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A JOURNEY THROUGH THE AMPHIBIAN AND REPTILE COLLECTIONS AT THE INSTITUTO HUMBOLDT IN COLOMBIA

UN VIAJE POR LAS COLECCIONES DE ANFIBIOS Y REPTILES DEL INSTITUTO HUMBOLDT EN COLOMBIA

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Resumen.– Las colecciones biológicas son un recurso importante para explorar la vida y entender la morfología, evolución, ecología, función e incluso las interacciones de los organismos a través de escalas temporales y espaciales. Aquí destacamos el valor de los especímenes de anfibios y reptiles depositados en el Instituto Humboldt en Colombia, junto con sus datos asociados, evaluando la cobertura taxonómica y geográfica de ambas colecciones en un contexto nacional y evaluando las tendencias temporales de los especímenes de referencia y los especímenes extendidos. Además, exploramos el uso de especímenes y sus datos asociados en estudios científicos mediante la realización de búsquedas sistemáticas de artículos publicados en Web of Science, Scopus, Google Scholar y GBIF. Identificamos que ambas colecciones incluyen más del 65 % de las especies de anfibios y reptiles registradas en los 32 departamentos de Colombia, destacando el Amazonas como el departamento más rico en términos de representatividad de especies en las colecciones. Las tendencias de crecimiento para ambas colecciones biológicas fueron heterogéneas en el tiempo, mostrando un pico durante las décadas de 1970 y 1980, así como durante la última década en la que el número de especímenes de referencia y colecciones extendidas (por ejemplo, tejidos y grabaciones de sonidos) aumentaron sustancialmente. Finalmente, revisamos un total de 112 artículos publicados que han utilizado especímenes de las colecciones del Instituto Humboldt y encontramos que los temas de investigación más representados consistieron en distribución junto con taxonomía y sistemática. En general, este estudio proporciona conocimientos valiosos para ayudar a guiar futuras nuevas direcciones de investigación para las colecciones de reptiles y anfibios alojadas en el Instituto Humboldt, enfocadas, por ejemplo, en ecología, toxicología y conservación, al tiempo que contribuye de manera más amplia al estado del conocimiento de las colecciones biológicas en Colombia, pretendiendo incentivar a otras instituciones nacionales y latinoamericanas a explorar de manera similar los datos alojados en sus colecciones para ayudar a guiar futuros esfuerzos de una manera complementaria y colaborativa.

Palabras clave.– Especímenes, herpetofauna, IAvH-Am, IAvH-R, repositorio de diversidad, revisión de literatura.

Abstract.– Biological collections are an important resource for exploring life and understanding the morphology, evolution, ecology, function, and even interactions of organisms across both temporal and spatial scales. Here we highlight the value of the amphibian and reptile specimens housed at the Instituto Humboldt in Colombia, along with their associated data, by evaluating

the taxonomic and geographic coverage of both collections within a national context and by assessing the temporal trends of both voucher specimens and extended specimens. Furthermore, we explore the use of specimens and their associated data in scientific studies by performing systematic searches of published papers on Web of Science, Scopus, Google Scholar, and GBIF. We identified that both collections include more than 65 % of the amphibian and reptile species recorded across the 32 departments of Colombia, highlighting the Amazonas Department as the richest in terms of species representativeness in the collections. Growth trends for both biological collections were heterogeneous in time, showing a peak during the 1970s and 1980s, as well as over the last decade during which the number of voucher specimens and extended collections (e.g., tissues and sound recordings) substantially increased. Finally, we reviewed a total of 112 published articles that have used specimens from the Instituto Humboldt collections and found that the most represented research topics were distribution, taxonomy and systematics. Overall, this study provides valuable insights to help guide new future research directions for the reptile and amphibian collections housed at the Instituto Humboldt, focused, for example, in ecology, toxicologý and conservation, while more froadly contributing to the state of knowledge of biological collections in Colombia. We aim to encourage other national and Latin American collections to explore their data in order to help guide future efforts in a complementary and collaborative way.

Keywords.– Biodiversity repository, herpetofauna, IAvH-Am, IAvH-R, literature review, specimens.

INTRODUCTION

Biological collections are a fundamental resource for documenting biodiversity patterns across temporal and spatial scales (Winker, 2004; Webster, 2017). These repositories make specimens and their associated data accessible to researchers in order to contribute to our understanding of biodiversity loss, climate change, species interactions, infectious diseases, and reproductive patterns, among many other research topics (Meineke et al., 2018; Johnson & Owens, 2023). Although biological collections have been traditionally thought of as important elements for scientific research, they also have important value in both management-oriented and applied sciences helping to resolve society's current problems (Winker, 2004). For example, scientific collections have been relevant from a political and administrative perspective in the execution of regulatory strategies associated with the preservation and conservation of natural resources (Núñez & Gálvez, 2015). Furthermore, they play a crucial role in scientific communication and education initiatives that aim to raise awareness and knowledge around biodiversity among academic and broader communities (Hilton et al., 2021).

These biodiversity repositories represent a mainstay in extremely diverse countries such as Colombia, which is known to have high rates of endemism, numerous undescribed taxa, and large knowledge gaps on biodiversity, while also facing socioeconomic difficulties (Kerr & Burkey, 2002; Giam et al., 2012; Moura & Jetz, 2021). They are fundamental to the study of different taxonomic groups, such as some species of reptiles and amphibians in the Neotropics, many of which are difficult to encounter in the field due to their cryptic behavior or low population densities. In Colombia, these taxa represent an important proportion of the global diversity with more than 850 species of amphibians, being ranked in second place after Brazil (Re:wild et al., 2023; Frost, 2023); and eight place in reptiles with more than 660 species (Uetz et al., 2023).

As of 2021, Colombia housed 80 Amphibian and Reptile Biological Collections formally registered in the Registro Nacional de Colecciones (RNC) (Vásquez-Restrepo, 2021). The herpetological collections of the Instituto de Ciencias Naturales (ICN), located at the Universidad Nacional in Bogotá, are the largest in the country with more than 66,000 and 20,000 amphibian and reptile specimens, respectively. The second largest collections in the list for both groups are the biological collections housed at the Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (Instituto Humboldt), located in the small town of Villa de Leyva, Boyacá, four hours from Bogotá. Within the colonial infrastructure of an antique cloister, the Amphibian Collection (IAvH-Am) houses more than 17,000 specimens, while the Reptile Collection (IAvH-R) is composed of more than 9,000 specimens (Fig. 1).

These collections were founded in 1968 and 1976, respectively, during the implementation of the National System of Protected Areas by the Instituto Nacional de Recursos Renovables y del Ambiente (INDERENA). Later in 1993, the INDERENA transferred all biological collections to the Instituto Humboldt. In 2002, and again starting in 2012, the data associated with specimens from both herpetological collections have been uploaded to the Global Biodiversity Information Facility (GBIF),

making this information available and free for common and scientific use (Borja-Acosta & Galeano, 2023a,b). Currently, both biological collections have a great diversity of national (and some international) specimens deposited mostly in ethanol, and include several dry preserved skulls, skins, and bones (Fig. 1).

With the intent of preserving high-quality information associated with the specimens, both collections have implemented the "extended specimen collections" framework. As such, these collections are defined as the sum of data types that reveal important aspects of individual phenotypes that may be lost during the fixation and preservation process (Webster, 2017). For example, the Amphibian Collection has recently grown its representation of sound records associated with voucher specimens, currently deposited at the Colección de Sonidos Ambientales Mauricio Álvarez Rebolledo (IAvH-CSA). Similarly, the Reptile Collection has recently increased its representation of snake and lizard hemipenes (male genitalia). Both collections also house an important representation of tissue samples deposited at the Colección de Tejidos (IAvH-CT) of the Instituto Humboldt, located at Palmira, Valle del Cauca.

In this study, we explore the taxonomic and geographic representation of the Amphibian and Reptile Collections of the Instituto Humboldt. We show their temporal growth trends and gather information on their use for scientific purposes, based on a revision of published articles spanning the last 22 years. Our main goal is to bring visibility to these collections and elucidate their representativeness, usage patterns, main gaps, and sampling limitations, thereby providing valuable insights to help guide future research directions. We believe that this work is an important contribution to the state of knowledge of Biological Collections in Colombia, and we encourage other national and Latin American collections to explore their data in order to help guide future collecting, georeferencing, digitization, and research efforts in a complementary and collaborative way.

Figura 1. Colecciones de Anfibios y Reptiles del Instituto Humboldt, ubicadas en el Claustro San Agustín, Villa de Leyva, Boyacá, Colombia. Fotos: John Bernal (A, B) y Felipe Villegas Vélez (C, D).

Figure 1. Amphibians and Reptiles Collections of the Instituto Humboldt, located in Claustro San Agustín, Villa de Leyva, Boyacá, Colombia. Photos: John Bernal (A, B) y Felipe Villegas Vélez (C, D).

METHODS

All data used to identify the taxonomic and geographic coverage of both collections, Amphibian and Reptiles, of the Instituto Humboldt, as well as their growth trends and usage by the scientific community, are based on articles published up until May 2023. The following sections describe the methods used for each of these approaches. All figures were made in R, through RStudio.

Taxonomic coverage

All information on the existing specimens in the Amphibians Collection (IAvH-Am) and Reptiles Collection (IAvH-R) was downloaded from the Specify software, the database used for Biological Collections at the Instituto Humboldt. To assess the taxonomic representation of these collections compared to the known diversity of amphibians and reptiles in Colombia, we implemented a revision process that involved eliminating specimens lacking species-level identification from our analysis, as well as international specimens. As references, we used the list of amphibian and reptile species reported for Colombia in Amphibians Species of the World (Frost, 2023) and The Reptile Database (Uetz et al., 2023), respectively. Posteriorly, we contrasted the families and species determined in each biological collection with those reported for Colombia, to obtain a general view of the representation that both biological collections harbor compared to the country's known diversity.

