seasonal evergreen forest of the foothills of the equatorial Pacific coastal mountain range and the semi-deciduous forest of the Jama-Zapotillo plain (Ministerio del Ambiente del Ecuador, 2012). In addition, it has a series of hills with slopes and streams that range from 50 to 507 m a.s.l. (Cun, 2012; Fig. 1). It is one of the few relicts of tropical dry forest and the largest remaining in Guayas and is currently threatened by non-metallic mining, logging, urban expansion, illegal hunting and intentional fires.

The field work was a compilation of non-systematic sampling throughout the BPCB area, carried out between October 2014 and December 2019, and complemented by additional observation walks in December 2023 and January 2024. Non-systematic sampling included unrestricted free searching, acoustic and visual recordings, as well as manual capture, according to Rödel and Ernst (2004). These samplings were complemented by a series of systematic samplings carried out between October and November 2021, and from April to May 2022. In this case,

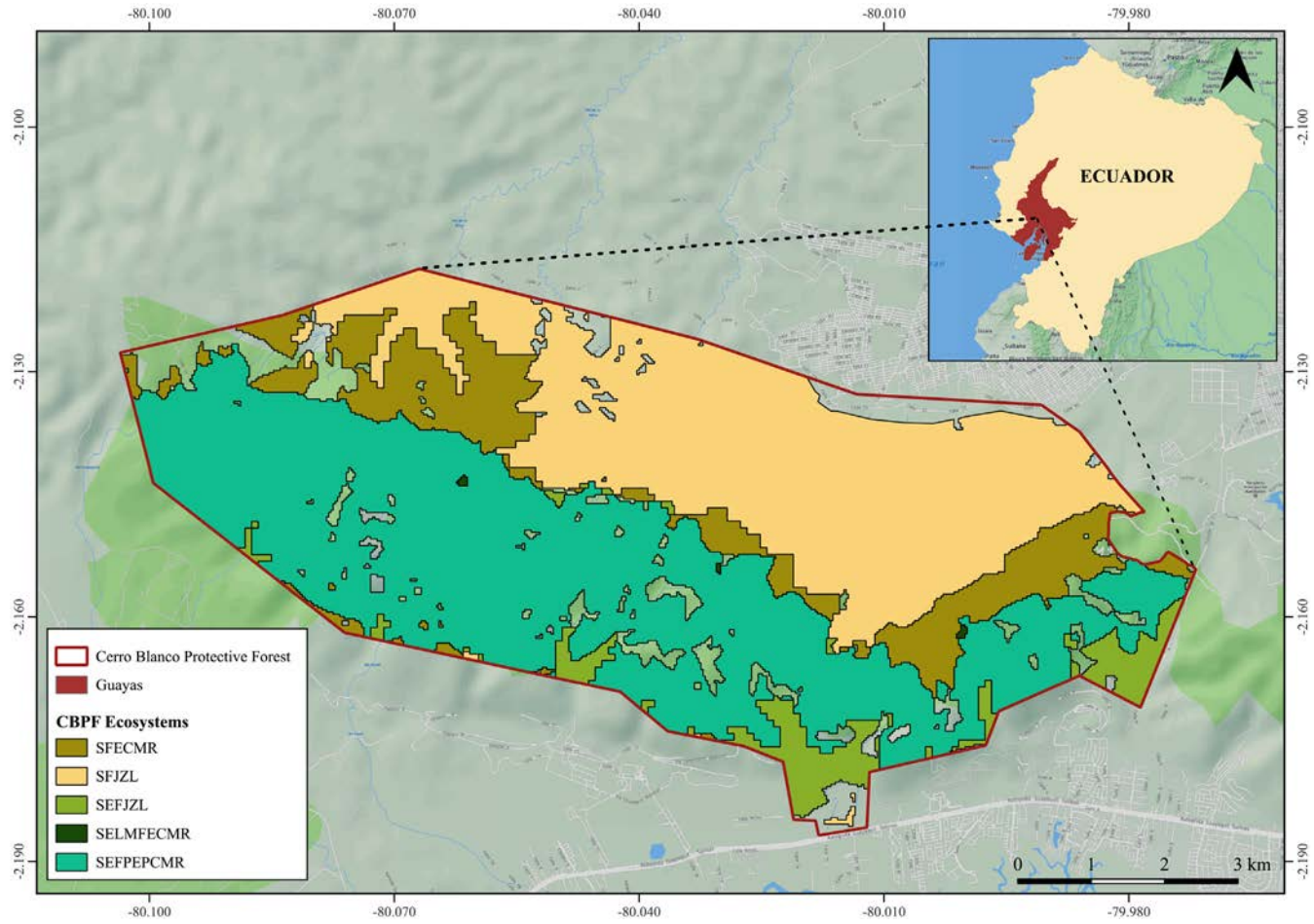

Figura 1. Mapa de ubicación geográfica del Bosque Protector Cerro Blanco (BPCB), Guayaquil, Ecuador, y los ecosistemas presentes en el área. SFECMR = Bosque Semideciduo de la Cordillera Costera del Pacífico Ecuatorial. SFJZL = Bosque Semideciduo de tierras bajas de Jama-Zapotillo. SEFJZL = Bosque Siempreverde Estacional de las tierras bajas de Jama-Zapotillo. SELMFECMR = Bosque Siempreverde Estacional Montano Bajo de la Cordillera Costera del Pacífico Ecuatorial. SEFPEPCMR = Bosque Siempreverde Estacional Piemontano de la Cordillera Costera del Pacífico Ecuatorial.

Figure 1. Geographic location map of the Bosque Protector Cerro Blanco (BPCB), Guayaquil, Ecuador, and the ecosystems present in the area. SFECMR = Semi-deciduous Forest of the Equatorial Pacific Coastal Mountain Range. SFJZL = Semi-deciduous Forest of Jama-Zapotillo Lowland. SEFJZL = Seasonal Evergreen Forest of the Jama-Zapotillo Lowlands. SELMFECMR = Seasonal Evergreen Low Montane Forest of the Equatorial Pacific Coastal Mountain Range. SEFPEPCMR = Seasonal Evergreen Forest of the Piemontane of the Equatorial Pacific Coastal Mountain Range

the BPCB was divided into 4 zones: Caseta Jaguar, Caseta Pigio, Tourist Zone and Zone 507 (Fig. 2).

The "Caseta Jaguar" (CJ) presents secondary forests on the mountain slopes, with a landscape characterized by a varied vegetation of shrubs and trees along its seasonal and temporary streams. The streams have steep rocky slopes and bodies of water, with a medium forest density and medium-thickness trees. At the top of the mountains, a secondary road is bordered by shrub vegetation and forest with medium to large-thickness trees, presenting a high canopy. Similarly, the "Caseta Pigio" (CP) is characterized by extensive secondary forests on the tops and slopes of the mountains, with some patches of primary forest in areas of difficult access. The temporary streams are mostly dry with stagnant bodies of water and present patches of intervened natural forest, with soils covered with leaf litter. There is secondary tropical forest with dry seasonal streams. At the top of the mountains, a secondary road is bordered by shrub vegetation and secondary forest with medium to large trees, presenting a high canopy. In addition, in the lower northern part of the mountainous area, there are two artificial lagoons surrounded by riparian vegetation. The "Tourist Zone" (TZ) is distinguished

by its secondary forest on the peaks and slopes, which includes trails intended for tourism and ground covered with leaf litter. A stream with constant water, surrounded by secondary forest with medium and large trees and a prominent canopy, evidences a notable tourist activity. In addition, it presents secondary forest with dry seasonal streams. In the lower areas of the mountains, there are recreational areas and secondary roads, with tourist infrastructure adjacent to the forest. Finally, "Zone 507" (507) is located in a mountainous area with steep slopes. At the top there are communication antennas, and on the slopes, there is a secondary road that leads to the antennas, as well as several routes for cyclists. The area has a secondary forest with medium and large trees, and a prominent canopy, affected by the cycling routes. It also includes a temporary stream, mostly dry, with shrub vegetation on its banks.

Throughout the BPCB, 32 quantitative transects measuring 150 m x 2 m and 20 qualitative transects measuring 300 m x 2 m were established. Each area was sampled for six days, with eight quantitative transects distributed in each one, which were evaluated for five consecutive days. In addition, five qualitative transects were designated per area, which were sampled on the sixth day of field work in each of the areas. All transects were separated by 500 meters. Each quantitative transect was surveyed by two researchers, while the qualitative transects were surveyed by four researchers. All sampling, both systematic and non-systematic, was carried out during the rainy and dry seasons. As described by Zambrano & Hernández (2007), historically, the rainy season in the city of Guayaquil begins in December and ends in April, while the dry season begins from May to November.

A total of 68 specimens were collected to document and confirm the presence of species in Cerro Blanco and to establish a reference collection, as no comprehensive collection currently exists in museums for this forest. The specimens were hand-captured, photographed, euthanized with a 2% anesthetic solution of roxicaine, fixed in 10 % formalin, and preserved in 70 % ethanol. Before fixation, tissue samples were taken from the collected individuals and preserved in 96 % ethanol, following the method described by Székely et al. (2016). Measurements of snout–vent length (SVL) were taken with digital calipers and rounded to the nearest 0.1 mm for small specimens, and with a tape measure for longer specimens (Appendix 1). The list of species was standardized using the taxonomy of Amphibian Species of the World (Frost, 2024) and The Reptile Database (Uetz et al.,

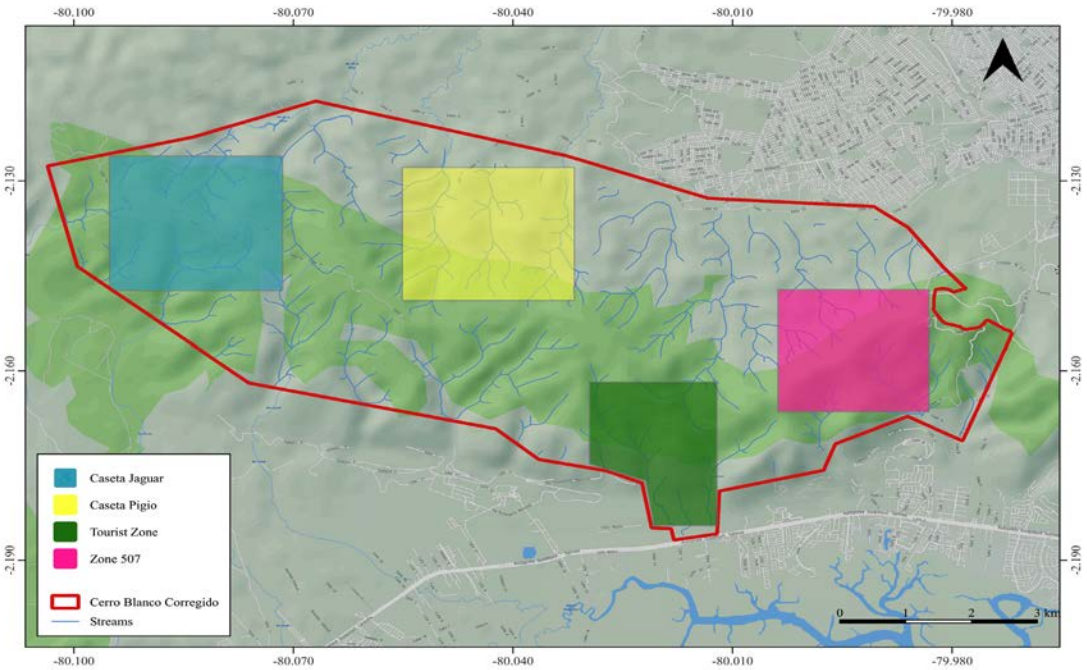

Figura 2. Mapa de las zonas de muestreo sistemáticos en el Bosque Protector Cerro Blanco (BPCB), Guayaquil, Ecuador. Se muestran las áreas designadas como Caseta Jaguar, Caseta Pigio, Zona Turística y Zona 507, delimitadas por una línea roja que marca los límites del BPCB, junto con las quebradas permanentes y estacionales representadas con una delgada línea azul.

Figure 2. Map of systematic sampling areas in the Bosque Protector Cerro Blanco (BPCB), Guayaquil, Ecuador. The areas designated as Caseta Jaguar, Caseta Pigio, Tourist Zone and Zone 507 are shown, delimited by a red line marking the BPCB boundaries, along with permanent and seasonal streams represented by a thin blue line.

2023). Species with taxonomic uncertainties, either because they are in the process of description, taxonomic updating or because their identification at the species level has not been achieved, were excluded from the present inventory due to the potential generation of uncertainty when including them, which could cause confusion. However, the individuals identified in this study that could not be collected and deposited in museums were photographed, focusing on the specific characters of each genus for subsequent identification according to the original descriptions of the species. The specimens are deposited in three zoological museums in Ecuador: Museo de Zoología de la Universidad San Francisco de Quito (ZSFQ), Quito, Ecuador; and Museo de Zoología de la Universidad Técnica Particular de Loja (MUTPL), Loja, Ecuador. The specimens were collected under permit No. MAAE-ARSFC-2022-2058; No. MAAE-DBI-DBI-CM-2022-0222 and No. MAATE-ARSFC-2023-0063 approved by the Ministerio del Medio Ambiente, Agua y Transición Ecológica del Ecuador.

Geographic coordinates and elevation data were obtained using a Garmin GPSMAP 62st GPS device. Three types of maps were created using QGIS version 3 software. The first type of map is designed to visualize the location of the BPCB and the ecosystems present there, while the second type is used for the delimitation of systematic sampling areas. This last type of map presents a summary of the distribution of each species recorded with less than 10 individuals throughout the BPCB, grouping them by classes and suborders for their representation.

RESULTS

Herpetofauna Diversity in the Bosque Protector Cerro Blanco (BPCB)

Between 2014 and 2024, recording of a total of 6,534 herpetofauna sightings. During this period, a total of 57 species were recorded (Tables 1, 2). In the class Amphibia, a total of 20 species distributed in two orders were recorded: Anura and Gymnophiona (Figs. 3, 4). The order Anura was composed of six families and 19 species, while the order Gymnophiona included one family and species. For the class Reptilia, 37 species were identified in two orders: Squamata (which includes amphisbaenids, lizards and snakes) and Testudines (turtles) (Figs. 5, 6, 7, 8). The order Squamata was subdivided into three suborders: Amphisbaenia, with one family and one species; Sauria (lizards), with nine families and 13 species; and Serpentes (snakes), with five families and 20 species. The order Testudines was composed of three families and three species. Nine species were found that are endemic to Ecuador. Several amphibian species were observed, each with fewer than ten records, including elusive, seasonal, and fossorial species such as *Barycholos pulcher*, *Boana rosenbergi*, *Caecilia tenuissima*, *Craugastor longirostris*, *Engystomops guayaco*, *Engystomops randi*, *Leptodactylus ventrimaculatus*, and *Smilisca phaeota* (Fig. 9). On the other hand, 27 reptile species were recorded, also with fewer than ten sightings each. This group comprised five species of lizards, three species of turtles, one species of amphisbaenia, and 18 species of snakes (Figs. 10, 11).

Detailed analysis of BPCB herpetofauna species

Class Amphibia

Order Anura

Family Bufonidae

Rhinella bella (Menéndez-Guerrero et al., 2024) Fig. 3a

Rhinella bella is a recently reclassified species that was previously confused with *R. horribilis* due to their close morphological similarities. However, *R. bella* can be distinguished by its significantly smaller body size (Menéndez-Guerrero et al., 2024). Additionally, *R. bella* has low and thick cephalic crests with borders with keratinized spicules (Menéndez-Guerrero et al., 2024). Also, the lack of expanded discs and the large and prominent parotoid glands are also characteristics that set *R. bella* (Páez-Rosales & Ron, 2024) apart from any other toad in the study area. One specimen was collected and deposited in the ZSFQ museum under the code ZSFQ4875. During fieldwork, 188 individuals were observed, mainly in areas impacted by human activities such as tourism and cycling. As a recently described species, it has not yet been evaluated by the IUCN (2024) or included in the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Family Ceratophyidae

Ceratophrys stolzmanni (Steindachner, 1882) Fig. 3b

Ceratophrys stolzmanni is a small-sized toad with very distinctive features: its skull and mouth, which are very wide compared to its body, allowing them to be voracious predators that feed on a variety of animals, including invertebrates and vertebrates such as frogs and snakes, without a correlation between the size of the prey and the toad (Székely et al., 2019). Due to their fossorial habits, during the dry season, they have spades on the soles of their feet which facilitate burrowing (Ortiz, 2024). During fieldwork, 10 individuals were found, of which one was collected while foraging near seasonal puddles and deposited in the ZSFQ

museum under the code ZSFQ4925. This species is classified as Vulnerable (VU) by both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Family Craugastoridae

Craugastor longirostris (Boulenger, 1898) Fig. 3c

It is a small frog with an average SVL of 40 mm, and it is distinguished by being the only member of its genus in the lowlands of western Ecuador (Boulenger, 1898; Lynch & Myers, 1983; Lynch & Duellman, 1997). The specimens observed in the study area were identified by their characteristic moderate interdigital membranes, which differentiate it from the most similar species, *P. achatinus*. This species also exhibits variable dorsal coloration, ranging from pale gray to reddish brown, with a prominent black hourglass-shaped mark and small round marks on the back and near the tympanum that are reddish brown or black (Read et al., 2022a). In the BPCB, two individuals were recorded: one was observed near a bushy area alongside a path, while the other was found in leaf litter adjacent to a trail. *C. longirostris* is classified as Least Concern (LC) by the IUCN (2024) and is similarly assessed by the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Family Dendrobatidae

Epipedobates machalilla (Coloma, 1995) Fig. 3d

This is a very small frog that is mainly distinguished by its "X"-shaped markings in the dark brown scapular region, a cream-colored abdomen, and diffuse orange markings in the armpits and groin. It is a diurnal and terrestrial species that lives in leaf litter, among stones, and in the mud on riverbanks, estuaries, waterfalls, and streams (Coloma, 1995; del Pino et al., 2004; Pyron & Wiens, 2011; Coloma et al., 2022a). During the field work, 1,148 individuals were found, of which six were collected and deposited in the ZSFQ museum with the codes ZSFQ4892, ZSFQ4893, ZSFQ4894, ZSFQ4895, ZSFQ4896, and ZSFQ4897. In the BPCB, it was observed in these same habitats, coexisting with Hyloxalus infraguttatus, with both species being very similar. This species is classified as Least Concern (LC) in the IUCN (2024) and in the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Hyloxalus infraguttatus (Boulenger, 1898) Fig. 3e

Hyloxalus infraguttatus is also a very small frog with a distinctive oblique cream line on the sides and interdigital membranes, and both, males and females, have white spots on the throat and abdomen (Boulenger, 1898; Coloma, 1995; Coloma et al., 2022b). They are very territorial, and the males exhibit parental care (Pazmiño-Otamendi, 2010; Coloma et al., 2022b).

During fieldwork, 2,507 individuals were encountered, and six were collected and deposited in the ZSFQ museum with the codes ZSFQ4878, ZSFQ4879, ZSFQ4880, ZSFQ4881, ZSFQ4882, and ZSFQ4883. All the specimens collected, along with others observed in the field, were found foraging near streams. It is classified as Vulnerable (VU) by both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Family Hylidae

Boana rosenbergi (Boulenger, 1898) Fig. 3f

Boana rosenbergi is a large tree frog. It can be differentiated from other large frogs like *B. boans* by its tuberculated skin, as *B. boans* has smooth skin and is not found in the study area. It also differs from *Trachycephalus jordani* by the absence of ossification on the head, as mentioned by MECN (2010). Furthermore, *B. rosenbergi* is recognized by its expanded toe discs and well-developed webbing between the toes (Duellman, 1970).

This species may exhibit aggressive behavior, especially among males, who use their prepollical spines as weapons in territorial disputes (Kluge, 1979). In the BPCB, a single specimen was observed perched on a trunk 160 cm high in a dense forest area at night. It is listed as Least Concern (LC) by both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Scinax quinquefasciatus (Fowler, 1913) Fig. 3g

Scinax quinquefasciatus is a medium-sized frog that are distinguished by a triangle-shaped marking on their heads, and their bellies tend to be white in males and pale yellow in females (Duellman, 1971; MECN, 2010; Ron et al., 2018). During fieldwork, 30 individuals were encountered, and three were collected and deposited in the MUTPL museum with the codes MUTPL-A-1831, MUTPL-A-1832, and MUTPL-A-1833. They were found on logs near trails and buildings within reserves, and their presence is uncommon in undisturbed forested areas. This species is classified as Least Concern (LC) by both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Scinax tsachila (Ron et al., 2018) Fig. 3h

Scinax tsachila is a medium-sized arboreal frog that is distinguished by the characteristic green color of its leg bones

and the absence of small tubercles scattered on its back, which are the main features that differentiate it from *S. quinquefasciatus*. Additionally, it has brown irises with orange spots or yellow-orange reticulations, no tubercles on the heel, and a clearly visible tympanum (Ron et al., 2018; Varela-Jaramillo & Paucar, 2022). In the BPCB, this species was observed on trunks and branches up to a height of 180 cm, with a total of 19 individuals recorded exclusively in secondary forest areas. The IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021) classify it as Least Concern (LC).

Smilisca phaeota (Cope, 1862) Fig. 3i

Smilisca phaeota is a large frog characterized by a dark band that extends from the posterior edge of the eye to the insertion of the arms. It also exhibits many color variations, ranging from bright green, pale green, light brown and bronze, with the back adorned with green or brown spots and a copper-colored iris (Duellman, 1970; Leenders, 2001; Ron et al., 2022a). Males have double vocal sacs and are active during the rainy season, singing from the water's surface in isolated places next to temporary pools or streams (Duellman, 1970; Savage, 2002; Solís et al., 2008). This species is rare in the BPCB, with only one individual observed during all field sampling. This individual was found in the northern part of the BPCB area, among low bushes near small ponds, which underlines its association with this type of ecosystem. It is classified as Least Concern (LC) by both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Trachycephalus jordani (Stejneger & Test, 1891) Fig. 3j

T. jordani is a large frog that is distinguished from any other by the high ossification of its head, giving it a helmet-like shape, from which its common name is derived (Stejneger & Test, 1891; MECN, 2010; Read et al., 2022b). This hard head is used to seal bromeliads and holes in tree trunks where it lives (Lutz, 1954; Bokermann, 1966). Reproduction is triggered by heavy rains and occurs in slow bodies of water where they lay their eggs (MECN, 2010; Icochea et al., 2004). In the fieldwork, 34 individuals were observed, and two specimens were collected and deposited in the ZSFQ museum under codes ZSFQ4870 and ZSFQ4871. The collected specimens were found perched on branches at heights of 120 cm and 200 cm. The remaining individuals were observed perched on branches, trunks, and artificial structures such as pipes and walls. It is classified as Least Concern (LC) by both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Trachycephalus quadrangulum (Boulenger, 1882) Fig. 3k

It is a medium-sized, endemic frog with brown coloring and dark spots on its back (Boulenger, 1882). *T. quadrangulum* is distinguished by having expanded discs on the fingers and a head that is wider than it is long (Boulenger, 1882; Varela-Jaramillo, 2022). Additionally, it secretes a sticky white substance when handled, which causes severe irritation to mucous membranes. During the fieldwork, 33 individuals were observed, and three were collected and deposited in the ZSFQ museum with the codes ZSFQ4872, ZSFQ4873, and ZSFQ4874. It was relatively common in BPCB, like its congener *T. jordani*, often found perched on trees or shrubs near buildings within the reserve, especially during the rainy season. It is classified as Least Concern (LC) by both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Family Leptodactylidae

Engystomops guayaco (Ron et al., 2005) Fig. 4l

This small frog endemic to Ecuador, with an average SVL of 17 mm, is primarily distinguished by having scattered tubercles on its back skin, a truncated snout in dorsal view and rounded in lateral view, present parotoid glands, absence of a tarsal tubercle, and the first finger of the hand shorter than the second finger (Ron et al., 2005; Read et al., 2022c). During the fieldwork at the BPCB, only four individuals were observed foraging near tourist trails and secondary roads. Males are known to sing while floating in shallow water, from ditches to flooded fields, especially at night (Ron et al., 2005). Classified as Vulnerable (VU) in both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Engystomops pustulatus (Shreve, 1941) Fig. 4m

Engystomops pustulatus is a small to medium-sized frog, with males averaging 27.1 mm SVL and females 31 mm SVL, a key characteristic distinguishing it from *E. guayaco* and *E. randi* (Ron et al., 2022b). This species exhibits darker bars on its extremities, a white belly with black and dark brown spots extending towards the chest, a dark throat, and brown irises (Shreve, 1941; Ron, 2018). It predominantly inhabits dry coastal scrublands, becoming more abundant during the rainy season in areas influenced by human activities (Ron et al., 2004). During fieldwork, 209 individuals were observed, but only two were collected. These were deposited in the ZSFQ museum with the codes ZSFQ4888 and ZSFQ4889. At the BPCB, individuals are primarily found in leaf litter within open areas near trails or

secondary roads with sparse shrub vegetation. Classified as Least Concern (LC) by both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Engystomops randi (Ron et al., 2004) Fig. 4n

Engystomops randi, a very small endemic frog distinguished by numerous tubercles on its back, as well as parotoid and flank glands, and the absence of a tarsal tubercle (Ron et al., 2004; Read et al., 2022d). During fieldwork, five individuals were observed, and two were collected and deposited in the ZSFQ museum under codes ZSFQ4890 and ZSFQ4891. In the BPCB, it has been mainly recorded in leaf litter of open areas near trails or secondary roads with sparse bushy vegetation, and it is commonly observed during the rainy season near temporary streams or small artificial pools of water, although it is less common than *E. pustulatus*. Classified as Least Concern (LC) in both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Leptodactylus labrosus (Jiménez de la Espada, 1875) Fig. 4o

Leptodactylus labrosus is a medium-sized toad with an SVL of approximately 57 mm. This species is characterized by the absence of webbing between the toes and the lack of expanded discs on the toes, along with large, protruding eyes; round pupils; extensive and transparent lower eyelids; and a circular tympanum (Heyer, 1978; Ron et al., 2022c). It exhibits sexual dimorphism in coloration; males have a cream-chocolate dorsal surface with dark brown spots, while females have a reddish-copper dorsal surface with light brown spots (Heyer, 1978; MECN, 2010; Ron et al., 2022c). During the fieldwork, 251 individuals were observed, and two were collected and deposited in the ZSFQ museum with codes ZSFQ4876 and ZSFQ4877. In the BPCB, it has been most frequently recorded in leaf litter of open areas near trails with sparse shrub vegetation. Classified as Least Concern (LC) in both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Leptodactylus melanonotus (Hallowell, 1861) Fig. 4p

Leptodactylus melanonotus is a medium-sized toad with an SVL of around 50 mm, where males have spines on their thumbs but not on their chest, distinguishing them from *L. labrosus* and *L. ventrimaculatus*, the most similar species west of the Ecuadorian Andes (Read et al., 2022e). It also features cutaneous ridges on the fingers and well-developed subarticular tubercles (Hallowell, 1861; Heyer, 1970).

Its diet is primarily insectivorous, but adults can also prey on small frogs (Hoffman, 2006). In the BPCB, a total of 88 individuals were recorded in leaf litter found in open areas near trails, secondary roads, and spaces with sparse vegetation and pools of water. Males sing throughout the year, preferring small water-filled cavities in fields with wet grass, though their activity may decrease during the semi-dry season (Hoffman, 2006). Classified as Least Concern (LC) by both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Leptodactylus ventrimaculatus (Boulenger, 1902) Fig. 4q

This medium-sized toad reaches a SVL of up to 58.35 mm in adulthood (MECN, 2010). This species is identified in situ by the presence of tubercles on the posterior surface of the tarsus, a characteristic that similar species *L. labrosus* and *L. melanonotus*, which coexist in the same locality, do not possess. Additionally, it lacks skin ridges and horny spines on the thumb, as well as folds on the flanks (Heyer, 1978; de Sá et al., 2014).

It has been reported that when living in sympatry with *L. labrosus*, it tends to move towards forests while *L. labrosus* inhabits open areas (Heyer & Maxson, 1982; MECN, 2010). In the BPCB, only eight individuals of this species were recorded and they were observed in leaf litter within primary and secondary forests, as well as near secondary roads and tourist trails. This species is listed as Least Concern (LC) in both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Family Strabomantidae

Barycholos pulcher (Boulenger, 1898) Fig. 4r

Barycholos pulcher is a small endemic species, with an SVL of approximately 25 mm. It has a light brown to grayish back with dark hourglass-shaped markings and a cream-colored belly (Heyer, 1969; Boulenger, 1898; Yánez-Muñoz et al., 2022). Its fingers have particular proportions, such as the third toe being longer than the fifth and the first finger being longer than the second (Heyer, 1969; Boulenger, 1898). These characteristics distinguish it from *Pristimantis achatinus*, the most similar species in the area. In the BPCB, this species has been primarily recorded in leaf litter in open areas near trails or secondary roads, with only two individuals observed. This species is classified as Least Concern (LC) by both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Pristimantis achatinus (Boulenger, 1898) Fig. 4s

Pristimantis achatinus is one of the most common species on the Ecuadorian coast. It is a medium-sized frog (Camacho-Badani et al., 2022). This species exhibits a wide range of dorsal coloration, from pale yellow to dark brown. It has dorsolateral folds and finger I is longer than finger II, without a membrane between the fingers, but with skin ridges on the feet, and Finger V is somewhat longer than finger III (Boulenger, 1898; Lynch & Myers, 1983; Lynch & Duellman, 1997). Considered a colonizing and generalist species, *P. achatinus* has a peculiar biology, as its eggs produce fully developed small frogs without undergoing metamorphosis (MECN, 2010). During fieldwork, 556 individuals were observed, but only four were collected and deposited in the ZSFQ museum under the codes ZSFQ4884, ZSFQ4885, ZSFQ4886, and ZSFQ4887. In the BPCB, it has been recorded mainly in the leaf litter of open areas near trails, secondary roads, or open spaces, and individuals have also been found perched on walls or posts at a height of no more than 180 cm. It is classified as Least Concern (LC) in both the IUCN (2024) and the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Order Gymnophiona

Family Caeciliidae

Caecilia tenuissima (Taylor, 1973) Fig. 4t

Caecilia tenuissima is a small and elongated endemic caecilian, with between 174 and 190 incomplete primary grooves on its back, except in the area before the cloaca (Taylor, 1973). It lacks a terminal shield, and its semi-ovate head has a rounded snout that protrudes beyond the edge of the mouth when viewed from the side (Taylor, 1973; Lynch, 1999; Fletcher-Laso, 2002). It is a subterranean species and there is no information about its reproduction and ability to adapt to secondary habitats (IUCN SSC Amphibian Specialist Group, 2019). This species is rare, with only one individual observed along a secondary road during heavy rainfall. This specimen was collected and deposited in the ZSFQ museum under the code ZSFQ4898. It is classified as Data Deficient (DD) in the IUCN (2024), while it has the category of Endangered (EN) in the Red List of Amphibians of Ecuador (Ortega-Andrade et al., 2021).

Class Reptilia

Order Squamata: Amphisbaenia

Family Amphisbaenidae

Amphisbaena fuliginosa varia (Laurenti, 1768) Fig. 5a

This species, due to its fossorial lifestyle, is difficult to observe (Ribeiro et al., 2008; Ray et al., 2015). It is characterized by having a body with 190-205 rings, a tail with 23-27 rings, and approximately 40-50 segments in a ring in the middle of the body, in addition to 6-8 preanal pores (Peters & Donoso-Barros, 1970). They are presumed to spend most of their time underground in burrows that they build themselves, although they have also been collected in underground colonies of cutter ants (Gans, 1969; Riley et al., 1986; Ray et al., 2015). In the BPCB, this species was recorded only twice; the individuals were both sighted on a trail in the middle of a secondary forest. It is non-venomous and therefore completely harmless to humans (MECN, 2009). It is classified as Least Concern (LC) by the IUCN (2024), while it has the category of Near Threatened (NT) on the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Order Squamata: Sauria

Family Alopoglossidae

Alopoglossus festae (Peracca, 1904) Fig. 5b

Alopoglossus festae is a medium-sized lizard that has keeled scales, mostly granular, small on the sides of the neck, and gular scales arranged in four longitudinal rows, with the middle pair clearly widened (Köhler et al., 2012). This diurnal species is associated with leaf litter in primary and secondary forests, in humid environments near bodies of water (Ortega-Andrade et al., 2010), precisely the type of ecosystem where it was found in BPCB. During fieldwork, 40 specimens were observed but only two were collected and deposited in the ZSFQ and MUTPL museums under the codes ZSFQ4916 and MUTPL-R-596. It is classified as Least Concern (LC) by the IUCN (2024); however, it is found in the Vulnerable (VU) category on the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Family Anolidae

Anolis binotatus (Peters, 1863) Fig. 5c

Anolis binotatus is a lizard distinguished by having a brown back, an interorbital bar on the head, a longitudinal lateral stripe on the sides of the body, and a banded tail, with brown irises (Poe, 2019). It also has scales between the second canthals, supraorbital semicircles separated by a scale, and a supraocular

disc with 7-8 enlarged scales (Williams et al., 1995). This species is differentiated from similar species, such as *A. gracilipes*, by having white ventrolateral stripes.

