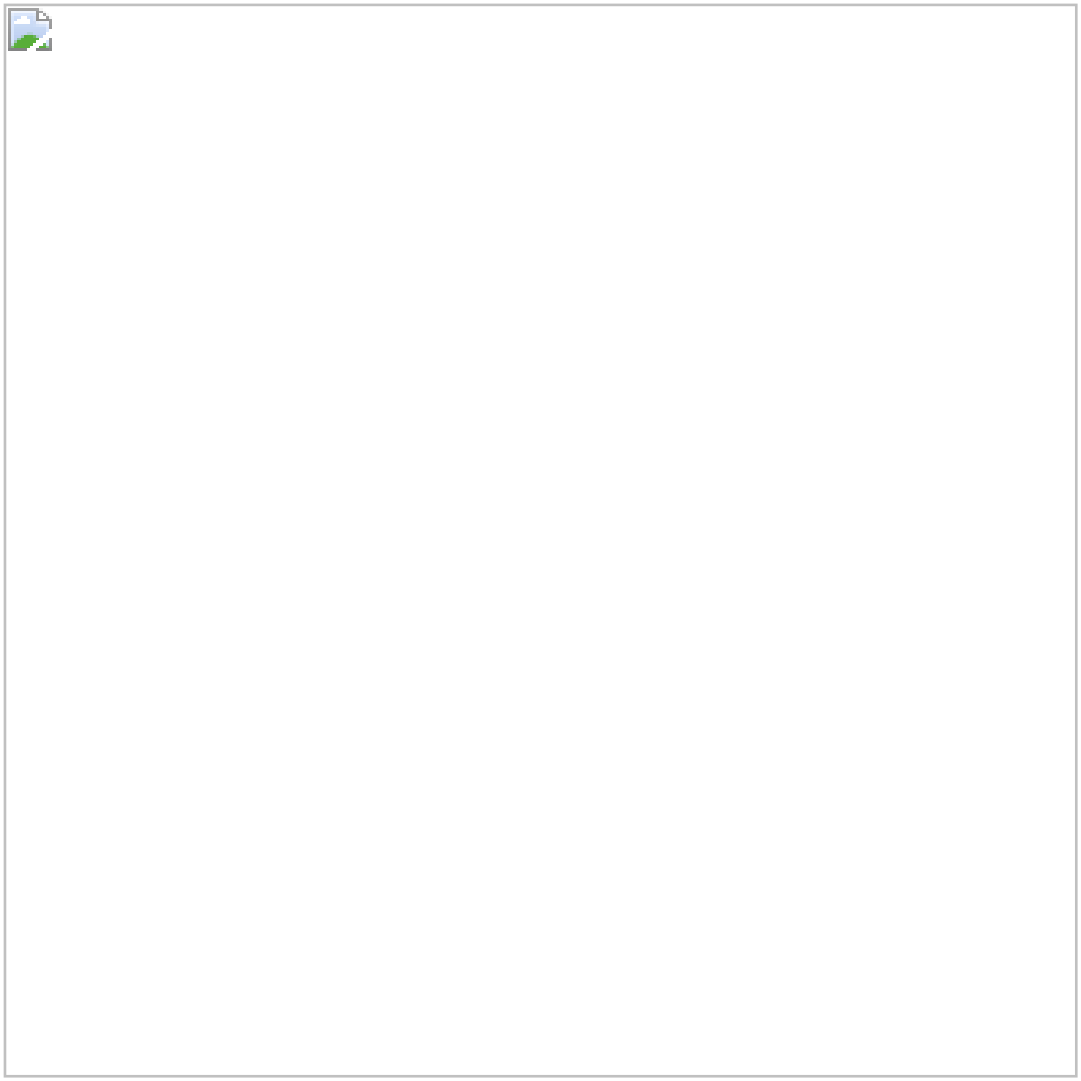

Current State of Knowledge of Páramo Amphibians in Colombia: Spatio Temporal Trends and Information Gaps to Be Strengthened for Effective Conservation

Authors: Saboyá Acosta, Liliana Patricia, and Urbina-Cardona, J. Nicolás

Source: Tropical Conservation Science, 16(1)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/19400829231169984

Review Article

Tropical Conservation Science
Volume 16: 1–23

DOI: 10.1177/19400829231169984
journals.sagepub.com/home/trc
SAGE

Current State of Knowledge of Páramo Amphibians in Colombia: Spatio Temporal Trends and Information Gaps to Be Strengthened for Effective Conservation

Liliana Patricia Saboyá Acosta[1] and J. Nicolás Urbina-Cardona[2]

Abstract

Background and Research Aims: Globally, Colombia is the country with the largest extent of Páramos (delimited in 36 complexes) and with the greatest number of amphibian species in this ecosystem. This work consolidated scientific literature on the amphibians of the Colombian Páramos to characterize temporal, taxonomic, thematic, and geographic patterns, which allow us to identify information gaps that must be fulfilled to achieve effective species conservation. **Methods:** We conducted a systematic literature survey with seven different search strategies and generated a database. We read each document's Abstract, Methods, Study Area, Results, and supplementary material, following the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) protocol. **Results:** We found 405 documents published between 1863 and 2021. The composition and richness of 142 amphibian species (95 endemics to Colombia), presented significant differences in Páramo complexes and between sectors. Since 2000, the diversity of research topics has increased with a high proportion of studies on Natural History, Systematics and Taxonomy, and Conservation, distributed between 19 and 22 of the departments with Páramos in their jurisdiction. However, much of this knowledge concentrates in less than 20% of total species in just 6% of Páramos complexes. **Conclusion:** We found critical shortfalls in taxonomy, spatial information, and conservation actions on Páramos amphibians. We need to increase studies that include field data in more geographic areas and research topics, such as Population and Community ecology, Natural history (from a quantitative approach), Infectious disease, and Ecophysiology. **Implications for Conservation:** The scientific information gaps represent a challenge in generating effective strategies to conserve Páramo amphibians, considering the high degree of endemism and threats to these species. More than 80% of the Páramo amphibian species only have the information of their descriptions and little is known about their ecological requirements, population size, or data related to specific threats.

Keywords

anura, caudata, high mountain, knowledge shortfalls, neotropics, publications, páramo ecosystem

Introduction

The Neotropical high montane includes a variety of unique ecosystems on the planet, including montane and high Andean forests and large areas dominated by native grasses (Gradstein et al., 2008; Hofstede, 2013). The tropical alpine grasslands of America are located on mountain peaks at elevations above 3,000 m. The humid and dry punas of the Andes, the high-altitude grassland in southeastern Brazil, and the equatorial Páramos are classified within these grasslands (Ruiz et al., 2008; Christmann & Oliveras, 2020). Páramos

[1]Pontificia Universidad Javeriana, Facultad de Estudios Ambientales y Rurales. Carrera 7 N 40 – 62, Bogotá, Colombia.
[2]Pontificia Universidad Javeriana, Facultad de Estudios Ambientales y Rurales, Departamento de Ecología y Territorio. Carrera 7 N 40 – 62, Bogotá, Colombia.

Corresponding Author:
Liliana Patricia Saboyá Acosta, Pontificia Universidad Javeriana, Facultad de Estudios Ambientales y Rurales. Carrera 7 N 40 – 62, Bogotá, Colombia.
Email: lilianasaboya@javeriana.edu.co

are part of the high montane ecosystems with the largest extension, being distributed in the equatorial Andes and southern Central America, above the limit of the high Andean forests and below the snow line (Lauer, 1981; Hofstede et al., 2003; Anthelme & Peyre, 2019).

In Colombia, Páramos are considered strategic ecosystems of great importance due to the ecosystem services they provide, such as carbon sequestration and the regulation of almost 70% of the country's drinking water (Rivera Ospina & Rodríguez, 2011; Hofstede, 2013; Cabrera, 2014). The Colombian Páramos have a unique diversity in terms of species richness and endemicity on the planet. This is explained mainly by the complex geological and environmental history of the Andes (Navas, 1999; Gregory-Wodzicki, 2000; Doan, 2003; Madriñán et al., 2013). The high speciation rates are associated with differences in environmental conditions within mountain systems, which are compared to continental islands (Vuilleumier, 1970; Navas, 2002; Mendoza et al., 2015).

Amphibians are one of the most diverse lineages of vertebrates in Colombian Páramos (Ardila-Robayo & Acosta-Galvis, 2000; Lynch & Suárez, 2002). Given their life history and physiological traits, both salamanders and anurans have adapted and diversified in these environments. Their low metabolisms rates, behavior, morphological traits, and thermal adaptations contributed to compensate for overexposure to wind and UV rays or heat loss in an ecosystem where the daily circadian cycle changes abruptly. (Navas, 1996a; Navas, 2006; Carvajalino-Fernández et al., 2011; Navas et al., 2013). Most studies of Páramo amphibians focus on descriptions or species lists (Rueda-Almonacid & Hoyos, 1991; Ardila-Robayo & Acosta-Galvis, 2000; Lynch, 2001; Buitrago-González et al., 2016; Henao et al., 2019), as well as some research in Ecophysiology (Carvajalino-Fernández et al., 2011; Guarnizo & Cannatella, 2014; Navas, 1996b, 1996), morphology (Hoyos et al., 2015; González-Durán et al., 2017; Mendoza - Henao et al., 2019), bioacoustics (Fandiño et al., 1997; Gutiérrez & Lüddecke 2002) and community ecology (Gutiérrez-Lamus et al., 2004; Roach et al., 2020; Duarte-Ballesteros et al., 2021). However, despite a large amount of research carried out in the Colombian Páramos, scientific publications are scattered in various sources and some of them are difficult to access.