Geographic coverage

To evaluate the species richness represented in both collections across Colombia, we mapped the number of species across the 32 departments delimiting the country. For this, we eliminated all specimens that were not determined to species level (e.g., specimens determined only to the genus or family level). Additionally, to evaluate the geographical coverage of fieldwork conducted by researchers at the Instituto Humboldt and other researchers that have deposited biological material in these collections, we mapped the number of specimens deposited within the departments of Colombia. We eliminated all records lacking information at the department level.

To assess the quality and completeness of the geographical data in both collections, we also mapped all specimens with associated geographical coordinates. All geographic coordinates were validated up to the department and municipality level using spatial ArcGIS 10.2 analysis tools. If a coordinate was not accurate with the municipality, we further checked if it was located within its political border by including a 1 km buffer radius. If the coordinates did not comply with our validity criteria, the data point was removed from the map. Heatmaps were constructed in the program QGIS Version 3.28.3.

Temporal trends

To evaluate the temporal trend of specimens housed in both collections, we first removed individuals that lacked a collection date from the analysis. We then plotted the number of specimens collected every four years as well as the accumulation of specimens over time. We also evaluated the growth trends for the following three extended collections associated to voucher specimens: 1) the Colección de Sonidos Ambientales (IAvH-CSA) for amphibian sound records, 2) the hemipenes collection extracted from lizards and snakes, and 3) the Colección de Tejidos (IAvH-CT) for tissue samples for both groups. Finally, we assessed the taxonomic and geographic representation of the extended specimen collections considering the number of species in each family and department.

Type material

To evaluate the taxonomic representation of the type material housed in the Instituto Humboldt, we examined holotype and paratype material based on the original species description, corroborating the voucher numbers [IAvH or INDERENA (IND)] within the original articles. Subsequently, we determined the most representative families among the holotypes and paratypes of each collection.

Use of collections

In order to identify studies in which specimens from the Amphibians and Reptiles Collections, or their associated datasets published in GBIF, have been used for research and publication purposes, we first performed a systematic search of published literature over the past 22 years using two online databases, Web of Science and Scopus, as well as the Google Scholar search engine via the software program Publish (Harzing, 2023). Independent searches were made for amphibians and reptiles between January 2000 and May 2023 in each database or search engine. The following keywords were used: ("IAvH-Am" OR "INDERENA" OR "IND-AN" OR "Instituto de Investigación de Recursos Biológicos Alexander von Humboldt" OR "Alexander von Humboldt Biological Resources Research Institute") AND ("Amphibian" OR "Anfibio" OR "Anura" OR "Caudata" OR "Gymnophiona") for amphibians, and ("IAvH-R" OR "INDERENA" OR "IND-R" OR "Instituto de Investigación de Recursos Biológicos Alexander von Humboldt" OR "Alexander von Humboldt Biological Resources Research Institute") AND ("Reptile" OR "Reptil" OR "Squamata" OR "Testudines" OR "Crocodylia") for reptiles. The searches made in Google Scholar were limited to the first 250 entries, following recommendations by Haddaway et al. (2015).

Next, we conducted a manual search in GBIF to identify all articles referencing both the Amphibians and Reptiles Collections that have used the datasets associated with specimens of both collections (Borja-Acosta & Galeano, 2023 a, b). To accomplish this, we performed a search for "Colección de Anfibios del Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH-Am)" and "Colección de Reptiles del Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH-R)" within the "Get data" section of the GBIF platform. Subsequently, we accessed the "citations" subsection for each of these searches to obtain a list of all articles that cited both occurrence datasets. We consolidated the results from all searches and eliminated any duplicates. Then, we read and reviewed each study individually to filter out those publications that did not incorporate specimens from the collections or their associated GBIF datasets.

The remaining articles were reviewed to define: 1) the collection resources used (specimens or associated datasets uploaded in GBIF), and 2) the research topics addressed by each study. Research topics were assigned to each publication based on twelve previously established categories: taxonomy and systematics, natural history, ecology, distribution, morphology and anatomy, evolution, toxicology, physiology, genetics, bioprospecting, conservation, and species listings. These categories were selected based on literature addressing the usage of biological collections (Simmons & Muñoz-Saba, 2005). Each publication was assigned more than one research topic when it focused on two or more categories.

RESULTS

Taxonomic coverage

As of May 2023, the Amphibian Collection of the Instituto Humboldt (IAvH-Am) holds a total of 17,446 specimens. From this total, 17,311 specimens were collected in Colombia, while 135 came from other countries such as Ecuador (n = 30), Uruguay (n = 28), the United States (n = 25), Venezuela (n = 20), Costa Rica (n = 17), Peru (n = 6), and Brazil (n = 2). Among the total specimens collected in Colombia, 16,347 have been identified to species level, while 964 specimens require further taxonomic curation. More than half of these undetermined specimens (n = 644) belong to the genus *Pristimantis*.

All three amphibian orders (Anura, Caudata, and Gymnophiona) are represented prominently in the Amphibian Collection. This collection contains representatives of 19 out of 20 families known to occur in Colombia, and approximately 65 % (580) of the total number of amphibian species reported in the country. The only family not represented was Dermophiidae, which is known to have one single anuran species in Colombia (*Dermophis glandulosus*) (Fig. 2A). Within the order Anura (frogs and toads), the collection holds 100 % representation of the species documented in the country for two families: Ceratophryidae (horned frogs), and Ranidae (water frogs). Furthermore, there is a significant representation (>75 %) of the known Colombian species for three families (Leptodactylidae, Craugastoridae and Pipidae), and more than 50 % of the known species for nine additional families: Aromobatidae, Bufonidae, Centrolenidae, Dendrobatidae, Eleutherodactylidae, Hemiphractidae, Hylidae, Microhylidae, and Strabomantidae. In the Caudata order (salamanders), which only has one family known for Colombia (Plethodontidae), the collection houses specimens of 63 % of the species known to occur in the country (Fig. 2A). Finally, within the Gymnophiona order (caecilians), there is representation of more than 75 % of the species for two families in the country, Siphonopidae and Typhlonectidae. The remaining two families, Caecilidae and Rhinatrematidae, are represented by less than 50 % of the Colombian caecilians (Fig. 2A).

As of May 2023, the Reptile Collection holds a total of 9,479 specimens. A significant number of specimens were collected outside of Colombian territory (n = 148), mainly in the United States (n = 49), Costa Rica (n = 41), Peru (n = 13), Brazil (n = 11), Venezuela (n = 7), Israel (n = 3), Kenya (n = 3), Sweden (n = 3), Guatemala (n = 2), Chile (n = 1), Mexico (n = 1), Suriname (n = 1), and Turkey (n = 1). Among the 9,331 specimens collected in Colombia, 9,145 have been determined to species level, while the remaining 186 still require further taxonomic curation. The highly diverse and complex genus of ground snakes *Atractus* still requires further taxonomic curation, representing 49 of these 186 undetermined specimens.

In terms of species representation for the Colombian territory, the Reptile Collection includes species of all three orders expected for the Western hemisphere. All 35 families known to occur in Colombia are represented, as well as approximately 67 % of Colombian species (n = 431). Within the order Crocodylia (crocodiles and alligators), all Colombian species are represented in the collection (Fig. 2B). The Testudines order (turtles) is also well represented, with specimens for all species of six families occurring in Colombia: Cheloniidae, Chelydridae, Dermochelyidae, Kinosternidae, Podocnemididae, and Testudinidae. The remaining three turtle families reported for the country (Chelidae, Emydidae, and Geoemydidae) are represented by 90 %, 75 %, and 60 % of the Colombian species, respectively. In the Squamata order (lizards and snakes), all known Colombian species are represented within the collection

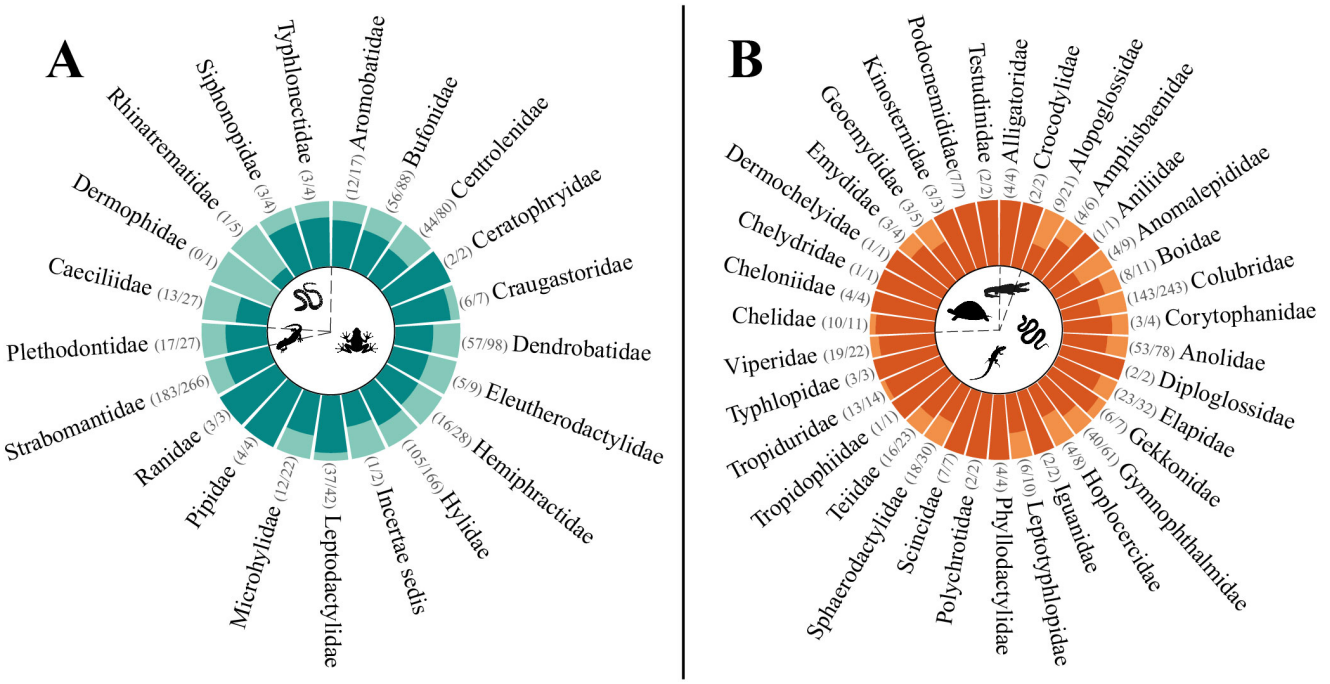

Figura 2. Proporción de la cobertura taxonómica de especies por familia de (A) anfibios y (B) reptiles depositados en las dos colecciones biológicas del Instituto Humboldt, en comparación con la diversidad conocida para Colombia. El azul y el naranja oscuros representan la proporción de especies depositadas en las Colecciones de Anfibios (IAvH-Am) y Reptiles (IAvH-R), respectivamente. El azul y el naranja claros representan la proporción de especies que se sabe que ocurren en Colombia, pero que no están representadas en las colecciones de anfibios y reptiles, respectivamente. Los números al lado de cada familia representan el número bruto de especies depositadas en las colecciones biológicas del Humboldt en comparación con el número conocido de especies reportadas en Colombia. *Incertae sedis* se refiere a *Geobatrachus walkeri* y *Atopophrynus syntomopus*, ya que no se sabe con certeza a qué familia pertenecen estas especies.