It can inhabit mature forests, intervened forests, open areas, crops, or estuaries, where it moves on the ground, bushes, and trees, often no more than 2 meters above the ground (Cruz-García, 2017; Ayala-Varela et al., 2020). During fieldwork, only three specimens were reported, and none were collected. In the BPCB, it can be observed in secondary forests and near secondary roads or trails. It is classified as Least Concern (LC) by the IUCN (2024); however, in the Red List of Reptiles of Ecuador (Carrillo et al., 2005) it is listed as Data Deficient (DD).

Anolis festae (Peracca, 1904) Fig. 5d

Anolis festae is a small lizard, with a thin and elongated body, olive green back, and an immaculate belly. Males have a large, white gular sac with a black base and blue irises (Williams et al., 1995; MECN, 2010). A. festae is associated with human-modified habitats such as teak and cocoa plantations, roadside vegetation, and grasslands (Miyata, 2013).

During fieldwork, seven specimens were reported, but just two were collected deposited in the ZSFQ museum with the code ZSFQ4918 and in the MUTPL museum with the code MUTPL-R-598. In the BPCB, this species was found on tree trunks at heights ranging from 100 cm to 400 cm, near buildings, secondary roads, and trails. It is classified as Near Threatened (NT) by the IUCN (2024) and on the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Anolis gracilipes (Boulenger, 1898) Fig. 5e

Anolis gracilipes is a small lizard that reaches a maximum size of 54 mm SVL (MECN, 2010). This species has a thin body and a slightly widened, light-colored face (Williams et al., 1995; MECN, 2010). It also has a lateral stripe that runs along the flanks to the inguinal region, and the belly is greenish-yellow while the gular sac is orange with black longitudinal scales. It feeds on insects and is oviparous (Arteaga et al., 2013; Uetz et al., 2023). At night, they can be found sleeping at the ends of ferns and bushes, clinging to thin branches, sometimes up to 200 cm from the ground (MECN, 2010). During fieldwork, 41 specimens were reported, and just an adult female was collected and deposited in the ZSFQ museum with the code ZSFQ4917. In the BPCB, they have been sighted in exactly these locations, near vegetation along secondary roads and trails. It is classified as Least Concern (LC) by the IUCN (2024) and on the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Family Gekkonidae

Hemidactylus frenatus (Duméril & Bibron, 1836) Fig. 5f

Hemidactylus frenatus is a lizard characterized by long divided digital pads, non-retractable claws, and digits without basement membranes (Zug et al., 2007). This species is known for emitting vocalizations that vary according to their state (Savage, 2002) and is frequently associated with man-made structures, such as buildings, where it moves rapidly on vertical surfaces and roofs (Zug et al., 2007). It feeds on arthropods, especially attracted by electric lights and spiders, and seeks refuge in cracks, holes, and cavities (Savage, 2002). During fieldwork, 19 specimens were reported, and just an adult specimen was deposited in the ZSFQ museum with the code ZSFQ4911. In fact, in the BPCB, it is mainly recorded in various types of buildings within the reserve, with few sightings in forested areas. It is classified as Least Concern (LC) by the IUCN (2024) and Not Evaluated (NE) in the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Family Iguanidae

Iguana iguana (Linnaeus, 1758) Fig. 5g

It is a very large lizard, reaching up to 200 cm including its tail (MECN, 2010). This species is easy to recognize; its dorsal coloration varies between intense green and brownish-green, with gray tones forming transverse bands, and it may also exhibit reddish hues (Boulenger, 1885; Köhler, 1999; MECN, 2010). Additionally, it has a large dorsal crest extending over more than a third of its tail, and a gular pouch with front-facing spikes that can be fully extended (Taylor, 1956; Köhler, 1999; Savage, 2002). They are sedentary and can remain in the same tree for several weeks. Communication occurs through body language, such as head tilting and scratching movements (Köhler, 1999; MECN, 2010; Guerra-Correa & Rodríguez-Guerra, 2020). During the fieldwork were observed seven individuals and none were collected. They are a common species in the canopy of trees near human buildings and secondary roads, but not within forested areas. Classified as Least Concern (LC) by the IUCN (2024) and in the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Family Phyllodactylidae

Phyllodactylus reissii (Peters, 1862) Fig. 5h

Phyllodactylus reissii is a lizard characterized by having tubercles on the head, torso, and tibias, excluding the femurs. It also has an enlarged row of scales under the tail and terminal lamellae on the digits that are moderately enlarged and truncated in

a T-shape (Dixon & Huey, 1970; MECN, 2010). This species has nocturnal and climbing habits and is mainly associated with urbanized coastal and island habitats, rarely reported in natural environments (MECN, 2010). During fieldwork, 63 individuals were observed but only one individual was collected and deposited in the ZSFQ museum with the code ZSFQ4910. In the BPCB, it has been observed feeding on building walls, rocks, tourist bridges, signposts, and even bathrooms. It is categorized as Least Concern (LC) by the IUCN (2024) and in the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Family Polychrotidae

Polychrus femoralis (Werner, 1910) Fig. 5i

This is an intermediate-sized lizard with a thin, laterally compressed body, along with a long, semi-prehensile tail. It also has a pointed snout, a smooth dorsal surface of the head, and smooth gular scales, as large as the ventral ones, forming longitudinal rows (Schluter, 2013; Guerra-Correa, 2020). This lizard is found in areas of deciduous forest or open areas near rivers, where it usually perches on branches 150 cm high and uses a bipedal jump to move between the branches, although it does not use its tail as a mechanism to hold on to them (Schluter, 2013; Guerra-Correa, 2020). During fieldwork this species were sighted only four times. In the BPCB, it is uncommon and has been observed perching on trunks or bushes at a height of no more than 300 cm in the reserve's secondary and primary forests. This species is classified as Least Concern (LC) by the IUCN (2024); however, on the Red List of Reptiles of Ecuador (Carrillo et al., 2005), it is listed as Near Threatened (NT).

Family Sphaerodactylidae

Gonatodes caudiscutatus (Günther, 1859) Fig. 5j

This small lizard reaches 45.4 mm SVL, with 89-101 scales around the midbody. Adult males display elongated orange-yellow spots on the dorsal surface of the head (Sturaro & Avila-Pires, 2013) and a large blue ocellus bordered in black on each shoulder, with scattered blue dots on the flanks and back (Carvajal-Campos & Torres-Carvajal, 2012). *G. caudiscutatus* can be mistaken for *Lepidoblepharis buchwaldi*; key features for differentiation include coloration, with male *G. caudiscutatus* being quite distinctive, and free nails but is more commonly observed in urban areas, such as house roofs (MECN, 2010). Its diet mainly consists of small arthropods (Vitt & de la Torre, 1996; Vitt et al., 1997). During fieldwork 435 individuals were reported, but just two were collected and deposited in the ZSFQ museum with the codes ZSFQ4914, ZSFQ4915, and ZSFQ4915. It is categorized as Least Concern (LC) by the IUCN (2024) and the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Lepidoblepharis buchwaldi (Werner, 1910) Fig. 6k

Lepidoblepharis buchwaldi is one of the smallest species in its genus, measuring only 28 mm in SVL (MECN, 2010). This tiny lizard is characterized by juxtaposed dorsal scales that are not keeled and are of uniform size (Peters & Donoso-Barros, 1970), as well as claws covered by a symmetrical sheath typically consisting of six scales (MECN, 2010). Its natural history remains largely understudied; however, based on studies of its congeners, its diet likely consists of arthropods and small amphibians (Ayala & Castro, 1983; Vitt et al., 2005). During the fieldwork 14 specimens were sighted but only one adult were collected and deposited in the ZSFQ museum with the code ZSFQ4913. Within the BPCB, it has been observed among the leaf litter near facilities and in the vicinity of small bodies of water, mostly in less disturbed areas. It is classified as Least Concern (LC) by the IUCN (2024); however, it is listed as Near Threatened (NT) on the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Family Teiidae

Holcosus septemlineatus (Duméril & Duméril, 1851) Fig. 6l

Holcosus septemlineatus is a conspicuous medium-sized lizard, particularly striking in its youth when its vivid blue tail and contrasting pattern of a black dorsum with interrupted orange lateral stripes make it stand out (Peters, 1964; MECN, 2010). Adult lizards have a black dorsal coloration with interrupted pale-yellow lateral bands, while their bellies are pale-yellow with broad, smooth scales (MECN, 2010). Its diet mainly includes orthopterans, and it exhibits active hunting behavior, especially on sunny days when its activity peaks (MECN, 2010; Valencia et al., 2008). During fieldwork 210 specimens were recorded but only a juvenile female was collected and is catalogued in the ZSFQ museum under code ZSFQ4923. Within the BPCB, this lizard is very common in both well-preserved areas and tourist-frequented zones. Observations indicate that it basks in the sun on sunny days along trails, atop rocks, or on fallen logs. The species is classified as Least Concern (LC) by both the IUCN (2024) and the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Medopheos edracanthus (Bocourt, 1874) Fig. 6m

This species is distinguished by a unique or bifurcated frontal scale and eight longitudinal rows of ventral scales (Peters,

1964). Its dorsal coloration is olive green with five longitudinal yellowish lines, which become less distinct and often interrupted on the flanks (Barbour & Noble, 1915; Harvey et al., 2012). During fieldwork four specimens were recorded, but only an adult male was collected and deposited in the ZSFQ museum under the code ZSFQ4924. It has only been observed occasionally along tourist trails on sunny days, similar to *H. septemlineatus*, this species is very elusive. It is classified as Least Concern (LC) by both the IUCN (2024) and the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Family Tropiduridae

Stenocercus iridescens (Günther, 1859) Fig. 6n

Stenocercus iridescens is a medium-sized lizard characterized by a brown back with dark chevrons, most prominent on the neck, and sometimes light blue vertebral scales in males (Torres-Carvajal, 2007; Carvajal-Campos, 2020). During fieldwork 457 specimens were observed and two of them were collected and deposited in the ZSFQ museum: a female under the code ZSFQ4921 and a male with the code ZSFQ4922. At the BPCB, this species was the most frequently observed lizard, found foraging among leaf litter and perching on rocks or logs during the day, sometimes reaching heights of up to 200 cm. An individual was even observed in a vertical position on a tree trunk at a height of 160 cm. Observations were made in various habitats, including primary and secondary forests, near shrubs, leaf litter on secondary roads, buildings, and trails throughout the year. It is classified as Least Concern (LC) by both the IUCN (2024) and the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Order Squamata: Serpentes

Family Boidae

Boa imperator (Daudin, 1803) Fig. 6o

Boa imperator is a large snake, with adults reaching up to 4,000 mm (MECN, 2010). A distinctive feature of this species is the presence of pelvic vestiges, such as claws on either side of the cloaca. It also lacks labial pits and has small scales on the top of its head and snout (loreal region) (Duellman, 1978; Savage, 2002; O'Shea, 2007). Its diet primarily includes mammals, birds, lizards, and amphibians. Although non-venomous, it employs various hunting techniques, including ambushes and active foraging, capturing and consuming prey headfirst through constriction (Mattison, 1995; Roveri-Scartozzoni & de Barros-Molina, 2014). During fieldwork four individuals were observed but none were collected. This snake has been mostly observed in anthropogenically affected areas within the BPCB, such as tourist trails, leaf litter in secondary forests, and thickets no higher than 200 cm. It is categorized as Least Concern (LC) by the IUCN (2024) and Vulnerable (VU) on the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Family Colubridae

Chironius flavopictus (Werner, 1909) Fig. 6p

Chironius flavopictus is a moderately sized non-venomous snake, reaching up to 1,000 mm in total length (TL) (MECN, 2010). This species has distinctive features, including a divided anal plate, 12 rows of dorsomedial scales, and white or yellow spots on most of the dorsal scales. However, adult coloration alone is usually sufficient for species identification (Dixon et al., 1993). Its back is dark with white, bright orange, golden, light brown, or yellowish spots, and the ventral scales range from ivory, pale yellow, or orange to pale faded greenish orange (Dixon et al., 1993; MECN, 2010). During fieldwork this species was observed only once. It was reported in the area affected by tourism, found near trails in areas with predominant bush vegetation, where this species can find its main prey, frogs (Dixon et al., 1993). It is categorized as Data Deficient (DD) by the IUCN (2024) but classified as Vulnerable (VU) in the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Clelia clelia (Daudin, 1803) Fig. 6q

Clelia clelia is a large non-venomous snake, reaching up to 2,500 mm in adulthood (MECN, 2010). It can be distinguished from its congeners by the following characteristics: rows of dorsal scales in the middle of the body number 17-19; ventral scales 218-225 in males and 228-242 in females; subcaudal scales 94-96 in males and 77-86 in females (Duellman, 1978; Schwartz & Henderson, 1992; Martins & Oliveira, 1998). This snake has a peculiar ontogenetic change, with its color shifting from red with a black head and yellow collar in juveniles to a grayish-black or fully black body in adulthood (Duellman, 1978; Martins & Oliveira, 1998; MECN, 2010). Additionally, it has ophiophagous habits, feeding on both vipers and colubrids, suggesting resistance to the venom of some venomous snakes (Cerdas & Lomonte, 1982; Lomonte et al., 1990). It is a very elusive and fast snake; during fieldwork, only two individuals were observed. In the BPCB, it has been sighted only once, the specimen was found hidden among the leaves at the base of a mature tree near permanent streams, but when it was discovered, it quickly retreated. Both the IUCN (2024) and the Red List of Reptiles of Ecuador (Carrillo et al., 2005) categorize it as Least Concern (LC).

Coniophanes dromiciformis (Peters, 1863) Fig. 6r

Coniophanes dromiciformis is a small snake species distinguished from its congeners by the rows of dorsal scales midway down the body, the dorso-medial stripe that generally occupies five rows of scales in width, and the thin white lines that cross the dark lateral stripes (Bailey, 1939; Myers, 1969; Peters & Orejas-Miranda, 1970). Although there is little information about its natural history, it is known to be oviparous, terrestrial, and nocturnal (Myers, 1969). During fieldwork six specimens were reported and some male specimens were collected and deposited in the ZSFQ and MUTPL museums with the codes ZSFQ4904, ZSFQ4905, and MUTPL-R-605. In the BPCB, its presence has been recorded in the vicinity of primary forests and in adjacent areas of secondary forest, as well as near buildings in areas with human intervention. This small snake is listed as Vulnerable (VU) by the IUCN (2024) and Near Threatened (NT) according to Carrillo et al. (2005) in the Red List of Reptiles of Ecuador.

Dendrophidion brunneum (Günther, 1858) Fig. 6s

Dendrophidion brunneun is a medium-sized snake with the dorsal coloration ranges from green to greenish-brown, often with yellowish or bronzy reflections, while the belly is light with dark spots, distinguishing it from *D. nuchalis* and *D. percarinatus* (Cadle, 2010; MECN, 2010). This diurnal snake is terrestrial or semi-arboreal, is not venomous, but displays defensive behaviors when handled (MECN, 2010). Also, it is often found basking in sunlight in open areas and foraging along pool edges (Cadle, 2010; MECN, 2010), the latter being the exact habitat where the collected individual was found. During fieldwork four specimens were observed but only one juvenile individual was deposited in the MUTPL museum under the code MUTPL-R-595. It holds a conservation status of Least Concern (LC) by the IUCN (2024) and Near Threatened (NT) in the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Dipsas georgejetti (Arteaga et al., 2018) Fig. 6t

This medium-sized snake, endemic to Ecuador, with males reaching up to 710 mm and females up to 850 mm, this snake has a jaw design is specialized for feeding on gastropods (Arteaga et al., 2018). Also, it can be distinguished from other *Dipsas* species by its smooth dorsal scales in a 15-15-15 arrangement, with the loreal and prefrontal scales not contacting the orbit, absence of infralabials touching behind the symphysis, and possessing 172-180 ventral scales in males and 177 in females (Arteaga et al., 2018). According to Cadle and Myers (2003), dipsadines are substantially docile snakes that do not attack when handled, although they may modify their head posture defensively in response to threats. During fieldwork, two specimens were sighted. In the BPCB it was observed in disturbed areas, perching on branches of medium-sized shrubs and foraging in leaf litter at night. Currently, it is categorized as Not Evaluated (NE) in both the IUCN (2024) and the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Drymarchon melanurus (Duméril et al., 1854) Fig. 7u

Drymarchon melanurus is a large snake characterized by four distinctive black stripes, vertical or oblique, below the eyes (Peters & Orejas-Miranda, 1970; Guerra et al., 2012) being this very conspicuous of this species. While it is terrestrial, it is often found near bodies of water. During the fieldwork six specimens were sighted, but none were collected. In the BPCB, this species was observed near disturbed areas and in different areas of secondary and primary forest. Their diet includes small vertebrates from birds to turtles and even other snakes (Venegas, 2005; Guerra et al., 2012).

It is listed as Least Concern (LC) by the IUCN (2024), while it is considered as Near Threatened (NT) in the Red List of Reptiles of Ecuador (Carrillo et al., 2005). It is important to mention that, in the BPCB tourist area, a visibly thin individual was observed, which was in the process of shedding its skin and had an infestation of 127 ticks of the Amblyomma genus near its head (G. Brito, pers. comm., May 27, 2024).

Imantodes cenchoa (Linnaeus, 1758) Fig. 7v

Imantodes cenchoa is a medium-sized snake, with adult males reaching up to 1,240.4 mm and females up to 1,500 mm (MECN, 2010). It features a laterally compressed body and a long tail, which constitutes about one-third of its total length. Its head is enlarged and distinct from the neck, characterized by bulging eyes and vertical elliptical pupils (Duellman, 1978; MECN, 2010). The diet of this snake primarily consists of frogs from the genus *Pristimantis* and arboreal lizards (*Anolis*), along with eggs from reptiles and other frogs (Savage, 2002). During fieldwork four specimens were observed but only one individual was collected and deposited in the MUTPL museum under the code MUTPL-R-601.Within the BPCB, it has been observed in bushes near secondary roads or trails in secondary forests, at heights not exceeding 200 cm. This species is listed as Least Concern (LC) by both the IUCN (2024) and the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Lampropeltis micropholis (Cope, 1860) Fig. 7w

The medium-sized species reaches up to 1900 mm in males and 1,400 mm in females, featuring a cylindrical body, a short tail, and a small head with medium-sized eyes, not distinctly separated from the neck (MECN, 2010). It can be identified by its rows of dorsal scales, typically 19 or 21, and its temporal scales, usually 1+2 or 2+3 (Williams, 1994). Its diet includes small mammals, birds, eggs, snakes, and lizards (Savage, 2002). Although non-venomous, its dorsal coloration mimics that of a coral snake. In the BPCB, sightings are rare; during this study, it was observed only once at night near a tourist trail by a stream. It is classified as Least Concern (LC) by the IUCN (2024) but is considered Endangered (EN) in the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Leptodeira ornata (Bocourt, 1884) Fig. 7x

Leptodeira ornata is a medium-sized snake, with a cylindrical and laterally compressed body (Savage, 2002; MECN, 2010). Its head is well differentiated from the neck and features a pattern of brown dorsal spots on a cream to reddish tan back, with between 20 and 70 dark to black spots (Savage, 2002). Although relatively docile and rarely biting when handled, if it does bite, it can inflict a painful but not serious bite with its grooved rear fangs (Savage, 2002; MECN, 2010). During fieldwork 26 specimens were observed but only three were collected, and deposited in the ZSFQ and MUTPL museums under the codes ZSFQ4900, MUTPL-R-600, and MUTPL-R-606 respectively, This snake was observed in all sampled areas in the BPCB, covering a variety of ecosystems, including stream areas, primary and secondary forests, as well as areas affected by human activity such as secondary roads and trails. *L. ornata* is listed as Least Concern (LC) by the IUCN (2024) and in the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Leptophis occidentalis (Günther, 1859) Fig. 7y

These diurnal snakes are medium-sized, reaching a TL of 2,000 mm, and are characterized by a distinctive deep green coloration on the back. They differ from other western colubrid snakes by their 15 rows of scales halfway down the body (MECN, 2010). Their speed allows them to flee quickly when discovered, but they can exhibit defensive behavior by biting if cornered. However, their venom does not pose a threat to people (MECN, 2010). During fieldwork, four specimens were observed, and one of them was collected and deposited in the MUTPL museum under the code MUTPL-R-603. In the BPCB, they are often seen perched on branches of moderately sized bushes and occasionally on signs within the forest. This species is classified as Not Evaluated (NE) by the IUCN (2024) and the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Mastigodryas pulchriceps (Cope, 1868) Fig. 7z

Mastigodryas pulchriceps is a medium-sized snake with a total length that can reach up to 1,400 mm (MECN, 2010). It is distinguished from its congeners by its rows of 17-17-15 dorsal scales, third, fourth and fifth supralabial scales that touch the eye, divided cloacal scale and banded body coloration pattern (Stuart, 1941; Montingelli, 2009). Its dorsal coloration presents dark brown rectangular markings separated by light brown intermediate spaces; on the flanks, the markings are slightly quadrangular with grayish-cream spaces (MECN, 2009). In the BPCB, its sighting has been recorded on only one occasion, finding it foraging inside a secondary forest. Classified as Least Concern (LC) in the IUCN (2024) and Near Threatened (NT) in the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Mastigodryas reticulatus (Peters, 1863) Fig. 7aa

This endemic snake is distinguished by its striped dorsal pattern and a light lateral stripe formed by rows of scales 4 and 5. Its dorsal scales have dark apical edges, and the basal and naked regions of the elongated hemipenes feature enlarged and thin lateral spines leading to the spermatic groove (Montingelli et al., 2011). This diurnal snake's diet includes lizards, frogs, small mammals, and bird and snake eggs (Montingelli, 2009). During fieldwork, five specimens of this species were observed, but only two individuals were collected and deposited in the ZSFQ and MUTPL museums under the codes ZSFQ4901 and MUTPL-R 472. In the BPCB, it has been sighted in tourist areas and primary forests. It is a fast species and poses no danger to humans if bitten. It is categorized as Near Threatened (NT) by both the IUCN (2024) and the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Oxybelis transandinus (Torres-Carvajal et al., 2021) Fig. 7ab

Oxybelis trasandinus is a medium-sized, endemic snake in Ecuador, reaching up to 1,600 mm in total length (Torres-Carvajal et al., 2021). This species is distinguished within the *O. aeneus* complex by specific characteristics, such as the second pair of chin shields being in contact with each other for most of their length, a midventral dark stripe on the first quarter of the belly, supraocular scales longer than the prefrontal ones, and approximately 176-187 ventral scales in females and 178-190 in males (Torres-Carvajal et al., 2021). This diurnal species exhibits

arboreal habits, often found sleeping on leaves or branches up to 4 m high at night. In fact, an adult male was found asleep on a branch near a trail. It shows aggressive behavior when handled but it is not venomous (Torres-Carvajal et al., 2021). During fieldwork nine specimens were sighted and two of them were collected and deposited in the ZSFQ and MUTPL museums under the codes ZSFQ4902 and MUTPL-R-599. It is categorized as Not Evaluated (NE) by both the IUCN (2024) and the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Oxyrhopus petolarius (Linnaeus, 1758) Fig. 7ac

Oxyrhopus petolarius is a medium-sized snake, with adults capable of exceeding 1,120 mm in total length (Lynch, 2009; MECN, 2010). Known as a false coral due to its coloration mimicking true corals of the genus *Micrurus*, it features a distinctive dorsal pattern with dark rings and light reddish interspaces, where the dark rings are two or three times wider than the interspaces, while the belly is white (Lynch, 2009). This mimicry serves as a defense mechanism (Campbell & Lamar, 2004). Typically docile, this snake may bite if it feels threatened; however, its venom, though mildly toxic, does not pose significant harm to humans (Savage, 2002; Lynch, 2009; Vidal et al., 2010; Alencar et al., 2013; MECN, 2010).

During fieldwork six specimens were observed and two of them been deposited in the MUTPL museum under the codes MUTPL-R-593-3668 and MUTPL-R-602. In the BPCB, this snake can be observed in various environments, including primary forest areas, secondary forests, and regions with human intervention such as secondary roads and trails, predominantly found foraging among the leaf litter. This species is classified as Least Concern (LC) by both the IUCN (2024) and the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Stenorrhina degenhardtii (Berthold, 1846) Fig. 7ad

This small to medium-sized snake, reaching up to 900 mm in total length in adults, features a slender, cylindrical body with a short tail and a head that is not distinctly differentiated from the body (Solórzano, 2004; MECN, 2010). Within the genus *Stenorrhina*, it is distinguished by specific characteristics such as an enlarged rostral plate, a shovel-shaped snout, a fused internasal to the anterior nasal, and a generally present loreal plate (Savage, 2002; Natera-Mumaw et al., 2015).

This species exhibits semifossorial or cryptozoic habits, making encounters with it rare. It is primarily diurnal and crepuscular but has occasionally been observed active at night near streams (Savage, 2002; Solórzano, 2004). During fieldwork five specimens of this species were sighted. An individual of this species that was deposited in the ZSFQ museum under the code ZSFQ4903. This species is categorized as Least Concern (LC) by the IUCN (2024) and Near Threatened (NT) on the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Tantilla capistrata (Cope, 1875) Fig. 8ae

Tantilla capistrata is a small snake with a cylindrical body that reaches 500 mm in total length, with a short tail and a head that is poorly differentiated from the neck (MECN, 2010). It is distinguished by specific characteristics such as a narrow dark stripe on the dorsomedial row of dorsal scales, a pale nuchal band and between 130-156 ventral and 46-71 subcaudal scales (Wilson, 1985).

It has a back that varies between yellowish and reddish tones with black longitudinal lines, a white belly and a prominent pale spot on the snout (Wilson, 1985; MENC, 2010). During fieldwork within the BPCB, four specimens were observed. Sightings of this snake have mainly occurred in tourist areas, where it has been observed foraging through leaf litter on tourist trails in secondary forests. And individual was collected and deposited in the MUTPL museum under the code MUTPL-R-597. It is listed as Data Deficient (DD) in the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Family Elapidae

Micrurus bocourti (Jan, 1872) Fig. 8af

Micrurus bocourti is a medium-sized venomous snake, reaching up to 700 mm in total length, with a distinctive body pattern featuring only two black rings in the first triad, and a tail with 5 to 8 yellow or black-and-white rings in males and 4 to 6 in females (Roze, 1996; Campbell & Lamar, 2004). Their primary defense when threatened lies in their warning coloration, and their behavior in the face of danger includes hiding their head between their body coils, moving jerkily back and forth, and displaying their shiny tails as a decoy (Valencia et al., 2016). Eight specimens were observed during the fieldwork, three of them have been deposited in the ZSFQ and MUTPL museums with the codes ZSFQ4908, ZSFQ4909, and MUTPL-R-604. In the BPCB, this species is mainly found foraging among the leaf litter and rocks of streams at night, although one individual was observed searching for food during the day. It is cataloged as Least Concern (LC) by the IUCN (2024) and Vulnerable (VU) on the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Family Leptotyphlopidae

Epictia subcrotilla (Klauber, 1939) Fig. 8ag

Epictia subcrotilla is a small snake, with adults exceeding 188 mm in total length. This species is characterized by 324-331 dorsomedial scales, 17 subcaudal scales, and 10 scales around the middle region of the tail, along with a white spot on the rostral and caudal spine (Schmidt & Walker, 1943; Francisco et al., 2012). Like other species in the Leptotyphlopidae family, *E. subcrotilla* has fossorial habits, feeding mainly on larvae and eggs of social insects. It lives primarily beneath the soil surface and organic matter (Webb et al., 2000; Adalsteinsson et al., 2009; Vitt & Caldwell, 2013). This snake was sighted only once in the BPCB during all years of sampling, observed on a daytime occasion after a brief rain near leaf litter on a tourist trail. It is registered as Least Concern (LC) by the IUCN (2024) and as Data Deficient (DD) on the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Family Viperidae

Bothrops asper (Garman, 1884) Fig. 8ah

This is a large venomous snake with a distinctive characteristics such as a brown or tan back with V- or X-shaped markings, which can be dark gray or black with pale crossbars (Campbell & Lamar, 2004; MECN, 2010). Juvenile males have yellow tail tips, which is why they are called "rabo de hueso" in Spanish, while juvenile females are uniformly brown (Campbell and Lamar, 2004). In the BPCB, this was the only species of viper identified, occupying diverse habitats including primary forests, secondary forests, and areas with human intervention such as buildings on the forest edges. Specimens were found in leaf litter, on tourist trails, secondary roads, low shrubs (less than 150 cm), and rocky soils in streams. Their behavior is unpredictable when they feel threatened, as they can move quickly and defend themselves vigorously (Campbell & Lamar, 2004). During fieldwork, 38 specimens were observed, two of them were deposited in the ZSFQ museum with the codes ZSFQ4906 and ZSFQ4907. This species is classified as Least Concern (LC) by both the IUCN (2024) and the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Order: Testudines

Family Chelydridae

Chelydra acutirostris (Peters, 1862) Fig. 8ai

Chelydra acutirostris is a considerable-sized aquatic turtle, capable of reaching lengths up to 490 mm and weighing as much as 34 kg. Its shell is broad and flat, with roughly parallel lateral margins, featuring three keels that resemble individual protrusions over the rows of vertebral and costal shields, which tend to fade as the turtle ages (Rueda-Almonacid et al., 2007). It has an omnivorous diet and is a voracious predator, feeding on crabs, shrimps, fish, mollusks, worms, insects, frogs, turtle hatchlings, snakes, birds, and small mammals (Rodríguez-Guerra, 2020). At the BPCB, the presence of this species was recorded on only one occasion during this study, indicating its rare observation. The individual was found in a stream with permanent water, surrounded predominantly by bush vegetation, within a primary forest. The species is listed as Not Evaluated (NE) by the IUCN (2024), yet it remains Vulnerable (VU) on the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Family Geoemydidae

Rhinoclemmys annulata (Gray, 1860) Fig. 8aj

This medium-sized turtle species reaches up to 230 mm in length (Rueda-Almonacid et al., 2007). It is distinguished by its dorsally pointed and profile-truncated face, as well as its domed shell, which features a yellowish mid-dorsal keel and a flat presentation on the second, third, and fourth vertebral scutes (MECN, 2010). The plastron is dark brown or black towards the center, with a characteristic yellow ring-shaped band, which gives the species its name (MECN, 2010). In the BPCB, two specimens were sighted, they both have been observed in permanent streams. This turtle is categorized as Near Threatened (NT) according to the IUCN (2024) and Endangered (EN) on the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

Family Kinosternidae

Kinosternon leucostomum (Duméril & Duméril, 1851) Fig. 8ak

Kinosternon leucostomum is a medium-sized turtle, reaching up to 170 mm, although typically only reaching 120 mm (Rueda-Almonacid et al., 2007). It can be distinguished from other Kinosternon species by its smooth, flattened, oblong-shaped brown shell in adults and unicarinated shell in hatchlings and juveniles. Its plastron is slightly unscathed or very slightly fissured between the anal shields, yellowish-brown with blackened fissures, relatively wide, and completely covers the shell openings. Additionally, it has two pairs of chin barbels (Rhodin et al., 2009). In the BPCB, this species has been recorded only once, indicating that its sighting is unusual. The observed

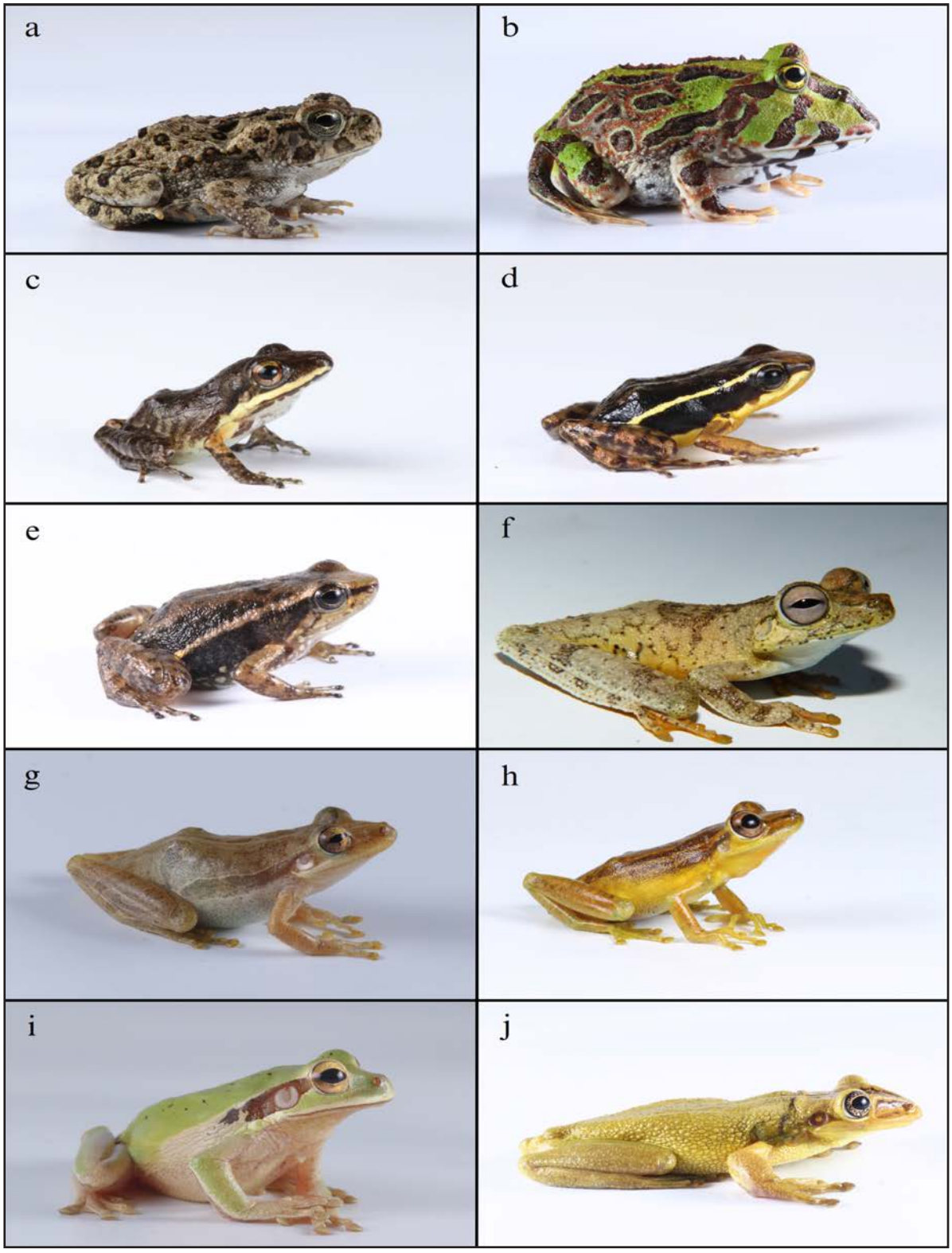

Figura 3. Especies de anfibios registrados en el Bosque Protector Cerro Blanco (BPCB) (Parte 1). a) *Rhinella bella*, b) *Ceratophrys stolzmanni*, c) *Craugastor longirostris*, d) *Epipedobates machalilla*, e) *Hyloxalus infraguttatus*, f) *Boana rosenbergi*, g) *Scinax quinquefasciatus*, h) *Scinax tsachila*, i) *Smilisca phaeota*, j) *Trachycephalus jordani*. Fotos: Keyko Cruz-García and Natalia Zapata-Salvatierra.