The study of anurans and salamanders diversity in the high mountains of Colombia is of vital importance given the accelerated loss of ecosystems in the tropical Andes (Etter & van Wyngaarden, 2000; Etter et al., 2008; Etter et al., 2018). Furthermore, habitat loss in synergy with climate change will increase the risk of extinction of amphibian species (Agudelo-Hz et al., 2019). These conservation problems are even more evident in the Páramo ecosystem because its transformation by human actions has recently increased (Alarcón et al., 2002; Rivera Ospina & Rodríguez, 2011; Cadena-Vargas & Sarmiento, 2015; Sarmiento et al., 2017). It is urgent to have a database that enables the consolidation of the current knowledge of amphibian studies in the Páramo and, from a bibliometric approach quantify and describe patterns in scientific publications and identify information gaps (Aldana-Domínguez et al., 2017; Arbeláez-Cortés, 2013a; Urbina-Cardona et al., 2023). There are some bibliometric analyzes in Colombia about birds (Estela et al., 2010), turtles (Bock & Páez, 2017), herpetofauna (Urbina-Cardona et al., 2023), and tropical dry forest ecosystem (Aldana-Domínguez et al., 2017), as well as a review on national biodiversity (Arbeláez-Cortés, 2013b). Bernal & Lynch (2008) reviewed the geographic distribution and altitude ranges of amphibian species in the Colombian Andes, but the state of knowledge of the amphibians that inhabit the Páramo ecosystem is unknown to date. Systematic reviews are currently popular and their important contribution to knowledge is increasingly recognized, which is related to the high quality and transparency that these works have (Siddaway et al., 2019). The aims of this study are 1) to describe the temporal patterns in scientific productivity between scientific articles in indexed and non-indexed journals; 2) to characterize the scientific productivity according to the taxonomic groups and the main research topics over the years; 3) to identify spatial patterns in the frequency of publications by sector, department, and Páramo complex; 4) to evaluate changes in the composition and richness of amphibian species in the Páramo complexes by sector in Colombia; and 5) discuss knowledge shortfalls that become challenges for the conservation of Páramo amphibians.

Methods

Study area: Páramos are present in Colombia, Costa Rica, Ecuador, Perú, and Venezuela (Hofstede et al., 2003; Cortés-Duque et al., 2013). In the case of Colombia, this ecosystem covers a total of 2.906.137 ha, which is close to 2.5% of the country's mainland and 50% of the world's Páramos (Morales et al., 2007). Páramos have political and administrative presence in 22 departments, and they are geographically present in the Central, Eastern, and Western Ranges, as well as in the Sierra Nevada de Santa Marta Mountain range (SNSM). As an environmental protection policy for the country, the government created a delimitation process that groups most of the Colombian Páramos under the figure "Páramo complexes" (Morales et al., 2007). This process resulted in a delimitation of 36 complexes grouped into five sectors (Rivera Ospina & Rodríguez, 2011; Sarmiento & Ungar, 2014; Sarmiento & León, 2015; Figure 1).

The Páramo ecosystem is part of the Colombian high mountains, the geographic space corresponding to the altitudinal culminations of the mountainous formations that occur from 2700 ± 100 m (Sarmiento et al., 2013). Until now, there is no consensus about the altitudinal limits between the ecosystems of the Andean, high Andean, and Páramo orobiomes since the species replacement between these ecosystems varies greatly throughout their distribution according to their location and climatic characteristics (Cuatrecasas, 1958; Lauer, 1981; Rangel & Rangel -CH, 2000; Rodríguez et al., 2006; Cortés-Duque et al., 2013; Hofstede et al., 2014).

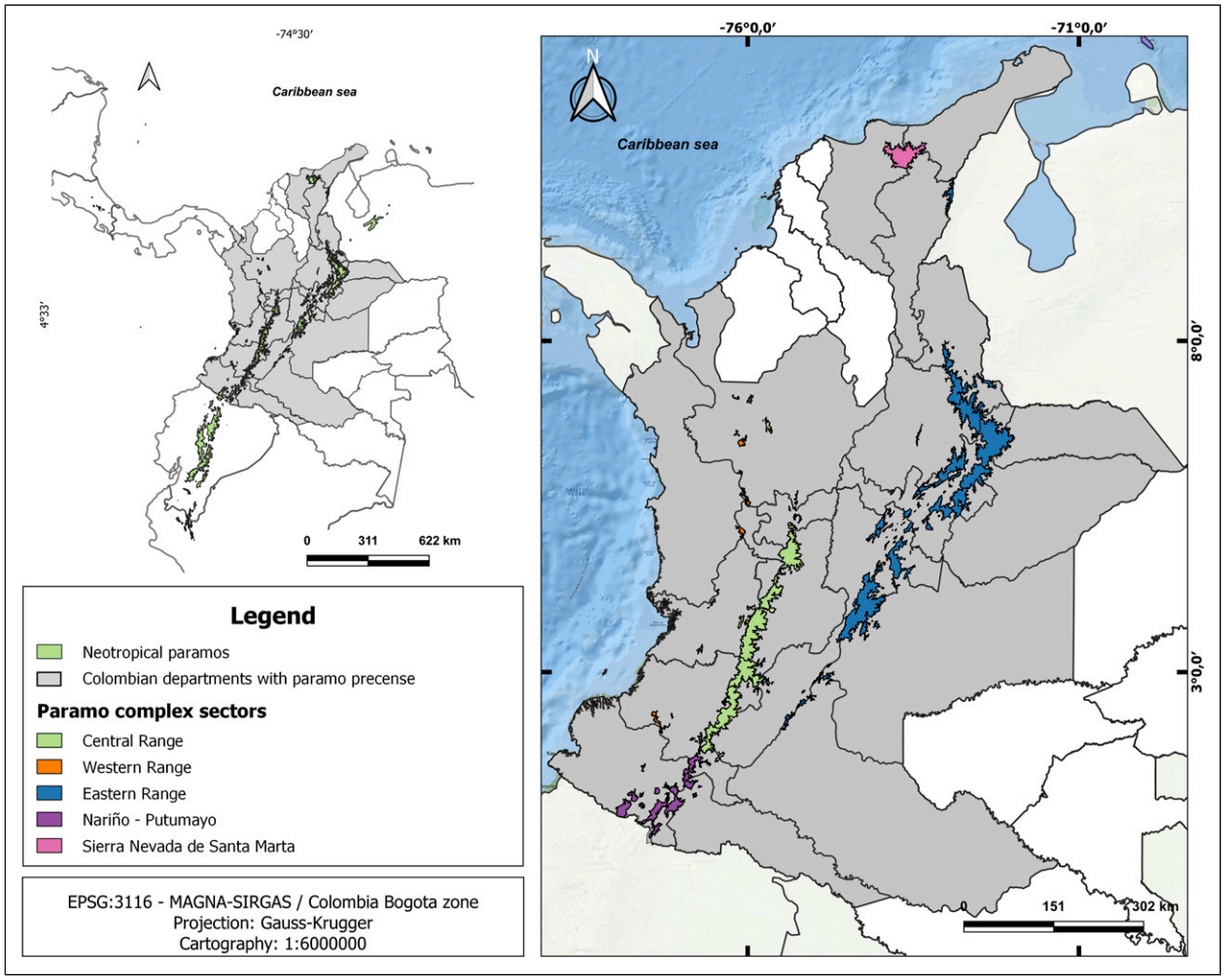

Figure 1. Study area. (A) Distribution of Páramos in the neotropics. (B) Distribution of the 5 sectors within which the 36 Páramo complexes are grouped, according to the delimitation process of Páramo complexes for Colombia (IAvH, 2012).

Literature search and databases: Our systematic literature survey included seven different search strategies to detect the largest number of documents published in indexed journals and local sources with low accessibility, between the years 1863 and 2021: 1) A comprehensive Title-Abstract-Keywords search in Web of Science (WoS including all databases: the Core collection, Korean journals and Scielo citation index) and SCOPUS on the 30th of November 2021, between the years 1927 and 2021 and using the following search syntax: (Páramo* OR "andean forest*" OR "Tropical High mountain") AND (anura* OR amphibian* OR tadpole* OR frog* OR toad* OR salamander OR caudata OR gymnophion* OR caecil *). 2) A search in all the published volumes and issues of all Colombian journals indexed by MinCiencias (Ministerio de Ciencia, Tecnología e Innovación de Colombia, 2018) with the research topics of natural sciences or biological sciences (online Appendix 1). 3) The same search syntax from search strategy 1 was used together with the term "Colombia" in the Biodiversity Heritage library (BHL) (Biodiversity Heritage, 2021) until 2021. 4) A deep search on the digital repositories of the Instituto de Investigación de Recursos Biológicos Alexander von Humboldt - IAvH (2019) (until 2021) and the book series "Colombia Diversidad Biótica" (Rangel-Ch, 2019). 5) We consolidate a taxonomic list of Páramo species reported in the scientific literature (Acosta-Galvis, 2000, Ardila-Robayo & Acosta-Galvis, 2000; Lynch & Suárez, 2002; Bernal & Lynch, 2008; Acosta-Galvis, 2015; Buitrago-González et al., 2016; Meza-Joya & Torres, 2016). 6) We compilated the available records of amphibians present in the Biodiversity Information System [by its Spanish acronym SiB], and the Global Biodiversity Information Facility (GBIF), from the delimitation of Páramos of Colombia project and the biological collections of the University of Antioquia (MHUA), National University of Colombia (ICN), Universidad del Valle (UVC), Universidad del Quindío (ARUQ) and the Alexander von Humboldt Research Institute (IAVH) to complement the geographic and taxonomic