Figure 2. Proportion of the taxonomic coverage of species per family of (A) amphibians and (B) reptiles deposited in the two biological collections of the Instituto Humboldt, compared to the known diversity for Colombia. Dark blue and dark orange represent the proportion of species deposited in the Amphibian (IAvH-Am) and Reptile (IAvH-R) Collections, respectively. Light blue and light orange represent the proportion of species that are known to occur in Colombia, but not represented in the amphibian and reptile collections, respectively. Numbers next to each family represent the raw number of species deposited in Humboldt Biological collections compared to the known number of species reported in Colombia. *Incertae sedis* refers to *Geobatrachus walkeri* and *Atopophrynus syntomopus*, as it is uncertain to which family these species belong.

for eight families (Aniliidae, Diploglossidae, Iguanidae, Phyllodactylidae, Polychrotidae, Scincidae, Tropidophiidae, and Typhlopidae) (Fig. 2B). Furthermore, 13 families are represented by more than 50 % of the species currently known in Colombia (Amphisbaenidae, Boidae, Colubridae, Corytophanidae, Anolidae, Elapidae, Gekkonidae, Gymnophthalmidae, Leptotyphlopidae, Spaherodactylidae, Teiidae, Tropiduridae, and Viperidae). The remaining families (Alopoglossidae, Anomalepididae, and Hoplocercidae) have specimens that represent between 40 % and 50 % of the species reported for the country.

Geographic coverage

The Amphibian Collection's geographical coverage reveals that the richness of species represented is not homogeneous across the 32 departments in Colombia. Specifically, some departments across the Andean and Chocó regions, and one in the Amazon region, have high representation with over 100 species (Amazonas and Antioquia) or more than 80 species (Cauca, Putumayo, and Boyacá) (Fig. 3A). In the Orinoquía region, the department with a greater number of species was Meta with over 70 species of amphibians. Contrarily, departments along the Caribbean coast, such as the Archipiélago de San Andrés, Providencia and Santa Catalina, La Guajira, Atlántico, as well as others in the Amazon region, such as Guainía and Guaviare, have less than 20 species represented within the collection (Fig. 3A).

The number of collected specimens across the 32 departments did not necessarily resemble the trend of amphibian species richness observed in the collection. On one hand, departments closest to the capital city of Bogotá, such as Casanare, Cundinamarca, Santander, and Boyacá, presented the highest number of specimens with more than 1000 individuals (Fig. 3C). Some other departments located at a considerable distance from

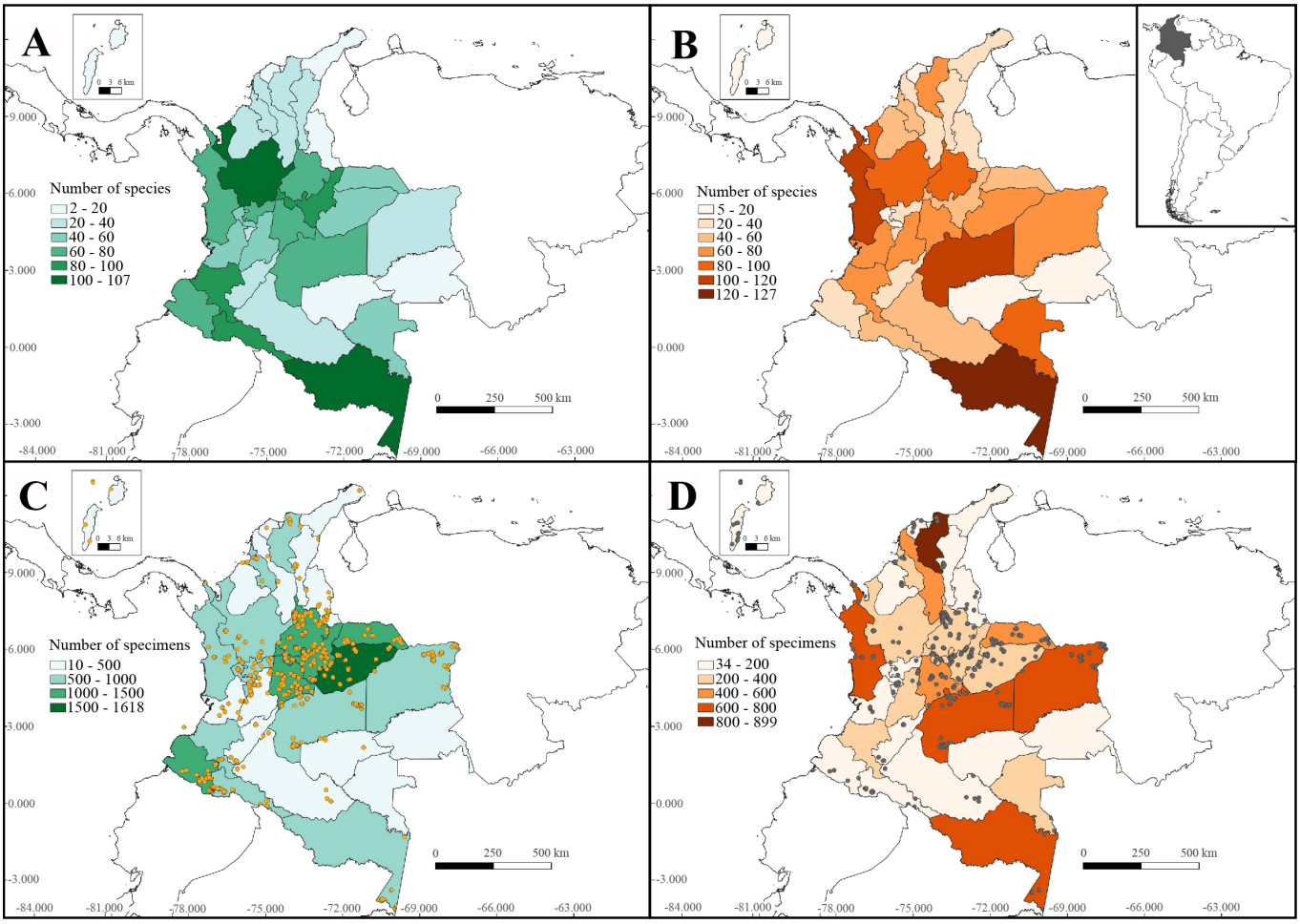

Figura 3. Cobertura geográfica de las Colecciones de Anfibios y Reptiles del Instituto Humboldt, representada por el número de especies de (A) anfibios y (B) reptiles por departamento, y el número de especímenes de (C) anfibios y (D) reptiles por departamento. Los colores más oscuros representan valores más altos de especies o especímenes depositados en las colecciones, mientras que los colores más claros representan valores más bajos. Los puntos amarillos y grises muestran todos los especímenes con coordenadas geográficas precisas para la colección de anfibios y reptiles, respectivamente.

Figure 3. Geographic coverage of the Amphibian and Reptile Collections of the Instituto Humboldt, represented by the number of (A) amphibian and (B) reptile species per department, and the number of (C) amphibian and (D) reptile specimens per department. Darker colors represent higher values of species or specimens deposited in the collections, while lighter colors represent lower values. Yellow and gray dots show all the specimens with accurate geographical coordinates for the amphibian and reptile collection, respectively.

the capital, such as Arauca and Nariño, were also represented by more than 1000 specimens. On the other hand, departments with less than 25 specimens, mostly located in the Caribbean and the Amazon regions, resemble the observed trend of species richness (i.e., Archipiélago de San Andrés, Providencia and Santa Catalina, La Guajira, Atlántico, Guainía, and Guaviare) (Fig. 3C, Appendix 1).

Within the Reptile Collection, the Amazonas department showed the highest species richness, with over 120 species (Fig. 3B), followed by Meta and Chocó, located in the Orinoquía and Pacific regions, with more than 100 species each. Antioquia, Santander, and Vaupés were also diverse, and represented 80-100 species each. In contrast, departments represented by less than 20 species are located in the Caribbean region (i.e., Archipiélago de San Andrés, Providencia y Santa Catalina, and Atlántico), as well as the Amazon (Guainía and Guaviare) and Andean regions (Risaralda) (Fig. 3B).

In assessing the number of specimens per department, we found that the Magdalena department, located in the Caribbean region, holds the highest values, with approximately 900 individual specimens, followed by the Chocó department and three Cis-Andean departments (Vichada, Amazonas, and Meta),

all with a representation of 600-800 specimens (Fig. 3D). On the other hand, the least sampled departments were Guaviare, Risaralda, Guainía, Norte de Santander, Quindío, and Atlántico, with less than 60 specimens each (Fig. 3D).