Figure 3. Amphibian species recorded in the Bosque Protector Cerro Blanco (BPCB) (Part 1). a) *Rhinella bella*, b) *Ceratophrys stolzmanni*, c) *Craugastor longirostris*, d) *Epipedobates machalilla*, e) *Hyloxalus infraguttatus*, f) *Boana rosenbergi*, g) *Scinax quinquefasciatus*, h) *Scinax tsachila*, i) *Smilisca phaeota*, j) *Trachycephalus jordani*. Photos: Keyko Cruz-García and Natalia Zapata-Salvatierra.

Figura 4. Especies de anfibios registrados en el Bosque Protector Cerro Blanco (BPCB) (Parte 2). k) *Trachycephalus quadrangulum*, l) *Engystomops guayaco*, m) *Engystomops pustulatus*, n) *Engystomops randi*, o) *Leptodactylus labrosus*, p) *Leptodactylus melanonotus*, q) *Leptodactylus ventrimaculatus*, r) *Barycholos pulcher*, s) *Pristimantis achatinus*, t) *Caecilia tenuissima*. Fotos: Keyko Cruz-García and Natalia Zapata-Salvatierra.

Figure 4. Amphibian species recorded in the Bosque Protector Cerro Blanco (BPCB) (Part 2). k) *Trachycephalus quadrangulum*, l) *Engystomops guayaco*, m) *Engystomops pustulatus*, n) *Engystomops randi*, o) *Leptodactylus labrosus*, p) *Leptodactylus melanonotus*, q) *Leptodactylus ventrimaculatus*, r) *Barycholos pulcher*, s) *Pristimantis achatinus*, t) *Caecilia tenuissima*. Photos: Keyko Cruz-García and Natalia Zapata-Salvatierra.

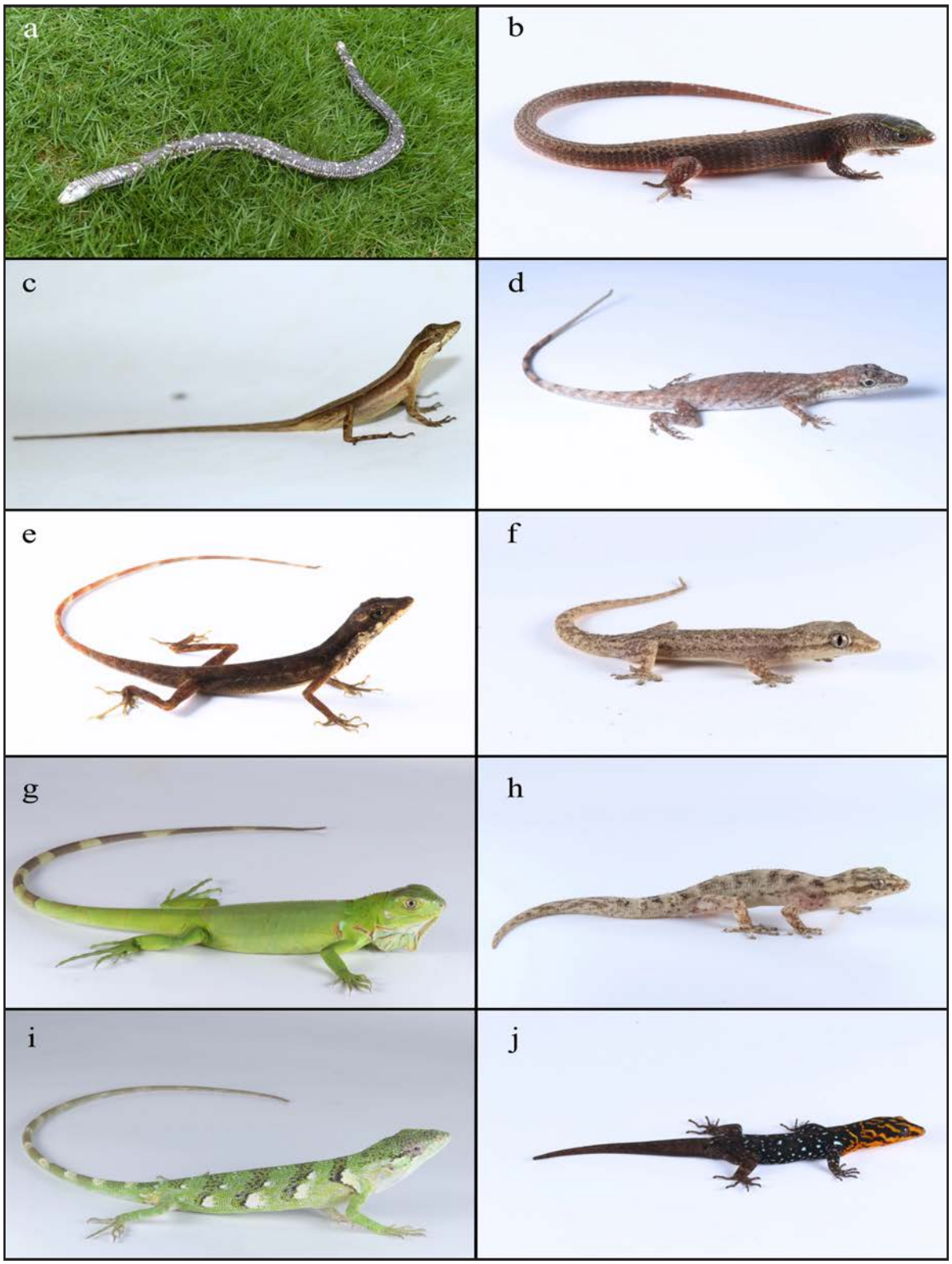

Figura 5. Especies de reptiles registrados en el Bosque Protector Cerro Blanco (BPCB) (Parte 1). a) *Amphisbaena varia*, b) *Alopoglossus festae*, c) *Anolis binotatus*, d) *Anolis festae*, e) *Anolis gracilipes*, f) *Hemidactylus frenatus*, g) *Iguana iguana*, h) *Phyllodactylus reissii*, i) *Polychrus femoralis*, j) *Gonatodes caudiscutatus*. Fotos: Keyko Cruz-García and Natalia Zapata-Salvatierra.

Figure 5. Reptile species recorded in the Bosque Protector Cerro Blanco (BPCB) (Part 1). a) *Amphisbaena varia*, b) *Alopoglossus festae*, c) *Anolis binotatus*, d) *Anolis festae*, e) *Anolis gracilipes*, f) *Hemidactylus frenatus*, g) *Iguana iguana*, h) *Phyllodactylus reissii*, i) *Polychrus femoralis*, j) *Gonatodes caudiscutatus*. Photos: Keyko Cruz-García and Natalia Zapata-Salvatierra.

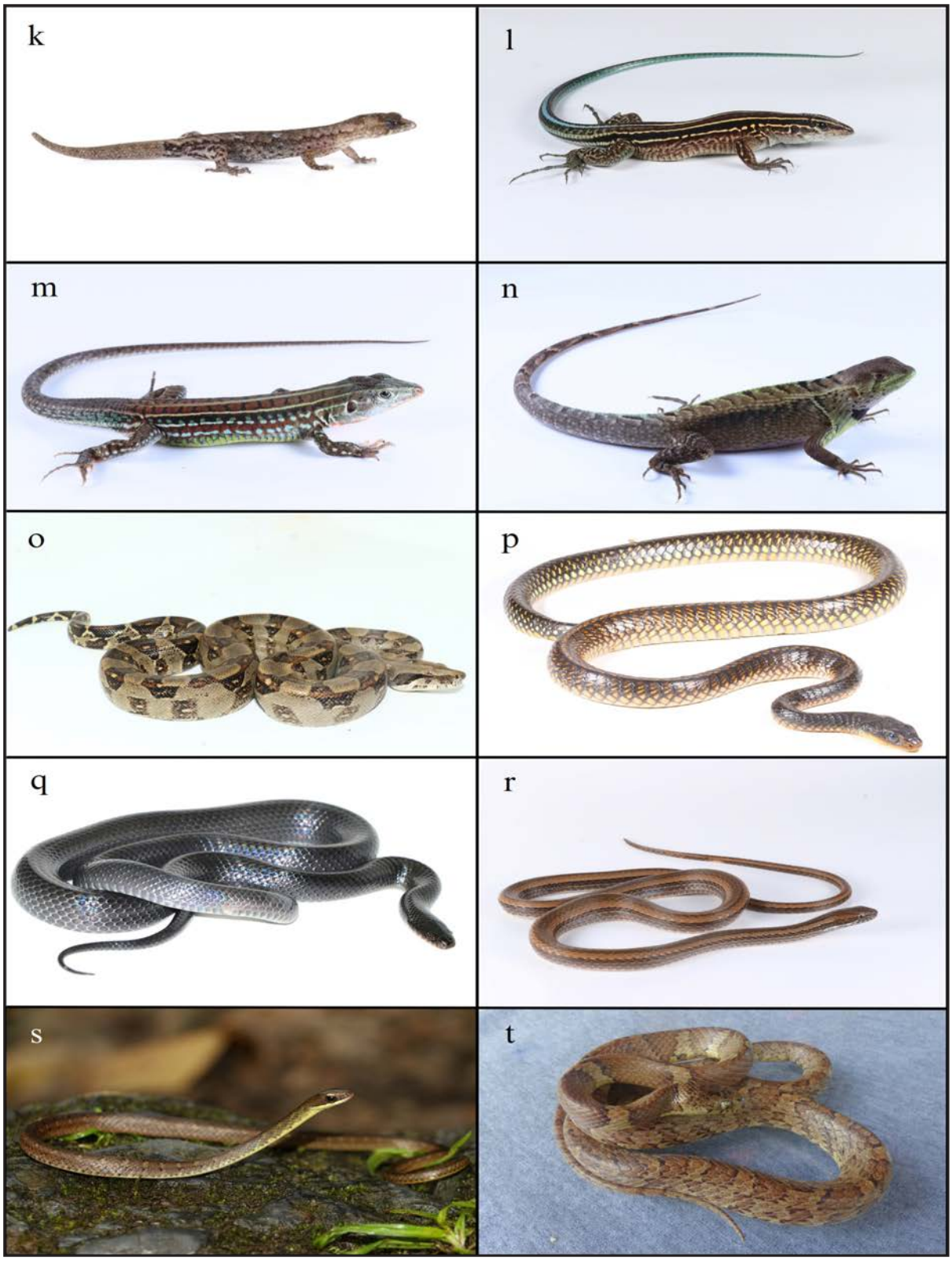

Figura 6. Especies de reptiles registrados en el Bosque Protector Cerro Blanco (BPCB) (Parte 2). k) *Lepidoblepharis buchwaldi*, l) *Holcosus septemlineatus*, m) *Medopheos edracanthus*, n) *Stenocercus iridescens*, o) *Boa imperator*, p) *Chironius flavopictus*, q) *Clelia clelia*, r) *Coniophanes dromiciformis*, s) *Dendrophidion brunneum*, t) *Dipsas georgejetti*. Fotos: Keyko Cruz-García and Natalia Zapata-Salvatierra.

Figure 6. Reptile species recorded in the Bosque Protector Cerro Blanco (BPCB) (Part 2). k) *Lepidoblepharis buchwaldi*, l) *Holcosus septemlineatus*, m) *Medopheos edracanthus*, n) *Stenocercus iridescens*, o) *Boa imperator*, p) *Chironius flavopictus*, q) *Clelia clelia*, r) *Coniophanes dromiciformis*, s) *Dendrophidion brunneum*, t) *Dipsas georgejetti*. Photos: Keyko Cruz-García and Natalia Zapata-Salvatierra.

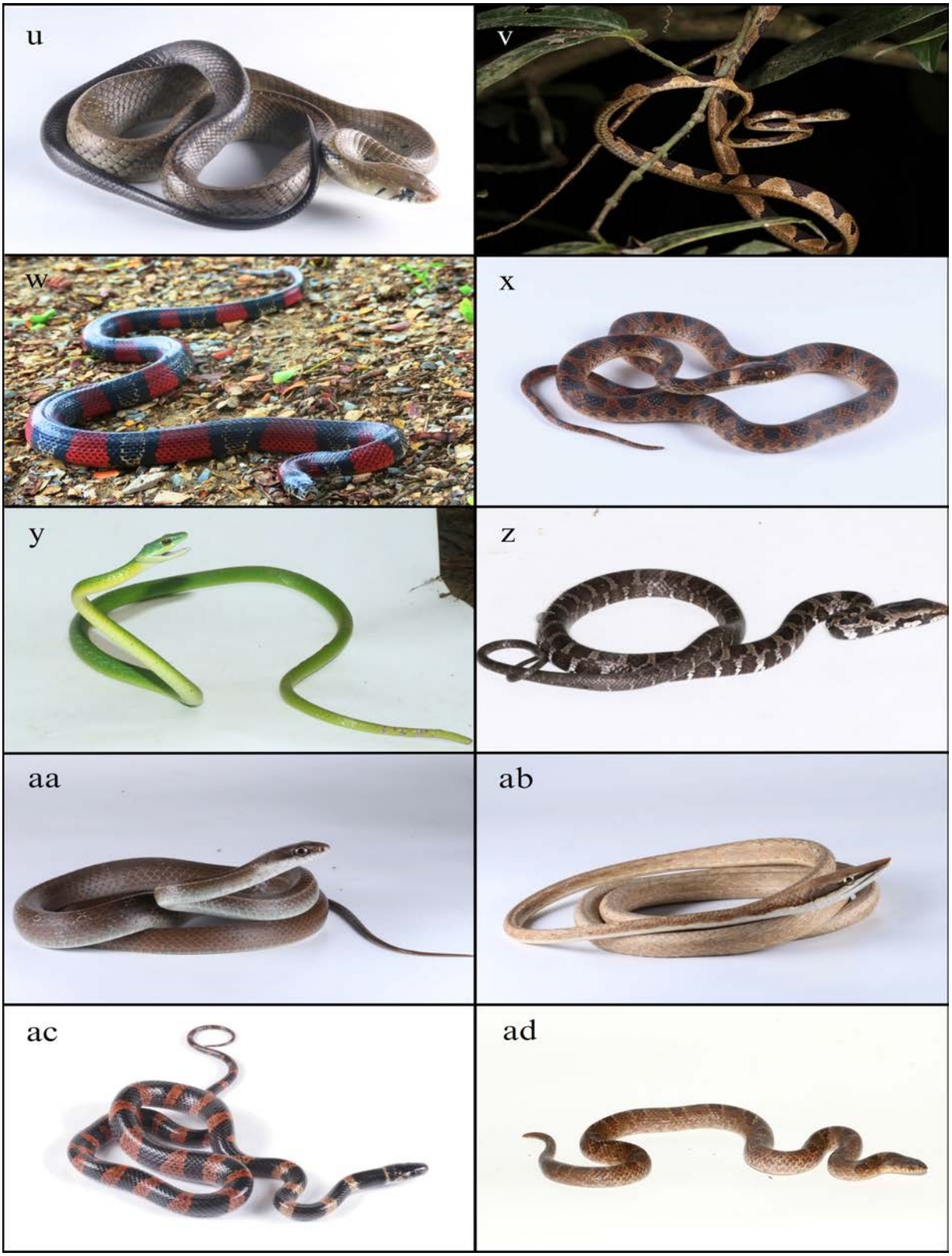

Figura 7. Especies de reptiles registrados en el Bosque Protector Cerro Blanco (BPCB) (Parte 3). u) *Drymarchon melanurus*, v) *Imantodes cenchoa*, w) *Lampropeltis micropholis*, x) *Leptodeira ornata*, y) *Leptophis occidentalis*, z) *Mastigodryas pulchriceps*, aa) *Mastigodryas reticulatus*, ab) *Oxybelis transandinus*, ac) *Oxyrhopus petolarius*, ad) *Stenorrhina degenhardtii*. Fotos: Keyko Cruz-García and Natalia Zapata-Salvatierra.

Figure 7. Reptile species recorded in the Bosque Protector Cerro Blanco (BPCB) (Part 3). u) *Drymarchon melanurus*, v) *Imantodes cenchoa*, w) *Lampropeltis micropholis*, x) *Leptodeira ornata*, y) *Leptophis occidentalis*, z) *Mastigodryas pulchriceps*, aa) *Mastigodryas reticulatus*, ab) *Oxybelis transandinus*, ac) *Oxyrhopus petolarius*, ad) *Stenorrhina degenhardtii*. Photos: Keyko Cruz-García and Natalia Zapata-Salvatierra.

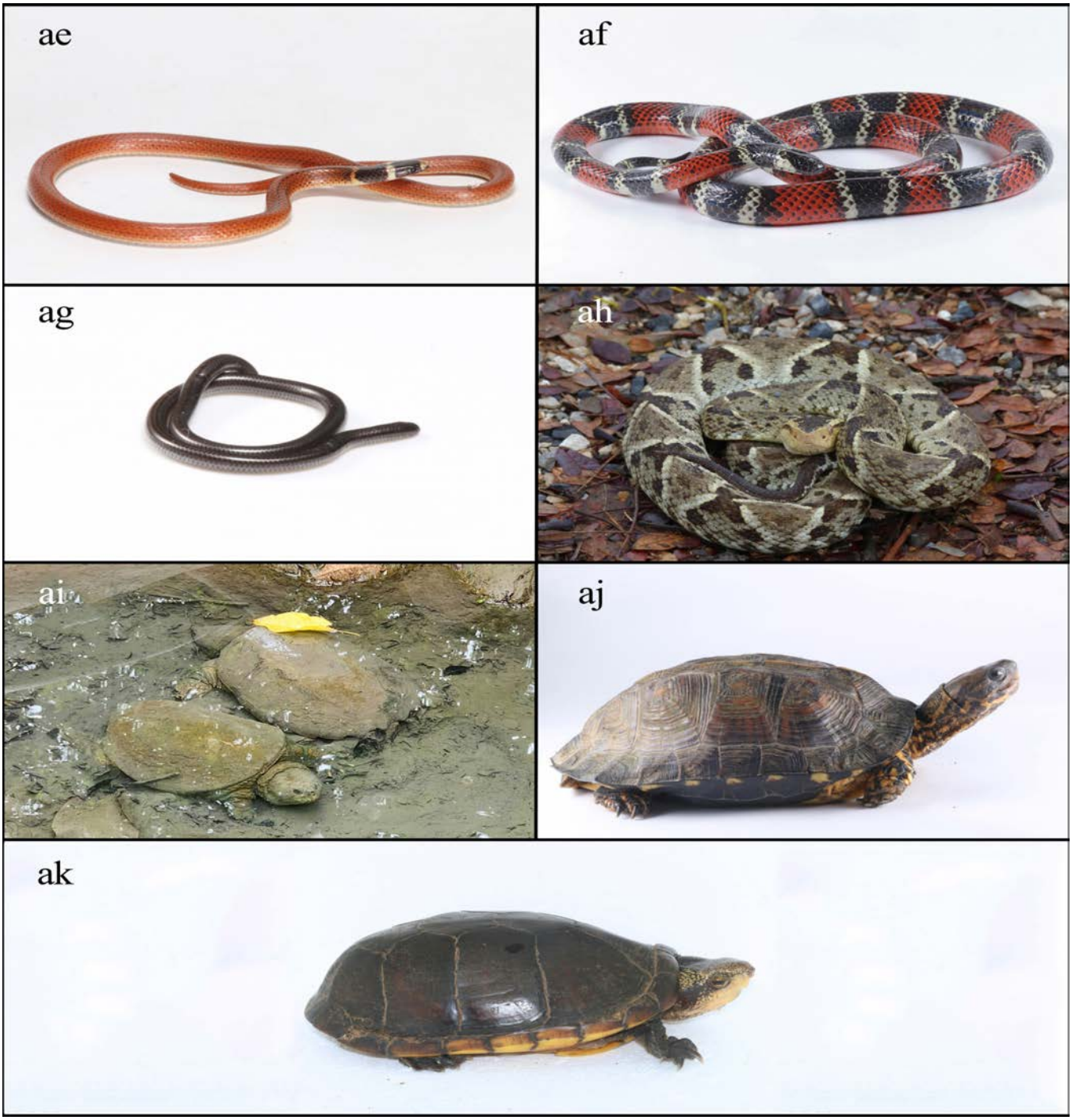

Figura 8. Especies de reptiles registrados en el Bosque Protector Cerro Blanco (BPCB) (Parte 4). ae) *Tantilla capistrata*, af) *Micrurus bocourti*, ag) *Epictia subcrotilla*, ah) *Bothrops asper*, ai) *Chelydra acutirostris*, aj) *Rhinoclemmys annulata*, ak) *Kinosternon leucostomum*. Fotos: Keyko Cruz-García and Natalia Zapata-Salvatierra.

Figure 8. Reptile species recorded in the Bosque Protector Cerro Blanco (BPCB) (Part 4). ae) *Tantilla capistrata*, af) *Micrurus bocourti*, ag) *Epictia subcrotilla*, ah) *Bothrops asper*, ai) *Chelydra acutirostris*, aj) *Rhinoclemmys annulata*, ak) *Kinosternon leucostomum*. Photos: Keyko Cruz-García and Natalia Zapata-Salvatierra.

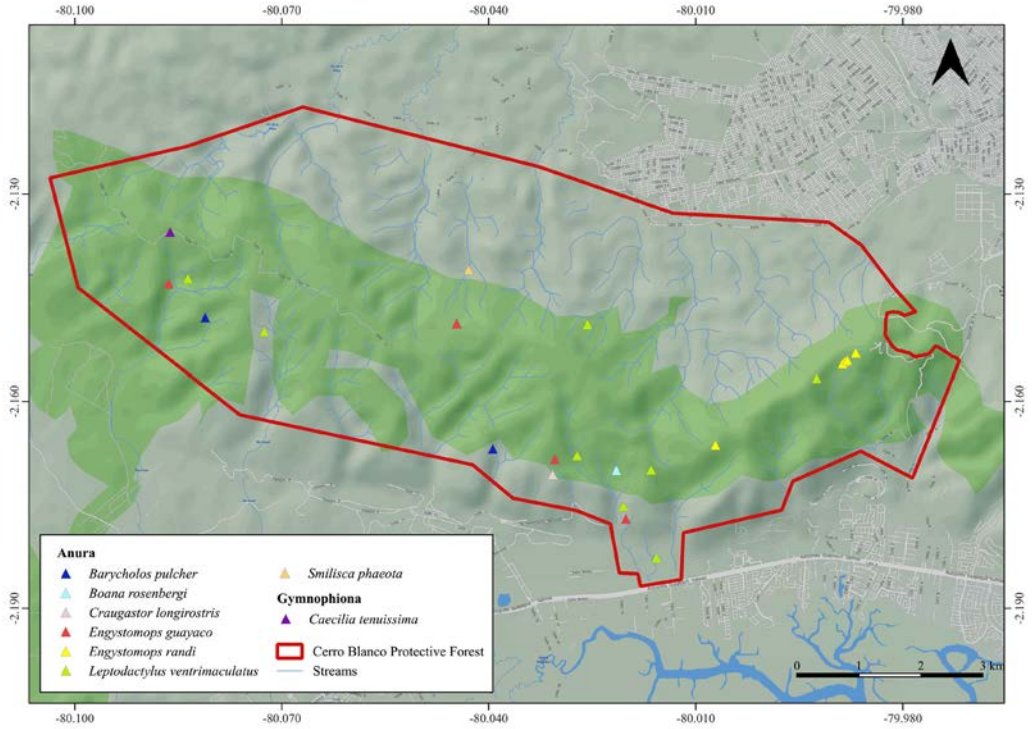

Figura 9. Mapa de distribución de anfibios que se registraron en menos de 10 ocasiones a lo largo del estudio en el Bosque Protector Cerro Blanco (BPCB).
Figure 9. Distribution map of amphibians that were recorded on less than 10 occasions throughout the study in the Bosque Protector Cerro Blanco (BPCB).

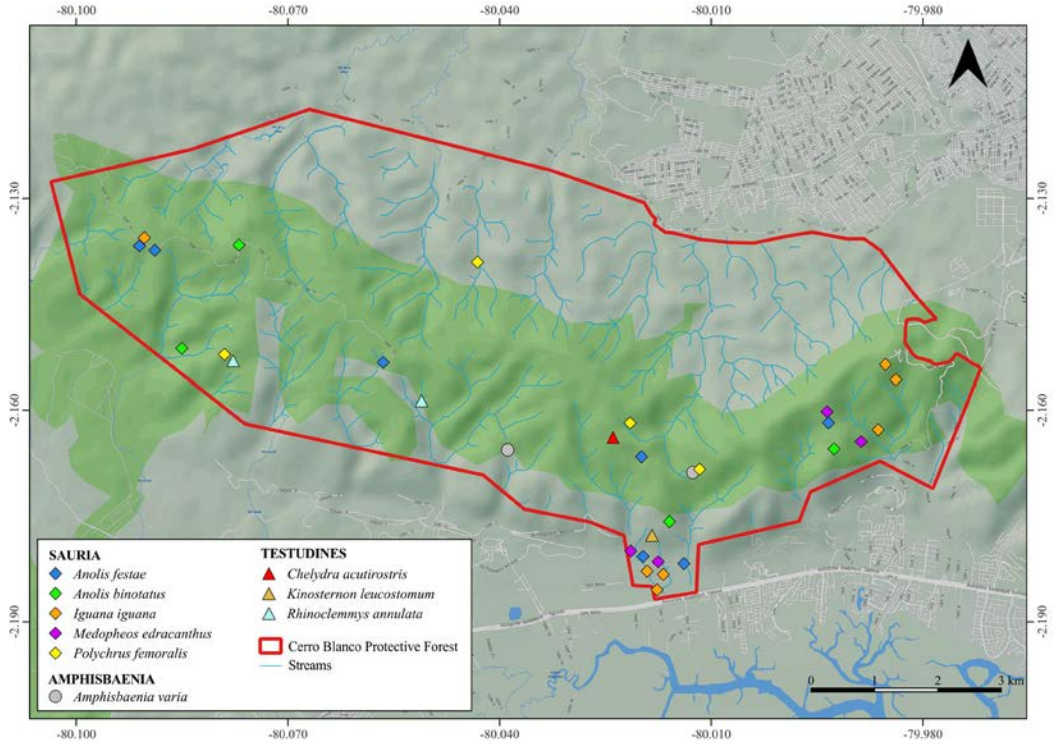

Figura 10. Mapa de distribución de anfisbenios, lagartijas y tortugas que se registraron en menos de 10 ocasiones a lo largo del estudio en el Bosque Protector Cerro Blanco (BPCB).
Figure 10. Distribution map of amphisbaenians, lizards and turtles that were recorded on less than 10 occasions throughout the study in the Bosque Protector Cerro Blanco (BPCB).

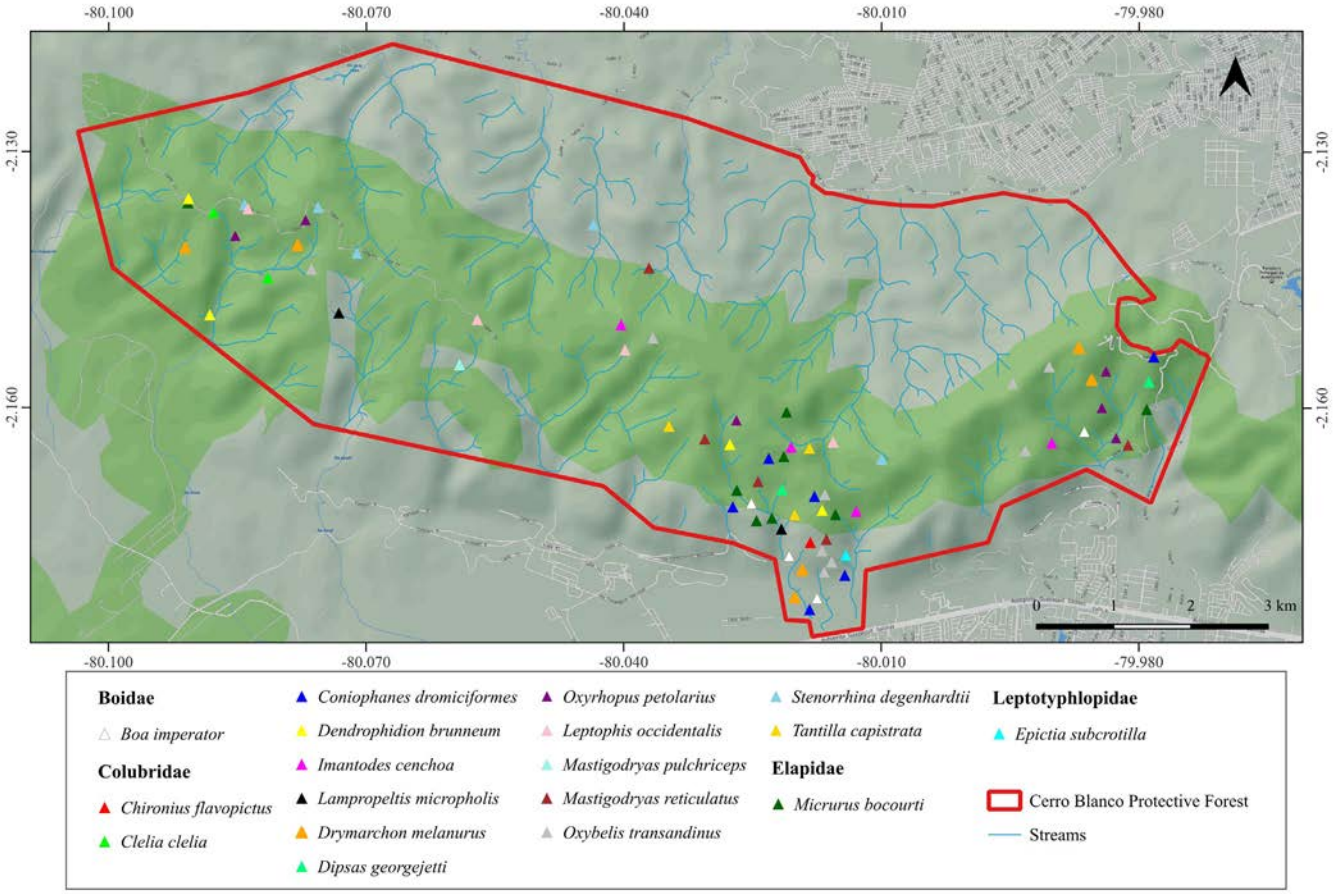

Figura 11. Mapa de distribución de serpientes que se registraron en menos de 10 ocasiones a lo largo del estudio en el Bosque Protector Cerro Blanco (BPCB).
Figure 11. Distribution map of snakes that were recorded on less than 10 occasions throughout the study in the Bosque Protector Cerro Blanco (BPCB).