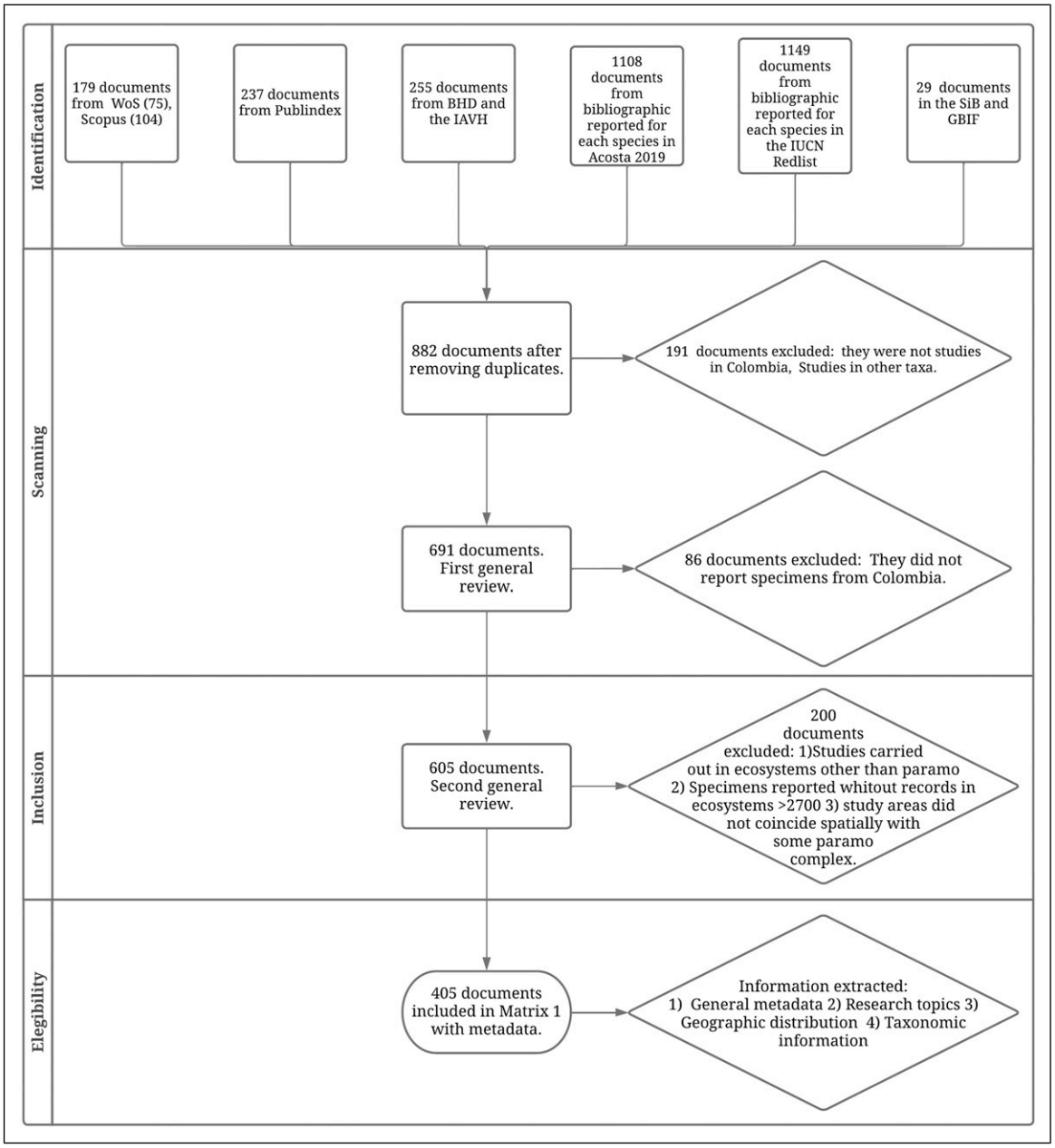

Figure 2. PRISMA methodology (Liberati et al., 2009) used in the present study. Acronyms: BHL = Biodiversity Heritage library; IAVH = Alexander von Humboldt Research Institute; IUCN = International Union for Conservation of Nature; GBIF = Global Biodiversity Information Facility; SIB = Biodiversity Information System of Colombia

information of the species. And, finally, 7) We searched the bibliographic references for each species (until May 2021) reported in the International Union for Conservation of Nature (IUCN) red list assessments (IUCN, 2021) and the list of amphibians of Colombia by Acosta-Galvis (2021).

We generated a database and manually removed duplicates for a total of 882 documents. For each of these documents, the abstract, methods, study area, results, and supplementary material were read following the PRISMA protocol (Liberati et al., 2009; Shamseer et al., 2015), to ensure that all eligible documents met at least one of the following inclusion criteria: 1) It includes studies in ecosystems above 2700 m in Colombia; 2) It presents data on species reported in the taxonomic list compiled from the scientific literature (search strategy 5), and available records (search strategy 6); and 3) Study areas coincide spatially with some Páramo complex. After a complete review and exclusion of documents that did not meet the selection criteria (n = 477 documents), we consolidated a final database (Figure 2) comprising 405 eligible documents (online Appendix 2) to search the following information:

1. General metadata: Type of document (research article, book, book chapter, herpetological note, literature review, data paper, IUCN Red list assessment, SiB-GBIF occurrence data, and Colombian Association of Herpetology catalog files [by its Spanish acronym CARC], keywords, title, publication, year, and source of information: Database: (GeneBank, SiB-GBIF, IUCN), field data, laboratory data, biological collections, and literature.

2. Research topics: Adapting the proposal of Urbina-Cardona et al., (2023), the first author LPS classified each of these documents within some of the following 21 research topics: Anatomy and Morphology, Bioacoustics, Biogeography, Climate change, Community ecology, Conservation, Diet, Ecophysiology, Ethology, Evolution, Functional ecology, Genetics, Geographic distribution, Infectious diseases, Molecular biology, Natural history, Phylogenetics, Population ecology, Reproductive biology, Systematics and Taxonomy, Taxonomic list. A document could be classified within more than one research topic.

3. Geographic distribution: Information on the sector (Central, Eastern, Western Ranges, Sierra Nevada de Santa Marta -SNSM, and Nariño-Putumayo; See Figure 1), as well as on the department and on the Páramo complex (Sarmiento & Ungar, 2014).

4. Taxonomic information: The taxonomic list of studied species, as well as the order and the family. We updated the entire list according to Frost (2021) until January 2022.

Data analysis: Knowledge regarding Páramos amphibians was explored through descriptive graphs to visualize temporal patterns in publications over the years and by type of document. We used bar plots to contrast the number of papers in scientific journals within the Journal Citation Reports (JCR) (Web of Science Group - Clarivate) and Scimago (SJR) (Scopus) with publications in non-indexed sources to contrast in which source of information (indexed or non-indexed) the literature of amphibians Páramos is being generated and their temporal trends. In this way, it can be evidenced if the literature produced on this topic in the country is remaining in easily accessible repositories and if they are published in high-impact scientific journals. Documents were characterized according to the 21 research topics for each taxonomic order and visualized through a Foam tree (Carrot Search FoamTree, 2019). In the Foam tree, each category is divided into polygons of different colors and sizes according to their class and frequency, respectively.

We extracted the information on "Research topics" from online Appendix 2 to describe the number of publications by research topic and year range and we transformed this data into a square root to calculate the association index of Whittaker (1952). With the Whittaker matrix, we created a heat map to show the temporal patterns in the 21 research topics. In the heat map, the frequency of research topics is represented by a color gradient that goes from low association (cold tones) to a high degree of association (warm tones) (Somerfield & Clarke 2013). Additionally, based on the similarity profiles (SIMPROF routine; Clarke et al., 2008), the grouping between 21 research topics was statistically validated to identify sets of topics that had similar productivity patterns over time.

To identify the spatial patterns in productivity, we generated a database from 1) Each record by species and geographical unit (department, Páramo complex, sector), reported in the documents of online Appendix 2; 2) The information on the Extent of Occurrence (EOO) from each species of the taxonomic list (search strategy 5) and available in the last Red list assessments (IUCN, 2021); and 3) The records downloaded from the GBIF and the SIB. For this procedure, we used the "intersection" geoprocessing tool in QGis 3.24.1 (Qgis.org, 2022) and both the occurrences (GBIF and SIB) and the EOO in the Redlist (IUCN, 2021) were extracted and overlapped with the cartographic information on the Páramo complexes delimitation of Colombia at a scale of 1:100,000 (IAvH 2012). We excluded from this analysis all the papers related to taxonomic lists that only presented general information at the department level without reporting records in the Páramo (n = 8). We also excluded 372 records from the literature with uncertain geographic information about the association of the amphibian species to the Páramo ecosystem and 775 GBIF records that did not intersect with Páramo complexes.

The final database (online Appendix 3) contains a total of 2835 records with the following information: species, publication, year, Páramo complex, sector, and department. Given that, in the same study, a species could occur in different departments or Páramo complexes, the information is reported for each of the geographical units (Páramo complex within a sector and in a department). From the online Appendix 4, the number of publications per geographic unit was estimated and maps were generated using the QGis 3.24.1 program (Qgis.org, 2022). Similarly, heat maps were created (Somerfield & Clarke, 2013) to explore the association between 21 research topics by departments. And the grouping (SIMPROF routine) between research topics and departments was statistically validated in the PRIMER 7.0.13 and PERMANOVA add on program (Clarke & Gorlye, 2006, Anderson et al., 2008; Clarke & Gorley, 2015).

Finally, based on the specific records (museum specimen with data georeferenced or verifiable Páramo locality or EOO polygon coincidence with Páramo complex; n = 1979), a taxonomic list of amphibians was generated for the Colombian Páramo complexes. We excluded from this analysis all specimens that were reported as "sp." "cf." or "aff." or within species complexes (eg *Atelopus* "*ignescens*") (n = 1101). We run a multivariate analysis of variance based on permutations (PERMANOVA; Anderson, 2001) to determine the effect of the geographic sector of the Páramo complex on amphibian alpha and beta diversities. The Jaccard similarity index was calculated to evaluate changes in the composition of the assemblages, and for richness, the Euclidean distances between the Páramo complexes were also calculated. The analysis was

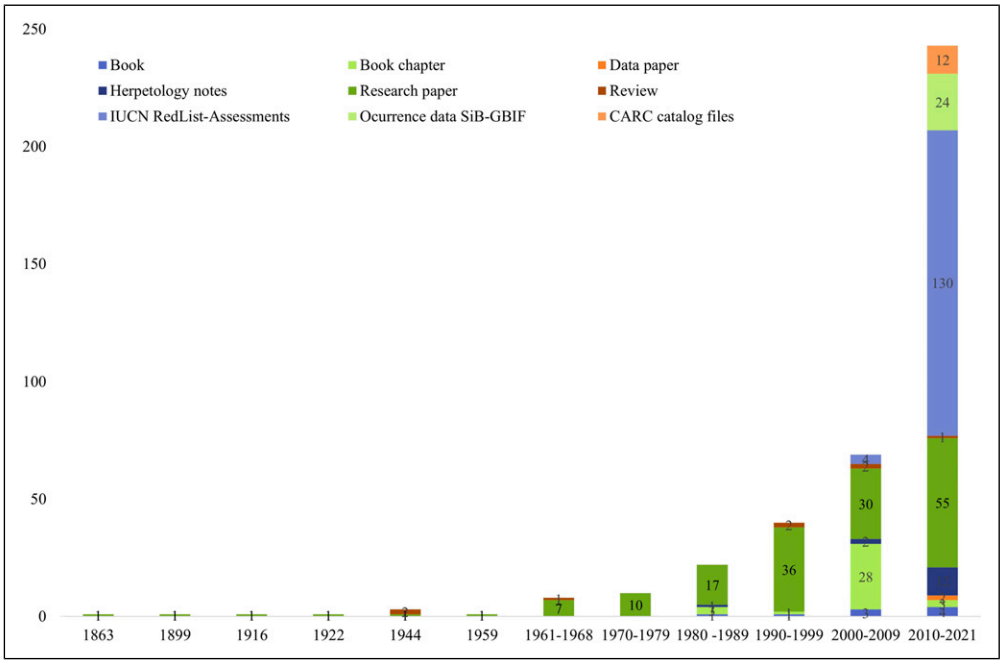

Figure 3. Temporal pattern of scientific productivity on amphibians from the Colombian Páramo differentiated by the type of document.

performed under a partial sum of squares (type III) and 9999 permutations of the residuals under a reduced model. When differences between sectors were found, a student's t-test was calculated as a post hoc test. Finally, we explore the association of the presence of species by Páramo complex and sector with a heat map (Somerfield & Clarke, 2013). The classification of species was validated with the SIMPROF routine in PRIMER 7.0.13 and PERMANOVA add on program (Anderson et al., 2008; Clarke & Gorley, 2015).