Across both collections, more than half of the deposited specimens lack geographical coordinates. In the Amphibian Collection, only 43 % of specimens (7,243) have geographical coordinates, while only 15 % of the individuals (1331) had this information in the reptile collection (Figs. 3C and 3D). Most of the specimens without geographical coordinates were collected before the 1980's when obtaining this type of data was difficult due to the lack of GPS devices.

Temporal trends

Both collections witnessed a growth in specimens during the 1970s and 1980s, with a substantial increase in reptiles occurring during the late 1970s and for amphibians between the late 1980s and early 1990s (Fig. 4A). In the late 1990s, a decline in specimen collections was observed, which remained relatively stable until 2011. However, after a period of low specimen entry, both collections experienced an increase in number of specimens from 2012 to the present day (Fig. 4B). During this time, almost 8,000 amphibian specimens (representing 45 % of the collection) and almost 1,250 reptile specimens (representing 13 % of the collection) were deposited.

In the last decade, a significant growth was observed in the extended collections. The Colección de Sonidos Ambientales (IAvH-CSA) increased from almost zero to 129 sound recordings associated with anuran voucher specimens from the Amphibian Collection. These recordings were all collected over the last five years since previous call records were not associated with voucher specimens (Fig. 5A). These 129 records represent eight families of anurans, with Hylidae being the most represented family (53 % of the records, 20 species), followed by Leptodactylidae (16 %, 8 species), Bufonidae (12 %, 6 species), and Strabomantidae (10 %, 5 species) (Appendix 2). Most of the samples were collected in the Santander department (33 % of the total) in the Andean region, followed by Meta (21 %) in the Orinoco, and Putumayo (15 %) in the Amazon region (Appendix 3).

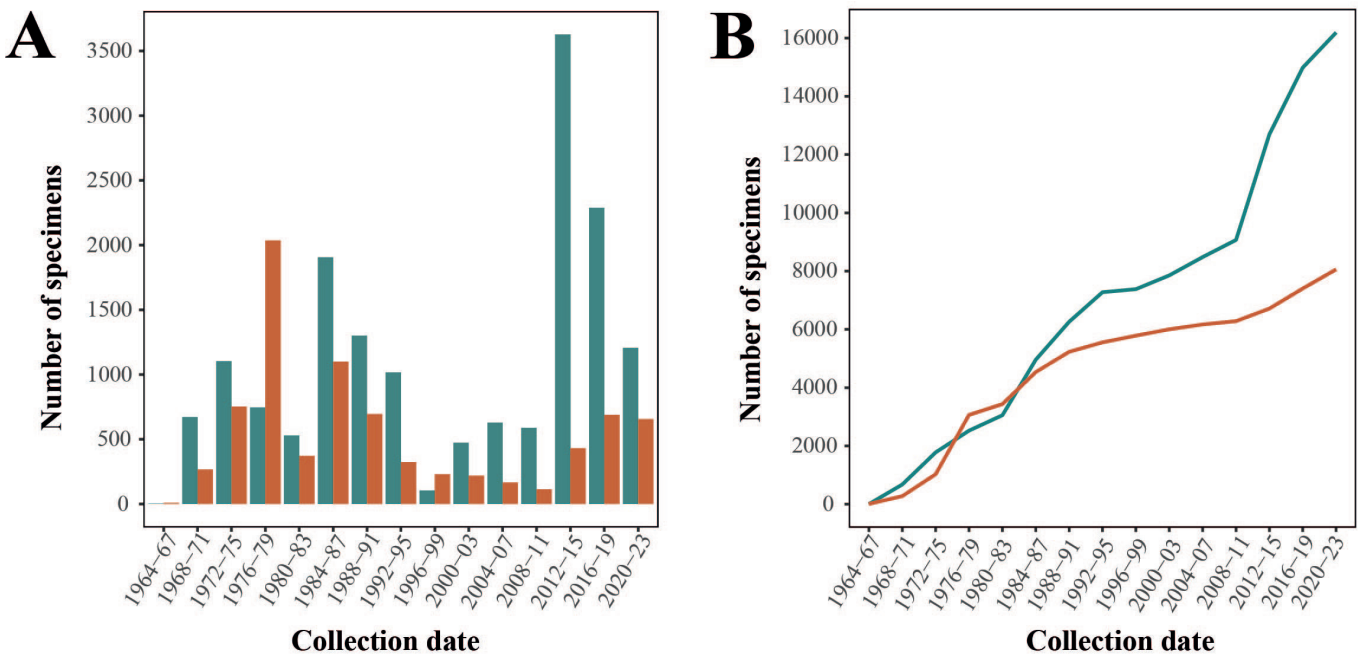

Figura 4. Tendencias temporales de los especímenes recolectados y depositados en las Colecciones de Anfibios (azul) y Reptiles (naranja) del Instituto Humboldt. (A) Las barras representan el número de especímenes depositados cada cuatro años, mientras que (B) las líneas representan el crecimiento acumulativo a lo largo del tiempo de ambas colecciones.

Figure 4. Temporal trends of specimens collected and deposited in the Amphibian (blue) and Reptile Collections (orange) of the Instituto Humboldt. (A) Bars represent the number of specimens deposited every four years, while (B) lines represent the cumulative growth through time of both collections.

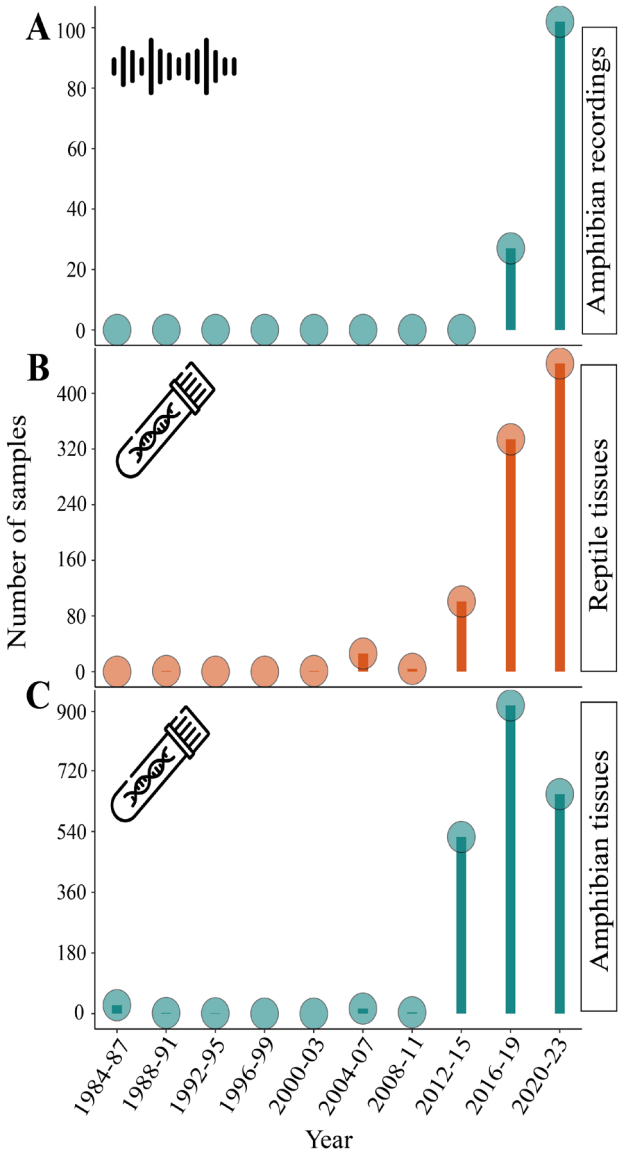

Figura 5. Número de muestras en algunas de las colecciones extendidas dentro de las Colecciones de Anfibios y Reptiles del Instituto Humboldt. (A) grabaciones de sonidos de anfibios, (B) tejidos de reptiles y (C) tejidos de anfibios.

Figure 5. Number of samples in some of the extended collections within the Amphibian and Reptile Collections at the Instituto Humboldt. (A) amphibian sound recordings, (B) reptile tissues, and (C) amphibian tissues are represented.

As for the tissue samples, the Colección de Tejidos (IAvH-CT) deposited its first amphibian sample in 1986 (Fig. 5C) and its first reptile sample in 2007 (Fig. 5B). However, it was not until 2013 that an important increase in tissue samples was observed, with 2,084 tissues deposited for amphibians and 877 for reptiles. The tissue collection is the largest of the extended collections, with 2,176 samples from 250 amphibian species representing 19 families (Appendix 4). The following families are the four most represented: Strabomantidae (38 % of amphibian samples, 81 species), Hylidae (22 %, 48 species), Leptodactylidae (15 %, 25 species), and Bufonidae (6 %, 18 species). The remaining 15 families are represented by less than 4 %. Most tissues were collected from specimens from four departments: Santander (19 %), Boyacá (14 %), Meta (11 %), and Putumayo (11 %). All other departments have less than 4 % representation or none (Appendix 5).

The reptile tissue repository is composed of a total of 916 samples, representing 181 species from 26 families (Appendix 4). Colubridae has the highest representation (27 % of reptile samples, 62 species), followed by Anolidae (22 %, 24 species), Sphaerodactylidae (10 %, 12 species), and Gymnophthalmidae (9 %, 14 species). The remaining 22 families are each represented by less than 4 % of the total samples in the Tissue Collection. Most of the tissues were collected from specimens from the departments of Santander (27 % of samples), Meta (12 %), and Boyacá (11 %) (Appendix 6).

As for the representation of Squamata hemipenes, growth trends through time could not be identified due to the absence of cataloging dates for these samples. However, between 2022 and 2023, the size of this extended collection has increased by 24 %, reaching a total of 250 samples from 88 species represented in 15 families (Appendix 7). Three families represent more than 80 % of the samples, being Colubridae (56 %, 41 species), Viperidae (20 %, 11 species), and Elapidae (8 %, 8 species). The remaining 12 families have less than 4 % representation.