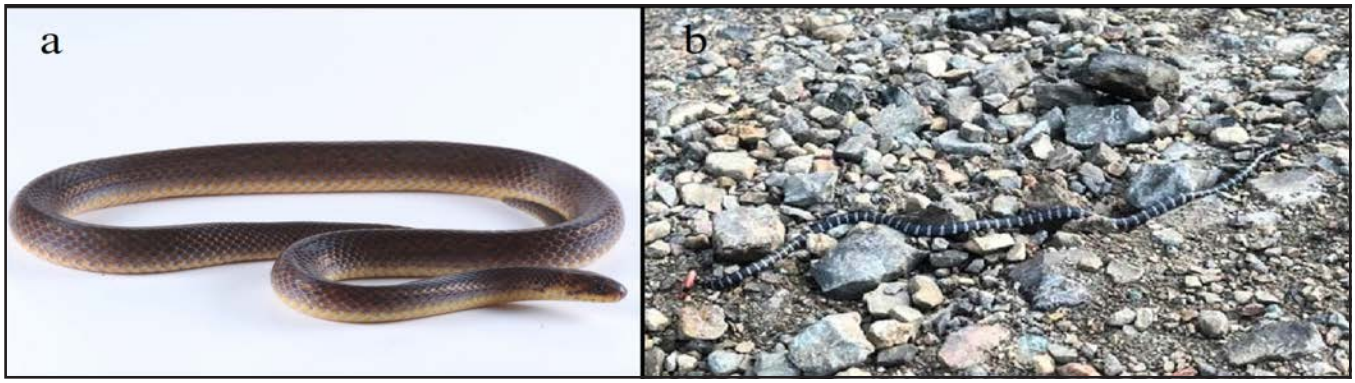

Figura 12. Especies relevantes con registros no completamente verificados en el Bosque Protector Cerro Blanco: a) *Atractus aff. microrhynchus*, confirmada en el BPCB, pero con identificación taxonómica aún no totalmente corroborada; y b*)* *Micrurus mipartitus*, registrada fotográficamente en áreas adyacentes al BPCB, aunque no dentro de sus límites. Fotos: Keyko Cruz-García and Natalia Zapata-Salvatierra (a), and Melba Morán Soto (b).

Figure 12. Notable species with records not fully verified in the Bosque Protector Cerro Blanco: a) *Atractus aff. microrhynchus*, confirmed in BPCB but with taxonomic identification not yet fully corroborated; and b) *Micrurus mipartitus*, photographed in areas adjacent to BPCB but not within its boundaries. Photos: Keyko Cruz-García and Natalia Zapata-Salvatierra (a), and Melba Morán Soto (b).

individual was found in a seasonal stream. It is categorized as Not Evaluated (NE) in the IUCN (2024), but it is listed as Endangered (EN) in the Red List of Reptiles of Ecuador (Carrillo et al., 2005).

DISCUSSION

Despite the lack of an updated record of species in the area, previous studies, such as Salvatierra et al. (2010), report only 22 species in the BPCB, including seven amphibians and 15 reptiles. In contrast, our multitemporal study has identified 57 species, including 20 amphibians and 37 reptiles, which represents a significant increase in records for the area.

Some previous studies, such as those by Parker & Carr (1992), Salvatierra et al. (2010), and Amador & Martínez (2011), focused mainly on areas such as the Canoa stream and its surroundings, located in the Tourist Zone of the BPCB, which is strongly influenced by ecotourism. This limitation in the sampling area may have affected the number of species recorded in these studies. Unlike these studies, our sampling aimed to cover extensively the entire area of the BPCB, from the tourist areas to the most pristine ones. Although we faced various climatic, logistical and even security obstacles, we managed to cover a large part of the BPCB, including areas where herpetological sampling had not been carried out before, such as the Caseta Jaguar, Caseta Pigio and Zone 507 (Fig. 2).

Fieldwork was conducted over ten years, covering both the rainy and dry seasons. This is important as seasonal changes affect temperature, availability of water, food and shelter, influencing the predominance of certain species at different times of the year (Martin & Freeland, 1988). In this context, 15 species were recorded that were only observed in a specific season, of which seven were amphibians and eight were reptiles. All amphibians found in a single season were observed during the rainy season, while of the reptiles, six were found only in the rainy season and two in the dry season (Tables 1, 2).

Twenty amphibian species were found at the BPCB, of which 19 are anurans (Figs. 3, 4). This diversity highlights the presence of varied habitats hosting species with different ecological needs, including terrestrial, arboreal, aquatic and seasonal habits. In addition, 14 lizard species and one amphisbaenian were found (Figs. 5, 6), reflecting the complexity of the BPCB ecosystem. The study also identified 20 snake species, outnumbering the number of amphibian species (Figs. 6, 7, 8). The high snake diversity is due to the varied structure of the forest, which creates diverse habitats.

Our study revealed an interesting finding: the presence of a notable abundance of herpetofauna in areas with intense ecotourism activity. This phenomenon coincides with the statement of Posse-Sarmiento & Banks-Leite (2024), who point out that forest edges can have a positive impact on temperature, which, in turn, is positively related to diversity of amphibian species. Just like *P. achatinus*, this species is frequently found in transition zones between forests and disturbed areas, it has been documented that it shows high resilience to human disturbances (Urbina-Cardona & Londoño, 2003, Isaacs & Urbina-Cardona, 2011). Therefore, this observation of high abundance could be explained by changes in habitat that have generated new favorable conditions for certain species, as well as the availability of resources that attract a wide variety of amphibians and reptiles. Similarly, at the top of the BPCB there is a transition from secondary forest to primary forest, which, although considered scarce, has been documented in previous studies (Horstman et al., 2017), and where a high abundance of species has also been recorded. This phenomenon is also attributed to the edge effect, where the overlap of ecosystems, known as ecotone, promotes significant diversity and species abundance (Ting & Shaolin, 2008). However, no specific species were found to be present only in the primary forest areas, probably because these primary forest areas are limited compared to the extent of secondary forests in the area.

Although our observation records span almost a decade, some extremely rare species, such as *A. varia*, *C. tenuissima* and *E. subcrotilla*, were sighted only once or twice. The rare occurrences of these species are largely due to their fossorial habits, which make them inconspicuous and present aspects of their biology that are still unknown (Adalsteinsson et al., 2009; Lowie et al., 2022). At BPCB, a specimen of *C. tenuissima* was collected on a single occasion, suggesting that the species still inhabits the locality, as no other collections have been made in Guayaquil or its surroundings since its discovery in 1973 (Taylor, 1973). However, it is important to highlight the work of Fernández-Roldán & Lynch (2023), in which they expose several problems with the original description of *C. tenuissima*; the holotype (USNM 12353), claimed to be from Guayaquil, was likely transported to the United States from this seaport in the 20th century. The absence of a collection date and field data raises doubts about its origin. The description indicates that the specimen's head was damaged and dissected (Taylor, 1973), leading Taylor to "estimate" the head measurements. The specimen is now in poor condition, with a dried body, two mid-body incisions, and a missing head (Fernández-Roldán & Lynch, 2023). So, this rediscovery of the species in a location where it had not been observed for over 50 years confirms its continued presence in the area.

Tabla 1. Lista de anfibios registrados en el Bosque Protector Cerro Blanco. * = Endémico de Ecuador. Meses: Jan = Enero, Feb = Febrero, Mar = Marzo, Apr = Abril, May = Mayo, Jun = Junio, Jul = Julio, Aug = Agosto, Sep = Septiembre, Oct = Octubre, Nov = Noviembre, Dec = Diciembre. Especies por aparición estacional: R. S. = Temporada lluviosa, D. S. = Temporada seca. Lista Roja de Especies Amenazadas de la Unión Internacional para la Conservación de la Naturaleza (IUCN) y Lista Roja de Anfibios del Ecuador (RLAE): NE = No Evaluada, DD = Datos insuficientes, LC = Preocupación Menor, VU = Vulnerable, EN = En Peligro.

Table 1. List of amphibians registered in the Cerro Blanco Protective Forest. * = Endemic to Ecuador. Months: Jan = January, Feb = February, Mar = March, Apr = April, May = May, Jun = June, Jul = July, Aug = August, Sep = September, Oct = October, Nov = November, Dec = December. Species by seasonal appearance: R. S. = Rainy Season, D. S. = Dry season. The International Union for Conservation of Nature's Red List of Threatened Species (IUCN) and Red List of Amphibians of Ecuador (RLAE): NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, VU = Vulnerable, EN = Endangered.

Taxa	Months												Seasonal Occurrence		Conservation status	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	R. S.	D. S.	IUCN	RLAE
Order Anura																
Family Bufonidae																
Rhinella bella	X	X	X	X		X	X	X	X	X	X	X			NE	LC
Family Ceratophyidae																
Ceratophrys stolzmanni	X	X	X									X	X		VU	VU
Family Craugastoridae																
Craugastor longirostris												X	X		LC	LC
Family Dendrobatidae																
*Epipedobates machalilla**	X	X	X	X	X	X	X	X	X	X	X	X			LC	LC
Hyloxalus infraguttatus	X	X	X	X	X	X	X	X	X	X	X	X			VU	VU
Family Hylidae																
Boana rosenbergi		X											X		LC	LC
Scinax quinquefasciatus	X	X	X	X	X	X	X		X	X	X	X			LC	LC
Scinax tsachila			X	X	X	X									LC	LC
Smilisca phaeota				X											LC	LC
Trachycephalus jordani	X	X	X		X		X	X	X		X	X			LC	LC
*Trachycephalus quadrangulum**	X	X	X	X		X	X		X	X		X			LC	LC
Family Leptodactylidae																
*Engystomops guayaco**	X	X	X									X	X		VU	VU
Engystomops pustulatus	X	X	X	X								X	X		LC	LC
Engystomops randi	X	X	X	X								X	X		LC	LC
Leptodactylus labrosus	X	X	X	X	X	X	X	X	X	X	X	X			LC	LC
Leptodactylus melanonotus	X	X	X	X	X						X	X			LC	LC
Leptodactylus ventrimaculatus	X	X			X				X	X					LC	LC
Family Strabomantidae																
*Barycholos pulcher**			X					X							LC	LC
Pristimantis achatinus	X	X	X	X	X	X	X	X	X	X	X	X			LC	LC
Order Gymnophiona																
Family Caeciliidae																
*Caecilia tenuissima**				X									X		DD	EN

Tabla 2. Lista de reptiles registrados en el Bosque Protector Cerro Blanco. * = Endémico de Ecuador. Meses: Jan = Enero, Feb = Febrero, Mar = Marzo, Apr = Abril, May = Mayo, Jun = Junio, Jul = Julio, Aug = Agosto, Sep = Septiembre, Oct = Octubre, Nov = Noviembre, Dec = Diciembre. Especies por aparición estacional: R. S. = Temporada lluviosa, D. S. = Temporada seca. Lista Roja de Especies Amenazadas de la Unión Internacional para la Conservación de la Naturaleza (IUCN)e y Lista Roja de Anfibios del Ecuador (RLRE): NE = No Evaluada, DD = Datos insuficientes, LC = Preocupación Menor, NT = Casi Amenazado, VU = Vulnerable, EN = En Peligro.

Table 2. List of amphibians registered in the Cerro Blanco Protective Forest. * = Endemic to Ecuador. Months: Jan = January, Feb = February, Mar = March, Apr = April, May = May, Jun = June, Jul = July, Aug = August, Sep = September, Oct = October, Nov = November, Dec = December. Species by seasonal appearance: R. S. = Rainy Season, D. S. = Dry season. The International Union for Conservation of Nature's Red List of Threatened Species (IUCN) and Red List of Amphibians of Ecuador (RLAE): NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, VU = Vulnerable, EN = Endangered.

Taxa	Months												Seasonal Occurrence		Conservation status	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dic	R. S.	D. S.	IUCN	RLAE
Order Squamata: Amphisbaenia																
Family Amphisbaenidae																
Amphisbaena varia		X				X									**NE**	**NT**
Order Squamata: Sauria																
Family Alopoglossidae																
Alopoglossus festae	X	X	X					X	X			X			**LC**	**VU**
Family Anolidae																
Anolis binotatus			X				X			X					**LC**	**DD**
Anolis festae		X		X	X		X			X	X				**NT**	**NT**
Anolis gracilipes	X	X		X		X	X		X		X	X			**LC**	**LC**
Family Gekkonidae																
Hemidactylus frenatus	X	X		X	X	X	X	X	X	X	X	X			**LC**	**LE**
Family Iguanidae																
Iguana iguana	X	X	X	X	X	X			X	X	X	X			**LC**	**LC**
Family Phyllodactylidae																
Phyllodactylus reissii	X	X	X	X	X	X	X	X	X	X	X	X			**LC**	**LC**
Family Polychrotidae																
Polychrus femoralis	X	X								X		X			LC	NT
Family Spheaerodactylidae																
Gonatodes caudiscutatus	X	X	X	X	X	X	X	X	X	X	X	X			LC	LC
*Lepidoblepharis buchwaldi**	X		X	X	X			X		X	X	X			LC	NT
Family Teiidae																
Holcosus septemlineatus	X	X	X	X	X	X	X	X	X	X	X	X			LC	LC

Tabla 2 (cont.). Lista de reptiles registrados en el Bosque Protector Cerro Blanco. * = Endémico de Ecuador. Meses: Jan = Enero, Feb = Febrero, Mar = Marzo, Apr = Abril, May = Mayo, Jun = Junio, Jul = Julio, Aug = Agosto, Sep = Septiembre, Oct = Octubre, Nov = Noviembre, Dec = Diciembre. Especies por aparición estacional: R. S. = Temporada lluviosa, D. S. = Temporada seca. Lista Roja de Especies Amenazadas de la Unión Internacional para la Conservación de la Naturaleza (IUCN)e y Lista Roja de Anfibios del Ecuador (RLRE): NE = No Evaluada, DD = Datos insuficientes, LC = Preocupación Menor, NT = Casi Amenazado, VU = Vulnerable, EN = En Peligro.

Table 2 (cont.). List of amphibians registered in the Cerro Blanco Protective Forest. * = Endemic to Ecuador. Months: Jan = January, Feb = February, Mar = March, Apr = April, May = May, Jun = June, Jul = July, Aug = August, Sep = September, Oct = October, Nov = November, Dec = December. Species by seasonal appearance: R. S. = Rainy Season, D. S. = Dry season. The International Union for Conservation of Nature's Red List of Threatened Species (IUCN) and Red List of Amphibians of Ecuador (RLAE): NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, VU = Vulnerable, EN = Endangered.

Taxa	Months												Seasonal Occurrence		Conservation status	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dic	R. S.	D. S.	IUCN	RLAE
Medopheos edracanthus				X	X					X					LC	LC
Family Tropiduridae																
Stenocercus iridescens	X	X	X	X	X	X	X	X	X	X	X	X			LC	LC
Order Squamata: Serpentes																
Family Boidae																
Boa imperator		X		X	X						X				LC	VU
Family Colubridae																
Chironius flavopictus							X							X	DD	VU
Clelia clelia				X								X	X		LC	LC
Coniophanes dromiciformis	X	X	X	X	X			X		X	X	X			VU	NT
Dendrophidion brunneum	X		X									X		X	LC	NT
*Dipsas georgejetti**		X			X										NE	NE
Drymarchon melanurus		X		X	X					X	X				LC	NT
Imantodes cenchoa	X				X			X		X	X	X			LC	LC
Lampropeltis micropholis			X										X		LC	EN
Leptodeira ornata	X	X	X	X	X		X		X	X	X	X			LC	LC
Leptophis occidentalis	X	X		X				X							NE	NE
Mastigodryas pulchriceps	X												X		LC	NT
*Mastigodryas reticulatus**				X	X							X			NT	NT
*Oxybelis transandinus**	X	X		X			X			X	X	X			NE	NE
Oxyrhopus petolarius		X		X	X							X			LC	LC
Stenorrhina degenhardtii				X	X										LC	NT
Tantilla capistrata	X		X					X				X			LC	DD

Tabla 2 (cont.). Lista de reptiles registrados en el Bosque Protector Cerro Blanco. * = Endémico de Ecuador. Meses: Jan = Enero, Feb = Febrero, Mar = Marzo, Apr = Abril, May = Mayo, Jun = Junio, Jul = Julio, Aug = Agosto, Sep = Septiembre, Oct = Octubre, Nov = Noviembre, Dec = Diciembre. Especies por aparición estacional: R. S. = Temporada lluviosa, D. S. = Temporada seca. Lista Roja de Especies Amenazadas de la Unión Internacional para la Conservación de la Naturaleza (IUCN)e y Lista Roja de Anfibios del Ecuador (RLRE): NE = No Evaluada, DD = Datos insuficientes, LC = Preocupación Menor, NT = Casi Amenazado, VU = Vulnerable, EN = En Peligro.

Table 2 (cont.). List of amphibians registered in the Cerro Blanco Protective Forest. * = Endemic to Ecuador. Months: Jan = January, Feb = February, Mar = March, Apr = April, May = May, Jun = June, Jul = July, Aug = August, Sep = September, Oct = October, Nov = November, Dec = December. Species by seasonal appearance: R. S. = Rainy Season, D. S. = Dry season. The International Union for Conservation of Nature's Red List of Threatened Species (IUCN) and Red List of Amphibians of Ecuador (RLAE): NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, VU = Vulnerable, EN = Endangered.

Taxa	Months												Seasonal Occurrence		Conservation status	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dic	R. S.	D. S.	IUCN	RLAE
Family Elapidae																
Micrurus bocourti	X	X		X	X					X	X	X			LC	VU
Family Leptotyphlopidae																
Epictia subcrotilla									X				X		LC	DD
Family Viperidae																
Bothrops asper	X	X	X	X	X		X	X		X	X	X			LC	LC
Order Testudines																
Family Chelydridae																
Chelydra acutirostris			X										X		NE	VU
Family Geoemydidae																
Rhinoclemmys annulata		X			X										NT	EN
Family Kinosternidae																
Kinosternon leucostomum				X									X		NE	EN

On the other hand, species such as *C. stolzmanni* also had few observations, which is due to their dependence on water availability (Cuadrado et al., 2020). This species is strictly seasonal and only appears during the peak of the rainy season to reproduce (Amador & Brito, 2013). Despite the duration of our ten-year sampling, the detection of *C. stolzmanni* was limited due to its low abundance in the Cerro Blanco study area and rainfall conditions that were not always optimal for its activity.

In comparison, species such as *E. guayaco*, *E. pustulatus* and *E. randi* also require water for their survival (Cuadrado et al., 2020), but they are not as demanding as *C. stolzmanni*. These species do not need intense rainfall to reproduce and can appear as soon as seasonal pools form. The limited visibility of these species may reflect a combination of factors, including variations in water availability over the years, as well as their adaptation to less extreme conditions, which facilitates their appearance in periods of more modest rainfall. The scarcity of records of *C. stolzmanni* during the study period highlights its rarity in the area and the influence of climatic conditions on its detectability.

Two important species should be mentioned that were not included in the results because they were not fully verified records in the BPCB. During our sampling at the BPCB, a specimen of *Atractus* aff. *microrhynchus* was found (Fig. 12a). We decided not to include this species in the results due to the considerable uncertainty surrounding its identification, unlike other species in this study that were identified but not collected. In the methodology, it is explained that species that could not be determined at the species level were not considered in the

final analysis. However, the fact that *Atractus* aff. *microrhynchus* was recorded in this area is significant, as this species has not been observed in the Guayaquil locality since 1868 (Cope, 1868). Therefore, although its identification is not yet confirmed, its presence is relevant and could be indicative of changes in the species' distribution or new populations. This finding underlines the need for further research to confirm the identity of the specimen and assess its status in the region. Additionally, recent photographic evidence suggests the presence of *Micrurus mipartitus*, with a photograph taken by Melba Morán Soto in the Cerro Azul Forest on May 4, 2024 (Fig. 12b). Although its presence in the BPCB has not yet been confirmed, the similarity of the ecosystems of both forests suggests a high probability that *M. mipartitus* is also present in the study area. Although further confirmation is necessary to verify its identification, the external characteristics of the snake make its recognition relatively simple, which reinforces the probability that it is indeed *M. mipartitus*.

This updated compendium identifies nine endemic species (Table 1), such as *C. tenuissima*, *L. buchwaldi*, and *B. pulcher*, as well as several threatened species according to the IUCN (2024), including *C. stolzmanni* and *H. infraguttatus*, classified as Vulnerable (VU), and *A. festae*, listed as Near Threatened (NT). These species are found throughout the BPCB, despite the forest's exposure to pressures from deforestation, illegal mining, and other anthropogenic activities. This highlights the critical need for a thorough assessment of their conservation status, given the severe alterations to their original habitats. The environmental challenges faced by these species underscore the urgency of implementing conservation measures and maintaining ongoing monitoring efforts to safeguard their specific habitats within the BPCB.

One significant finding of this investigation is the strong abundance of *H. infraguttatus*, across various water bodies within the BPCB such as the Canoa, Cóndor and Guitarra streams, which maintain water even during dry periods, forming puddles. The three species of turtles documented in this study were found in these same aquatic ecosystems: *Rhinoclemmys annulata*, *Chelydra acutirostris* and *Kinosternon leucostomum* (Fig. 8). These turtles were located in some streams of the BPCB. This discovery underlines the importance of these aquatic ecosystems in safeguarding endemic and vulnerable species, as they act as crucial refuges.

The tropical dry forest of the BPCB, although facing various pressures such as hunting, deforestation and limestone mining, remains an ecosystem of crucial importance, particularly as it is the largest remnant of this type of forest in Guayaquil. The presence of species listed as threatened by the IUCN (2024), such as *C. stolzmanni*, *C. dromiciformis*, *H. infraguttatus* and *E. guayaco*, raises questions about the effectiveness of current conservation measures and underlines the need to strengthen the protection of these habitats. Furthermore, the detection of extremely rare endemic species, such as *C. tenuissima*, suggests that the BPCB is home to a unique biodiversity that is at risk, inviting deeper reflection on the management and conservation strategies implemented in the region. This context highlights the importance of protected areas not only as refuges for biodiversity, but also as vital spaces for the continuous monitoring of species, some of which have been rediscovered after long periods without records. Therefore, it is essential to continue and strengthen conservation initiatives to ensure the persistence of these species and the ecological integrity of the BPCB.

CONCLUSIONS

The present research has provided a significant advance in the knowledge of the herpetofauna of the Bosque Protector Cerro Blanco (BPCB), revealing a notable increase in the number of documented species, going from 22 to 57 species, composed of 20 amphibians and 37 reptiles. This increase is attributed to an extensive and multi-temporal sampling effort that covered both anthropogenically affected areas and more pristine areas of the BPCB, carried out over a decade and in different seasons of the year. Among the findings, two additional species could potentially be included, raising the total to 59. One of these, *Atractus microrhynchus*, is confirmed in CB but with its taxonomic identification not yet fully verified. The other, *Micrurus mipartitus*, was photographed in areas adjacent to BPCB, and while not confirmed within its limits, its proximity suggests it could be present.

One of the most interesting findings is the high abundance of herpetofauna in areas with intense ecotourism activity, a phenomenon that could be explained by the edge effect that generates favorable conditions for various species. This observation highlights the importance of transition zones between forests and disturbed areas, which can promote species diversity and abundance. Despite the extensive period of study, some extremely rare species were observed only once or twice, which is due to their fossorial habits and poorly understood biology.

However, the presence of threatened species according to the IUCN Red List (IUCN, 2024), such as *C. tenuissima*, *C. stolzmanni* and *H. infraguttatus*, as well as records of endemic species

underline the urgency of protecting the BPCB against threats such as hunting, deforestation and mining. In conclusion, the BPCB is a crucial ecosystem that hosts a rich and diverse herpetofauna, including rare and threatened species. The preservation of this tropical dry forest is crucial to preserve the biodiversity and ecological balance of the region, being one of the most threatened ecosystems in Ecuador. The research highlights the importance of protected areas as biodiversity refuges and the need to maintain continuous monitoring efforts to safeguard these valuable species.

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APPENDIX

Apéndice 1. Listado de especímenes colectados en el Bosque Protector Cerro Blanco y depositados en el Museo de Zoología, Universidad San Francisco de Quito (ZSFQ), Quito, Ecuador, y el Museo de Zoología de la Universidad Técnica Privada de Loja (MUTPL), Loja, Ecuador.

Appendix 1. List of specimens collected in the Bosque Protector Cerro Blanco and deposited at the Museo de Zoología, Universidad San Francisco de Quito (ZSFQ), Quito, Ecuador, and the Museo de Zoología de la Universidad Técnica Particular de Loja (MUTPL), Loja, Ecuador.

Class Amphibia

Rhinella bella (n= 1): ZSFQ4875 (SVL= 46 mm).

Ceratophrys stolzmanni (n= 1): ZSFQ4925 (SVL= 57 mm).

Epipedobates machalilla (n= 6): ZSFQ4892 (SVL= 16 mm), ZSFQ4893 (SVL= 10.3 mm), ZSFQ4894 (SVL= 13 mm), ZSFQ4895 (SVL= 13 mm), ZSFQ4896 (SVL= 16 mm), ZSFQ4897 (SVL= 15 mm).

Hyloxalus infraguttatus (n= 6): ZSFQ4878 (SVL= 17 mm), ZSFQ4879 (SVL= 19 mm), ZSFQ4880 (SVL= 20 mm), ZSFQ4881 (SVL= 22 mm), ZSFQ4882 (SVL= 21 mm), ZSFQ4883 (SVL= 22 mm).

Scinax quinquefasciatus (n= 3): MUTPL-A-1831 (SVL= 24.6 mm), MUTPL-A-1832 (SVL= 33.25 mm), MUTPL-A-1833 (SVL= 31.7 mm).

Trachycephalus jordani (n= 2): ZSFQ4870 (SVL= 55 mm), ZSFQ4871 (SVL= 39 mm).

Trachycephalus quadrangulum (n= 3): ZSFQ4872 (SVL= 60 mm), ZSFQ4873 (SVL= 70 mm), ZSFQ4874 (SVL= 72 mm).

Engystomops pustulatus (n= 2): ZSFQ4888 (SVL= 28 mm), ZSFQ4889 (SVL= 25 mm).

Engystomops randi (n= 2): ZSFQ4890 (SVL= 25 mm), ZSFQ4891 (SVL= 24 mm).

Leptodactylus labrosus (n= 2): ZSFQ4876 (SVL= 30.1 mm), ZSFQ4877 (SVL= 30.5 mm).

Pristimantis achatinus (n= 4): ZSFQ4884 (SVL= 35 mm), ZSFQ4885 (SVL= 37 mm), ZSFQ4886 (SVL= 40 mm), ZSFQ4887 (SVL= 33 mm).

Caecilia tenuissima (n= 1): ZSFQ4898 (SVL= 623 mm).

Class Reptilia

Alopoglossus festae (n= 2): ZSFQ4916 (SVL= 50 mm), MUTPL-R-596 (SVL= 50.10 mm).

Anolis festae (n= 2): ZSFQ4918 (SVL= 47 mm), MUTPL-R-598 (SVL= 51.96 mm).

Anolis gracilipes (n= 1): ZSFQ4917 (SVL= 57 mm).

Hemidactylus frenatus (n= 1): ZSFQ4911 (SVL= 39 mm).

Phyllodactylus reissii (n= 1): ZSFQ4910 (SVL= 67 mm).

Gonatodes caudiscutatus (n= 2): ZSFQ4914 (SVL= 37 mm), ZSFQ4915 (SVL= 34 mm).

Lepidoblepharis buchwaldi (n= 1): ZSFQ4913 (SVL= 18 mm).

Holcosus septemlineatus (n= 1): ZSFQ4923 (SVL= 70.3 mm).

Medopheos edracanthus (n= 1): ZSFQ4924 (SVL= 69 mm).

Stenocercus iridescens (n= 2): ZSFQ4921 (SVL= 71 mm), ZSFQ4922 (SVL= 93 mm).

Coniophanes dromiciformis (n= 3): ZSFQ4904 (SVL= 351 mm), ZSFQ4905 (SVL= 244 mm), MUTPL-R-605 (SVL= 290.5 mm).

Dendrophidion brunneum (n= 1): MUTPL-R-595 (SVL= 250.3 mm).

Imantodes cenchoa (n= 1): MUTPL-R-601 (SVL= 340.3 mm).

Leptodeira ornata (n= 3): ZSFQ4900 (SVL= 578 mm), MUTPL-R-600 (SVL= 480.30 mm), MUTPL-R-606 (SVL= 700.9 mm).

Leptophis occidentalis (n= 1): MUTPL-R-603 (SVL= 360.1 mm).

Mastigodryas reticulatus (n= 2): ZSFQ4901 (SVL= 800 mm), MUTPL-R-472 (SVL= 735 mm).

Oxybelis transandinus (n= 2): ZSFQ4902 (SVL= 677 mm), MUTPL-R-599 (SVL= 850.5 mm).

Oxyrhopus petolarius (n= 2): MUTPL-R-593 (SVL= 290.2 mm), MUTPL-R-602 (SVL= 430.6 mm).

Stenorrhina degenhardtii (n= 1): ZSFQ4903 (SVL= 362 mm).

Tantilla capistrata (n= 1): MUTPL-R-597 (SVL= 210.8 mm).

Micrurus bocourti (n= 3): ZSFQ4908 (SVL= 703 mm), ZSFQ4909 (SVL= 769 mm), MUTPL-R-604 (SVL= 550.9 mm).

Bothrops asper (n= 2): ZSFQ4906 (SVL= 256 mm), ZSFQ4907 (SVL= 398 mm).

THERMAL MICROHABITAT AND THE OBSERVED AESTIVATION TEMPERATURES OF THE MUD TURTLE *KINOSTERNON CHIMALHUACA* (CHELONIA: KINOSTERNIDAE)

MICROHÁBITAT TÉRMICO Y LAS TEMPERATURAS DE ESTIVACIÓN OBSERVADAS DE LA TORTUGA DEL FANGO *KINOSTERNON CHIMALHUACA* (CHELONIA: KINOSTERNIDAE)

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Resumen.– El nicho térmico representa las condiciones de temperatura que afectan la historia de vida y la ecología de cualquier especie. Estudiar cómo las especies responden al nicho térmico es crucial para comprender su adaptabilidad al ambiente. Las características demográficas de la tortuga del fango *Kinosternon chimalhuaca* han sido evaluadas recientemente, pero aún se desconoce información sobre muchos aspectos ecológicos. Aquí, exploramos las temperaturas del nicho térmico de *K. chimalhuaca* durante un periodo estacional de sequía. Medimos, registramos y recopilamos información sobre las temperaturas corporales seleccionadas de microhábitat y ambientales en tortugas activas de un sitio acuático y comparamos esta información con las temperaturas de microhábitat y ambientales percibidas por tortugas estivando en un sitio terrestre. La temperatura corporal en las tortugas no estivando fue de 24 °C, las temperaturas seleccionadas en el laboratorio estuvieron entre 23-25 °C, temperaturas voluntarias mínimas de 22 °C y temperaturas voluntarias máximas de 28 °C. El rango de temperaturas en el microhábitat bajo el agua fue de 23-28 °C. Las temperaturas en el microhábitat para la estivación (dentro del bosque) fueron de 15 a 25 °C. Las condiciones térmicas fuera del bosque (temperaturas del suelo) fueron más altas que las temperaturas en el microhábitat utilizado para la estivación. Las temperaturas en el agua poco profunda fueron relativamente más bajas que las temperaturas del aire registradas alrededor del hábitat acuático. Además de la estivación facultativa de *K. chimalhuaca*, nuestros datos muestran diferentes condiciones térmicas entre los microhábitats de actividad y dormancia con el potencial de ser favorables con respecto a las temperaturas circundantes del medio ambiente.