Results

Scientific productivity on Páramo amphibians: Types of publication and temporal trends

The 405 documents were published between 1863-2021 and included: 160 research articles, 134 IUCN species Red list assessments, 35 book chapters, 29 SiB and GBIF data occurrence reports, 15 herpetological notes, 12 CARC catalog files, 8 review articles, 9 books, and 2 data papers. The number of publications increased by 77.18% since the year 2000, mainly with contributions from the IUCN Red list assessments, research articles in scientific journals (indexed or non-indexed), and herpetological notes (Figure 3).

The scientific articles (data papers, research articles, reviews, and herpetological notes n = 185), were published in 73 journals. 115 of these publications (62%) are found in 42 journals indexed in the JCR of Web of Science (45.36%) or the Scopus SRJ (54.63%), of which the ones with the greatest contribution were, in descending order: Caldasia, Zootaxa, Herpetologica and Journal of Herpetology (Figure 4A). On the other hand, 285 documents are not indexed, of which 25.26% correspond to articles published in scientific journals, 46.26% to evaluations of the IUCN Red list assessments, 12.45% to book chapters, 8.54% to occurrences from SiB-GBIF, 4.27% to the catalog of the CARC catalog files, and 3.20 % to books. The 43.75% of the non-indexed publications are Colombian and within these, we found two scientific journals (Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales and Biota Colombiana) and two books: El Libro Rojo de Anfibios de Colombia (Rueda-Almonacid et al., 2004) and Ranas Arlequines (Rueda-Almonacid et al., 2005) as the most representative from this group (Figure 4B).

Taxonomic and thematic characterization of scientific literature

A total of 142 species were recorded within the Amphibia class with distribution in Colombia's Páramo complexes: Order Anura with 134 species in six families, and Order Caudata with five species in one family (Plethodontidae) (See online Appendix 4). 95 species of our proposed list are reported as endemic to Colombia. Most of the publications were about anurans (94.68%), while 20 documents were reported for salamanders, and no information was found for the order Caecilia in the Páramos of Colombia. At the family level, Strabomantidae presented the highest number of studies (n = 219), of which the genera *Pristimantis* (n = 201) and *Niceforonia* (n= 34) were the most representative. The second-best represented family in the documents was Bufonidae (n = 116) with the genera *Atelopus* (n = 89), and *Osornophryne* (n= 32), followed by the family Hylidae

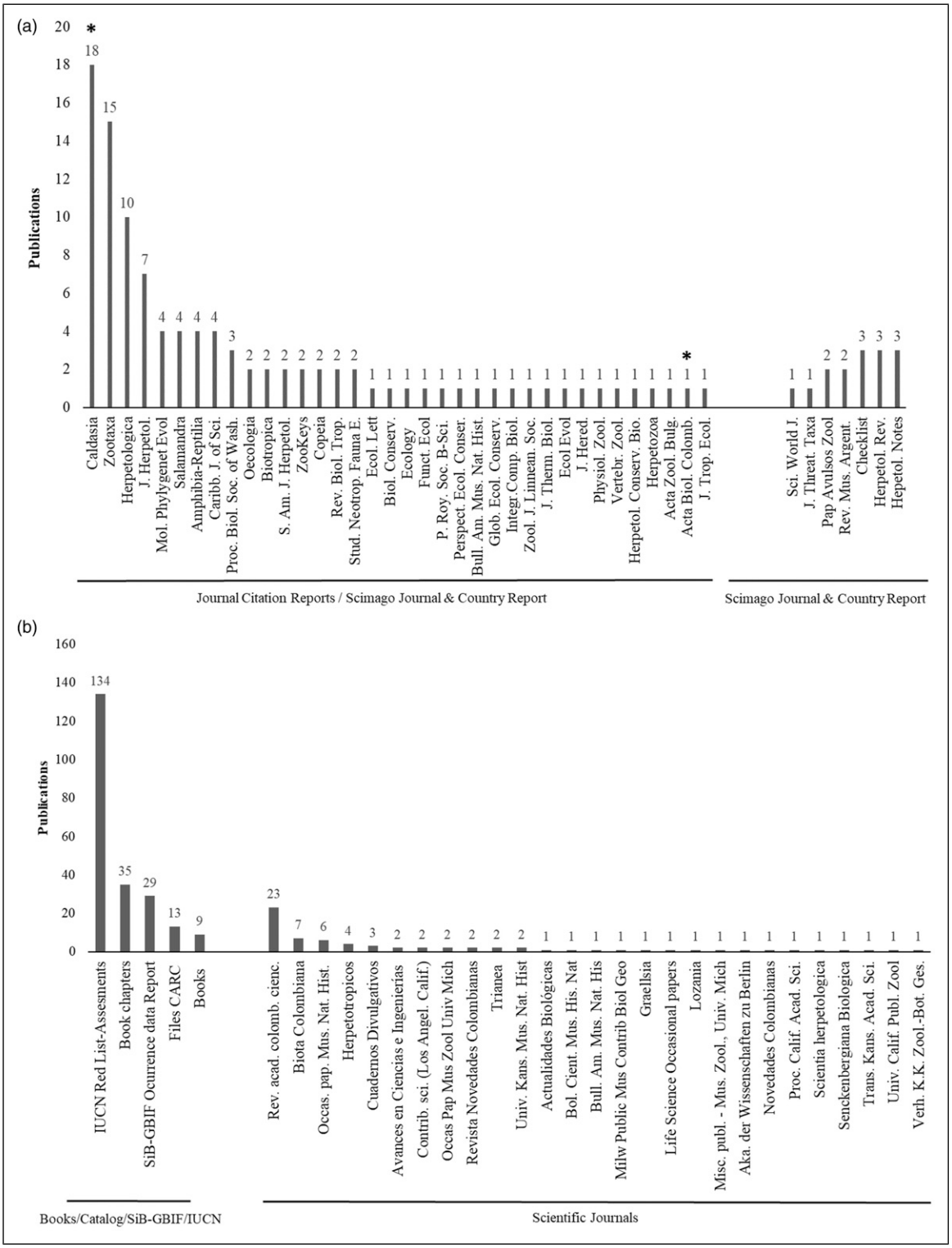

Figure 4. The number of publications on Páramo amphibians in Colombia in (A) journals indexed in SRJ and JRC. (*) correspond to internationally indexed journals from Colombian and (B) in non-indexed publications.

(n=79) with the genera *Dendropsophus* (n= 62) and *Hyloscirtus* (n=44). The species with the highest frequency of appearance in the database publications were *Dendropsophus molitor* (Schmidt, 1857) (n=59), *Pristimantis bogotensis* (Peters, 1863) (n=44), *Hyloxalus subpunctatus* (Cope, 1899) (n=29) and *Atelopus carrikeri* Ruthven 1916 (n=27).

The most frequent research topics within the anuran documents were Natural history (242), Conservation (138),

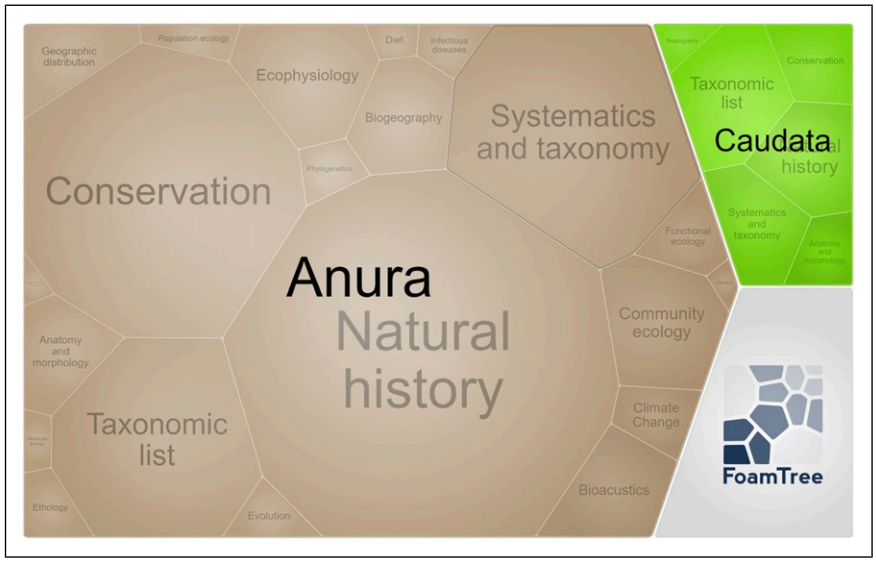

Figure 5. Polygons´ visualization of the research topics within which the scientific literature on the amphibians from the Colombian Páramo separated by taxonomic order was classified.