Type material

The Amphibian Collection holds 405 type specimens, including 27 holotypes and 378 paratypes, representing a total of 54 species. Three species are represented only by holotypes, 24 species have holotype and paratypes, and 27 species are only represented by paratypes. The Strabomantidae family is the best represented, with 12 holotypes and 25 paratypes, followed by the Dendrobatidae family with 6 holotypes and 9 paratypes (Fig. 6A).

The Reptile Collection holds 40 type specimens. All of the 16 species were described after 1982. Two of these species are represented only by the holotype, three by both the holotype and paratypes, and 11 species are only represented by paratypes. The families best represented are Anolidae with 2 holotypes and 5 paratypes, followed by Colubridae with 1 holotype and 3 paratype (Fig. 6B).

Use of collections

A total of 1,416 articles were obtained from searches performed across three online databases and GBIF. Of these, only 112 articles were selected and carefully reviewed based on the established criteria (52 % focused exclusively on amphibians, 44 % on reptiles, and 4 % on both taxa). The most represented research topics were: distribution with 25 articles for amphibians and 27 for reptiles (three publications included both taxa), taxonomy and systematics (29 for amphibians, 22 for reptiles, and one which included both taxa), natural history (8 for amphibians, 3 for reptiles), conservation (6 for amphibians, 3 for reptiles), morphology and anatomy (4 for amphibians, 5 for reptiles), and ecology (5 for amphibians, 2 for reptiles) (Fig. 7A). Other research topics like species listing, toxicology, and evolution were represented by less than three studies. Genetics, physiology, and bioprospecting were not represented by any articles (Fig. 7A). In terms of the collection resource used, 80.3 % of the studies reviewed specimens housed in the collections (53 studies included amphibians and 40 included reptiles, three of which included both taxa), whereas 19.6 % used only the associated datasets (mainly geographical data) of the specimens published in GBIF (10 included amphibians, 12 included reptiles, and two including both taxa). Studies that used the GBIF repository focused mainly on distribution and conservation as research topics (Appendix 8).

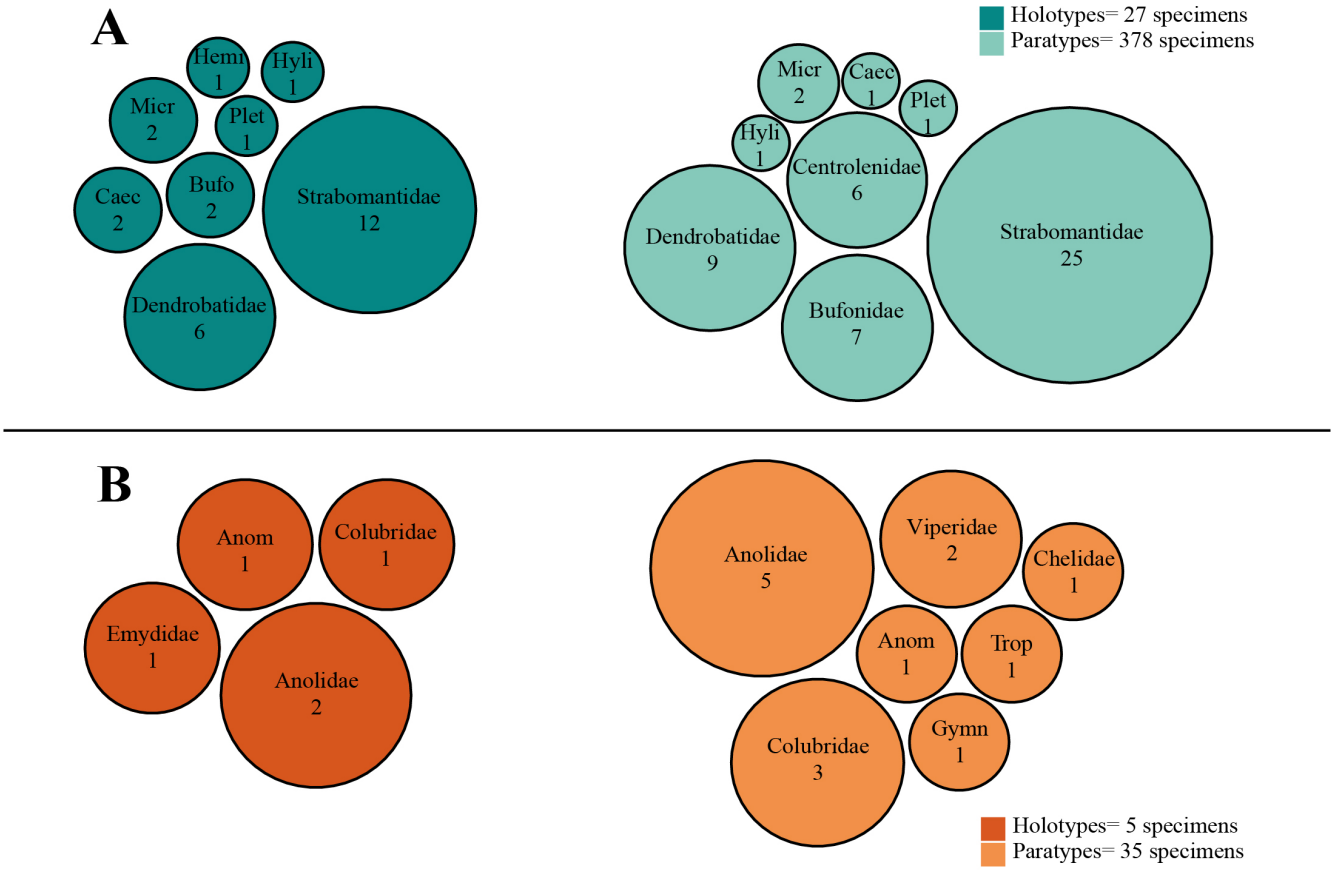

Figura 6. Número de especies representadas por especímenes tipo por familia de (A) anfibios (azul) y (B) reptiles (naranja) en las Colecciones Biológicas del Instituto Humboldt. El número de especies esta representado por el número dentro del círculo. Los holotipos están representados por azul y naranja oscuros, mientras que los paratipos están representados por azul y naranja claros. Caec = Caeciliidae, Hemi = Hemiphractidae, Hyli = Hylidae, Micr = Microhylidae, Bufo = Bufonidae, Anom = Anomalepididae, Gymn = Gymnophthalmidae, Trop = Tropiduridae, Plet = Plethodontidae.

Figure 6. Number of species represented by type specimens per family of (A) amphibians (blue) and (B) reptiles (orange) in the Biological Collections of the Instituto Humboldt. The number of species is represented by the number inside each circle. Holotypes are represented by dark blue and dark orange, while the paratypes are represented by light blue and light orange. Caec = Caeciliidae, Hemi = Hemiphractidae, Hyli = Hylidae, Micr = Microhylidae, Bufo = Bufonidae, Anom = Anomalepididae, Gymn = Gymnophthalmidae, Trop=Tropiduridae, Plet = Plethodontidae.

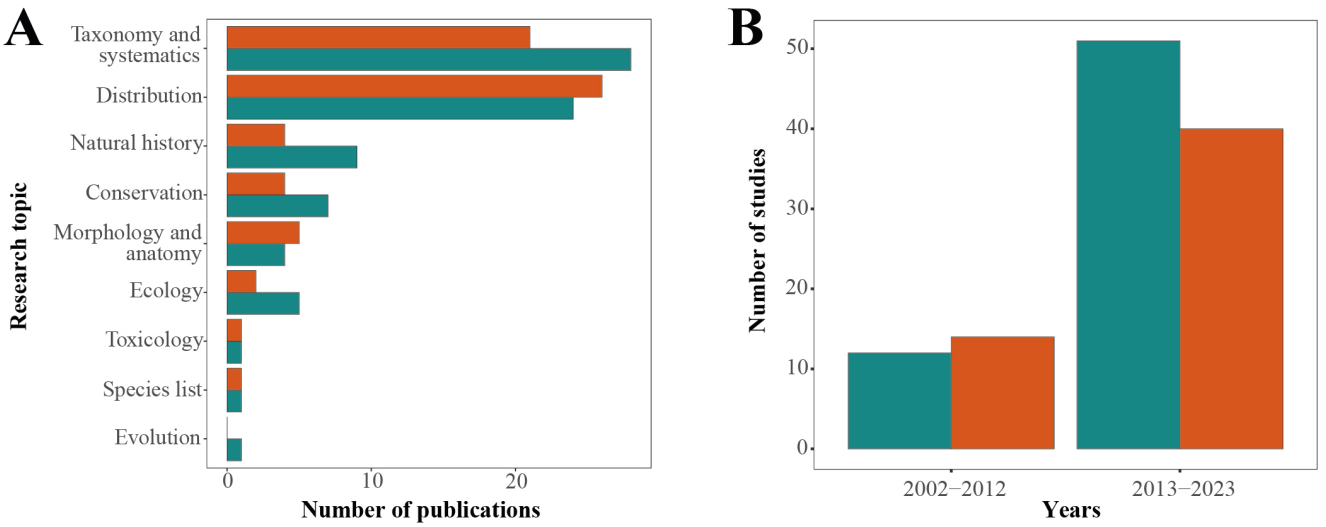

Figura 7. Uso de las colecciones de Anfibios (azul) y Reptiles (naranja) durante los últimos 22 años. Esto se representa en (A) por el número de estudios categorizados por temas de investigación, y en (B) por el número de estudios publicados entre 2002-2012 y 2013-2023.

Figure 7. Use of Amphibian (blue) and Reptile (orange) collections over the past 22 years. This is represented in (A) by the number of studies categorized by research topics, and in (B) by the number of studies published between 2002-2012 and 2013-2023.

We also observed an unequal use of specimens or their associated data between the decades of 2002-2012 and 2013-2023 (Fig. 7B). The earlier decade had less than half the number of publications for both collections compared to the last decade. In the last decade, the number of amphibian publications slightly exceeded those of reptiles (Fig. 7B).