Palabras clave.– Ambiente tropical, ecología térmica, dormancia, nicho térmico, temperatura bajo el agua, tortugas de agua dulce.

Abstract.– The thermal niche is the temperature conditions that affect the life history and ecology of any species. Studying how species respond to thermal niche is crucial to understanding their adaptability to the environment. Demographic characteristics of the mud turtle *Kinosternon chimalhuaca* have been recently evaluated, but information on many ecological aspects is still unknown. Here, we explored the thermal niche temperatures of *K. chimalhuaca* during a seasonal period of drought. We measured, recorded, and compiled information on body, selected microhabitat and environmental temperatures in active turtles of an aquatic site and compared this information with the microhabitat and environmental temperatures perceived by aestivating turtles in a terrestrial site. The body temperature in active turtles was 24 °C, selected temperatures in the lab were between 23-25 °C, minimal voluntary temperatures of 22 °C and maximal voluntary temperatures of 28 °C. The range temperatures in the underwater microhabitat were 23-28 °C. Temperatures in the microhabitat for aestivation (inside forest) were 15 to 25 °C. Thermal conditions outside the forest

(soil temperatures) were higher than the temperatures in the microhabitat used for aestivation. Temperatures in the shallow water were relatively lower than the air temperatures recorded around the aquatic habitat. In addition to facultative aestivation of *K. chimalhuaca*, our data show different thermal conditions between activity and dormancy microhabitats with the potential to be favorable regarding the surrounding temperatures of environment.

Keywords.– Dormancy, freshwater turtles, thermal niche, thermal ecology, tropical environment, underwater temperature.

INTRODUCTION

The thermal ecology of species is a topic of scientific interest due to accelerated and widespread climatic and habitat changes (Tuff et al., 2016; Buckley et al., 2022). Currently it is necessary to understand the state of the ecological requirements and adaptive responses of species to threats such as global warming (Davis et al., 2005; Dahlke et al., 2018; Sinervo et al., 2024). In animals, dormancies are defined as inactivity and adaptative responses that are generally induced by adverse environmental conditions (Withers & Cooper, 2010; Wilsterman et al., 2021). For example, aestivation is a survival strategy for dealing with arid conditions that can occur in response to high temperatures, droughts or food shortages (Storey, 2002; Storey & Storey, 2012). Environmental conditions and dormancy responses are two ecological topics requiring further investigation in many species of ectotherms (Osborne & Wright, 2018; Lownds et al., 2023).

Aestivation in turtles is a behavioural trait that has evolved several times and independently in larger lineages of pleurodires and cryptodires species (Macip et al., 2023). Laboratory studies on metabolic and physiological traits in active and aestivating turtle species are those that dominate the contribution to current knowledge (Roe et al., 2008; Haskins & Tuberville, 2022; Jiang et al., 2023). For example, Ligon and Peterson (2002) suggest that turtles under prolonged aestivation periods have a significant reduction in metabolic and body water evaporation rates. While turtles with short periods of aestivation or no aestivation have high percentages of dehydration (29-32 % hydrated body mass) and almost unaltered metabolic rates. Unlike laboratory studies, radio tracking monitoring of turtles facilitates some technical possibilities to understand more about their ecology and behavior during active or inactive periods in the field (McKnight & Ligon, 2020; Bowers et al., 2021), even to record short migrations to a new habitat (Gibbons et al., 1983). Research on the thermal ecology in turtles that alternate periods of activity and aestivation is a topic with little biological knowledge (Litzgus & Brooks, 2000; Jiang et al., 2023).

The mud turtles (family Kinosternidae) are exclusively distributed in the New World (Berriozabal-Islas et al., 2020). The genus *Kinosternon* showed their largest diversity in Mexico (Legler & Vogt, 2013). There are at least five endemic species with limited distribution along the Pacific coast of Mexico (Macip-Ríos et al., 2015), one of these endemic species is the Jalisco Mud Turtle, *Kinosternon chimalhuaca*, which was described in the 90's (Berry et al., 1997). However, very few information is published besides their description (Casas-Andreu, 2002). A recent ecological study showed that an urban population can be highly abundant with sexual ratios biased towards females than a population in the conserved forest (Garrido et al., 2021). In addition, monitored individuals of *K. chimalhuaca* in an urban aquatic habitat showed a population trend of growth and stability in their demographic structure and reproductive condition (Raya-García et al., 2025). The aestivation of 242 days in *K. chimalhuaca* has been observed only in individuals that inhabit the dry tropical forest (Macip-Ríos et al., 2023), while urban individuals apparently have a behaviour of non-aestivation in the presence of an aquatic and perennial habitat (pers. obs.). The aim of this research is to document the basic thermal biology of *K. chimalhuaca* and compare the environmental temperatures between the aquatic-active microhabitat and the terrestrial-aestivation microhabitat during a seasonal period of drought.

MATERIALS AND METHODS

During November 2021, we look for turtles in the urban locality of Emiliano Zapata (19° 23' 11.76" N, 104° 58' 2.2794" W) and the Chamela-Cuixmala biosphere reserve (19° 29' 54.24" N, 105° 2' 39.48" W). Both sites located on the coast of Jalisco, Mexico with mean annual temperature of 24.9 °C (range 13.8-32 °C; Bullock, 1986) and highly seasonal precipitation with an average of 749 mm from June to September.

Urban turtles were captured in a ditch used by the town to move the grey waters and forest turtles were captured in an ephemeral stream with many shallow pools. We sampled turtles from both sites overnight using partially submerged hoop-nets baited with sardines in soy or olive oil (Moll & Legler, 1971). Captured turtles were individually marked using Cagle (1939)

code. Each turtle was measured using an analogue calliper (Swiss, Precision Instruments, Altstätten, Switzerland; 0.1 mm) and weighted with digital scale (American Weight Scales, Cumming, Georgia).

Prior to release, we attached VHF telemetry transmitters (TXC-125G Telenax, Playa del Carmen, Quintana Roo) and temperature micro dataloggers (iButton Thermochrons, Dallas Semiconductor, Dallas, TX; accuracy 70.5 °C) to the posterior carapace of each turtle using epoxy clay (Grayson & Dorcas, 2004). Before attachment, dataloggers were programmed to record temperatures at 90-min intervals and were then covered in plastic tool dip (Plasti-Dip International, Circle Pines, MN) to prevent water damage. A thick layer of epoxy was used as an insulating base to prevent contact between the iButton and the turtle's shell, allowing a closer record of environment (microhabitat temperatures) rather than shell temperatures. The microhabitat temperatures in free-ranging turtles were recorded during the dry months of January to April. Additionally, three thermal data loggers (Hobo® Pendant temp/light) were placed for recording environmental temperatures of December to March in the air, water, and soil external habitats. The water data logger was under the ditch water (submerged about 20 cm), air data logger was hidden and hanging under a tree (< 1 m high and close to the ditch) in Emiliano Zapata village, and one data logger was the forest soil (clear and exposed area) in the Chamela forest. The environment data loggers (water, air and soil) were programmed to record temperatures at 60 min intervals. In addition, we used a Blackview BV9900-Pro smartphone equipped with a FLIR thermal camera (Lepton 2.5 IR Sensor) during the turtle monitoring to record the microhabitat and shell temperature of aestivating turtles and avoid interrupting the *in situ* dormancy.

During March 2022 we monitored eight individuals and in August we remove the devices and recover the information from all data loggers. Later in December, we collected and recorded the body temperature of the shell and cloaca of aquatic and active individuals from Emiliano Zapata and carry out thermal gradient experiments to record selected temperatures in the lab of the Instituto de Biología, Biological Station at the Chamela-Cuixmala Biosphere Reserve. The thermal gradient design was a dry and linear environment inside an acrylic plastic container (150 x 30 x 30 cm) with decreasing temperatures. The temperature gradient ranged from 20-40 °C and the length of the tests was 17:30-23:30 h with body temperature recordings every 30 min.

The selected temperature range was obtained by averaging the first and third quartiles of all data. The minimum and maximum voluntary temperatures were calculated by obtaining the average of lowest and highest data recorded in each individual throughout the experiment. All body (shell and cloacal) and selected temperatures of active individuals were recorded using a digital thermometer (Amprobe model TMD-50) and a K thermocouple (± 0.1 °C) immediately after of handling (< 60 sec). The nets remained in the water for approximately 30 min and then individual by individual was extracted from the nets between 9:00-11:00 hours to measure temperatures. We used a two-way ANOVA to look for differences between shell and cloacal body temperatures and for differences between sexes. All statistical tests were conducted in R version 4.1.2 (R Core Team, 2019).

RESULTS

We captured and recovered a total of four active individuals and one aestivating individual of the *K. chimalhuaca* turtle with fully functioning data loggers and transmitters. An individual from Emiliano Zapata was collected with data logger and transmitter damaged and one individual from the Chamela forest was found dead between the forest and the dry stream path with a functioning transmitter but a missing data logger. One remaining individual was never located or recaptured. The aestivating individual was sheltered under the roots of trees and plant detritus within the dry tropical forest of Chamela, approximately 5-7 m away from the path that forms the mainstream (Fig. 1). The shell temperature of the aestivating turtle was 15 °C and the average thermal around the microhabitat was 17 °C, with a minimum of 15 °C and a maximum of 20 °C (Fig. 1).

The average of the cloacal temperature in 63 active and aquatic individuals was 23.6 ± 0.5 °C and was not significantly different than the average of 23.5 ± 0.6 °C of the temperature in the shell ($F = 0.44$, $p = 0.50$) between sexes ($F = 3.63$, $p = 0.06$) or the sex/body interaction ($F = 0.04$, $p = 0.83$). The temperature for the underwater microhabitat showed two patterns of day-night oscillation, the first during January and February ranging from 25 °C to 28°C and the next during March-April ranging from 23 °C to 27 °C (Fig. 2A). The range of selected temperatures for 14 adult individuals was 23 °C to 25 °C (Fig. 2A). The minimum voluntary temperature was 22 °C and the maximum voluntary temperature was 28 °C, covering the microhabitat, body, and selected temperatures recorded for *K. chimalhuaca* (Fig. 2A). The temperature in the microhabitat for aestivation showed a day-night oscillation ranging from 15 °C to 25 °C, mostly not meeting the average of body and selected temperatures recorded for active individuals (Fig. 2B).

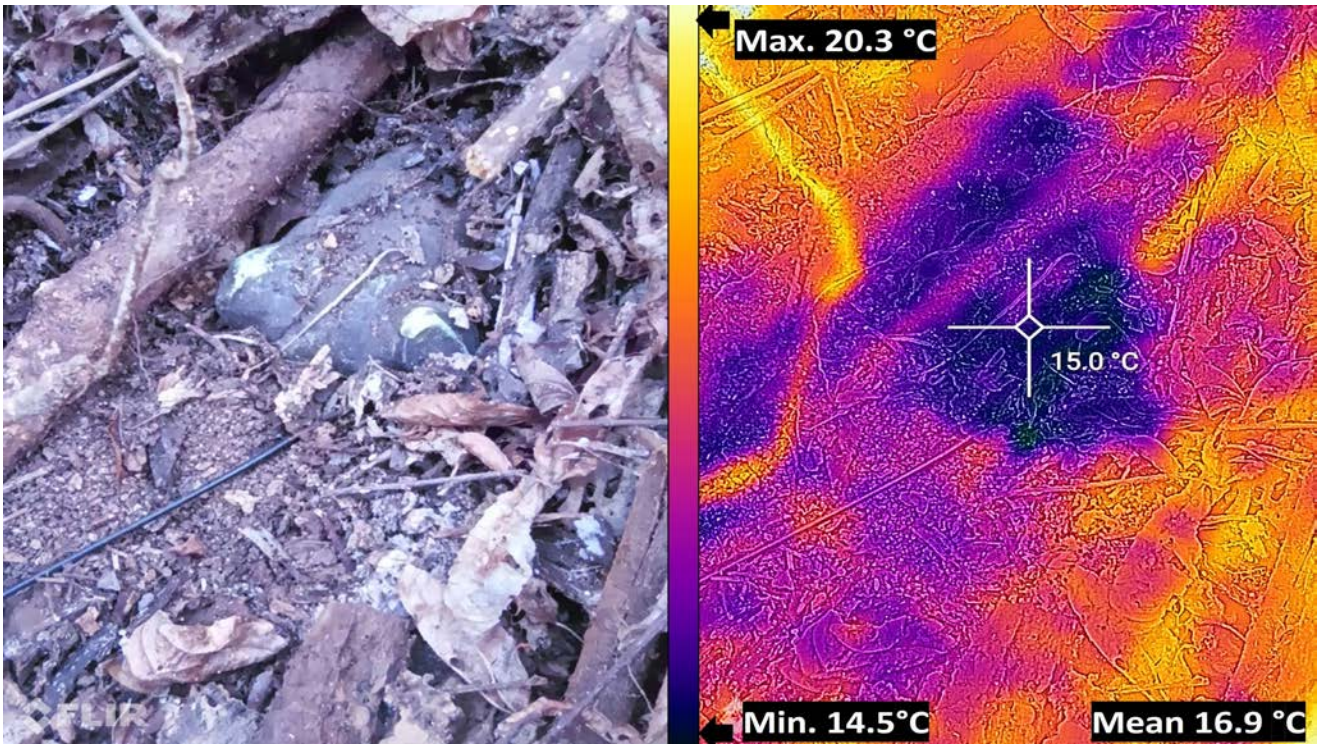

Figura 1. Estivación y temperaturas del microhábitat en la tortuga del fango *Kinosternon chimalhuaca* visualizadas por termografía en el bosque tropical de Chamela, Jalisco.
Figure 1. Aestivation and microhabitat temperatures in the mud turtle *Kinosternon chimalhuaca* visualized by thermography in the tropical forest of Chamela, Jalisco.

The environmental temperatures recorded on the dry soil of the terrestrial habitat were highly variable with nocturnal temperatures of 13 °C to 25 °C, and diurnal temperatures of 25 °C to 46 °C (Fig. 3A). Environmental temperatures in the shallow water of the aquatic habitat (Fig. 3B) showed more variation than the microhabitat temperatures in the deep underwater (Fig. 2A). Environmental temperatures in the air around the aquatic habitat (Fig. 3C) were higher than the temperatures in shallow water (Fig. 3B) but with thermal ranges smaller than the temperature ranges in the soil of the terrestrial habitat (Fig. 3A).

DISCUSSION

Although the kinosternids are a diverse group of turtles (Legler & Vogt, 2013), thermal ecology has been a scientific topic with limited research in the family Kinosternidae and other families of semi aquatic turtles (Macip-Rios et al., 2015; Berriozabal-Islas et al., 2020). A study by Berriozabal-Islas (2018) makes a significant contribution to the study of the thermal ecology of several species of mud turtles of the genus *Kinosternon* from Mexico. Some of the main conclusions of Berriozabal-Islas (2018) were that mud turtles have low to moderate thermal preferences (17-22 °C), low thermal precision, thermal limits of 37-41 °C for high temperatures and 6-8 °C for low temperatures, and generalized thermoconformity. Although results of Berrizoabal-Islas (2018) showed a low thermal quality of the habitat for *Kinosternon chimalhuaca*, their study focuses on the terrestrial environment with limited description on the used microhabitats. Our results show a subaquatic and an aestivation microenvironment with thermal conditions that have the potential to be favorable for active and inactive turtles. Results for body and selected temperatures in *K. chimalhuaca* of Berrizoabal-Islas (2018) differ slightly with our results. The voluntary temperatures reported in our study suggests that the basic thermal requirements of active individuals are covered by temperatures provided by the subaquatic environment. Additionally, the minimum 7 °C and maximum 41 °C of critical temperatures reported by Berrizoabal-Islas (2018) for *K. chimalhuaca*, suggest that turtles of our study are out of thermal stress both inside the water and aestivation sites during a hot and dry period in the environment.

Understanding how species respond to thermal heterogeneity is a fundamental question in ecology (Angilletta, 2009; Buckley et al., 2015). Ectotherms in water experience rates of heat transfer at least two orders of magnitude greater than in air (Fitzgerald & Nelson, 2011). Therefore, the aquatic habitat could constrain the thermoregulatory capabilities. However, body temperatures in some turtles can be modulated via subaquatic behaviors such

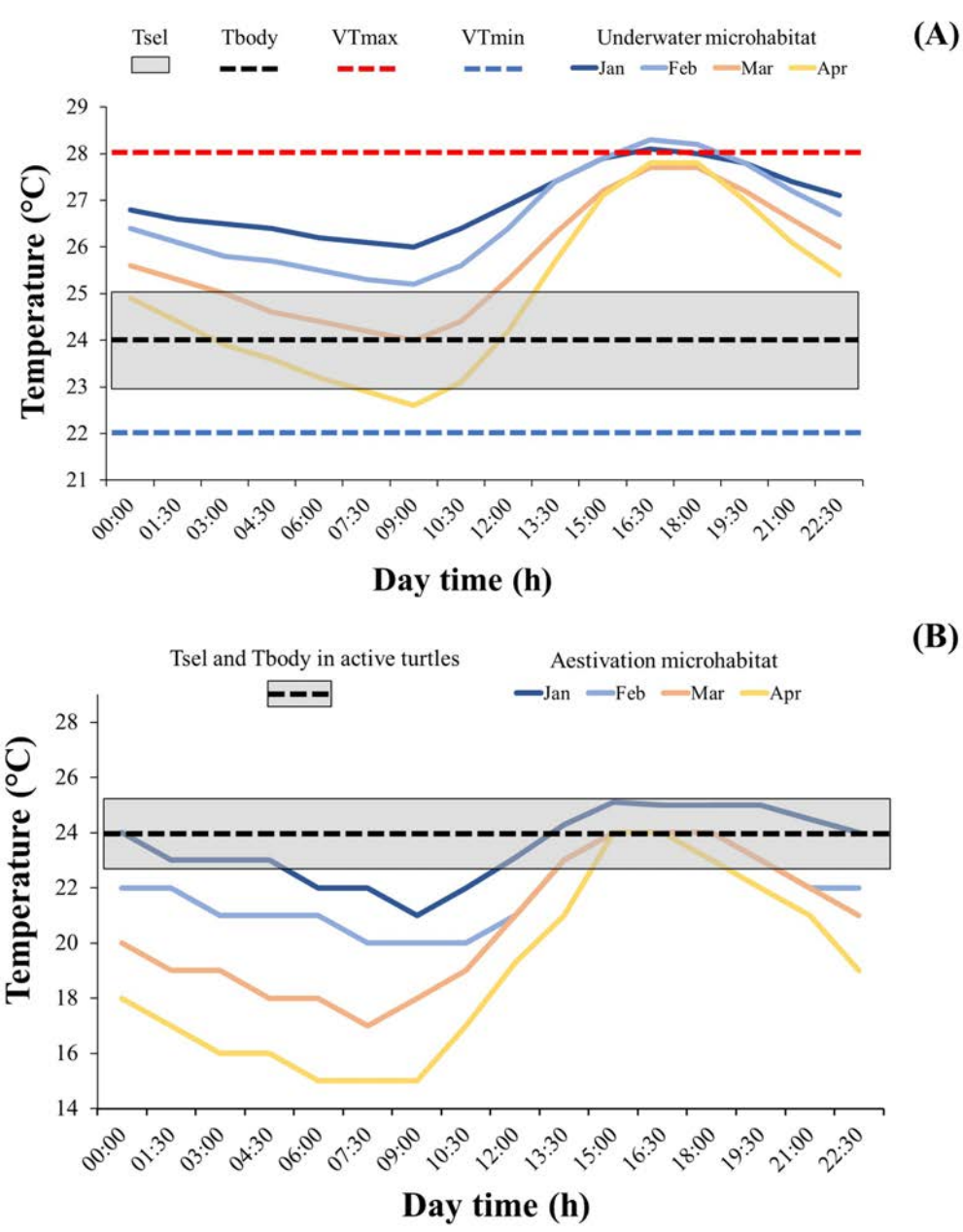

Figura 2. Temperaturas diarias en los microhábitats bajo el agua (A) y estivación (B) de *Kinosternon chimalhuaca* durante un periodo estacional seco en Jalisco, México. Temperaturas de la cloaca (Tbody), temperaturas seleccionadas (Tsel), temperaturas voluntarias máximas (VTmax) y temperaturas voluntarias mínimas (VTmin).

Figure 2. Daily temperatures in the underwater (A) and aestivation microhabitat (B) of *Kinosternon chimalhuaca* during a dry seasonal period in Jalisco, Mexico. Cloacal temperatures (Tbody), selected temperatures (Tsel), maximum (VTmax) and minimum (VTmin) voluntary temperatures.

as selecting thermally favorable microhabitats (Akins et al., 2014; Chandler et al., 2020). So far, our data suggests that free-ranging turtles were accessing underwater temperatures that do not exceed their voluntary thermal range. However, it is important to note that underwater temperatures during February and March are entirely above the preferred temperatures. This climatic condition may be due to a reduction in thermal conditions in the environment since the tropical study area receives the first intense droughts during the winter and water temperatures decrease, which probably motivates the turtles to seek warmer

water columns. However, our study requires a continuation over time to determine the thermal factors under the water (e.g., temperatures in mud depth and water column) and terrestrial environments (basking temperatures and duration) that best explain the body temperature and the thermal niche in this species.

Otherwise, we have observed that unlike other species of turtles from temperate climates, *K. chimalhuaca* does not appear to have a diurnal basking (R. Macip & E. Raya, direct observation), and although having greater activity times during the night, nocturnal basking may also not be occurring. Our data indicate that temperatures outside the aquatic habitat (aerial environment) are regularly cooler at night (e.g. < 23 °C from 00:00 onwards) which does not match with the warmer temperatures recorded in the aquatic microhabitat during the night (e.g. >23 °C from 00:00 onwards). The underwater habitat appears to have a low cost for thermoregulation of this tropical mud turtle, but additional studies could evaluate the unknown role of physical and chemical properties of the water (e.g., turbidity, pH, solubility), biotic factors (e.g., vegetation, predation, competition), and their interactions on the thermoconformity observed in Kinosternids.

Aestivation is often induced by high temperatures and the absence of water, which raises the question of how aestivating animals regulate their body temperatures in response to environmental changes (Jiang et al., 2023). The body temperature (Tb) of ectotherms is determined by the ambient temperature (Ta) to which they are exposed during hypometabolic states (Jiang et al., 2023). In semi-aquatic turtles, the metabolic responses can be decreased exponentially with lower temperatures (Haskins & Tuberville, 2022). Our study denotes that temperatures in the aestivation microhabitat of *K. chimalhuaca* are lower than physiological temperatures of active individuals, which suggests that the body temperatures of aestivating turtles could be influenced by moderately cool microhabitats within the forest vegetation compared to the external habitat (soil forest temperatures) that was usually warmer. These apparently favorable thermal conditions of aestivation and subaquatic microhabitats in *K. chimalhuaca* require greater research effort. For example, with the help of biophysical models it is necessary to address the accuracy of thermal niches in different and potential aestivation sites. At this same address, it is necessary to devise practical solutions for the use of optimized biophysical models for the recording of operating temperatures at underwater conditions for active turtles. In the future, much scientific research is required to evaluate how the threats of global warming and loss-degradation of habitat affect thermal and dormancy ecology in semi-aquatic reptiles.

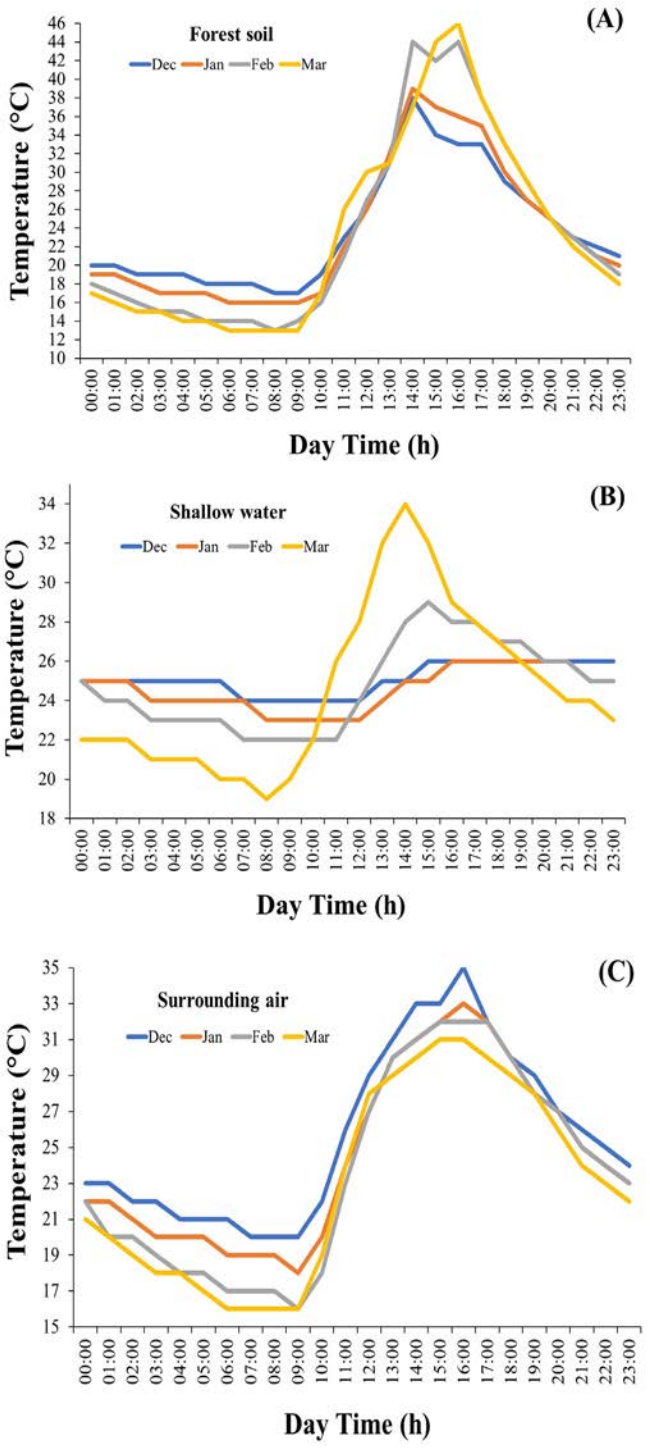

Figura 3. Temperaturas ambientales diarias en el hábitat terrestre (A) y hábitat acuático (B, C) de *Kinosternon chimalhuaca* durante un periodo estacional seco en Jalisco, México

Figure 3. Daily environmental temperatures in the terrestrial (A) and aquatic habitat (B, C) of *Kinosternon chimalhuaca* during a dry seasonal period in Jalisco, Mexico.

Acknowledgments.– We thank the Estación Biológica Chamela from the Instituto de Biología, UNAM and the people from Emiliano Zapata and Francisco Villa for their help during field work and facilities. The turtles were captured under the permit FAUT-0304 (SGPA/DGVS/01208/19). This study was funded by the DGAPA-PAPIIT IN201921 project "Ecología Evolutiva de la Estivación en Tortugas". No turtle was harm or die by human handing during field work.

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FIRST RECORD OF *HYLOXALUS ANTHRACINUS* EDWARDS, 1971 (ANURA: DENDROBATIDAE) IN PERU

PRIMER REGISTRO DE *HYLOXALUS ANTHRACINUS* EDWARDS, 1971 (ANURA: DENDROBATIDAE) EN PERÚ

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The genus *Hyloxalus* is the most diverse among dendrobatid frogs (Santos et al., 2009) with 64 species currently recognized (Frost, 2024) and not least than ten species awaiting descriptions (Grant et al., 2017). This genus is defined by molecular characters and characterized by being mostly cryptically colored (except *H. azureiventris* and *H. nexipus*) and distributed throughout Panama, Colombia, Ecuador, and Peru on the Pacific coast; Andean Venezuela, Colombia, Ecuador, Peru, as well and eastern foothills of the Andes in Bolivia to Venezuela, east to the upper Amazon Basin (Grant, 2006). *Hyloxalus anthracinus* was described by Edwards (1971) and accounts were provided by Coloma (1995), Almendáriz and Orcés (2004, short account). To date, records of *H. anthracinus* have been restricted to a narrow altitudinal zone between 2,710 – 3,500 m a.s.l. on the Cordillera Oriental and the Mazán River in southern Ecuador (Coloma, 1995). The distribution lies in the Ecuadorian provinces of Azuay, Cañar (online records by Coloma et al. 2022), Morona Santiago, and Zamora Chinchipe, where the species inhabits paramo, very humid montane forest, and lower humid montane forest (Coloma, 1995).

This species is listed as Critically Endangered by Ortega-Andrade et al. (2021) and the IUCN Red list of Threatened species (IUCN, 2022, assessed on 07 October 2020). Due to a drastic population decline in the 1990s, possibly caused by the chytridiomycosis or a combination of factors, the surviving subpopulations are very small (≤ 50 mature individuals) being more vulnerable to the habitat loss or degradation (IUCN SSC Amphibian Specialist Group, 2022).

Surveys carried out in 2007 in the montane ecosystems of the Piura Department, as part of biological inventories in order to protect the headwaters of Huancabamba River, have resulted in the observation and collection of *H. anthracinus*, which we report as follows.

On September 2007, we collected one female (CORBIDI 8966) and five males (CORBIDI 8964–65, 8967–69) of *H. anthracinus* that were found by day in a paramo, calling from the base of bunchgrass, at a swamp area close to the drainage of San Antonio lagoon (4.768725° S, 79.454228° W; WGS 84), at an elevation of 3,214 m a.s.l. (Fig. 1), Huamba District, Ayabaca Province, Piura Department, Peru. These specimens are the first record of *H. anthracinus* in Peru and represent a range extension of approximately 96 km SW from the nearest locality Abra Zamora, in the borderline between Loja and Zamora Chinchipe provinces, in Ecuador (Fig. 1). The six specimens were fixed in formalin and then stored in ethanol 70 %, and are housed in the herpetological collection of Centro de Ornitología y Biodiversidad (CORBIDI), Lima, Peru.

No color photographs of the six specimens of *H. anthracinus* exist (Fig. 2), only the following field notes of live coloration taken by PJV. Dorsally, brown with two paravertebral rows of dark brown blotches, forearms darker than arms, forelimbs bearing darker diagonal bands, dorsolateral stripe absent, oblique lateral stripe present as a broad creamy tan stripe (see Fig. 2G), and flanks dark brown with a tan labial stripe. Ventrally, males with throat, chest, forelimbs, shanks, palms, and soles solid black with the axillae, belly and thighs red. In two males (CORBIDI 8965, 8969) the ventral surface of shanks was black and in the other three black with red blotches. Ventrally, the female (CORBIDI 8966) had the throat and part of the chest brownish orange and the arms, belly and thighs creamy orange.