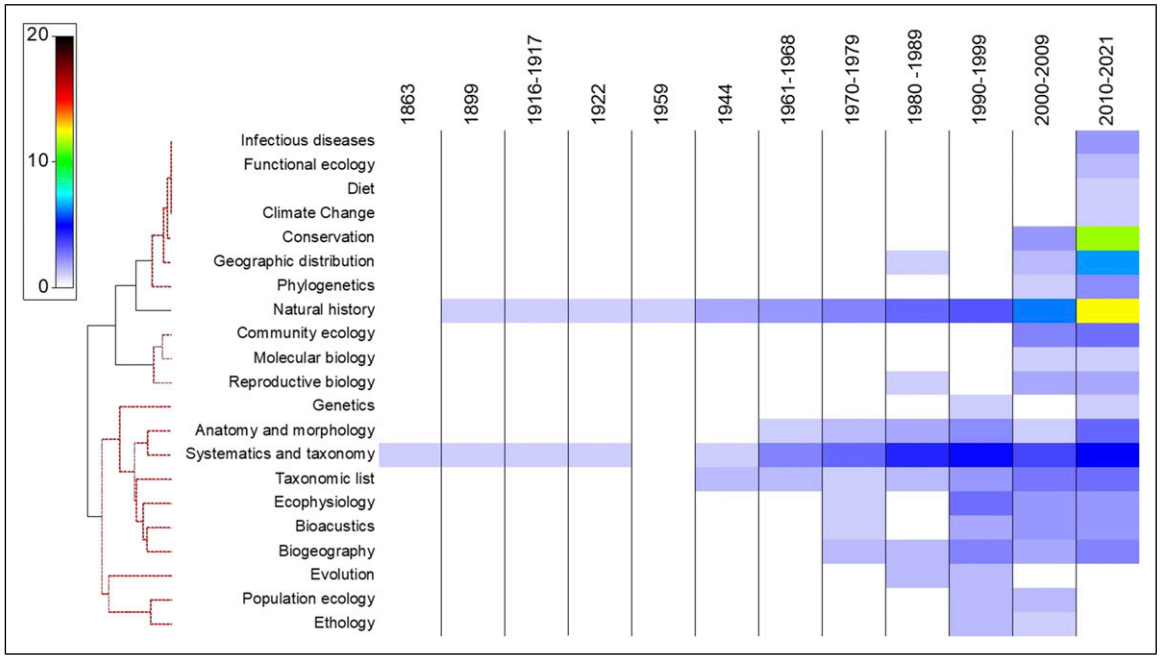

Figure 6. Heat map of the study research topics on amphibians from the Colombian Páramo over time. The tree on the left shows the classification of the 21 research topics into 4 groups according to their degree of association (Whittaker index) with the year ranges.

and Systematics and Taxonomy (109). In contrast, the order Caudata was included more often in Taxonomic lists (12), Natural history (10), and Systematics and Taxonomy (8) studies (Figure 5).

The publication on Natural history and on Systematics and taxonomy has been maintained over the years, but the state of knowledge on Páramo amphibians in Colombia has been enriched since the 2000s with other 19 research topics. These topics were classified into four groups with similar patterns, of which 47,6% were classified in the same group, and the other three groups presented between 1 and 7 research topics (Figure 6). The first studies in Biogeography, Ecophysiology and Bioacoustics, as well as an increase in publications on topics such as Systematics and Taxonomy, and Natural history, can be traced back to the 70s. Later, in the 90s, publications on Ecophysiology and Bioacoustics continued to increase; and, from the 2000s onwards, new topics have appeared such as Infectious Diseases, Community ecology,

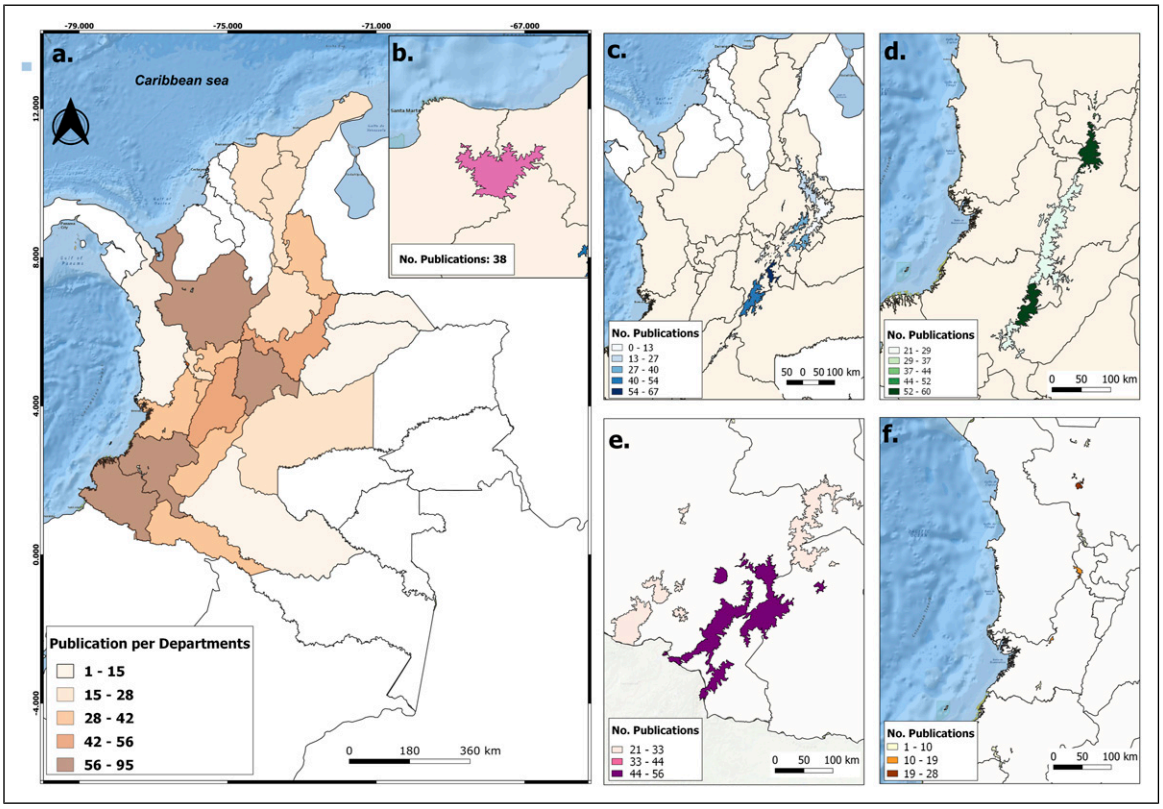

Figure 7. Geographic patterns the number of documents on amphibians of Colombian Páramos (A) by department (B) Sierra Nevada de Santa Marta (C) Eastern range sector, (D) Central range sector, (E) Nariño-Putumayo sector, (F) Western range sector.

Reproductive ecology, Diet, and Climate change. In contrast, research topics in Population ecology, and Ethology have shown stagnation or decline. Geographic distribution, Conservation, and Natural history are some of the most representatives of the last decade.

Spatial patterns from the scientific literature

Of the 22 departments with Páramos in Colombia, Cundinamarca registered the highest number of studies (n= 93), followed by Antioquia (n=64), Nariño (64), Cauca (n=61), and Boyacá (59) (Figure 7A). The highest number of publications were reported in the Eastern ranges sector (n=159), in which 17 Páramo complexes are distributed, and the Central sector (n=129), in which eight Páramos complexes are present (Figure 7C-D). The Páramo complexes that registered the highest number of studies were Chingaza (N=70), in the Eastern range sector; Los Nevados (n=62), in the Central range sector; and La Cocha-Patascoy (n=56), in the Nariño-Putumayo sector.

From the number of publications by research topics, the departments were classified into nine groups according to the degree of association with research topics. Besides, the 21 research topics were classified into 4 groups with similar patterns showing great thematic diversity between departments. Three of these departments (Nariño, Cauca, and Cundinamarca) are grouped with many publications on Natural history and Conservation (Figure 8). Cundinamarca represented 85% of the research topics; followed by Antioquia, Boyacá, Tolima, Caldas, Cauca, Nariño, Quindío, and Putumayo, which presented between 10 and 16 topics. Whereas the departments with the lowest number of publications were Arauca, Caquetá, Huila, Tolima, Cauca, Norte de Santander, and Santander, which represented between 1 and 2 research topics.

Composition of amphibians in Páramo complexes and comparison between sectors

We found differences in the species richness (Pseudo-F= 13.8; p.perm= 0.0001; size effect = 68%) and in the composition of the amphibian assemblages (Pseudo-F= 4.15 p.perm= 0.0001; size effect = 34.3%) between sectors. The general pattern in assemblage composition shows that Sierra Nevada de Santa Marta (SNSM), Cordillera Central, and Nariño-Putumayo presented noticeable differences from other sectors such as Eastern ranges and Western, which is associated with the high rate of species turnover that occurs in the high Colombian mountain. The 142 species were classified into 42 groups according to their distribution in the 35 Páramos complexes (Picachos was not included because we do not report species in this complex) and within the five

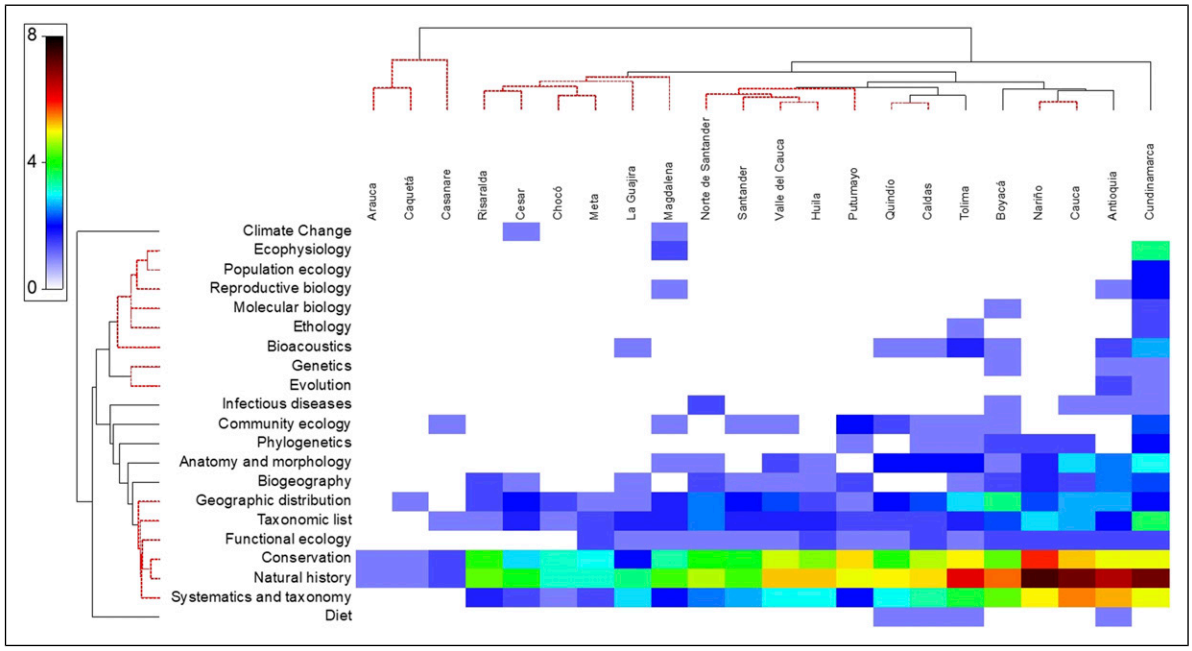

Figure 8. Heat map of research topics by Department. The tree on the left shows the classification into 4 groups of the 21 research topics by their degree of association (Whittaker index) with the departments. The classification of the 22 departments into 9 groups is also evident. Classification trees represent, with red nodes, those entities that have similar publishing patterns. The degree of association is shown as a gradient of colors ranging from warm tones (high degree of association) to cold tones (low degree of association).