DISCUSSION

Our study presents a comprehensive analysis of the taxonomic and geographical coverage, growth trends, and usage of specimens and datasets of the Amphibian and Reptile Collections at the Instituto Humboldt, the second largest in Colombia. We elucidated some of the main gaps and sampling limitations within both collections and explored the various scientific applications and uses of the specimens and their associated datasets through the review of publications over the last two decades. By doing so, we aimed to create a valuable reference of these two collections for other national and regional museums, contributing to the state of knowledge of biological collections in Colombia and highlighting their role in the advancement of research.

Both collections exhibited an important taxonomic representation, covering approximately 65 % of the amphibian species and 67 % of the reptile species documented in the country. This high representation was particularly evident in families with limited diversity, evidenced by the complete species coverage for select groups such as those comprising no more than five amphibian species (e.g., Ceratophryidae, Ranidae, and Pipidae) or 10 reptile species (e.g., Cheloniidae, Alligatoridae, Crocodylidae, Aniliidae, and Phyllodactylidae among others) (Frost, 2023; Uetz et al., 2023). However, the broad taxonomic coverage is not limited to families with poor species diversity in the country. Diverse families such as Leptodactylidae, Hylidae, Bufonidae, Dendrobatidae, and Centrolenidae in amphibians; and Anolidae, Colubridae, and Gymnopthalmidae in reptiles (just to name a few), also are represented by more than 50 % of the known species. This remarkable representation can be attributed in part to the national status of both collections that implement field expeditions across most of the Colombian territory, compared to the regional collections that serve as invaluable repositories to house and preserve the unique diversity from particular areas of the territory (Ortiz-Yusty et al., 2015; Ramírez-Chaves et al., 2021; Ramírez-Chaves et al., 2023).

Since the establishment of both collections, researchers have conducted expeditions across Colombia, accumulating invaluable specimens and data from all 32 departments. Particularly noteworthy for both collections are the high number of species from the department of Amazonas, located in a global biodiversity hotspot (Lynch et al., 1997; Duellman, 1999; Funk et al., 2012). The Amphibian Collection also presents a high number of species from the departments of Antioquia, Boyacá,

and Cauca, mostly Andean departments that harbor diverse biogeographic regions and climates ranging from lowland humid forests to páramos. Notably, these departments share Andean forests and páramos, both considered hotspots with high richness and endemism of amphibian species (Duellman, 1999; McKnight et al., 2007; Tenorio et al., 2023). As for reptiles, the departments of Meta and Chocó follow the Amazonas department in terms of species numbers. These departments contain lowland, Andean, and foothill ecosystems of the Western and Eastern Andean Mountains. Although there appear to be plausible biological explanations for the species richness observed across the different departments for both collections, fieldwork efforts, represented as the number of specimens, have highly influenced the observed species trends.

Fieldwork efforts undertaken by researchers throughout the territory have been unequal mainly due to geographical, political, and cultural factors, thus affecting the number of specimens collected and species represented from each department. For example, departments geographically close to large centralized urban centers and prominent universities or research institutions (e.g., Cundinamarca, Santander, Boyacá, and Meta) have benefited from extensive fieldwork and, consequently, have more specimens represented in both collections, which correlates with a greater reported diversity. Contrarily, departments difficult to access due to their remoteness, poor road infrastructure, or expensive flight tickets (e.g., Guainía in the Amazonian region and Guajira in the Caribbean region) show limited fieldwork efforts, resulting in fewer specimens and species represented. Furthermore, Colombia has suffered serious sociopolitical conflicts, including the presence of illegal armed groups, which has resulted in periodic restrictions and inaccessibility for sampling in many regions (e.g., Norte de Santander and Caquetá, among others) (Sánchez-Cuervo & Aide, 2013; Negret et al., 2017). The collective influence of all these factors strongly contributes to the geographical patterns evidenced in terms of species and specimens represented in the Instituto Humboldt collections.

Multiple national and regional projects and donations through time have nurtured the Amphibian and Reptile Collections at the Instituto Humboldt, influencing some of the observed trends. For example, the main peak observed for the Reptile Collection during the mid and late 1970s follows three main events: 1) a large donation by the Instituto Nacional de Salud (INS) of >730 specimens spanning over 20 Colombian departments and five additional countries; 2) the development of a national project focused on the study of malaria (UVMP), lead in Colombia by the Universidad del Valle in Colombia between 1975 and 1980 (Ayala & Castro, 1983), that deposited specimens in multiple collections, including >340 in the Reptile Collection of the Instituto Humboldt; and 3) a donation by José Vicente Rueda-Almonacid of >400 specimens from the Chocó department. While other peaks are observed in different periods, none of them approach the ~2,000 specimens accessioned between 1976-1979 in the reptile collection.

Other prominent peaks were observed between 2012 and 2019, mainly within the Amphibian Collection. The first of these, between 2012 and 2015, is attributed to the deposit of >3,500 specimens by ~60 researchers following the arrival of the curator M.Sc. Andrés R. Acosta, after a long period without a formal curator in the collection. In fact, between 1996-2013, the collections presented the lowest growth trend due to the absence of a curator. Most of the amphibian samples during this first peak were deposited by Dr. Argelina Blanco (~1,180 specimens), curator M.Sc. Andrés Acosta (~830), and Dr. Marvin Anganoy-Criollo (~410), coming from the Arauca, Casanare, and Nariño departments. The second peak, between 2016-2019, followed the Colombian peace agreement signing, which allowed scientists to return to areas previously inaccessible from national conflict. Projects referred to as the "BIO expeditions" — a governmental initiative started in 2017 with the primary goal of comprehensively exploring and documenting the biodiversity of pristine or poorly known areas with high biodiversity — and other institutional projects, contributed to the accessions of more than 2,300 specimens from multiple areas of the country (e.g., Colombia BIO: Ayala et al., 2018; Santander BIO: Torres & Quiñones, 2019; Boyacá BIO: Giraldo & Galeano, 2020). These expeditions resulted in a significant collection of specimens and the descriptions of new species, which strengthened the collections of national research institutes and universities.

As expected, the BIO expeditions also played an important role in the growth trend of the extended collections associated with the Amphibian and Reptile collections. Notably, the Colección de Tejidos (IAvH-CT) showed a remarkable increase since 2014 in both the number of samples and the species represented, with amphibians increasing from 52 to 251 species (>382 % growth), and reptiles from 72 to 184 (>55 % growth) (Arbeláez-Cortés et al., 2015). Also, the Colección de Sonidos Ambientales (IAvH-CSA) historically started as a branch of the Ornithology Collection, storing a diverse taxonomic representation of bird records and very few amphibian call recordings previous to 2016 (Mendoza-Henao et al., 2023). It has since grown to currently comprise recordings from 114 amphibian species representing approximately 14 % of the total anuran species diversity in Colombia (Mendoza-Henao et al., 2023). However,

records from only 49 species are associated with a specimen voucher, a figure that continues to grow. Finally, regarding the hemipenes collection, the absence of information regarding the preparation dates of the genitalia precluded an accurate estimation of the growth trends. Nonetheless, we highlight an important increase of 24 % in samples over the past two years, attributed primarily to the implementation of a recent project focused on the coevolution of snake genitalia. These extended collections incorporate multiple facets of the phenotype to explore and address intriguing questions concerning evolution, ecology, morphology, conservation, and other pertinent areas of research (Webster, 2017). They also represent a relevant tool for the implementation of integrative taxonomic approaches during new species descriptions (Padial et al., 2010), in which the incorporation of multiple lines of evidence, such as evolution (e.g., genes), behavior (e.g., sound recordings of amphibians), and morphological data (e.g., hemipenes for Squamata), are essential in ensuring accurate and robust species descriptions of amphibians and reptiles (Torres-Carvajal, 2009; Cadle, 2010; Glaw et al., 2010; Vera-Pérez et al., 2019; Passos et al., 2022; Patiño-Ocampo et al., 2022).

Species descriptions and taxonomic studies have conventionally been one of the most relevant research topics within the use of biological collections. This is evident by the finding that ~45 % of the published studies from both collections focused on taxonomy and systematics, as well as by the representation and diversity of 32 holotype specimens and over 400 paratypes housed at the Instituto Humboldt. The recent growth of the extended collections will likely also contribute to an increase of studies in this category in the following years. Similarly, studies centered around species distributions, encompassing extensions in geographic range, biogeography, or niche modeling, represented approximately 46 % of the published studies. These types of studies occupy an important position among the substantial research areas in which biological collections find a direct application (Pyke & Ehrlich, 2010). Together, these categories account for >90 % of all publications based on specimens or datasets associated with both collections.

However, museum specimens provide important information beyond how many species exist or where they are distributed. They also offer insights into other ecological and evolutionary aspects relevant to the study of biodiversity and global sustainability (Bartomeus et al., 2018; Schmitt et al., 2018). New technological approaches (e.g., historical DNA genome sequences, high-resolution x-ray CT imaging, automated analysis of sound records, and 3D laser scanning, among others) open opportunities for various novel research areas such as morphological and ecological shifts (MacLean et al., 2018; Schmitt et al., 2018), the origin and spread of emergent diseases (Schmitt et al., 2018; Flechas et al., 2023), intra- and inter-species interactions (Bartomeus et al., 2018), phenology (Park et al., 2018), and biological invasions (Beaulieu et al., 2018), among many others (Webster, 2017). Despite the large increase in publication numbers over the last decade, the Amphibian and Reptile Collections have been relatively poorly utilized for studying topics such as natural history, conservation, morphology, anatomy, ecology, toxicology, and evolution. This finding reflects the biased use of both collections in previous decades and highlights the need to find new opportunities for using the biological collections to study different and novel lines of research in order to comprehend and tackle current biodiversity challenges. Unfortunately, most specimens housed at the Instituto Humboldt still lack georeferenced data, a phenomenon shared with other Colombian collections holding specimens collected before the 1980's (when GPS devices became more commonly used by scientists in the country), highlighting the need to prioritize georeferencing older specimens. This will likely broaden the use of collections in studies focused on a diverse range of research topics (Vásquez-Restrepo, 2021).