Our specimens were easily identified as *Hyloxalus anthracinus* by the ventral black and red coloration of male specimens (PJV field notes September 2006), unique among the species of the genus. Furthermore, the specimens agree with the diagnostic characters given by Edwards (1971) and Coloma (1995) such as: disc on Finger III not expanded; Finger I = II; fringe absent on

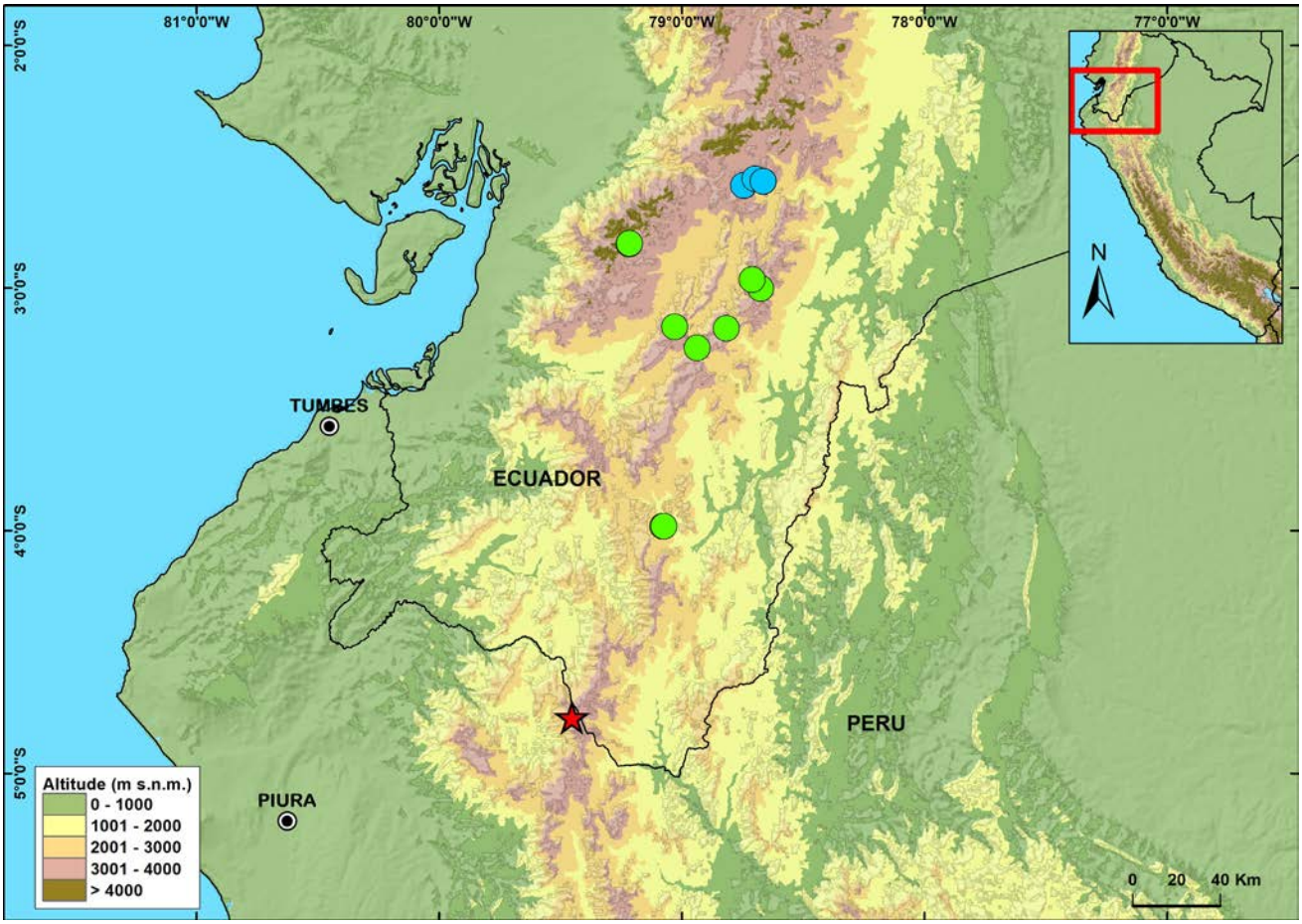

Figura 1. Distribución de *Hyloxalus anthracinus*. Los círculos representan la distribución previamente conocida [los círculos azules representan registros tomados de Coloma et al. (2022) y los círculos de color verde claro representan registros tomados de Coloma (1995)] y la estrella roja el nuevo registro de localidad.

Figure 1. Distribution of *Hyloxalus anthracinus*. Circles represent the previously known distribution [blue circles represent records taken from Coloma et al. (2022) and light green circles represents records taken from Coloma (1995)] and the red star the new locality record.

Finger II; disc on Toe IV not expanded; fringe absent on Toe IV; outer tarsal fold absent; toes unwebbed; dorsolateral stripe absent; ventrolateral stripe absent; Finger III not swollen in males; testes white; and the snout-vent length with 19.05–20.04, $n = 5$ in males and 21.73 in a female (16.2–19.0, $n = 14$ in males and 17.1–23.6, $n = 15$ in females; according to Coloma, 1995). Even our male specimens present the black arm gland, a taxonomic character reported for *H. anthracinus* by Grant et al. (2006, 2017).

Additionally, we examined four specimens of *H. anthracinus*, housed in the Museo de Zoología, Pontificia Universidad Católica del Ecuador (QCAZ), Quito, Ecuador and reported online by Coloma et al. (2022) (see Appendix I), to verify the state of diagnostic characters given by Coloma (1995). Finding the most relevant distinction between the Ecuadorian and Peruvian populations to be the presence of a well-defined narrow oblique lateral stripe [see photos of the holotype of *H. anthracinus* in Coloma et al. (2022) and plate 2E in Coloma (1995)], a feature ill-defined in the Peruvian specimens (Fig. 2G). The oblique lateral stripe in the Peruvian population is weakly defined in its upper edge given the appearance of a broad oblique stripe. Although the oblique lateral stripe is a widely used taxonomic character in *Hyloxalus* and other genera of Dendrobatidae and Aromobatidae (Coloma, 1995; Morales, 2002; Duellman, 2004; Grant, 2006; Grant et al., 2017), we prefer to interpret the state of the oblique lateral stripe in the Peruvian population of *H. anthracinus* as geographic variation on the southern extreme of distribution, rather than evidence of a distinct taxa from Peru. Nonetheless, this needs further verification by comparison of DNA sequences of both populations. According to Grant et al. (2017), *H. anthracinus* is the sister taxa of a group that includes *H. jacobuspetersi* + *H. delatorreae*, and *H. sylvaticus* + *H. pulcherrimus*.

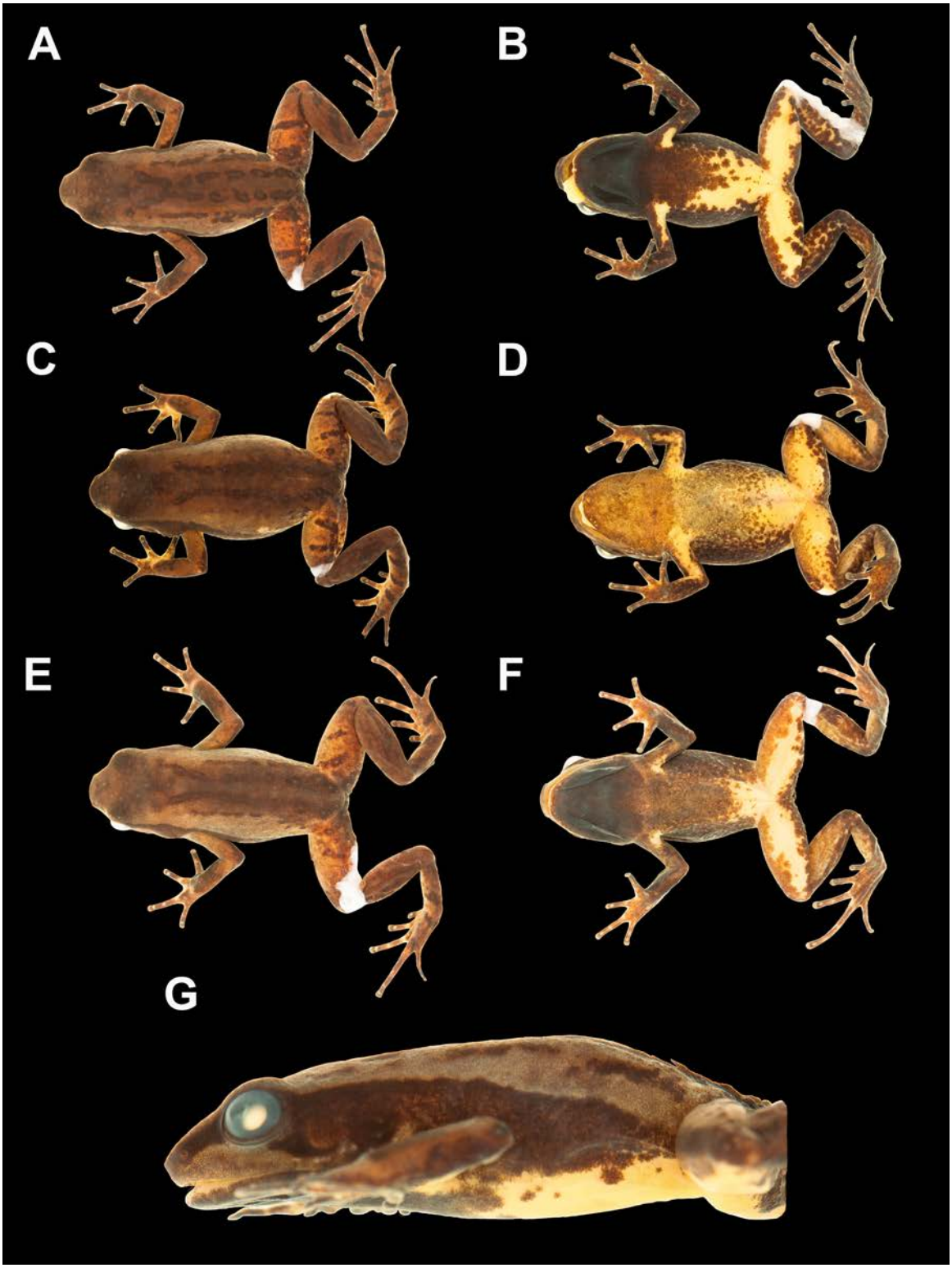

Figura 2. Ejemplares de *Hyloxalus anthracinus* (en preservante) colectados en la laguna San Antonio, Distrito de Huamba, Provincia de Ayabaca, Región Piura, Perú. (A) vistas dorsal y (B) ventral del macho CORBIDI 8968, SVL = 19.4 mm; (C) vistas dorsal y (D) ventral de la hembra CORBIDI 8966, SVL = 21.5 mm; (E) vistas dorsal y (F) ventral del macho CORBIDI 8969, SVL = 19.5; (G) vista lateral del macho CORBIDI 8969, SVL = 19.5 mm. Foto: Pablo J. Venegas.

Figure 2. Specimens of *Hyloxalus anthracinus* (in preservative) collected in San Antonio lagoon, Huamba District, Ayabaca Province, Piura Region, Peru. (A) dorsal and (B) ventral views of male CORBIDI 8968, SVL = 19.4 mm; (C) dorsal and (D) ventral views of female CORBIDI 8966, SVL = 21.5 mm; (E) dorsal and (F) ventral views of male CORBIDI 8969, SVL = 19.5; (G) lateral view of male CORBIDI 8969, SVL = 19.5 mm. Photo: Pablo J. Venegas.

The population of *Hyloxalus anthracinus* in San Antonio Lagoon looked healthy in 2007, with several males calling from the bunchgrass and abundance of tadpoles. After the collection of these specimens no more surveys were done in this lagoon. However, several herpetological inventories to the paramos of Piura during 2023 and begins of 2024, that even surveyed other lagoons in the vicinity of San Antonio, fail in recorded *H. anthracinus* (G. Chávez com. pers.). Likewise, although to date the area of San Antonio Lagoon and adjacent lagoons not showed more anthropogenic activities beyond cattle ranching, fires caused by livestock farmers to green pastures burn the paramo of Piura Department every year during the dry season (Jun-October). Therefore, being this a small isolated population of *H. anthracinus*, affected by continuous habitat degradation, as in the range of the Ecuadorian populations, the threat situation is the same in both countries. Future surveys are needed to confirm the survival of *H. anthracinus* and assess its population status in the San Antonio Lagoon. According to the species reported by Frost (2024), this record increases to 21 the number of *Hyloxalus* species known from Peru.

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APPENDIX

Appendix 1. Specimens examined.

Hyloxalus anthracinus.—ECUADOR: Azuay: Páramos de Matanga, 3.244° S, 78.93699° W, QCAZ 2697; Cañar: Azoguez: Parque Nacional Sangay, Reserva Mazar, 2.574616° S, 78.74554° W, QCAZ 49436–37; Cañar: Reserva Mazar, La Libertad, 2.54762° S, 78.69884° W, QCAZ 49771

DEPREDACIÓN DE LA TORTUGA DEL BOLSÓN DE MAPIMÍ (*GOPHERUS FLAVOMARGINATUS*) POR EL LEÓN DE MONTAÑA (*PUMA CONCOLOR*) EN LA RESERVA DE LA BIÓSFERA MAPIMÍ, DURANGO, MÉXICO

PREDATION OF THE MAPIMÍ BOLSON TORTOISE (*GOPHERUS FLAVOMARGINATUS*) BY THE MOUNTAIN LION (*PUMA CONCOLOR*) IN THE MAPIMÍ BIOSPHERE RESERVE, DURANGO, MEXICO

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Abstract.– The Mapimí Bolsón tortoise (*Gopherus flavomarginatus*) is an endemic species of Mexico whose distribution is restricted to the Mapimí Bolsón region, in the Mexican Chihuahuan desert. Studies identifying the natural predators of *G. flavomarginatus* are limited. However, it is known that carnivorous mammals such as foxes feed on their eggs, and that coyotes and mountain lions could prey on individuals. In this work, we present the first evidence of predation of a young individual (scute size no greater than 26 mm long and 18 mm wide) of the turtle by a mountain lion, based on the review of the content of one of their scat. We consider that this predation event occurred opportunistically, since this predator specializes in consuming ungulates. Finally, this information is relevant to learn more about the natural history of the species and some of its ecological interactions.

Keywords.– Conservation, Chihuahuan desert, interaction, predator, scat.

Resumen.– La tortuga del Bolsón de Mapimí (*Gopherus flavomarginatus*), es una especie endémica de México cuya distribución se restringe a la región del Bolsón de Mapimí, en el desierto chihuahuense mexicano. Los estudios que identifican a los depredadores naturales de *G. flavomarginatus* son limitados. Sin embargo, se sabe que mamíferos carnívoros como zorros se alimentan de sus huevos, y que coyotes y leones de montaña podrían depredar individuos. En este trabajo, presentamos la primera evidencia de depredación de un individuo joven (tamaño de los escudos no mayor a los 26 mm de largo y a los 18 mm de ancho) de la tortuga por un león de montaña, a partir de la revisión del contenido de una de sus excretas. Consideramos que este evento de depredación ocurrió de manera oportunista, ya que este depredador se especializa en consumir ungulados. Finalmente, esta información resulta relevante para conocer más de la historia natural de la especie, y algunas de sus interacciones ecológicas.

Palabras clave.– Conservación, depredador, desierto Chihuahuense, excreta, interacción.

La tortuga del Bolsón de Mapimí (*Gopherus flavomarginatus*), es la especie de tortuga terrestre más grande de Norteamérica, es una especie endémica y emblemática de la región del Bolsón de Mapimí, perteneciente a la Reserva de la Biosfera Mapimí. Este último ubicado en el centro de la región del desierto chihuahuense mexicano (Lemos-Espinal & Smith, 2007). Es un organismo fosorial que cava y utiliza sus madrigueras como refugio ante los depredadores y las condiciones climáticas extremas de esta zona (Adest et al., 1989; Valenzuela-Ceballos et al., 2018). Su alimentación se basa principalmente en el consumo de pastos, arbustos, frutos y tallos de cactáceas (Lemos-Espinal & Smith, 2007). Desde el siglo XX su población ha disminuido drásticamente debido la expansión de áreas de agricultura y pastoreo, y por actividades como la cacería y el tráfico ilegal (Ureña-Aranda et al., 2015), resultando en algunas subpoblaciones de distribución restringida, y con baja variabilidad genética (Kiester et al., 2018); problemáticas que han incrementado su vulnerabilidad a la extinción, por tanto, en la ley mexicana se encuentra bajo el criterio de "Peligro de extinción" (NOM-059-SEMARNAT-2010; DOF, 2019) y por la

Lista Roja de Especies Amenazadas de la Unión Internacional para la Conservación de la Naturaleza (IUCN) se encuentra como especie en "Peligro crítico" (Kiester et al., 2018), además de encontrarse enlistada en el apéndice I de CITES (Convención sobre el Comercio Internacional de Especies Amenazadas de Fauna y Flora Silvestres) y formar parte del Top 25 de tortugas más amenazadas del mundo (Turtle Conservation Coalition, 2018).

En cuanto a la interacción de *G. flavomarginatus* con sus depredadores naturales, el conocimiento es limitado, se sabe que sus huevos son depredados por zorros (*Urocyon cinereoargenteus* y *Vulpes macrotis*), zorrillos, cuervos (*Corvus corax* y *C. cryptoleucus*) y correcaminos (*Geococcyx californianus*) (Valenzuela-Ceballos et al., 2018). De acuerdo con algunos registros, se sugieren a los coyotes (*Canis latrans*), tejones (*Taxidea taxus*), gatos monteses (*Lynx rufus*) y leones de montaña (*Puma concolor*) como potenciales depredadores de ejemplares adultos (Morafka, 1972; Herrera-Flores, 2022). Sin embargo, hasta el momento no se cuenta con evidencia contundente que confirme estas interacciones.

El puma, o león de montaña, es un depredador de emboscada que caza a través de la estrategia "sit and wait". Está especializado en la depredación de ungulados de gran tamaño, como el venado bura (*Odocoileus hemionus*) y el venado cola blanca (*O. virginanus*) (Bernanrd et al., 2023). No obstante, también es un depredador oportunista que ocasionalmente consume presas de tamaño mediano y pequeño de diferentes grupos taxonómicos (Moss et al., 2016; Prude & Cain 2021; LaBarge et al., 2022).

En este trabajo, reportamos la primera evidencia de depredación de un individuo joven de la tortuga del bolsón de Mapimí por el león de montaña en la Reserva de la Biosfera Mapimí, a partir de los restos alimentarios extraídos de una excreta.

El 7 de marzo de 2024, se colectó una excreta en las coordenadas (26° 41' 27.92" N, 103° 44' 11.12" W, 1,154 m s.n.m), en la Reserva de Biósfera Mapimí ubicada al norte de México, entre los estados de Chihuahua, Coahuila y Durango. Esta reserva, tiene una extensión de 342 ha (CONANP, 2006) caracterizada por grandes extensiones de matorral xerófilo y pastizales naturales (García-Arévalo, 2002), así como un clima árido y caluroso con baja humedad y precipitación fluvial (García & Ureña, 2018).

La excreta recolectada fue identificada como perteneciente a *Puma concolor* a partir de sus caracteres diagnósticos, descritos en las guías de campo de Aranda (2000) y de Elbroch (2003). La excreta mostraba indicios de restos de algún reptil (Fig. 1). La limpieza y extracción del contenido de la excreta se realizó siguiendo la metodología descrita por Alanis-Hernández et al. (2024).

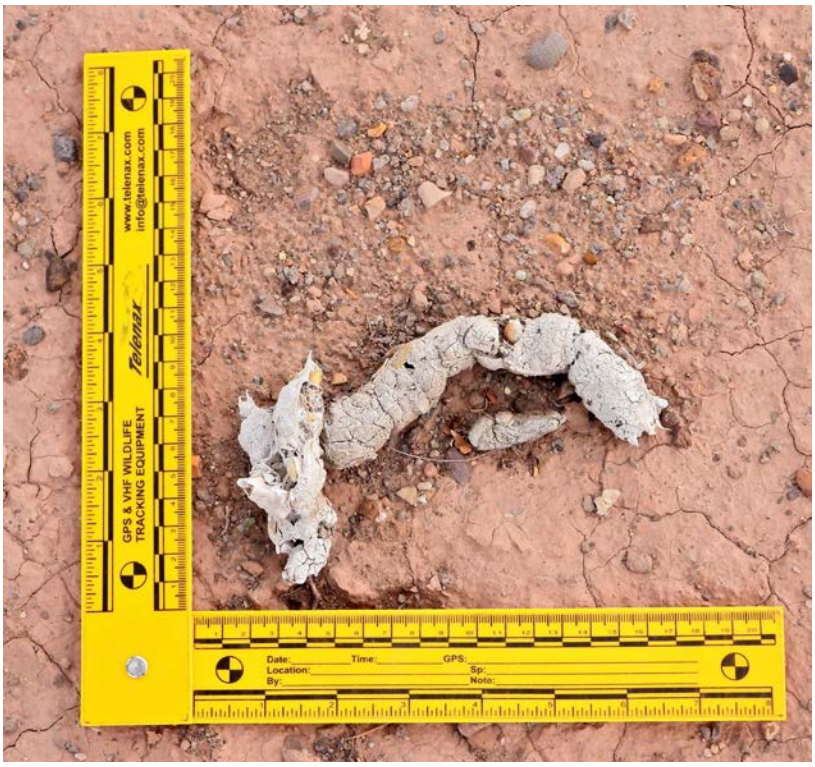

Figura 1. Excreta de *Puma concolor* ubicada en la Reserva de la Biosfera de Mapimí, Durango, México. Foto: Dante A. Hernández-Silva.

Figure 1. *Puma concolor* scat located in the Mapimí Biosphere Reserve, Durango, Mexico. Photo: Dante A. Hernández-Silva.

Como resultado de esta inspección y con el apoyo de la revisión de literatura especializada (Lemos-Espinal & Smith, 2007; Reyes-Molina et al., 2011), se identificó la depredación de un individuo joven de la tortuga del Bolsón de Mapimí (*Gopherus flavomarginatus*) de acuerdo con las medidas de los diferentes escudos revisados. De la excreta, se contabilizaron cuatro escudos del caparazón, dos escudos del plastrón, dos patas y seis uñas. Todos los escudos presentaron un alto grado de desgaste, sin embargo, por su forma y tamaño consideramos que tres son escudos costales (1 = 26 mm largo, 19 mm ancho, 2 = 19 mm - 13 mm, 3 = 22 - 18 mm), uno es un escudo marginal (17 mm - 10 mm), y dos escudos del plastrón (1 = 25 mm - 18 mm, 2 = 19 mm, 10 mm). Determinamos que se trata de un individuo joven debido a que las medidas de los escudos revisados están muy por debajo de lo reportado por Germano (1993) para ejemplares adultos, sin embargo, es difícil determinar una edad aproximada debido al alto grado desgaste que presentaron. Con respecto a las patas, identificamos que una corresponde a la zona posterior debido al número de dedos presentes (cuatro), y la otra no se pudo identificar debido al grado de deterioro en el que se encontraba (Fig. 2).

La tortuga del Bolsón de Mapimí, resulta ser una pieza sumamente valiosa en el desierto chihuahuense. Es considerada una importante dispersora de semillas, principalmente de zacate toboso (*Pleuraphis mutica*), especie dominante en pastizales halófilos y que compone más del 60 % de su dieta (Becerra-López et al., 2014). Con sus madrigueras mantiene la aireación en el suelo, provee de refugio a una gran variedad de especies y promueve la interacción entre ellas (Valenzuela-Ceballos et al., 2018). Sus huevos y crías forman parte de la dieta de varias especies de carnívoros y aves (Valenzuela-Ceballos et al., 2018),

Figura 2. Restos alimentarios que corresponden a un individuo joven de la tortuga del Bolsón de Mapimí, extraídos de una excreta del león de montaña o puma (*Puma concolor*) colectada en la Reserva de la Biosfera Mapimí, Durango, México. A) escudos costales, B) escudo marginal, C) escudos del plastrón, D) patas y E) uñas. Foto: Luis A. Alanis-Hernández.

Figure 2. Food remains corresponding to a young individual of the Mapimí Bolson Tortoise, extracted from a mountain lion or puma (*Puma concoclor*) scat collected in the Mapimí Biosphere Reserve, Durango, Mexico. A) costal shields, B) marginal shield, C) plastron shields, D) legs and E) nails. Photo: Luis A. Alanis-Hernández.

mientras ejemplares jóvenes y adultos son presas potenciales para carnívoros medianos y grandes (Morfka, 1972; Herrera-Flores, 2022). Con este trabajo a partir de la colecta y revisión del contenido fecal confirmamos al león de montaña como un depredador de la tortuga del Bolsón en la Reserva de la Biósfera Mapimí, lo cual hasta ahora no se tenía evidencia.

En términos de conservación, particularmente para la Reserva de la Biósfera Mapimí, *G. flavomarginatus* es la especie emblema, por la cual se decretó como área protegida desde hace 45 años esta reserva y que desde entonces se promueven y llevan a cabo diferentes estrategias para su conservación (Montero-Bagatella et al., 2020; Colmenero-Robles et al., 2023). Sin embargo, pese al seguimiento constante que se tiene de la especie en la reserva por investigadores y personal de la CONANP, la información sobre sus interacciones con otras especies, y en particular con sus depredadores naturales, es escasa.

Aunque su gran tamaño y sus hábitos cavadores, hacen de esta especie una presa difícil de consumir, su abundancia podría representar un importante recurso en este ecosistema árido, especialmente para grandes depredadores. Por otro lado, este hallazgo concuerda con lo mencionado por Landers et al. (1995) quienes mencionan que a pesar de que durante el primer año de vida las tortugas del género *Gopherus* es la etapa de mayor vulnerabilidad ante depredadores, en especies de este grupo de tortugas terrestres el endurecimiento de su caparazón tarda de 7 a 10 años, por lo que los juveniles también resultan un recurso trófico para los depredadores.

A pesar de que este es el primer registro de *G. flavomarginatus* en la dieta del león de montaña, ya existe evidencia del consumo de otra especie de tortuga del mismo género taxonómico. En el sureste de Texas, a través de una observación directa se registró la depredación de la tortuga de Texas (*G. berliandieri*) por un individuo joven del león de montaña (Adams et al., 2006), el cual al igual que el reportado por nosotros, parece tratarse de un evento ocasional y oportunista, debido a que la dieta del león de montaña se basa principalmente por el consumo de presas de tallas grandes como ungulados, y en menor frecuencia de especies de tallas pequeñas (Prude & Cain 2021; LaBarge et al., 2022).

Finalmente, considerando que *G. flavomarginatus* se encuentra en un estado crítico de conservación (Kiester et al., 2018; NOM-059-SEMARNAT-2010; DOF, 2019), es poco probable que el león de montaña tenga un impacto negativo significativo en su población, dada la ocurrencia ocasional en la alimentación de este depredador. Sin embargo, es crucial realizar estudios futuros sobre la dieta de la tortuga del Bolsón de Mapimí, y otros depredadores, para comprender mejor el efecto de la depredación en su supervivencia. Estos estudios son fundamentales para apoyar su conservación y ampliar nuestro conocimiento de la especie.

Agradecimientos.– Agradecemos al INECOL, en especial al Dr. Alberto González Romero y a la Dra. Sonia Antonieta Gallina Tessaro por la invitación al curso "Técnicas para el estudio de la fauna y su hábitat en zonas áridas", que se llevó a cabo en "El Laboratorio del Desierto", que se encuentra en el centro de la Reserva de la Biosfera de Mapimí, México, efectuado en el mes de marzo del año 2024, debido a que de esta manera se hizo el hallazgo de la excreta del puma y se realizó este trabajo.

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NEW RECORDS OF THE TUNGARA FROG *ENGYSTOMOPS PUSTULOSUS* COPE, 1864 (ANURA: LEPTODACTYLIDAE) IN CAMPECHE, MEXICO

NUEVOS REGISTROS DE LA RANA TÚNGARA *ENGYSTOMOPS PUSTULOSUS* COPE, 1864 (ANURA: LEPTODACTYLIDAE) EN CAMPECHE, MÉXICO

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Engystomops pustulosus is a small-sized amphibian (25-35 mm in snout-vent length, SVL), with females typically larger than males. This species is characterized by its relatively globose and rounded body, and its dorsal skin has a high density of glands, giving it a warty appearance. The snout is pointed in dorsal view, and well-developed parotid glands are present at the base of the head. The dorsal coloration is gray, brown, or tan with irregular blotches, while the venter is cream with dark spots. Males possess a dark sub-gular vocal sac with a distinctive white line down the middle (Lee, 1996; Ospina-L & Bedoya-Cañón, 2018).

Engystomops pustulosus is distributed from southern Oaxaca and Veracruz in Mexico, extending through Central America, to the northern portion of South America, in Colombia, Venezuela, Trinidad and Tobago, and Guyana (Lee, 1996; Ospina-L & Bedoya-Cañón, 2018). In the Mexican Yucatan peninsula, this species has been recorded in several localities in southern Campeche and Quintana Roo (Lee, 1996). Here, we report new records of *E. pustulosus* in Campeche, Mexico. The photographs of the specimens were deposited in the digital collection of the Centro de Investigaciones Biológicas of the Universidad Autónoma del Estado de Hidalgo, and in the figure 1 is presented the map with the new and old records.

Calakmul Biosphere Reserve. On April 20th, 2023, at 21:19 h, during a herpetofauna survey conducted in the Calakmul Biosphere Reserve, we encountered an *E. pustulosus*, approximately 30 mm SVL (CH-CIB-151; Fig. 2A, B), actively moving over the leaf-litter in a semi-deciduous tropical forest near to the abandoned chiclero camp "La Esperanza", in the municipality of Calakmul, Campeche, Mexico (18.166346° N, 90.04234° W, WGS 84, 190 m a.s.l.). This observation is located 33.7 km southeast (airline distance) from the nearest records, 5.6 km south of Chan Laguna, Calakmul, Campeche, México.

Engystomops pustulosus has been previously recorded in the Balam-Ku Biosphere Reserve in the Calakmul region (Barão-Nóbrega et al., 2022), however, that record was outside the boundaries of Calakmul Biosphere Reserve, with no records of this frog within this reserve (Cedeño-Vázquez et al., 2006; Barão-Nóbrega et al., 2022). Therefore, our observation represents the first record of *E. pustulosus* within the Calakmul Biosphere

Reserve, increasing to 106 the herpetofauna registered for this Natural Protected Area, and to 23 species of amphibian fauna (Colston et al., 2015; Barão-Nóbrega et al., 2022; Jesús-Espinosa et al., 2024).

Municipality of Campeche. On January 16th, 2022, at 15:30 h, during a herpetofauna survey, we found an *E. pustulosus* approximately 20 mm SVL (CH-CIB-148; Fig. 3A) inside a small den in the ground, 6.3 km southwest Tixmucuy in the municipality of Campeche, Campeche, Mexico (19.553828° N, 90.369358° W, WGS 84, 26 m a.s.l.). The individual was found at the edge of a temporary body of water approximately 25 m long (Fig. 3B), surrounded by flooded vegetation and elements of semi-deciduous tropical forest. This observation is located 104.3 km northeast (airline distance) from the nearest previously reported locality, 7.1 km north of Escárcega, Campeche (Fig. 2).

On November 26th, 2022, at 11:45 h, during a wildlife rescue survey, another *E. pustulosus* (SVL: 20 mm; CH-CIB-149; Fig. 4A) was encountered in an artificial vertical hole in the ground near to an old trail line, approximately 1.5 km southeast of the town of Chiná, Municipality of Campeche, Campeche, México (19.758484° N, 90.479752° W, WGS 84, 24 m a.s.l.). This individual was found within semi-deciduous tropical forest and secondary vegetation (Fig. 4B). It is plausible that the frog accidentally fell into the hole, unable to climb the walls. This observation is located 25.4 km northwest (air distance) from the nearest record previously reported in this document, at 6.3 km southwest Tixmucuy, and at 122.5 km northeast (airline distance) from the record at 7.1 km north of Escárcega, Campeche.