sectors (Figure 9, Table 1). A high degree of endemicity can be observed in Páramos complexes such as SNSM in which all species are unique to this area including the genus *Serranobatrachus* (Arroyo et al., 2022). Complexes like Perijá, located in the north region of the eastern sector, also report endemic species like *Pristimantis reclusus* (Lynch, 2003) and *Tachiramantis cuentasi* (Lynch, 2003), and the Duende complex (Western Sector) presents unique fauna like *Bolitoglossa hiemalis* Lynch 2001, *Pristimantis duende* (Lynch, 2001) and *Pristimantis xeniolum* (Lynch, 2001). Almost all the Páramos complexes of the eastern sector share species with wide distribution in the eastern range like *Pristimantis elegans* (Peters, 1863), *P. bogotensis*, *D. molitor* or *Bolitoglossa adspersa* (Peters, 1863). On the other hand, complexes in the Central sector located to the south (Guancas-Puracé-Coconucos and Sotará) share around 12 species with the complexes Doña Juana Chimayoy and La Cocha Patascoy (Nariño-Putumayo sector).

Discussion

Based on the 405 published documents, this review is the study with the highest bibliographic, geographical, thematic, and taxonomic coverage of amphibians of the Páramo ecosystem. Generally, the literature compiling data on Páramo amphibians was limited to species lists constructed from literature reviews in scientific journals (Lynch & Suárez, 2002; Buitrago-González et al., 2016) and in some cases, it was complemented with information from biological collections (Ardila-Robayo & Acosta-Galvis, 2000; Bernal & Lynch, 2008). However, our study, revels that a low percentage of this literature is published in scientific journals indexed in the JCR of Web of Science or the SRJ of Scopus. The highest percentage of the publications in our database are unindexed and are represented mainly by the IUCN red list assessments, which are open access (IUCN, 2021). Most discontinued journals (national or foreign) like Lozania, Trianea, Life Science Occasional paper, and Miscellaneous publications (University of Michigan. Museum of Zoology) are found in repositories that are not always easy to track or access and do not have major visibility.

In the present study, we included two documents considered grey literature, specifically books and reports from government institutions. These documents were accessed through search strategies 4 and 7, followed in the methodology. Several authors recognize the importance of grey literature in creating an overview of knowledge for a particular topic, as noted by Mahood et al. (2013), Hortal et al. (2015), and Adams et al. (2017). This type of literature often contains anecdotal scientific data or data obtained through an absent or lax research design (e.g.Christie et al., 2020, 2021). Still, it complements state-of-the-art on underexplored sites or understudied species. This is especially relevant to complement conservation actions for populations of native species and their habitat, as such measures depend on baseline information about natural history, life histories, geographic distribution, and their short-, medium- and long-term spatial dynamics. For species with a distribution restricted to

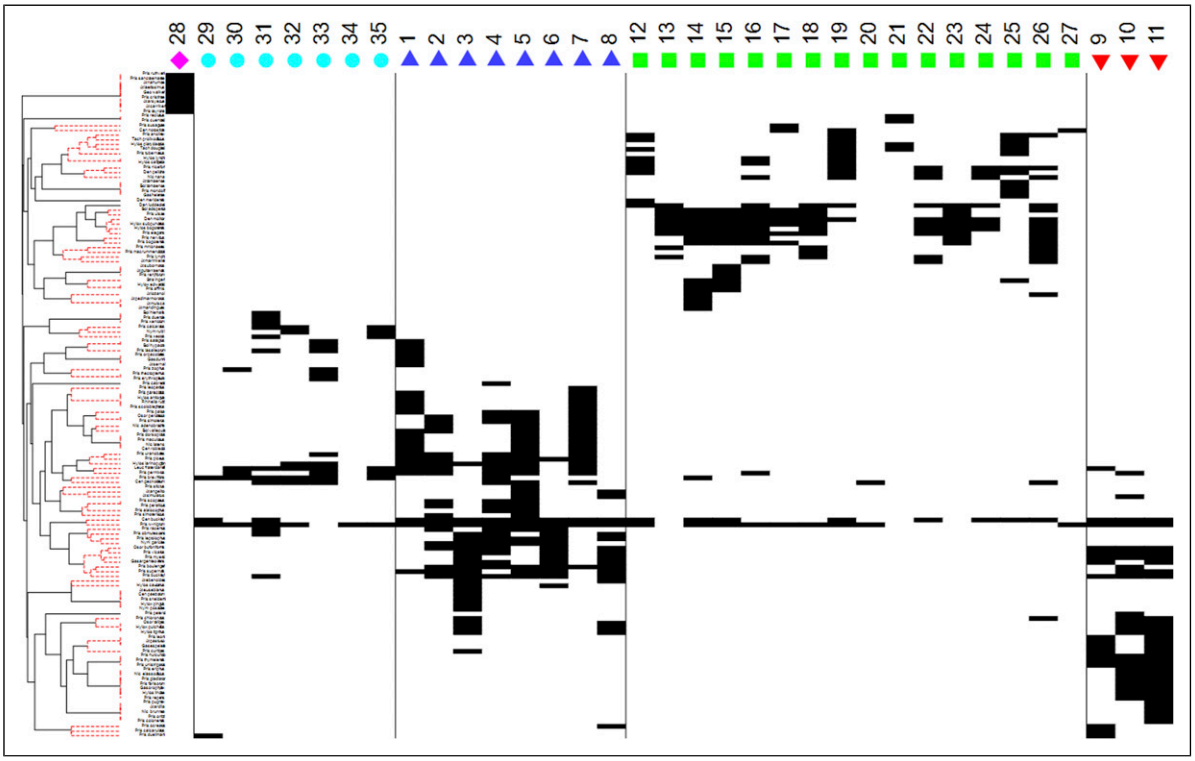

Figure 9. Heat map of species by Páramo complex. The tree on the left shows the classification into 42 groups of 142 species. The classification trees validated with the SIMPROF routine, represent with red nodes, those entities that have similar distribution patterns by Páramo complex (see Table 1) and by sector: ▲.= Central; ▼ = Nariño-Putumayo; ■ = Oriental; ◆= Sierra Nevada de Santa Marta; and ●= Western.

Table 1. Number of Studies and Species Reported by the Scientific Literature in the Páramo Complexes Within Five Sectors of Colombia.

Sector	Páramo Complex	Departments	Studies	Species reported	Species restricted / endemic to these areas
Central range	Belmira (1), Chilí – Barragán (2), Guanacas – Puracé – Coconucos (3), Las Hermosas (4), Los Nevados (5), Nevado del Huila – Moras (6), Sonsón (7), Sotará (8).	Antioquia, Quindío, Cauca, Huila, Risaralda, Tolima, Valle del Cauca	129	62	37
Nariño – Putumayo	Chiles – Cumbal (9), Doña Juana – Chimayoy (10), La Cocha – Patascoy (11)	Cauca, Nariño, Putumayo	67	39	24
Eastern range	Almorzadero (12), Altiplano Cundiboyacense (13), Chingaza (14), Cruz Verde-Sumapaz (15), Guantiva – La Rusia (16), Guerrero (17), Iguaque – Merchán (18), Jurisdicciones – Santurbán – Berlín (19), Los Picachos, Miraflores (20), Perijá (21), Pisba (22), Rabanal y Río Bogotá (23), Sierra Nevada del Cocuy (24), Tamá (25), Tota – Bijagual – Mamapacha (26), Yariguíes (27).	Boyacá, Caquetá, Cesar, Huila, Cundinamarca, Norte de Santander, Santander, Casanare, Arauca, Meta	159	48	42
Sierra Nevada de Santa Marta	Sierra Nevada de Santa Marta (28)	La Guajira, Magdalena, Cesar	35	9	9
Western Range	Cerro Plateado (29), Citará (30), El Duende (31), Farallones de Cali (32), Frontino-Urrao (33), Paramillo (34), Tatamá (35)	Antioquia, Valle del Cauca, Chocó, Cauca, Risaralda	43	25	9

naturally fragmented ecosystems (e.g., páramo amphibians), grey literature repositories may represent the only information available to guide management and conservation actions.

Open data provided by databases and reported in our study (e.g., GeneBank, IUCN, SiB-GBIF) have accelerated research in the field of Conservation biology, as well as in research topics in Evolutionary biology and Systematics (Lacher et al., 2012; Baxevanis & Bateman, 2015). However, despite being in an open science context, we found just two data papers in our database (Henao et al., 2019; Mendoza-Henao et al., 2019). Data papers are a type of recent academic publication that offers relevant information regarding the visibility and re-use of data that can be available for public use and maintains both scientific rigor and public confidence (Roche et al., 2015; Jiao & Darch, 2020; Machuca-Martínez, 2020). This is of great importance as the public availability of primary biodiversity data is essential for ecological research (Huang et al., 2013), future meta-analyses, and decision-making in critical ecosystems such as the Páramo. However, the low frequency of these types of papers may be because the authors 1) do not want to share their primary data before they are published; 2) do not want to undergo a peer review procedure again, which may place an additional burden; or 3) do not want to subject their data to a statistical reanalysis by other colleagues (Huang et al., 2013; Wicherts et al., 2011). To advance the state of knowledge of Páramo amphibians it is essential that authors have the good practice of uploading their raw data in repositories (e.g. Dryad, Mendeley Data or ResearchGate) and report the download link in their publications.