Although there have been numerous worldwide initiatives aimed at digitizing specimen data from biological collections, such as the US National Science Foundation's Advancing Digitization of Biodiversity Collections program, the European Union's Distributed System of Scientific Collections, the Atlas of Living Australia, and more recently GBIF, Colombia has yet to witness the emergence of similar national funded initiatives that promote and finance the digitization of museum material (Monfils et al., 2022). Unfortunately, over 60 % of the herpetological collections in Colombia lack public representation of their data on the GBIF platform, limiting their usage (Vásquez-Restrepo, 2021). However, initiatives such as the Biodiversity Information System (SIB Colombia), the Colombian node for GBIF, continuously promote the need and relevance to make biodiversity data obtained from research studies or biological collections accessible (SIB Colombia, 2024). Furthermore, specialized collection management platforms like Specify, EMu, and Arctos facilitate the processing and integration of biological collection data, allowing researchers to link information from multiple sources across various types of extended specimens (Thomer et al., 2018). These platforms also permit researchers to directly share specimen-related data with open-access repositories like GBIF, or efficiently generate the required file formats for data submission, such as Darwin Core files for GBIF.

Other digital representations of specimens, such as images, have recently been incorporated into both collections, starting with type specimens. The capture of digital images of specimens is a process that not only facilitates their usage for answering biological questions, but also leads to the democratization of collections, expanding their use across numerous fields including social sciences and artistic expression inspired by nature. Likewise, as an essential component of biodiversity documentation, this initiative contributes to establishing computer networks that facilitate the flow of information (Crisci, 2006). As the lack of a digital voucher hampers the accessibility and utilization of biological collections for various research and non-research related undertakings, we expect to continue pursuing the goal of digitizing specimens to be made freely accessible.

CONCLUSIONS

Overall, this study provides clear information on the taxonomic and geographic representation of the second largest reptile and amphibian collections in Colombia, elucidating some of the main knowledge gaps and sampling efforts to help guide future efforts. We also hope to encourage other national and Latin American collections to similarly explore the data housed in their collections to help guide future collecting, georeferencing, digitization and research efforts in a complementary and collaborative way. Considering the importance of natural history museums for research, education, outreach, and their potential to help understand and address current challenges, such as those imposed by the triple planetary crisis, taking steps towards these common goals is imperative in modern times.

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Apéndice 1. Número de especies y especímenes por cada departamento depositados en las colecciones biológicas de Anfibios (IAvH-Am) y Reptiles (IAvH-R).

Appendix 1. Number of species and specimens for each department deposited in the biological collections of Amphibians (IAvH-Am) and reptiles (IAvH-R).

Departament	Amphibians (IAvH-Am)		Reptiles (IAvH-R)	
	No. Species	No. Specimens	No. Species	No. Specimens
Amazonas	101	811	127	670
Antioquia	107	578	96	319
Arauca	45	1113	60	578
Atlántico	3	24	5	58
Bolívar	25	176	39	549
Boyacá	89	1014	60	379
Caldas	69	553	37	136
Caquetá	37	158	57	158
Casanare	51	1618	67	289
Cauca	97	844	74	321
Cesar	22	76	22	103
Chocó	78	710	113	750
Córdoba	22	105	41	125
Cundinamarca	69	1415	69	450
Guainía	6	13	17	41
Guaviare	10	18	13	34
Huila	38	245	30	93
La Guajira	6	20	23	73
Magdalena	38	716	78	899
Meta	73	949	120	665
Nariño	78	1010	26	75
Santander	16	147	27	54
Putumayo	90	670	53	163
Quindío	28	574	22	56
Risaralda	45	619	19	35
San Andrés, Providencia y Santa Catalina	2	10	12	78
Santander	78	1103	91	385
Sucre	30	583	59	231
Tolima	45	290	65	270
Valle del Cauca	55	186	61	164
Vaupés	45	171	86	212
Vichada	35	589	77	704

Apéndice 2. Número de especies y registros individuales de sonidos para las familias de anuros con especímenes de referencia en la Colección de Anfibios del Instituto Humboldt (IAvH-Am) y la Colección de Sonidos Ambientales (IAvH-CSA).

Appendix 2. Number of species and individual sound records for anuran families with both specimen vouchers in the Amphibian Collection of Instituto Humboldt (IAvH-Am) and the Colección de Sonidos Ambientales (IAvH-CSA).

Family	No. Species	No. Records
Aromobatidae	2	4
Bufonidae	6	15
Centrolenidae	4	12
Hylidae	20	68
Leptodactylidae	8	14
Microhylidae	1	2
Phyllomedusidae	3	5
Strabomantidae	5	9
Total	**49**	**129**

Apéndice 3. Representación taxonómica de registros de sonidos de anfibios en departamentos colombianos. Los números entre paréntesis corresponden al recuento de especies con registros de sonidos y especímenes de referencia para cada familia abreviada. Las abreviaturas de las familias son las siguientes: Arom: Aromobatidae, Bufo: Bufonidae, Cent: Centrolenidae, Hyli: Hylidae, Lept: Leptodactylidae, Phyl: Phyllomedusidae, Stra: Strabomantidae.

Appendix 3. Taxonomic representation of sound records of amphibians in Colombian departments. Numbers in parentheses correspond to the count of species with both sound records and voucher specimens for each abbreviated family. Family abbreviations are as follows: Arom: Aromobatidae, Bufo: Bufonidae, Cent: Centrolenidae, Hyli: Hylidae, Lept: Leptodactylidae, Phyl: Phyllomedusidae, Stra: Strabomantidae.

Departments	Family
Bolívar	Hyli (2)
Boyacá	Hyli (2), Stra (2)
Casanare	Bufo (1), Hyli (5),
Córdoba	Hyli (7), Lept (1)
Cundinamarca	Cent (7), Hyli (2), Stra (5)
Huila	Cent (1), Hyli (3), Lept (1)
Meta	Bufo (1), Hyli (16), Lept (6), Micr (2), Phyl (2)
Putumayo	Arom (2), Bufo (3), Cent (3), Hyli (8), Lept (1), Phyl (1), Stra (1)
Santander	Arom (2), Bufo (10), Cent (1), Hyli (23), Lep (5), Phyl (2)

Apéndice 4. Número de especies con muestras de tejido para las familias de anfibios y reptiles alojadas en la Colección de Tejidos del Instituto Humboldt (IAvH-CT).

Appendix 4. Number of species with tissue samples for amphibian and reptile families housed at the Tissue Collection of Instituto Humboldt (IAvH-CT).

Class	Family	No. Species	No. Tissue samples	No. Specimens
Amphibia	Aromobatidae	5	29	670
	Bufonidae	18	129	319
	Centrolenidae	16	54	578
	Ceratophryidae	1	2	58
	Craugastoridae	4	59	549
	Dendrobatidae	20	79	379
	Eleutherodactylidae	1	1	136
	Hemiphractidae	3	9	158
	Hylidae	48	473	289
	Leptodactylidae	25	320	321
	Microhylidae	5	59	103
	Phyllomedusidae	7	25	750
	Pipidae	1	2	125
	Ranidae	2	14	450
	Strabomantidae	81	760	41
	Plethodontidae	7	17	34
	Caeciliidae	3	6	93
	Siphonopidae	2	2	73
	Typhlonectidae	1	2	899
	TOTAL	**250**	**2042**	**665**

Apéndice 4 (cont.). Número de especies con muestras de tejido para las familias de anfibios y reptiles alojadas en la Colección de Tejidos del Instituto Humboldt (IAvH-CT).

Appendix 4 (cont.). Number of species with tissue samples for amphibian and reptile families housed at the Tissue Collection of Instituto Humboldt (IAvH-CT).

Class	Family	No. Species	No. Tissue samples	No. Specimens
Reptilia	Alligatoridae	3	7	75
	Alopoglossidae	3	16	54
	Anolidae	24	192	163
	Corytophanidae	3	10	56
	Diploglossidae	1	2	35
	Gekkonidae	3	27	78
	Gymnophthalmidae	14	86	385
	Iguanidae	1	5	231
	Phyllodactylidae	2	12	270
	Polychrotidae	2	3	164
	Scincidae	3	7	7
	Sphaerodactylidae	12	92	92
	Teiidae	11	27	27
	Tropiduridae	6	29	29
	Anomalepididae	1	3	3
	Boidae	6	16	16
	Colubridae	62	250	250
	Elapidae	5	12	12
	Leptotyphlopidae	2	2	2
	Viperidae	6	33	33
	Chelidae	3	9	9
	Emydidae	1	1	1
	Geoemydidae	1	1	1
	Kinosternidae	2	9	9
	Podocnemididae	3	18	18
	Testudinidae	1	1	1
	TOTAL	**181**	**870**	**870**

Apéndice 5. Representación taxonómica de muestras de tejido de anfibios alojadas en la Colección de Tejidos del Instituto Humboldt (IAvH-CT) a través de los departamentos de Colombia. Los números entre paréntesis corresponden al recuento de especies con muestras de tejido y especímenes de referencia para cada familia abreviada. Las abreviaturas de las familias son las siguientes: Arom: Aromobatidae, Bufo: Bufonidae, Caec: Caeciliidae, Cent: Centrolenidae, Crau: Craugastoridae, Dend: Dendrobatidae, Eleu: Eleutherodactylidae, Hemi: Hemiphractidae, Pipi: Pipidae, Hyli: Hylidae, Lept: Leptodactylidae, Micr: Microhylidae, Phyl: Phyllomedusidae, Plet: Plethodontidae, Rani: Ranidae, Siph: Siphonopidae, Stra: Strabomantidae, Typh: Typhlonectidae.