There is a record on the citizen science platform iNaturalist by the user enrique31 of an *E. pustulosus* observed around the

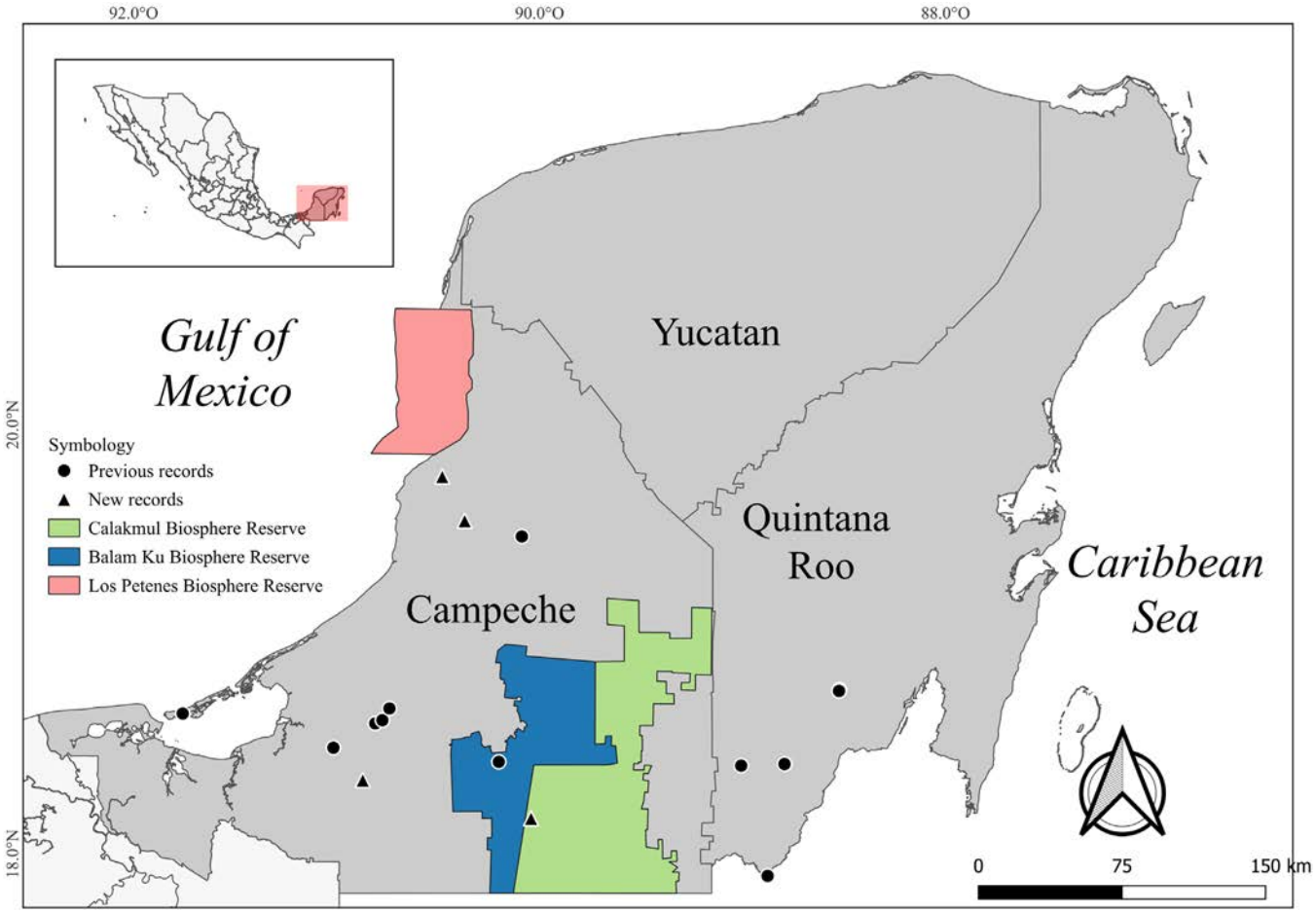

Figura 1. Nuevo registro (triángulo) y registro previo (círculo) de *Engystomops pustulosus* en el estado de Campeche, México.
Figure 1. New record (triangle) and previous record (circle) of *Engystomops pustulosus* in the state of Campeche, Mexico.

Figura 2. Vista lateral (A) y dorsal (B) de *Engystomops pustulosus* en la Reserva de la Biósfera de Calakmul, Campeche. Foto: Pedro E. Nahuat-Cervera.
Figure 2. Lateral (A) and dorsal (B) view of *Engystomops pustulosus* in Calakmul Biosphere Reserve, Campeche. Photo: Pedro E. Nahuat-Cervera.

Figura 3. *Engystomops pustulosus* (A) y hábitat (B) en el suroeste de Tixmucuy, Campeche. Fotos: Leonardo Ponce-Rosales.
Figure 3. *Engystomops pustulosus* (A) and habitat (B) in southwest Tixmucuy, Campeche. Photos: Leonardo Ponce-Rosales.

Figura 4. *Engystomops pustulosus* (A) y hábitat (B) en el sureste de Chiná, Campeche. Fotos: David Brindis-Badillo.
Figure 4. *Engystomops pustulosus* (A) and habitat (B) in southeast Chiná, Campeche. Photos: David Brindis-Badillo.

Figura 5. *Engystomops pustulosus* encontrado en Don Samuel, Escárcega, Campeche. Foto: Daniel Pérez Hernández.

Figure 5. *Engystomops pustulosus* found in Don Samuel, Escarcega, Campeche. Photo: Daniel Pérez Hernández.

community of Pich on October 9, 2019 (iNaturalist observation #44559796). This observation is located 30.6 km east of our record near the community of Tixmucuy (CH-CIB-148), and 51.3 km southeast of our record in Chiná, Campeche (CH-CIB-149). To our knowledge, our observations represent the northernmost records of this frog in the state of Campeche, as well as the Yucatan peninsula (Lee, 1996; 2000). It is important to highlight that the record CH-CIB-149 is located approximately 11.9 km from the southern boundary of the Los Petenes Biosphere Reserve, making it possible that this species is part of the herpetofauna of this protected natural area. It is recommended to conduct surveys in the southern portion of the reserve to determine if there is a population of *E. pustulosus* present.

Municipality of Escarcega. On October 19th, 2020, at 10:30 h, during a herpetofauna survey, we found a *E. pustulosus* (SVL: 21 mm; CH-CIB-150; Fig. 5) in the edges of a small temporary creek near an old trail line, approximately 1.9 km southern of the community of Don Samuel, municipality of Escarcega, Campeche, Mexico (18.345008° N, 90.871501° W, WGS 84, 93 m a.s.l.). This individual was found in semi-deciduous tropical forest. This observation is situated 22.6 km southeast (airline distance) from the nearest records, 8.2 km east of Mamantel, municipality of Carmen, Campeche, México, and 30.1 km south (airline distance) from the record at 7 km west of Escárcega, municipality of Escárcega, Campeche, México. This observation helps to complement the information on the distribution of *E. pustulosus* at the base of Campeche and fills a gap between records in the area.

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FIRST REPORT OF THANATOSIS IN *BOTHROPS ASPER* (GARMAN, 1883) (SERPENTES: VIPERIDAE) IN PANAMA

PRIMER REPORTE DE TANATOSIS EN *BOTHROPS ASPER* (GARMAN, 1883) (SERPENTES: VIPERIDAE) EN PANAMÁ

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Resumen.– La tanatosis es un comportamiento defensivo en animales que simulan la muerte para evitar ataques de depredadores. En serpientes, se ha documentado en varias familias, incluidos pitónidos, colúbridos, elápidos y vipéridos, aunque en América hay solo unos pocos registros en vipéridos. Observamos la conducta de tanatosis en *Bothrops asper* durante su rescate y reubicación, la serpiente mostró inmovilidad tónica y otros comportamientos, aparentando estar muerta. Este es el primer caso documentado para la especie.

Palabras clave.– Camuflaje, comportamiento, depredador, inmovilidad tónica, supervivencia.

Abstract.– Thanatosis is a defensive behavior in animals that simulates death to avoid attacks from predators. In snakes, it has been documented in several families, including pythonids, colubrids, elapids and viperids, although in America there are only a few records in viperids. We observed thanatosis in a *Bothrops asper* during its rescue and relocation, the snake showed tonic immobility and other behaviors, pretending to be dead. This is the first documented case for the species.

Keywords.– Behavior, camouflage, predator, survival, tonic immobility.

Thanatosis is a defensive animal behavior, which consists in a voluntary motor inhibition, and a reduction of the response to respond to external stimulation (Suzuki et al., 2013), Adopting a posture that mimics death, which can deter or discourage a predator's attack (Toledo et al., 2010; Humphreys & Ruxton, 2018; Fuentes et al., 2021). Thanatosis is considered an adaptive anti-predation strategy, which increases the chances of survival (Toledo et al., 2010).

In snakes, thanatosis has been documented in some taxa ranging from ancient lineages such as pythonids, to more recent ones such as colubrid, elapids and viperids (Muscat & Entiauspe-Neto, 2016; Gonzales & de Oliveira, 2020; Thomas et al., 2020; Salazar-Saavedra et al., 2021, Fuentes et al., 2021). In America there are only three records of thanatosis in viperids (Fuentes et al., 2021): *Crotalus cerastes* in the United States of America (Thomas et al., 2020), *Bothrops jararacussu* (Muscat & Entiauspe-Neto, 2016), and *Bothrops erythromelas* (dos Santos & Da Silva Muniz, 2012), both in Brazil (South America).

Bothrops asper (Garman, 1883) is known as the X-shaped viper in Panama and is considered the most common venomous snake (Batista & Miranda, 2020). It stands out for its generally aggressive temperament among all Viperidae and is the species that produces the largest amount of venom in Central America (Bolaños, 1982b). Up to 50 % of snakebite cases are attributed to *B. asper* in the region (Instituto Clodomiro Picado, 2009). It is distributed along the Atlantic slope, ranging from Tamaulipas, Mexico, south through Central America to northern Colombia, northern Venezuela, and the island of Trinidad. On the Pacific

slope, it can be found from Chiapas, Mexico, through Guatemala, and from northwestern Costa Rica down to northern Peru (Campbell & Lamar, 2004; Acosta-Chávez et al., 2015), in Mexico it is distributed from 0 to 1,400 m a.s.l. (Batista et al., 2020).

On August 12, 2021, at 11:56 h in Coclesito, Province of Colón, central Caribbean slope of the Republic of Panama (coordinates: 8.81521° N, 80.55565° W) (Fig. 1), a 1.60 m long *Bothrops asper* was found during a road clearing. The snake was rescued using a hook, tongs and a Snake Bagger's triangular frame, following all safety measures, and subsequently relocated to a safe place. During the rescue, the snake released cloacal fluids (defecation) when being held to place it in the herpetological bag. Upon reaching the relocation site and removing the snake from the bag, it showed Tonic Immobility (TI), Stiffness (ST), Contortions (C), Supination (S) and not responding to repeated stimuli near its head with the herpetological tongs. This led biologists to think it was dead. However, upon turning it over, the snake came out of thanatosis completely and withdrew from the area, the event last about 40 seconds (Appendix 1).

Bothrops asper shows a variety of distinctive behaviors that highlight it as a successful predator. When it feels threatened, it can respond aggressively and has a high tendency to bite (Bolaños, 1982a; Villalobos, 2008). It has a color pattern that allow it to camouflage in its natural environment to hunt, injecting their venom and subsequently tracking the wounded prey (Sasa et al., 2019). Furthermore, its defensive behavior includes actions such as raising and curling the front part of its body in an "S" shape, adopting a posture that allows it to be ready to attack and emitting a loud hiss as a warning before attacking (Bolaños, 1982a; Villalobos, 2008; Sasa et al., 2019), and shakes its tail or taps it against the ground as a warning (video in https://youtube.com/shorts/wVIROlPjpfw?feature=share, minute 1:12). Greene (1988) mentions that *B. asper* also employs various defensive strategies to avoid conflict and deter predators, such

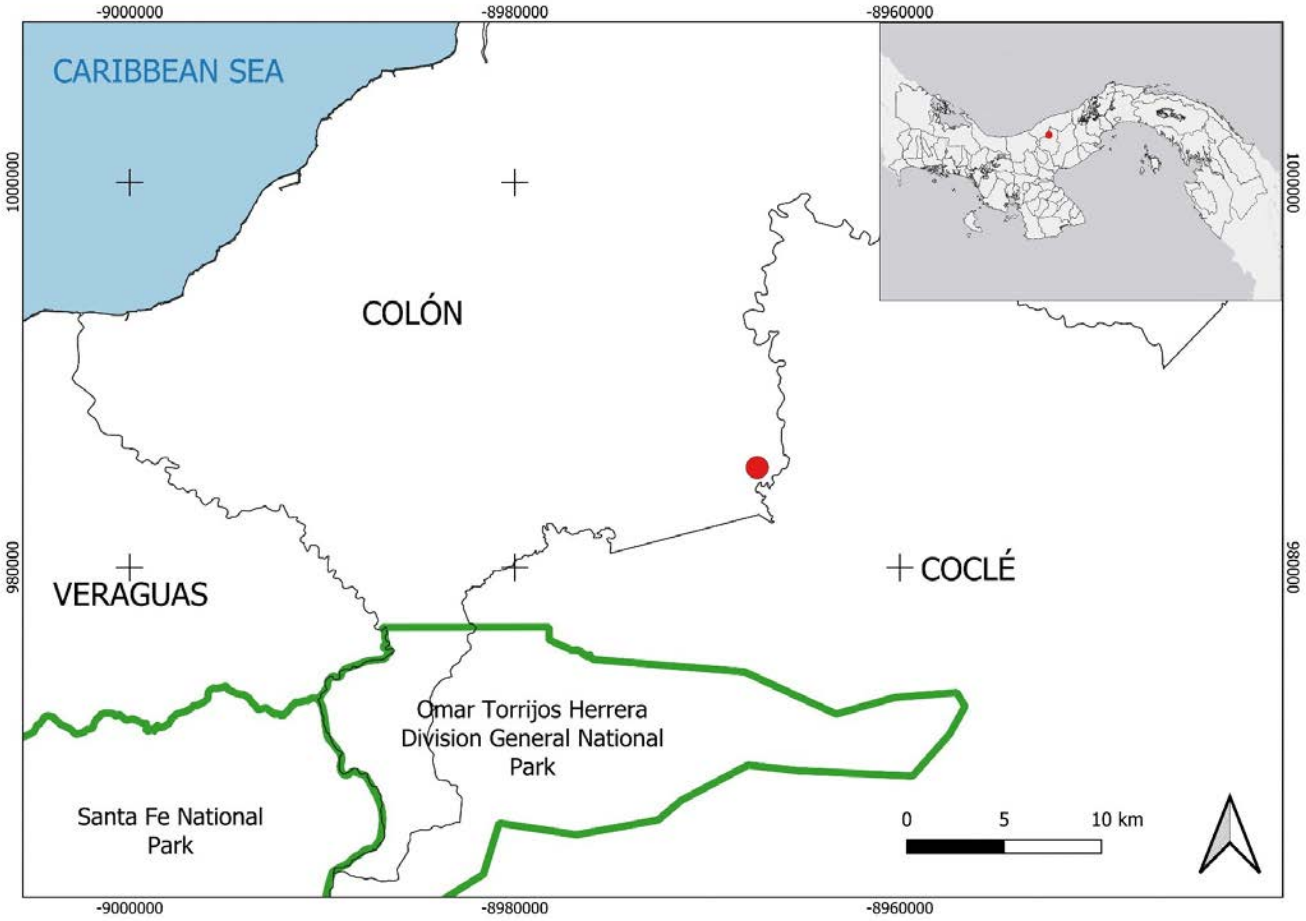

Figura 1. Mapa que muestra la ubicación del evento de tanatosis en *Bothrops asper*. /**Figure 1.** Map showing the location of the thanatosis event in *Bothrops asper*.

as tail vibrations, preemptive strikes, or aggressive defensive tactics, further reinforcing its position as a formidable predator in its habitat.

With so many strategies and qualities, is it necessary to play dead? We believe that this event was caused by the interaction between the rescue biologists and the snake as a predator-prey, similar to what was proposed by Humphreys and Ruxton (2018) and Fuentes et al. (2021), that circumstances such as the presence of a nearby predator, the intensity of the attack and the lack of escape possibilities, can affect the decision of whether or not to adopt thanatosis and the possible costs and benefits that it represents for the snake, since it can increase the chances of survival by preventing predators from finding and attacking them. However, immobility and lack of response might not work in some situations, and using this strategy prevents the snake from exhibiting other behaviors that could save it. In addition, the strategy might work with some specific predators but would expose the snake to different predators. Durso & Smith (2018) They emphasize that the complexity of snake behavior, along with various genetic and environmental factors, influences their evolution. They conclude that this defensive behavior arises from the intricate interactions between genetics, the environment, and the selective pressures faced by the species.

Evidence of this behavior in snakes in the wild is scarce and most cases were witnessed and documented in species in captivity or in controlled situations (dos Santos & Da Silva Muniz, 2012). This is the first case documented on video of thanatosis in the species *Bothrops asper* and the third for the genus *Bothrops* on the American continent.

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APPENDICES

Apéndice 1. Video del comportamiento de tanatosis en *Bothrops asper* registrado en Coclesito, Provincia de Colón, Panamá. https://youtube.com/shorts/wVIROlPjpfw?feature=share

Appendix 1. Video of thanatosis behaviour in *Bothrops asper* recorded in Coclesito, Province of Colón, Panama. https://youtube.com/shorts/wVIROlPjpfw?feature=share

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ESTADO ACTUAL DEL CONOCIMIENTO DEL ESCORPIÓN CHIAPANECO (*HELODERMA ALVAREZI*) Y PERSPECTIVAS DE SU CONSERVACIÓN

CURRENT STATE OF KNOWLEDGE AND CONSERVATION PERSPECTIVES OF THE BLACK BEADED LIZARD (*HELODERMA ALVAREZI*)

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Abstract.— The lizard *Heloderma alvarezi* lives in southeastern Mexico (Guerrero, Oaxaca and Chiapas) and part of Guatemala. For many years this species went unnoticed in the eyes of science, as several years passed since its description before researchers resumed studying this enigmatic reptile. Therefore, many aspects of the species' biology and ecology are unknown. The objective of this work focuses on collecting the authors' own information and published literature in order to identify the problems that the species faces, generating supporting literature for future conservation studies. *Heloderma alvarezi* occupies less than 5 % of the Mexican national territory. Currently there is no risk category in Mexican standards for *H. alvarezi*, so this study proposes for the first time, based on specific criteria, assigning a category for this species.

Keywords.— Central depression, state of knowledge, Helodermatidae, natural history, risk category, vulnerability.

Resumen.— *Heloderma alvarezi* es una especie de lagarto que habita el sureste mexicano (Guerreo, Oaxaca y Chiapas) y parte de Guatemala. Durante mucho tiempo esta especie pasó desapercibida a los ojos de la ciencia, ya que desde su descripción transcurrieron varios años antes que los investigadores retomaran el estudio de este enigmático reptil. Por lo que muchos aspectos de su biología y ecología son desconocidos. Debido a ello el objetivo de este trabajo se centra en recopilar información con la finalidad de identificar las problemáticas que la especie afronta, generando literatura de apoyo para futuros estudios de conservación. *Heloderma alvarezi* ocupa menos del 5 % del territorio nacional mexicano y no tiene una categoría de riesgo en las normas mexicanas, por lo que se propone por primera vez con base a criterios específicos asignar una categoría a esta especie

Palabras clave.— Categoría de riesgo, depresión central, estado del arte, Helodermatidae, historia natural, vulnerabilidad.

En México los helodermátidos son quizás uno de los grupos menos comprendidos y estudiados, al mismo tiempo de ser uno de los más estigmatizados por las personas, ocasionando daños en las poblaciones y desafíos para su conservación en vida libre (Domínguez et al., 2017). Actualmente la familia se encuentra conformada por cinco especies (Reiserer et al., 2013; García-Grajales et al., 2021), de entre los cuales *Heloderma alvarezi* es una de las especies menos estudiadas, lo que ha traído grandes afectaciones en su conservación, ya que desde su descripción por Bogert y Del Campo (1956) y algunas publicaciones realizadas a finales del siglo XX, dejaron de realizarse investigaciones sobre esta especie (Alagón et al., 1892; Ramírez & Guichard, 1989; Álvarez del Toro, 1972). Durante muchos años diferentes aspectos de la biología y ecología de *H. alvarezi* permanecieron desapercibidos por la ciencia, no fue sino hasta 20 años después cuando dio inició la elaboración de nuevos estudios

que retomaron el estudio de esta especie (Ariano, 2013; Aranda-Coello et al., 2019; García-Grajales et al., 2020, 2021; Gómez-Cruz et al., 2021; Reyes et al., 2022; Gómez, 2023). Sin embargo, gran parte de los estudios se han enfocado en analizar patrones de distribución (Domínguez-Vega et al., 2012; Ariano, 2013; García-Grajales et al., 2020, 2021; Gómez-Cruz et al., 2021).

Las investigaciones para comprender diferentes aspectos de la biología (comportamiento, distribución, temperatura y ecología térmica) de esta especie se han desarrollado cada vez con mayor frecuencia (Ariano, 2013: Aranda-Coello et al., 2019; García-Grajales et al., 2020; Gómez-Cruz et al., 2021; Gómez, 2023), sin embargo, aún falta mucho por conocer y sobre todo hace falta generar estrategias para su conservación. Derivado de la problemática que la falta de estudios ocasiona en la conservación de las especies (Reiserer et al., 2013; Mata-Silva et al., 2015; Domínguez-Vega et al., 2017; Barragán-Vázquez et al., 2022). El objetivo principal de este trabajo se centra en recopilar información publicada de *H. alvarezi* e identificar las problemáticas que histórica y actualmente afronta, generando una literatura de apoyo para futuros estudios de conservación. Para ello se buscó la literatura publicada en plataformas electrónicas como Google académico, Scince Direct, Scielo, Researchgate, además de observaciones propias de los autores.

Conociendo al Escorpión chiapaneco

El escorpión chiapaneco, escorpión negro, escupión, lagarto bufador o me'us (en lengua tzotzil) son algunos de los nombres vernáculos con los que se le conoce a *Heloderma alvarezi* (Fig. 1). Anteriormente la especie era considerada como una subespecie de *H. horridum*, siendo quizás una de las principales causas de la falta de estudios, no fue sino hasta que Reiserer et al. (2013) proponen elevarlo a categoría de especie (Tabla 1).

Figure 1. Two adult males of *Heloderma alvarezi* fighting during the breeding season. Photo: Aarón Gómez Cruz

Figura 1. Dos machos adultos de *Heloderma alvarezi* peleando durante la temporada de reproducción. Foto: Aarón Gómez Cruz.

Morfológicamente *H. alvarezi* es igual al resto de helodermátidos, diferenciándose principalmente por poseer una coloración totalmente negra en su etapa adulta, a diferencia del resto de especies que suelen tener patrones de pigmentación (en diferentes tonalidades de amarillo y naranja) durante toda su vida, *H. alvarezi* únicamente presenta este patrón durante los primeros años de vida y gradualmente va perdiéndolo.

Debido a la complejidad del grupo, en un principio *H. exasperatum*, *H. alvarezi* y *H. charlesbogerti* eran considerados como subespecies de *H. horridum*, por lo que no se conocía de manera específica los límites de distribución de cada una de las hasta entonces subespecies. La distribución conocida hasta entones sugería que *H. alvarezi* se distribuía principalmente en la Depresión Central de Chiapas, México desde el municipio de Arriaga hasta su continuación en Huehuetenango, Guatemala, creyéndose que se encontraba restringido a esta región geográfica (Álvarez del Toro, 1972; Ariano, 2013; Gómez-Cruz et al., 2021). A pesar de que Campbell y Vanninni (1988) plantearon que existían zonas de integración entre *H. alvarezi* y *H. horridum* en la región del Istmo de Tehuantepec, Oaxaca, no se realizaron esfuerzos para comprobar dicha hipótesis. No fue sino hasta años recientes cuando se tuvo el registro de *H. alvarezi* en las costas de Oaxaca y en la parte baja de Guerrero (García-Grajales et al., 2020, 2021), modificando la idea sobre la ocupación de la especie, planteando nuevas incógnitas y generando debates entre los investigadores (Fig. 2).

Dentro de todo esto cabe preguntarse si los nuevos registros en sitios tan distantes de lo conocido hasta el momento corresponden a una ampliación en la distribución ya sea de forma continua o disyunta, y de ser así ¿cómo se encuentran genéticamente emparentadas estas poblaciones? o bien si estos registros corresponden a individuos de *H. horridum* con un incremento en el melanismo. Aunque es un fenómeno poco usual, se han llegado a avistar individuos de *H. horridum* con una pigmentación en su mayoría de color negro (Bogert & Martín del Campo, 1956), por lo que sería importante considerar si existen cambios en la lepidosis (disposición y orden de las escamas) o a nivel genético, más allá de la pigmentación que permitan diferenciar a los individuos de ambas especies.

Se sabe que la distribución del escorpión chiapaneco ocurre principalmente en selvas bajas caducifolias y en sitios con buen estado de conservación, preferentemente a elevaciones de entre 400 y 1,000 m s.n.m., con temperaturas durante la temporada cálida entre los 28 y 30 °C y precipitaciones entre los 110 y 120 mm; lo que los hace excelentes bioindicadores de la calidad del hábitat (Ariano, 2013; Domínguez-Vega et al., 2017; Gómez, 2023). Sin embargo, aún hace falta mucho esfuerzo para conocer detalladamente cuales son los requerimientos específicos que esta especie necesita para poder persistir (e.g. ámbito hogareño, requerimientos térmicos y reproductivos, uso de hábitat, etc.). Esta información es imprescindible para desarrollar estrategias de conservación, ya que como muchos otros reptiles *H. alvarezi* se encuentra en una carrera de supervivencia contra el cambio climático, pues se espera que en escenarios futuros la distribución se reduzca de manera alarmante hacia el 2050 (Sinervo et al., 2010; Gómez-Cruz et al., 2021). Lamentablemente el cambio climático no es la única amenaza para el escorpión chiapaneco, ya que factores como la cacería, pérdida de hábitat, agricultura y tráfico comprometen la permanencia de esta especie.

Vulnerabilidad del escorpión chiapaneco

Actualmente en México las selvas bajas son uno de los ecosistemas más amenazados y con mayor pérdida de biodiversidad, anteriormente comprendían cerca del 10.8 % de la vegetación del país, sin embargo, debido a las actividades antrópicas se estima que la vegetación original es menor al 5 % (Maass, 1995; Ceballos & García, 1996; Massera et al., 1997; Trejo & Dirzo, 2000; Rickers et al., 2007; Rocha-Loredo et al., 2010). Convirtiéndose en un mosaico entre remanentes de vegetación primaria, vegetación sucesional, agricultura y ganadería; y debido al ámbito hogareño relativamente amplio de los helodermátidos (21.6 - 75.9 ha), el desplazamiento entre estos parches aumenta la probabilidad

Table 1. Taxonomic history of the genus *Heloderma*. / **Tabla 1.** Historia taxonómica del género *Heloderma*.

Wiegmann (1829) descripción del género y especie		Cope (1869) descripción de otra especie	Bogert y Del Campo (1956) descripción de subespecies	Campbell y Vannini (1988) descripción de nueva subespecie	Reiserer et al. (2013) recategorización de subespecies a especies
Heloderma	*H. horridum*	*H. suspectum*	*H. h horridum* *H. h exasperatum* *H. h alvarezi*	*H. h charlesbogerti*	*H. horridum* *H. exasperatum* *H. alvarezi* *H. charlesbogerti*

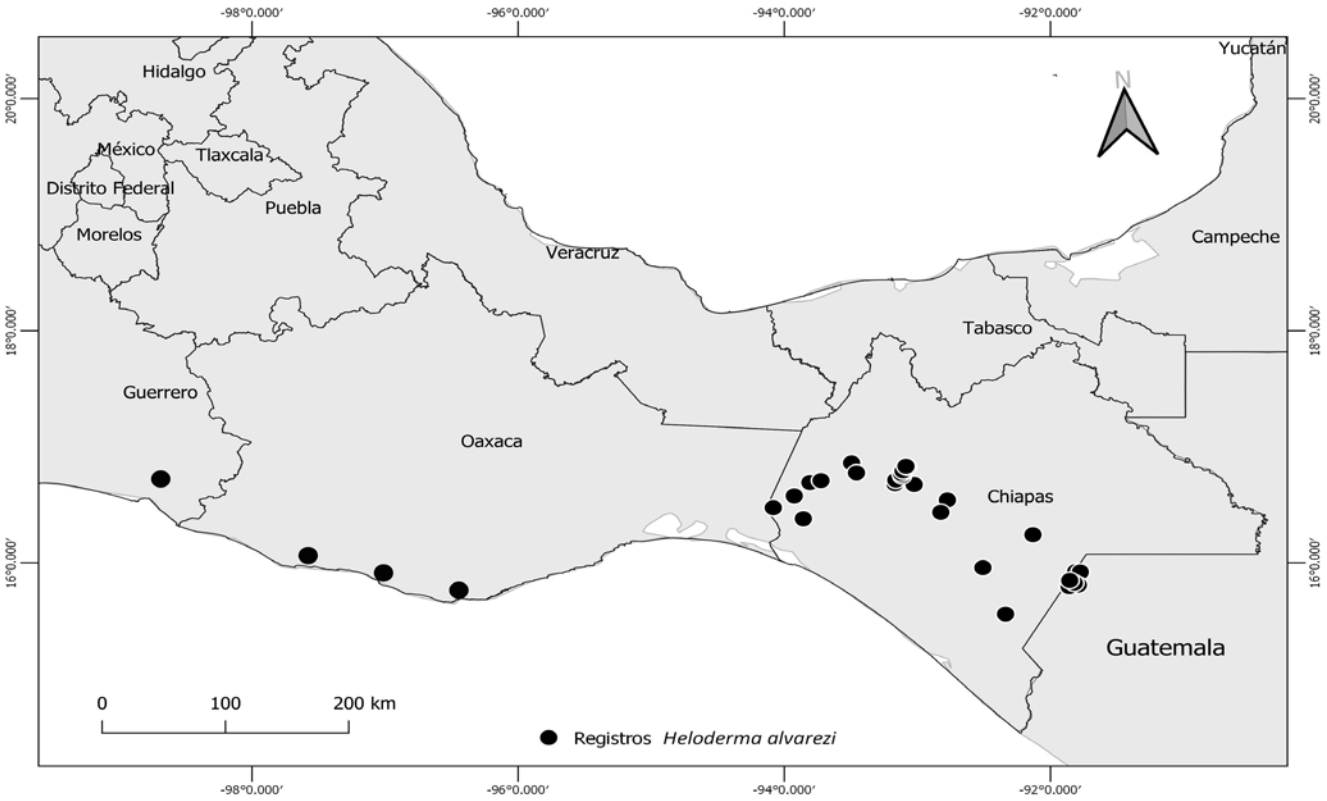

Figure 2. Ocurrence records of *Heloderma alvarezi*, with those from Oaxaca and Guerrero being the most recent.

Figura 2. Registros de presencia de *Heloderma alvarezi*, siendo aquellos de Oaxaca y Guerrero los más recientes.

de avistamientos, y con ello el riesgo de cacería aversiva (Beck & Lowe, 1991; Rodríguez et al., 2019; Ariano-Sánchez et al., 2020). Ya que gran parte de la distribución del escorpión chiapaneco se encuentra fuera de las Áreas Naturales Protegidas (ANP's), y únicamente cerca del 4.2 % se encuentra dentro de ellas, siendo el Parque Nacional Cañón del Sumidero el que integra una mayor parte de la distribución (Gómez-Cruz et al., 2021). Por otra parte, en distintas regiones de la depresión central de Chiapas donde no hay ningún tipo de protección cada año durante los meses de enero a marzo ocurren incendios con fines agrícolas, los cuales en la mayoría de las ocasiones llegan a salirse de control. El uso de estas prácticas tan invasivas indiscutiblemente pone en riesgo a las poblaciones de *H. alvarezi*, pues al tratarse de un reptil que tiene una capacidad de desplazamiento limitada (3.5 m/min) (Beck & Lowe, 1996) puede llegar a quedar atrapado dentro de estos incendios. Sin mencionar que los huevos son particularmente sensibles a cambios ambientales externos, y las elevadas temperaturas ambientales y de los incendios pueden afectar considerablemente la viabilidad de los huevos (Beck & Lowe, 1996; Ariano & Salazar, 2015).

El efecto de la actividad humana ha tenido repercusiones en algunas poblaciones de *H. charlesbogerti*, conduciéndolas a presentar una baja diversidad genética y alto grado de endogamia indicando efecto de cuello de botella para algunas poblaciones pese a las medidas de conservación implementadas. La pérdida de diversidad genética representa un riesgo alto para la especie ya que esto podría traer consecuencias en la adaptación frente a escenarios como el cambio climático, pérdida de hábitat, nicho térmico (Schrei, 2014; González, 2016; Andrade et al., 2017). Lo anterior representa un desafío en la implementación de estrategias que permitan incrementar la diversidad genética de la especie.