On the other hand, the biological collections provided data for 56.45% of the investigations reported in scientific articles (Data papers, research articles, reviews, and herpetological notes), mainly related to research topics such as Systematics and Taxonomy, Anatomy and Morphology, Natural history, taxonomic lists, biogeography, and geographical distribution. These data highlight the importance of collections as sources of scientific data to document the country's diversity (Medina et al., 2016). Nevertheless, the lack of availability and updating of records in several of the collections consulted in the GBIF is notorious. The largest number of specimens reported in our database are concentrated in the collections of the ICN and IAvH, but many of them lack georeferencing and altitudinal data. Other specimens are omitted in these GBIF reports and the oldest ones (mainly those of the nineteenth and twentieth centuries) present errors related to their localities that require an update (Vásquez-Restrepo, 2021).

We report a low percentage of studies whose data source is from fieldwork (24.19%) or laboratory data (2.22%). The lack of field information contributes to the underestimation of the amphibian diversity reported for the Páramos. There are recent efforts related to explorations promoted by academic or governmental institutions like Expedition BIO-MinCiencia; and Delimitation of Páramos of Colombia (Acosta-Galvis & Borja-Acosta, 2021; Henao et al., 2019; Ravelo & Martínez, 2019). These works sought to increase the knowledge of the Páramos fauna and flora. However, the information is not available for all paramos complexes and the reports accessible in the GBIF had more than 30% of taxonomic gaps most related to the *Pristimantis* genus. Other data from these reports just provided "Human Observation" but not a specimen deposited in a scientific collection. Some factors that could explain the low number of fieldwork are 1) the difficult access to these sites and the abrupt conditions of climate and topography, 2) political-economic deficiencies (Economic resources, research permits), and 3) public safety problems (Arbeláez-Cortés, 2013a). This represents a Linnean shortfall (Hortal et al. 2015) in which there is a large gap for the currently formally described species to approach the total number of amphibian species that inhabit the Páramos and are still unknown to us (Brito 2010).

Thematic information gaps

From the first study reported in 1863 to the years 2010-2021, the generation of new knowledge published in scientific articles is mainly dominated by research topics such as Systematics and Taxonomy, Natural history, and Anatomy and Morphology. Most of the indexed publications covered these topics in descriptions of new species or taxonomic reviews at the family level (Duellman & Hillis, 1987; Duellman et al., 2016; Estupiñan et al., 2016; González-Durán et al., 2017; Rivera-Correa et al., 2017). In many cases, these descriptions encompassed anatomical aspects of species and life history data. However, in most cases, the latter topic has been covered from anecdotal narratives or qualitative descriptions (Coloma et al., 2000; Hedges et al., 2008; Páez-Moscoso et al., 2011). In recent decades, the importance of data related to life history has been highlighted since this information allows a better understanding of the ecological strategies of species for conservation (Becker et al., 2010; Michaels et al., 2014); as well as their possible response to the current scenarios of climate change, land use, and land cover change that our planet is experiencing (Oliveira et al., 2017). In fact, we only found one study on climate change (Agudelo-Hz et al., 2019). This is alarming due to the current challenge that Colombia faces in relation to having data to measure the effects of climate change on appropriate time scales, as well as modeling and understanding interactions in ecosystems, both between biotic components and with other external transformation drivers (Londoño et al., 2019). For this reason, it is important to increase studies on this theme, but these should include quantitative and population information considered that Natural history data may be the key to the success of *ex-situ* conservation programs (Michaels et al., 2014).

From the 90s onwards, there has been an increase in topics such as Ecophysiology, Biogeography, Community ecology, and Bioacoustics; but there is still evidence of an information gap on themes like Infectious diseases, Functional ecology,

Climate change, Ethology, and Evolution. Not to mention that there are few studies carried out in Population ecology, which is a deficiency that is evident in herpetology studies in Colombia (Urbina-Cardona et al., 2023). Despite the incorporation of new research topics in recent decades, studies related to field or laboratory data collection have only concentrated in 19.58% of the species in our database. Just 17 Páramo complexes have at least one study different from the description of new species, being the complexes of Los Nevados (Central Sector) and Chingaza (Eastern sector) the most representative.

The increase of information available for species in research topics such as "geographical distribution" and "conservation"(since the 2000s) is mainly associated with the update made by the IUCN with the Red List assessments between the years 2016 – 2021 and the publication of the Colombian Association of Herpetology catalog (CARC) files, that compiles information on taxonomy, life history, morphology and geographic distribution of the Colombian amphibian and reptile species; the CARC also provide information on threats and conservation status. These documents have been key to collecting secondary and biological collection information, not only on Páramo amphibian species but also on the herpetofauna of Colombia (Urbina-Cardona et al., 2023).

Taxonomic information gaps

Colombia has the largest extension of Páramo in the world and the highest richness of amphibian species (142) in this ecosystem, compared to countries such as Costa Rica (n=14; Kappelle & Savage, 2005), Ecuador (n=56; Ron et al., 2020), Peru (n=35; Catenazzi & Von May, 2014) and Venezuela (n=14; Barrio-Amorós, 2004). However, the diversity of amphibians reported in Colombian Páramos is yet to be completed and it requires a greater sampling effort and genetic analysis (Ardila-Robayo & Acosta-Galvis, 2000; Lynch & Suárez, 2002; Acosta-Galvis, 2015). Our database reports a significant number of specimens that were cataloged, in scientific articles (>100) and data from the SiB-GBIF (>600), as “sp.” and in some cases with annotation of their future description (Buitrago-González et al., 2016; Acevedo et al., 2018; González-Durán et al., 2017), or species reported as “cf.” or “aff” due to uncertainty in their identification (Cisneros-Heredia & Gluesenkamp, 2010; Acevedo et al., 2018; López, 2017; Carvajal-C et al., 2019). Identifying discrete biological units is fundamental not only for taxonomy but also for understanding the processes that lead to lineage diversification and defining conservation strategies (Espíndola et al., 2016; Theodoridis et al., 2019). The lack of assigning a name to several specimens captured in these expeditions and reported in the SiB-GBIF or scientific articles shows that quantifying the diversity of Páramo amphibians could be hindered by the presence of a cryptic diversity, which is defined as the deep genetic divergence within nominal species but morphologically indistinguishable between populations (Bickford et al., 2007). These gaps in knowledge from the cryptic species increase the Linnean shortfall (Walters et al., 2021) for amphibians inhabiting the Páramos of Colombia.

Due to the ecological conditions related to the complex history of the Andean Mountain ranges (biogeography, topography, and glacial geomorphology), the description of new species in high mountain ecosystems is to be expected. This is because it is a pattern consistent with the hypotheses of allopatric and peripatric speciation in amphibians distributed in the neotropical Andes and particularly in the Páramos, where the assemblages are unique within each mountain system and with a high degree of endemism (Lynch & Suárez, 2002; Bernal & Lynch, 2008; Santos et al., 2009; García-R et al., 2012; Mendoza et al., 2015). Hence the importance of filling these shortfalls since the prioritization of conservation efforts at the regional scale is usually determined by the richness of species as a unit of analysis and their endemism (Riddler & Hafner, 1999; Fleishman et al., 2006; Mendoza et al., 2015, Espíndola et al., 2016). The identification of cryptic diversity or the description of new species from an integrative taxonomy (phylogeography, comparative morphology, population genetics, ecology) and fieldwork in unexplored Páramos is essential to estimate these parameters in the Colombian high mountains. In addition, taxonomic work has a strong impact not only on the generation of new knowledge of species, but also on international agreements on biodiversity conservation, environmental legislation, and distribution of economic resources that are allocated to the species monitoring programs (Garnett & Christidis, 2017; de Magalhães et al., 2018; Thompson et al., 2018). Therefore, it is important not to take for granted the implications of splitting species. Moreover, for the Páramo ecosystem, it is necessary to increase efforts in genuine taxonomic reviews and not only provide simple lists that end up being taken by environmental authorities as databases for decision-making.

Furthermore, we found few records (<2) or uncertain records (unverifiable locations) of species that share distribution in adjacent countries. In our database, we highlight the case of species contiguous to Ecuador such as *Pristimantis calcarulatus* (Lynch, 1976), *Pristimantis ortizi* (Guayasamin et al., 2004), *Pristimantis huicundo* (Guayasamin et al., 20 04), or *Pristimantis leoni* (Lynch, 1976), which only have occurrences from the SiB-GIF or IUCN for the Nariño Putumayo sector (Solarte Cruz, 2021). Similarly, towards the eastern mountain range adjacent to Venezuela, no records were found for the species *Atelopus tamaense* (La Marca, García-Pérez, & Renjifo, 1990) in the Tamá Páramo Complex in Colombia. For the species *Hyloscirtus platydactylus,* (Boulenger, 1905) the IUCN (2021) reports uncertainty of its presence in the Perijá mountain range, but Carvajal-C et al., (2019) and Moreno-Arias et al. (2007) report this species (although not for the Páramo zone). And for the characterization of the Perijá Páramo complex, georeferenced

specimens are recorded and deposited in the ICN biological collection (Borja-Acosta 2022; Cantillo, 2022).