Appendix 5. Taxonomic representation of tissue samples of amphibians housed at the Colección de Tejidos of the Instituto Humboldt (IAvH-CT) across different departments of Colombia. Numbers in parentheses correspond to the count of species with both tissue samples and voucher specimens for each abbreviated family. Family abbreviations are as follows: Arom: Aromobatidae, Bufo: Bufonidae, Caec: Caeciliidae, Cent: Centrolenidae, Crau: Craugastoridae, Dend: Dendrobatidae, Eleu: Eleutherodactilydae, Hemi: Hemiphractidae, Pipi: Pipidae, Hyli: Hylidae, Lept: Leptodactylidae, Micr: Microhylidae, Phyl: Phyllomedusidae, Plet: Plethodontidae, Rani: Ranidae, Siph: Siphonopidae, Stra: Strabomantidae, Typh: Typhlonectidae).

Departments	Family
Antioquia	Bufo (2), Crau (5), Hyli (1), Stra (38)
Arauca	Bufo (9), Dend (2), Hyli (17), Lept (16), Micr (1), Phyl (1)
San Andrés, Providencia y Santa Catalina	Lept (2)
Bolívar	Hyli (23), Lept (17), Micr (2)
Boyacá	Arom (14), Bufo (7), Cent (7), Crau (4), Dend (16), Hyli (67), Lept (10), Phyl (1), Stra (157), Plet (1)
Caldas	Lept (2), Stra (8)
Caquetá	Cent (1)
Casanare	Bufo (9), Dend (5), Hyli (14), Lept (20), Rani (2), Stra (8)
Cauca	Hyli (1), Stra (13)
Cesar	Bufo (1), Hyli (1), Lept (7)
Chocó	Cent (6), Crau (21), Dend (12), Hyli (4), Lept (1), Phyl (1), Plet (2), Stra (16)
Córdoba	Bufo (4), Hyli (21), Lept (13), Micr (7),
Cundinamarca	Arom (2), Bufo (10), Cent (11), Hyli (32), Lept (13), Plet (1), Stra (112)
Huila	Bufo (3), Cent (2), Dend (5), Hyli (7), Lept (5), Rani (3)
Magdalena	Cent (2), Dend (1), Hemi (7), Lept (1), Plet (3), Stra (2)
Meta	Arom (1), Bufo (24), Dend (1), Hyli (67), Lept (86), Micr (34), Phyl (5), Plet (1), Stra (13)
Nariño	Hemi (2), Stra (83)
Norte de Santander	Hyli (15), Stra (49), Typh (1)
Putumayo	Arom (5), Bufo (24), Cent (6), Dend (10), Hyli (55), Lept (17), Micr (1), Phyl (11), Plet (2), Rani (3), Stra (52), Siph (1)
Quindío	Cent (4), Dend (2), Stra (19),
Risaralda	Bufo (1), Dend (1), Hyli (2), Stra (34)
Santander	Arom (7), Bufo (20), Cent (6), Crau (23), Dend (20), Eleu (1), Hyli (119), Lept (65), Micr (14), Phyl (6), Plet (7), Rani (6), Stra (98), Caec (5)
Sucre	Lept (3), Caec (1), Typh (1)
Tolima	Bufo (2), Cent (2), Hyli (2), Lept (8), Siph (1), Stra (39)
Valle del Cauca	Bufo (5), Cent (7), Crau (6), Dend (4), Lept (1), Stra (19)
Vichada	Bufo (8), Hyli (25), Lept (33), Pipi (2)

Apéndice 6. Representación taxonómica de muestras de tejido de reptiles alojadas en la Colección de Tejidos del Instituto Humboldt (IAvH-CT) a través de los departamentos de Colombia. Los números entre paréntesis corresponden al recuento de especies con muestras de tejido y especímenes de referencia para cada familia abreviada. Las abreviaturas de las familias son las siguientes: Alli: Alligatoridae, Alop: Alopoglossidae, Anol: Anolidae, Anom: Anomalepididae, Cory: Corytophanidae, Dipl: Diploglossidae, Gekk: Gekkonidae, Gym: Gymnophthalmidae, Igua: Iguanidae, Phyl: Phyllodactylidae, Poly: Polychrotidae, Scin: Scincidae, Spha: Sphaerodactylidae, Teii: Teiidae, Trop: Tropiduridae, Boid: Boidae, Colu: Colubridae, Elap: Elapidae, Lept: Leptotyphlopidae, Vipe: Viperidae, Chel: Chelidae, Emyd: Emydidae, Geoe: Geoemydidae, Kino: Kinosternidae, Podo: Podocnemididae, Test: Testudinidae.

Appendix 6. Taxonomic representation of tissue samples of reptiles housed at the Colección de Tejidos of the Instituto Humboldt (IAvH-CT) across different departments of Colombia. Numbers in parentheses correspond to the count of species with both tissue samples and voucher specimens for each abbreviated family. Families abbreviations are as follows: Alli: Alligatoridae, Alop: Alopoglossidae, Anol: Anolidae, Anom: Anomalepididae, Cory: Corytophanidae, Dipl: Diploglossidae, Gekk: Gekkonidae, Gym: Gymnophthalmidae, Igua: Iguanidae, Phyl: Phyllodactylidae, Poly: Polychrotidae, Scin: Scincidae, Spha: Sphaerodactylidae, Teii: Teiidae, Trop: Tropiduridae, Boid: Boidae, Colu: Colubridae, Elap: Elapidae, Lept: Leptotyphlopidae, Vipe: Viperidae, Chel: Chelidae, Emyd: Emydidae, Geoe: Geoemydidae, Kino: Kinosternidae, Podo: Podocnemididae, Test: Testudinidae.

Departments	Family
Antioquia	Gymn (2), Geoe (1)
Arauca	Anol (2), Teii (2), Colu (5), Vipe (9), Kino (1)
San Andrés, Providencia y Santa Catalina	Anol (3), Gekk (1), Igua (1), Spha (1), Teii (1)
Bolívar	Anol (5), Gekk (1), Gymn (1), Spha (5), Teii (2), Anom (1), Colu (12)
Boyacá	Alop (3), Anol (16), Gekk (1), Gymn (36), Phyl (1), Poly (1), Spha (1), Teii (1), Trop (8), Colu (28), Elap (1), Vipe (2)
Casanare	Anol (1), Spha (6), Teii (1), Colu (8), Vipe (1)
Cesar	Anol (3), Cory (1), Gekk (1), Gymn (1), Phyl (1), Spha (3), Teii (1), Colu (3)
Chocó	Anol (17), Cory (1), Gymn (1), Phyl (1), Boid (2), Colu (7), Elap (1), Vipe (2), Kino (1)
Córdoba	Anol (10), Gekk (4), Gymn (6), Scin (2), Spha (9), Boid (1), Colu (13), Vipe (2)
Cundinamarca	Anol (9), Gymn (1), Spha (1), Trop (2), Colu (23), Vipe (1)
Huila	Anol (4), Gekk (1), Gymn (1), Phyl (2), Spha (7), Teii (1), Colu (3), Elap (1)
Magdalena	Spha (2), Trop (2), Colu (1)
Meta	Alli (6), Alop (9), Anol (24), Gekk (3), Gymn (5), Igua (3), Scin (3), Spha (15), Teii (5), Boid (3), Colub (18), Elap (1), Viper (5), Chel (5), Kino (1), Podo (7)
Putumayo	Alli (1), Anol (33), Gekk (2), Gymn (11), Phyl (1), Spha (5), Trop (2), Colu (19), Elap (3), Viper (3)
Quindío	Anol (5), Colu (7)
Santander	Alop (4), Anol (52), Cory (6), Dipl (2), Gekk (3), Gymn (20), Igua (1), Phyl (5), Poly (1), Spha (29), Teii (6), Trop (3), Anom (2), Boid (5), Colu (79), Elap (5), Lept (1), Vipe (7), Emyd (1), Kino (2)
Sucre	Anol (3), Cory (2), Phyl (1), Spha (2), Colu (4), Vipe (1)
Valle del Cauca	Gekk (1), Spha (4), Colu (2), Lept (1)
Vichada	Anol (5), Gekk (9), Gymn (1), Poly (1), Scin (2), Spha (2), Teii (7), Trop (12), Boid (5), Colu (18), Chel (4), Kino (4), Podo (11), Test (1)

Apéndice 7. Número de especies con hemipenes preparados para las familias de reptiles alojadas en la Colección de Reptiles del Instituto Humboldt (IAvH-R).

Appendix 7. Number of species with prepared hemipenes for reptile families housed at the Reptile Collection of Instituto Humboldt (IAvH-R).

Family	No. Species	No. Hemipenes
Alopoglossidae	1	1
Amphisbaenidae	1	1
Boidae	4	6
Colubridae	41	132
Corytophanidae	1	1
Anolidae	5	8
Elapidae	8	17
Gekkonidae	2	2
Gymnophthalmidae	2	3
Hoplocercidae	2	2
Scincidae	1	1
Sphaerodactylidae	1	4
Teiidae	5	5
Tropiduridae	3	4
Viperidae	11	49
TOTAL	**88**	**236**

Apéndice 8. Resumen de 112 fuentes publicadas que utilizaron la colección de Anfibios (A) y/o Reptiles (R) del Instituto Humboldt de 2000 a 2023. Se proporciona el número de referencias por recurso de la colección y tema de investigación para ambas colecciones.

Appendix 8. Summary of 112 published sources that used the Amphibian (A) and/or Reptile (R) collection of Instituto Humboldt 2000-2023. Provided are the number of references by collection resource and research topic for both collections.

Collection resource	Research Topic																				
	Taxonomy and systematics		Natural history		Ecology		Distribution			Morphology and anatomy		Evolution		Toxicology		Conservation			Species list	
	A	*R*	*A*	*R*	*A*	*R*	A	A	R	A	R	A	R	A	R	A	R	A	R	A
Specimen	26	16	6	2	3	2	21	16	1	5	0	0	0	1	5	0	2	2		
Tissues	0	3	0	0	1		1	4	0	0	0	0	0	0	0	1	0	0		
Hemipenes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Sounds	2	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0		
Eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Bones	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Metadata	1	2	1	0	1	0	3	7	0	0	0	0	0	0	2	3	1	0		