Es bien sabido que los helodermátidos sufren una presión muy fuerte por parte de la cacería aversiva, hasta el momento en Chiapas se ha reportado que el municipio de Villaflores es uno de los lugares que presentan los valores más elevados de cacería (Domínguez-Vega et al., 2017; Reyes et al., 2022). Sin embargo, es probable que lo mismo ocurra a lo largo de toda la distribución de la especie, ya que mediante observaciones directas se

han registrado las mismas actividades en las localidades de Venustiano Carranza, El Parral y Emiliano Zapata, donde se cree que estos organismos son extremadamente venenosos. Entre algunas de las creencias más populares se ha llegado a decir que a pesar de cortar a los individuos por la mitad, los sapos llegan en la noche y los lamen, haciendo que el individuo reviva y pueda escapar, por lo que la única forma efectiva de matarlos es clavándolos en el suelo con una estaca (Fig. 3a). Asimismo, al creerse que son capaces de escupir su veneno, se han llegado a confundir algunas ovoposiciones de algunos invertebrados con la saliva del escorpión (Fig. 3b).

Categoría de riesgo

Otra de las actividades que comprometen a las poblaciones del escorpión chiapaneco es el tráfico ilegal, razón por la que se encuentra en el apéndice dos del CITES, pues en algunas localidades de Chiapas se han tenido reportes sobre el comercio directo de compradores con algunos campesinos (*com. pers.*). Como se mencionó en un principio, durante mucho tiempo el escorpión chiapaneco permaneció como una subespecie de *H. horridum*, por lo que no estaba clasificado bajo ninguna categoría de riesgo en la norma mexicana (NOM-059-SEMARNAT-2010). Actualmente, pese a los nuevos trabajos publicados, *H. alvarezi* aún carece de una categoría propia, ya que se sigue tomando en cuenta a *H. horridum* como referencia. Debido a esto se considera justificable proponer que *H. alvarezi* sea atendida bajo una categoría propia dentro de la Norma Oficial Mexicana (NOM-059SEMARNAT-2010), dado que la especie cumple con los criterios definidos por el Método de Evaluación del Riesgo de Extinción de las Especies Silvestres en México (MER) (Sánchez-Salas et al., 2013). El MER es una herramienta que se aplica exclusivamente en México y se encarga de cuantificar de forma sencilla los factores que afectan a una especie en el país.

Figure 3. a) Common practice of hunting *Heloderma alvarezi* to prevent the individual from reviving and escaping. b) Oviposition of some invertebrates that in regions of Chiapas are often mistaken for saliva from the black beaded lizard. Photos: Aarón Gómez Cruz.

Figura 3. a) Práctica común de sacrificio de *Heloderma alvarezi*, para evitar que el individuo reviva y escape. b) Oviposiciones de algunos invertebrados que en regiones de Chiapas suele ser confundida con la saliva del escorpión. Foto: Aarón Gómez Cruz.

Estos factores son ampliamente reconocidos por incrementar la tendencia o vulnerabilidad a la extinción; y se encuentra constituido por cuatro criterios, tres de los cuales consideran la biología e historia natural de la especie, mientras que el ultimo básicamente se enfoca en la interacción con el hombre (SEMARNAT, 2010). Dicha sugerencia de categorización se basa en que *H. alvarezi* presenta las siguientes características: una distribución muy restringida (4 puntos de 4) abarcando menos del 5 % del territorio nacional mexicano; un hábitat intermedio o limitante (2 puntos de 3) con respecto a los requerimientos para el desarrollo natural de la especie, debido a su restricción a las selvas bajas caducifolias. Una vulnerabilidad media (2 puntos de 3) intrínseca a la biología de la especie, la cual requiere de grandes extensiones de hámbito hogareño, pero permite que la especie persista en bosques fragmentados y perturbados; y un alto impacto (4 puntos de 4) por parte de los humanos sobre la especie debido a la presión de las actividades agrícolas y ganaderas, la fragmentación del hábitat, la cacería aversiva, el comercio y tráfico ilegal de la especie. Con base a los criterios del MER aquellas especies con una puntuación de entre 12 y 14 puntos son consideradas es peligro de extinción (P); por lo que con base a la evaluación generada y con un valor de 12 puntos se plantea que *H. alvarezi* sea considerada como una especie en peligro de extinción.

Estudios más recientes como el de Reiserer et al. (2013) evalúan a *H. alvarezi* y le otorgan un Environmental Vulnerability Score (EVS) de 15 dentro de la clasificación de Wilson et al., (2013), siendo una especie con alta categoría de vulnerabilidad después de *H. horridum* y *H. charlesbogerti* (EVS= 17). Y posteriormente Aranda-Coello y Gómez-Cruz (2021) asignan a *H. alvarezi* en la categoría de vulnerable (Vu) en la lista roja de especies amenazadas de la Unión Internacional para la Conservación de la Naturaleza (IUCN, por sus siglas en ingles). Esto indiscutiblemente reafirma la necesidad de comenzar a realizar acciones que mitiguen el impacto hacia las poblaciones, siendo la base de toda estrategia un robusto entendimiento de la especie, así como la aplicación de las herramientas disponibles para hacer factibles los esfuerzos de conservación; por lo que la próxima década es clave para la implementación de estrategias destinadas a la preservación de la especie *in situ*.

Desafortunadamente en México y principalmente en Chiapas las estrategias implementadas para la conservación de *H. alvarezi* son sumamente escasas por lo que la presión sobre esta especie aún es latente, pues aún falta mucho por conocer sobre la biología del escorpión chiapaneco. En Guatemala Ariano-Sánchez (2003) integró a pobladores locales en los monitoreos realizados con el escorpión guatemalteco (*H. charlesbogerti*), posteriormente Ariano (2013) volvió a incluir a pobladores locales en su estudio con *H. alvarezi*, obteniendo resultados positivos tanto para el estudio como en la percepción de los pobladores sobre la especie, demostrando que esta actividad favorece a la conservación de estos saurios. Es por ello, que la divulgación de resultados obtenidos mediante investigaciones científicas con personas no involucradas en ese ámbito juega un papel importante para sentar las bases de la conservación y puede cambiar la desinformación que se tiene hacia los reptiles, ya que las personas que cohabitan e interactúan con estos organismos son la clave para que los planes de conservación tengan resultados favorables.

Claramente algunos de los requerimientos esenciales para la conservación de *H. alvarezi* se encuentran en la preservación de las selvas bajas caducifolias, así como en la participación de las Áreas Naturales Protegidas (ANP's) quienes incluso pueden utilizar a este fascinante reptil como una especie bandera. Brindando así la posibilidad de realizar estudios de investigación a largo plazo que nos permitan entender mejor los requerimientos biológicos para la especie y la viabilidad de las poblaciones. Por otra parte, una de las acciones que puede tener mayor impacto y resultados favorables en la conservación de esta especie se encuentra directamente asociada con la aplicación de programas de educación ambiental. De esta manera es posible generar sincretismo entre los pobladores disminuyendo así la frecuencia de cacería aversiva, funcionando como una herramienta importante que coadyuve en la permanencia de la especie.

CONCLUSIONES

Dada la falta de estudios realizados y publicados, cualquier esfuerzo por enriquecer el conocimiento del escorpión chiapaneco es esencial para los trabajos de investigación y conservación. Es necesario estudiar profundamente el tamaño de las poblaciones para reconocer el efecto de la cacería aversiva, para prevenir que ocurra un efecto de cuello de botella, ya que esta actividad puede traer efectos negativos en la variabilidad genética de las poblaciones, además de conocer el uso y el papel que cumple esta esta especie dentro del territorio que habita. Indiscutiblemente la divulgación de la información disponible con los pobladores locales de los sitios donde se encuentra la especie es crucial en la formación de concientización y consecuentemente la cooperación para su conservación. Además de ello es necesaria la participación de sectores gubernamentales y académicos para consolidar esfuerzos con las comunidades y asegurar el éxito de las diferentes estrategias de conservación.

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NOTES ON THREATS AND NEW RECORDS OF *KINOSTERNON INTEGRUM* (TESTUDINES: KINOSTERNIDAE)

NOTAS SOBRE AMENAZAS Y NUEVOS REGISTROS DE *KINOSTERNON INTEGRUM* (TESTUDINES: KINOSTERNIDAE)

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Resumen.– *Kinosternon integrum* es una especie nativa de México con amplia distribución. Sin embargo, a pesar de su abundancia la información sobre sus aspectos demográficos, historia natural y amenazas es escasa. Reportamos 18 nuevos registros de *K. integrum* en los estados de Oaxaca y Puebla. En estos datos se destacan amenazas como la contaminación de hábitats acuáticos remanentes y la extracción ilegal, la cual aún no ha sido considerada en las evaluaciones de riesgo para la especie.

Palabras clave.–Distribución geográfica, extracción ilegal, México, Oaxaca, Puebla, tortuga de agua dulce.

Abstract.– The Mexican mud turtle, *Kinosternon integrum*, is a native Mexican species with a wide distribution. However, despite its abundance, information on its demographics, natural history, and threats is scarce. We report 18 new records of *K. integrum* in the states of Oaxaca and Puebla. These data highlight threats such as contamination of remaining aquatic habitats and illegal extraction, which have not yet been considered in risk assessments for the species.

Key words.–Freshwater turtle, geographic distribution, illegal extraction, Mexico, Oaxaca, Puebla.

The Mexican mud turtle, *Kinosternon integrum* (Le Conte, 1854), is one of the largest species of the genus *Kinosternon* (Spix, 1824) in Mexico, with maximum adult sizes of 210 mm for males and 196 mm in females (Legler & Vogt, 2013). It is characterized by an elongated carapace ranging from pale tan to dark brown, head shield is large and spotted, mottled, triangular, or bell shaped, and posterior margin is convex, and skin is smooth (Iverson et al., 1998; Legler & Vogt, 2013). This species is native to Mexico and has a wide distribution from Sonora and Chihuahua through the Pacific slope and Central Mexico to the Río Verde in Oaxaca, from sea level to 2,545 m a.s.l. (Iverson et al., 1998; Legler & Vogt, 2013). Additionally, Luja et al. (2007) reported human introduction of the species in the state of Baja California Sur.

Despite its wide distribution and abundance, information on the demographic aspects and natural history of *K. integrum* is scarce (Iverson et al., 1998; Macip-Ríos et al., 2009; 2011). In Puebla, this species has been recorded in three of six physiographic regions, with no records in the Gulf Coastal Lowlands, Sierra Madre Oriental, and Sierra Madre del Sur (Woolrich-Piña et al., 2017). In Oaxaca, *K. integrum* is found in eight of the 12 physiographic regions, with no records

in the Montañas y Valles del Centro, Depresión Ístmica de Tehuantepec, Sierra Madre de Chiapas, and Planicie Costera del Pacífico (Ortiz-Pérez et al., 2004; Martínez-Coronel et al., 2021; Mata-Silva et al., 2021).

The species is considered of Least Concern by the IUCN (van Dijk et al., 2007) and under special protection (Pr) by Mexican laws (SEMARNAT, 2019). This mud turtle inhabits lentic temporary and permanent aquatic habitats, including slow-moving streams and temporary ponds (Legler & Vogt, 2013). As a freshwater species, it faces multiple threats to population stability, such as contamination of water bodies and habitat loss due to human actions (Dudgeon et al., 2006). The IUCN considers habitat loss and its edible use as part of their threats in the State of Mexico (van Dijk et al., 2007). However, illegal extraction is not considered one of the causes of population decline. Here, we report new municipal distribution records and describe the contamination in the remnants of their aquatic habitats. We also

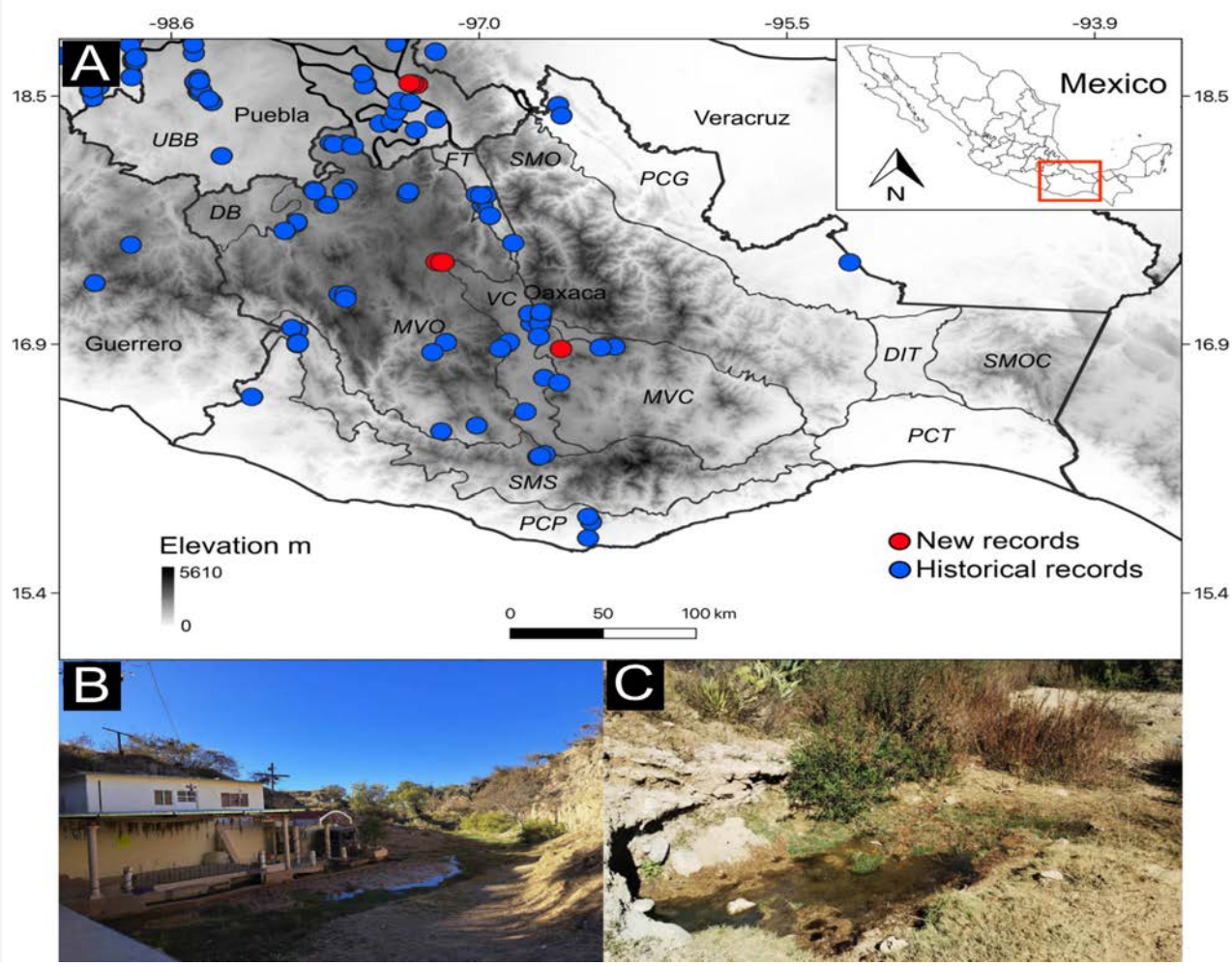

Figura 1. Registros y habitats de *Kinosternon integrum*. a) Mapa de los registros; b) Arroyo en Asunción Nochixtlán, Oaxaca. Foto: Medardo Arreortúa; c) Estanque natural en Tehuacán, Puebla. Foto: César Orozco. Las subprovincias fisiográficas que se muestra son Depresión del Balsas (DB), Montañas y Valles del Occidente (MVO), Fosa de Tehuacán (FT), Sierra Madre de Oaxaca (SMO), Valles Centrales de Oaxaca (VCO), Montañas y Valles del Centro (MVC), Sierra Madre del Sur (SMS), Planicie Costera del Pacífico (PCP), Planicie Costera de Tehuantepec (PCT), Depresión del Istmo de Tehuantepec (DIT), Sierra Madre del Sur de Oaxaca y Chiapas (SMOC), Planicie Costera del Golfo (PCG), y Upper Balsas Basin (UBB).

Figure 1. Records and habitats of *Kinosternon integrum*. a) Map of the records; b) Stream in Asunción Nochixtlán, Oaxaca. Photo: Medardo Arreortúa; c) Natural pond in Tehuacán, Puebla. Photo: César Orozco. The physiographic subprovinces shown are Depresión del Balsas (DB), Montañas y Valles del Occidente (MVO), Fosa de Tehuacán (FT), Sierra Madre de Oaxaca (SMO), Valles Centrales de Oaxaca (VCO), Montañas y Valles del Centro (MVC), Sierra Madre del Sur (SMS), Planicie Costera del Pacífico (PCP), Planicie Costera de Tehuantepec (PCT), Depresión del Istmo de Tehuantepec (DIT), Sierra Madre del Sur de Oaxaca y Chiapas (SMOC), Planicie Costera del Golfo (PCG), and Upper Balsas Basin (UBB).

present data on illegal extraction as one of the main threats to *K. integrum* in the states of Oaxaca and Puebla, Mexico.

During January 2022 and May 2023, monitoring was conducted in the municipalities of San Juan Teitipac, Asunción Nochixtlán (Oaxaca), and Tehuacán (Puebla) in Mexico. The surveyed areas included xerophilic scrub (INEGI, 2019) and water bodies. For some specimens, we recorded carapace length (CL), carapace width (CW), plastron length (PL), plastron width (PW), and mass (g) following da Silva et al. (2021). In some cases, it was impossible to record these information. The sex of each specimen was determined according to Legler and Vogt (2013). Coordinates and elevation were recorded at each observation point using a GPS (Garmin GPSMAP 65). Photographs of the specimens were deposited in the Colección Nacional de Anfibios y Reptiles (CNAR), Instituto de Biología, UNAM.

We used the rgbif package (Chamberlain et al., 2024) to obtain previous vouchered records of *K. integrum* (GBIF, 2024). Duplicate records and records without coordinates were removed using the CoordinateCleaner package (Zizka et al., 2019). Both analyses were conducted in R version 4.3.2 (R Core Team, 2023). Additionally, we include records obtained from the literature (De La Torre-Loranca et al., 2020; Martínez-Coronel et al., 2021) to generate a map (Fig. 1) using QGIS version 3.34 (QGIS Development Team, 2023). We calculate the distance between our records and historical records in km.

We found 849 previous records of *K. integrum* throughout its distribution range, with only 6.4% (55 records) corresponding to the state of Oaxaca and 3.4% (29 records) to Puebla (Fig. 1). It is important to highlight that our review is based on historical records of organisms within biological collections, which supports their identification. We detected that the species is distributed in Oaxaca, in the upper part of the Planicie Costera del Pacífico specifically in the municipality of San Pedro Pochutla according to records from the University of Colorado Boulder, Museum of Natural History (UCM 48857) and the University of Illinois, Museum of Natural History (UIMNH 9975). Regarding the records from Veracruz, we considered the organisms collected (ITSZ-R 250; MZFZ-IMG 194) by De La Torre-Loranca et al. (2020).

Here, we report 18 new records of *K. integrum* (Table 1). In Oaxaca, for the municipality of San Juan Teitipac (Fig. 2A), our records are located more than 14 km from the closest historical record (Herpetological Collection [ENCB] 16653). These records were found near a water pan for agricultural use, as well as crops, cornfields, and vegetable plots. In Asunción Nochixtlán, our new records are located approximately 40 km away from the nearest record (University of Michigan Museum of Zoology [UMMZ] 13205) (GBIF, 2024). These records were found in streams with xerophilous scrub in agricultural areas and as pets on private properties in surrounding areas (Fig. 2B, C, D).

In Puebla, our records in the municipality of Tehuacán are located more than 8 km from the closest published record, which dates back to 1939 and 1940 (GBIF, 2024). These were found in three different habitats: permanent streams, permanent and temporary natural ponds. We also observed a similar practice of keeping turtles as pets in captivity (Fig. 2E, F).

Kinosternon integrum inhabits nearby lentic temporary and permanent aquatic habitats, such as slow-moving streams and temporary ponds (Iverson, 1999; Legler & Vogt, 2013). These habitats are often surrounded by human-modified matrices that have been fragmented due to water extraction for crops and stone material mining (Berriozabal-Islas et al., 2023).

Additionally, we detected two serious threats to the populations of *K. integrum*. First, our records were found in areas with constant human activity (Fig. 1B). Considering that habitat disturbance and loss are the main causes of biodiversity loss, especially for freshwater environments (Harrison et al., 2018), the vulnerability of their populations increases. Secondly, during our field work, we observed people searching for and extracting turtles, a common practice for keeping them as pets. Due to their nocturnal and twilight habits, low mobility, high philopatry (Iverson, 1991; Tuma, 2006), and small home ranges (Slavenko et al., 2016), *K. integrum* is particularly prone to being captured by humans (Berriozabal-Islas et al., 2023). Although this extraction is not included in current risk assessments, it is a recurring practice in Mexico. Therefore, we highlight the need to increase research efforts in the remaining habitat of this species. These new records help to understand the processes of colonization and enhance our knowledge of the geographic range and biogeographic history of the species (Zunino & Zulini, 2003), as well as consider a broader perspective on the threats they face.

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Table 1. Datos de especímenes de *Kinosternon integrum* registrados en Oaxaca y Puebla, México. CL = Longitud del caparazón, CW = Ancho del caparazón, PL = Longitud del plastrón, y PW = Ancho del plastrón.

Tabla 1. Data of specimens of *Kinosternon integrum* recorded in Oaxaca and Puebla, Mexico. CL = Carapace length, CW = Carapace width, PL = Plastron length, and PW = Plastron width.

ID	Voucher	State	Municipality	Date	Coordinate	CL (mm)	CW (mm)	PL (mm)	PW (mm)	Mass (g)	Observation
1	CNAR-RF 962	Oaxaca	San Juan Teitipac	14/01/22	16.9121 °N, 96.6107 °W	127	82	116.3	75	353	Water pan for agricultural use; female
2	CNAR-RF 963	Oaxaca	San Juan Teitipac	14/01/22	16.9121 °N, 96.6107 °W	144	98	129	92	472	Water pan for agricultural use; male
3	CNAR-RF 964	Oaxaca	Asunción Nochixtlán	21/05/23	17.4473 °N 97.2086 °W	_	_	_	_	_	In captivity as pet
4	CNAR-RF 965	Oaxaca	Asunción Nochixtlán	21/05/23	17.4473 °N 97.2086 °W	_	_	_	_	_	In captivity as pet
5	CNAR-RF 966	Oaxaca	Asunción Nochixtlán	21/05/23	17.4473 °N 97.2086 °W	_	_	_	_	_	In captivity as pet
6	CNAR-RF 967	Oaxaca	Asunción Nochixtlán	21/05/23	17.4473 °N 97.2086 °W	_	_	_	_	_	In captivity as pet
7	CNAR-RF 968	Oaxaca	Asunción Nochixtlán	28/05/23	17.4535 °N, 97.2208 °W	80	54	73	35	80	Permanent stream; Site under constant human pressure; Juvenile
8	CNAR-RF 969	Oaxaca	Asunción Nochixtlán	28/05/23	17.4535 °N, 97.2208 °W	85	89	71	40	80	Permanent stream; Site under constant human pressure; Juvenile
9	CNAR-RF 970	Oaxaca	Asunción Nochixtlán	28/05/23	17.4521 °N, 97.2214 °W	135	85	125	60	_	Permanent stream; Site under constant human pressure; Male
10	CNAR-RF 971	Oaxaca	Asunción Nochixtlán	28/05/23	17.4521 °N, 97.2214 °W	130	80	110	55	_	Permanent stream; Site under constant human pressure; Female
11	CNAR-RF 972	Puebla	Tehuacán	20/09/22	18.5088 °N, 97.3677 °W	20	17	_	_	_	Permanent stream; Juvenile
12	CNAR-RF 973	Puebla	Tehuacán	20/09/22	18.5088 °N, 97.3677 °W	84	60	_	_	_	Permanent stream
13	_	Puebla	Tehuacán	26/05/23	18.5151 °N, 97.3606 °W	55	40	_	_	_	Natural pond
14	_	Puebla	Tehuacán	26/05/23	18.5151 °N, 97.3606 °W	55	40	_	_	_	Natural pond
15	_	Puebla	Tehuacán	15/12/23	18.5126 °N, 97.3575 °W	90	46	_	_	_	River
16	_	Puebla	Tehuacán	15/12/23	18.5126 °N, 97.3575 °W	71	58	_	_	_	Permanent stream
17	_	Puebla	Tehuacán	20/03/22	18.4983 °N, 97.3472 °W	_	_	_	_	_	In captivity as pet
18	_	Puebla	Tehuacán	20/03/22	18.4983 °N, 97.3472 °W	_	_	_	_	_	In captivity as pet

Figura 2. Individuos de *Kinosternon integrum* y sus amenazas registradas en campo. A) Adultos de San Juan Teitipac, Oaxaca. Foto: C. Camilo Julián-Caballero; B), C), D) Tortugas en cautiverio como mascotas en Asunción Nochixtlán, Oaxaca. Foto: Medardo Arreortúa; y E), F) Tortugas en cautiverio como mascotas en Tehuacán, Puebla. Foto: César Orozco.

Figure 2. Individuals of *Kinosternon integrum* and its threads recorded in the field. A) Adults from San Juan Teitipac, Oaxaca. Photo: C. Camilo Julián-Caballero; B), C), D) Turtles in captivity as pets in Asunción Nochixtlán, Oaxaca. Photo: Medardo Arreortúa; and E), F) Turtles in captivity as pets in Tehuacán, Puebla. Photo: César Orozco.

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BIFURCACIÓN CAUDAL EN UNA HEMBRA DEL ESCÍNCIDO VIVÍPARO *PLESTIODON INDUBITUS* (SCINCIDAE)

TAIL BIFURCATION IN A FEMALE OF THE VIVIPAROUS SKINK *PLESTIODON INDUBITUS* (SCINCIDAE)

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Abstract.– The self-induced shedding of all or part of the tail (caudal autotomy) is a widespread antipredator mechanism in lizards. It is commonly followed by the relatively rapid regeneration of a new tail, often of similar size to the original. In some cases, the tail partially fractures, without completely detaching from the organism, and stimulates a regenerative process that produces a forked tail. In recent decades, the number of reports of abnormal tail regeneration has increased considerably and it has been noted to occur in many families of lizards. In this note we report a case of abnormal tail regeneration in a female of the viviparous skink *Plestiodon indubitus*.

Keywords.– Antipredator mechanism, autotomy, lizard, tail regeneration.

Resumen.– El desprendimiento autoinducido de toda o parte de la cola (autotomía caudal) es un mecanismo antidepredatorio ampliamente extendido en lagartijas. Comúnmente es seguido por la regeneración relativamente rápida de una nueva cola, muchas veces de tamaño similar a la original. A veces la cola se fractura parcialmente, sin desprenderse del organismo, y estimula un proceso regenerativo que produce una cola bifurcada. En las últimas décadas ha aumentado considerablemente el número de reportes de regeneración anormal de la cola y se ha notado que ocurre en muchas familias de lagartijas. En esta nota reportamos un caso de regeneración anormal de cola en una hembra del escíncido vivíparo *Plestiodon indubitus.*

Palabras clave.– Autotomía, lagartija, mecanismo antidepredatorio, regeneración de cola.

La autotomía caudal, o el desprendimiento autoinducido de la cola, es una estrategia antidepredatoria común en lagartijas. Muchas especies poseen colas brillantes, verdes, rojas o azules, y en algunas de ellas se ha demostrado que funcionan como señuelos para dirigir los ataques depredatorios hacia esta parte corporal (Castilla et al., 1999; Watson et al., 2012; Fresnillo et al., 2014). Si bien la autotomía es un mecanismo antidepredatorio efectivo, también está asociado con una o más desventajas, las cuales dependen de la función o funciones de la cola antes de su pérdida. Las desventajas más obvias son el incremento en el riesgo de depredación debido a la pérdida del mecanismo antidepredatorio y el efecto negativo en la eficiencia de la locomoción (Maginnis, 2006).

En la mayoría de las lagartijas que exhiben autotonomía caudal, el desprendimiento de la cola estimula la regeneración de una nueva justo en el punto de la rotura (Arnold, 1984). La cola regenerada, si bien carece de vértebras y planos de fractura que faciliten un nuevo evento de autotomía, tiende a ser similar a la original (Lozito & Tuan, 2016). Con frecuencia el depredador pierde o abandona la cola y en estos casos puede ocurrir, como en algunas especies de *Scincella* y *Plestiodon* (Clark, 1971), que la lagartija autotomizada regrese al sitio de conflicto para comer su propia cola, recuperando de este modo parte de la energía perdida con la autotomización.

La regeneración de la cola no requiere del desprendimiento total de la misma. No obstante, para que la regeneración ocurra es necesario que quede al descubierto la membrana que reviste el canal central de la médula espinal de la cola, la cual es esencial para este propósito (Cox, 1969; Lozito & Tuan, 2016). De este modo, si una lagartija sufre una lesión que no produce autotomía caudal

completa, pero deja al descubierto esta membrana ependidimal, automáticamente comienza la regeneración de una nueva cola, originándose así una cola bifurcada o incluso multifurcada (Barr et al., 2020). Este fenómeno, es ampliamente extendido en lagartijas y recientemente ha despertado interés en muchos investigadores (Montes-Gavilán et al., 2018; Barr et al., 2020; Quah & Grismer, 2024). En esta nota reportamos el hallazgo de una hembra de *Plestiodon indubitus* con cola bifurcada.

El 8 de mayo de 2008 encontramos a la hembra (Fig. 1) debajo de una roca en el poblado de Landa, municipio de Taxco de Alarcón, Guerrero, México (18° 33.592' N; 99° 7.715' W; 1,837 m s.n.m.). Tenía una LHC = 53 mm y peso corporal de 3.25 g. La bifurcación inició a una longitud de 32.8 mm con respecto a la base de la cola. La parte de la cola a la derecha de la bifurcación era ligeramente más gruesa y alrededor de 3 mm más larga que la parte de la cola situada a la izquierda. La longitud total de la cola, considerando la porción más larga fue 51 mm.

Este es el primer registro de cola bifurcada para la especie *Plestiodon indubitus* y el noveno para el género en cuestión. Las especies de *Plestiodon* para las cuales se ha reportado la presencia de cola bifurcada son *P. anthracinus* (Walley, 1997), *P. fasciatus* (McKelvi & Stark, 2012), *P. inexpectatus* (Mitchel et al., 2012); *P. longirostris* (Turner et al., 2017), *P. chinensis* (Xu y Zhu, 2023), *P. skiltonianus* (Miles et al., 2020), *P. gilberti* (Perpignani & Alvarez, 2023) y *P. copei* (Suárez-Rodríguez et al., 2023). El género *Plestiodon* comprende 51 especies formalmente descritas (Pavón-Vázquez et al., 2018; García-Vázquez et al., 2021), por lo que el porcentaje de especies de *Plestiodon* con reportes de regeneración anormal de cola (9/51 x 100 = 17.6 %) es mucho más alto que el de cualquier otra familia de escamados, excepto por la familia Iguanidae (Fig. 2 de Bar et al., 2020). No es claro si esta diferencia tiene algún significado, una posibilidad es que esté relacionada con el riesgo de depredación y la frecuencia de ataques hacia la cola. Las colas azules brillantes, como las que caracterizan a los jóvenes, subadultos, e incluso adultos, de

Figure 1. Female *Plestiodon indubitus* with bifurcated tail captured in the town of Landa, Taxco de Alarcón, Guerrero, Mexico. Photo: Manuel Feria Ortiz.

Figura 1. Hembra con cola bifurcada de *Plestiodon indubitus* capturada en el poblado de Landa, Taxco de Alarcón, Guerrero, México. Foto: Manuel Feria Ortiz.

las especies de *Plestiodon*, actúan como señuelos para desviar la atención y el ataque del depredador hacia una parte no vital y desprendible del cuerpo (Cooper & Vitt, 1985; Murali et al., 2018). Se espera que los ataques dirigidos hacia la cola sean más frecuentes en especies con colas coloridas y brillantes que en especies con colas menos conspicuas y, por lo tanto, que la frecuencia de regeneración caudal anormal sea también mayor en las primeras.

Al igual que otros escíncidos de cola azul, *P. indubitus* es de hábitos terrestres y secretivos. Busca su alimento entre la hierba, hojarasca, rocas y otros escombros del suelo. Cuando se ve en peligro tiende a escabullirse debajo del suelo en espacios muy estrechos, como las raíces del pasto o de la hierba del lugar. Además, se desplaza debajo del suelo para ubicarse bajo rocas cimentadas al sustrato, las cuales usa como refugios diurnos temporales. De este modo, la posesión de una cola deformada (bifurcada), la cual muchas veces representa un peso adicional, podría afectar su habilidad para desplazarse en este tipo de ambiente (Bar et al., 2020).

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