Geographic information gaps

We included 18 species in our list given the coincidence of their EOO (IUCN 2016-2021) with some Páramo complex. Similarly, only 94 species of the reported 142 presented occurrence data with verifiable information in the GBIF (See online Appendix 4). The lack of adequate georeferencing in the studies and in the largest biological collections in the country (like ICN and IAvH) before the year 2000 is one of the most critical problems (Vásquez-Restrepo 2021) that makes it impossible to have certainty of the distribution of some species of amphibians in the altitudinal range of the Colombian high mountain (High Andean Forest, sub-Páramo, Páramo, or super-Páramo). Such is the case of species like *Rhinella nicefori* (Cochran & Goin, 1970), *Rhinella macrorhina*, (Trueb, 1971), *Atelopus subornatus* (Werner, 1899), *Centrolene notosticta* (Ruiz-Carranza & Lynch, 1991), *Hyloxalus pulchellus* (Jiménez de la Espada, 1875), *Pristimantis tubernasus* (Rivero, 1984), *Pristimantis susaguae* (Rueda-Almonacid, Lynch, & Galvis-Peñuela, 2003), *Serranobatrachus sanctaemartae* (Ruthven, 1917), and *Tachiramantis tayrona* (Lynch & Ruiz-Carranza, 1985); which have been considered in several lists of species as "paramunas" (Ardila-Robayo & Acosta-Galvis 2000; Buitrago-González et al., 2016). This gap in knowledge of the geographic distributions of Páramo amphibians is an example of the Wallacean shortfall (Hortal et al., 2015) that is present in the neotropics and constitutes a challenge for biodiversity conservation (Bini et al., 2006).

Historically, one of the main criteria used for the delimitation of Colombian Páramos has been altitude or elevation (Hofstede, 2013; Hofstede, et al., 2003; Sarmiento & León, 2015). However, given the geomorphological variety of the country, many Páramos are not homogeneous in their limits, such as the azonal Páramos of the Guamuez River (2500 – 2800m) in southern Colombia (Barriga et al., 2015; Ravelo & Martínez, 2019) or Páramos complexes that start from 2700 m (e.g., Perijá) while others have a lower limit of 3000 – 3500 m or more (e.g., Complexes located in the central mountain range). These differences are influenced by diverse factors such as location, soil types and climate (Lauer 1981; Rodríguez et al., 2006), and even the type and degree of human intervention determines the actual structure and functioning of the Páramo (Hofstede & Llambí, 2020). The altitudinal limits reported for species do not provide all the necessary information to determine the organisms that are endemic to the ecosystem or those that transit in the altitudinal gradient from high Andean Forest - Páramo and that have been able to establish populations in the Páramo ecosystem (Lynch & Suárez, 2002).

Of the 22 departments with the presence of Páramos in their territories, Arauca, Casanare, and Caquetá did not present records of field data or vouchers in biological collections. Similarly, despite the delimitation of 36 Páramo complexes in the country, we still report an information gap in Miraflores, Los Picachos, Yariguíes, Paramillo, Citará, and Cerro Plateado, of which no publication was found in scientific articles, books, or herpetological notes. The information presented for these geographic units corresponds to the occurrence data reported in the SiB-GBIF and the EOO coincidence of some species reported in the literature as "amphibian Páramos" and generated by the IUCN (2021). This fact shows the lack of intensive studies in the south of the Eastern range and north of the Central and Western ranges (Ardila-Robayo & Acosta-Galvis, 2000). Also, according to Acosta-Galvis (2015), the information provided for most Colombian Páramos cannot be considered as complete characterizations. There are many challenges in the Colombian high mountains, as well as information gaps that need to be filled. While there are departments where the absence of studies on research topics such as Reproductive biology, Ecophysiology, Population ecology, and Ethology are notorious; 85% of the research topics and fieldwork was concentrated in departments such as Cundinamarca, Antioquia, Boyacá, and Tolima.

Implications for Conservation

Colombian Páramos register an alarming degree of intervention with the replacement of natural cover and only 58.33% are within the national system of protected areas (Gómez et al., 2015, Cortés-Duque et al., 2013). According to the analyses carried out by the IAvH (Moreno et al., 2020) on a national scale, all Páramo complexes report an increase in transformed coverage from 0.6 to 0.9% due to agricultural activities, ranching, and mining (Burbano-Girón et al., 2020). On a regional scale, the Eastern, Central, and Nariño-Putumayo sectors show a pattern of increase in transformed areas up to 18.3% in the last decades, which could be associated with the "upward movement" or "upward expansion" of the agricultural frontier and the intensification of animal production in the sub-Páramo belt, which has been occurring in different parts of the equatorial Andes (Hess, 1990). These data can be worrying since these sectors account for more than 80% of the species reported as endemic to the Páramo or with populations established in these sites, and these are organisms with restricted areas of occupation compared to other biological groups. Impacts on the natural cover can lead to habitat conversion for many species of amphibians. They have a long-term negative effect on amphibian populations and increase the probability of direct mortality of species (Nowakowski et al., 2017; Catenazzi, 2015). Currently, 66.19% of Páramo amphibians are within some state of threat: Vulnerable (VU), Endangered (EN), Critically Endangered (CR); mainly due to 1) Areas of Occupation (AOO) between 10 and 2000 km2, associated with the low geographical records that exist per species and 2) the

increase in threats related to categories such as "Agriculture & Aquaculture", "Residential & commercial development", "Invasive and other problematic species, genes & diseases" and "Energy production & mining" (Stuart et al., 2008, IUCN, 2021).

The trend towards the transformation and replacement of natural Páramo cover by crops or grazing areas shows that habitat conservation is a high priority for the persistence of amphibian species. Studies carried out in some Páramos show the use of microhabitats associated with endemic plants from these areas, such as cushions and shrubs, tussock grasses (*Calamagrostis* spp.), rosette plants and stemmed rosette plants of *Espeletia* spp (Lynch, 1998; Lynch, 2000; Acosta-Galvis, 2015). Also, it is important to note that, at finer spatial scales, each Páramo can generate a unique variety of microclimates or microecosystems to which amphibians could be adapted (Navas, 1996a; Buitrago-González et al., 2016; Duarte-Ballesteros et al., 2021). However, the absence of population data or quantitative records of natural history data for most species is notorious, without regard to the large gaps that exist on a spatial and thematic scale and the concentration of studies on a few research topics, complexes of Páramos, and even common species. The gap in knowledge of species population dynamics is called a Prestonian shortfall and represents a challenge from long-term monitoring to assessing the risk of species extinction and implementing management and conservation actions for populations and their habitats (Hortal et al., 2015). More than 80% of the species that inhabit or transit the Páramo in Colombia only have their descriptions information or have been mentioned in the literature in species lists but little is known about their ecological requirements or data related to specific threats: Infectious diseases, invasive species, and climate change.

On the other hand, current information gaps related to the assignment of the nominal status of species and errors in geographical records can affect categorization in Red Lists, as they cause inaccuracy in the estimation of the EOO and AOO. Consequently, we could be hiding the status of some species with degrees of threat (de Magalhães et al., 2018). Currently, eight of the species with a presence in the Páramo are found with Deficient Data (DD). Two of them are uncategorized, and 80.85% of the species endemic to certain Páramos complexes are distributed only in one "Protected area" (natural parks or private ecological reserves) as a conservation figure (See appendix 4). Although a few studies report the use of good practice protocols for amphibian sampling (e.g., using gloves to handle animals), there is a clear lack of efforts to mitigate threats to the habitat of these species or to implement concrete actions for their conservation. (i.e., amphibian translocation, citizen science, engagement of landowners and other volunteers in managing land for amphibians, or management plans with the support of environmental institutions; Sutherland et al. 2019. This lack of effort is mainly due to the absence of field data, including population size, distribution and trends, life history and ecology, population trends, and even taxonomy (IUCN, 2021). The knowledge shortfalls identified in this paper (Linnean, Wallacean, Prestonian shortfalls; Hortal et al., 2015) show thematic, spatial, and temporal biases that skew the possible evidence on the conservation (*sensu* Christie et al., 2020, 2021)) of amphibians inhabiting the páramos of Colombia. In a regional context, this is of great importance since the tropical Andes is the place in the world with the largest number of amphibian species with protection figures gaps in terms of protected areas (Nori et al., 2015).

These data reveal the need to increase the knowledge not only of the Páramos inventory but of the biology and distribution of the species that inhabit them, because this information contributes to the generation of monitoring programs and conservation actions focused on the attributes of the habitat of the species. Moreover, the information generated in the scientific literature and records in databases (such as SiB and GBIF) can strengthen other initiatives like the Colombian community of practice called "Biomodelos" (http://biomodelos.humboldt.org.co/es), which seek to generate more accurate distribution models and in which only 30 species (only 21.12%) of our list are reported. Once validated by experts, the distribution of species in Biomodelos is used as input to calculate different metrics including AOO and EOO, distribution in protected areas, and changes in distribution under future scenarios of landscape transformation (Velásquez-Tibatá et al., 2019). For this reason, it becomes an indispensable tool to make the processes of amphibian extinction risk assessment in Colombia more efficient (Urbina-Cardona et al., 2023). It is important to highlight that generating data *in situ* involves a greater sampling effort, the use of specialized equipment, and reagents for tissue collection or animal experimentation. These are activities that require greater financial support, which is a challenge since the country is currently investing > 1% of its gross domestic product in science, technology, and innovation (The World Bank, 2018; Guevara, 2021).

Acknowledgments

We thank Ana María Suárez for assistance with Maps in QGis, Camila Rodríguez for her comments on English version and Pontificia Universidad Javeriana for academic database access.This manuscript is the fourth publication of the Semillero Javeriano en Ecología y Conservación de Anfibios y Reptiles-SECAR.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Vicerectory of Research, for the support for doctoral thesis projects of the Pontificia Universidad Javeriana

(VRI05-19) (Grant ID 20083_120130Z0401200) with the project: Morphological and physiological responses of anuran species to environmental heterogeneity at different scales: the relationship between diversity and functional traits in the Páramo of Chingaza National Park, Colombia.

ORCID iD

Liliana Patricia Saboyá Acosta https://orcid.org/0000-0002-0499-6664

Supplemental Material

Supplemental material for this article is available online.

References

Acevedo, A. A., Sanguino, O. A., Olarte, C. A., Solano, L., Albornoz, M. M., Cabrera, A, J. A., Carrero-Sarmiento, D. A., & Ramírez-Pinilla, M. (2018). Potential species richness of frogs and diurnal butterflies in three biogeographical units from northeastern Colombia: Conservation implications. *Acta Biológica Colombiana*, *23*(2), 151–162. https://doi.org/10.15446/abc.v23n2.65300

Acosta-Galvis, A. R. (2000). Ranas, Salamandras y Caecilias (Tetrápoda: Amphibia) de Colombia. *Biota Colombiana*, *1*(3), 289–319. https://doi.org/10.1017/CBO9781107415324.004

Acosta-Galvis, A. R. (2015). Una Nueva Especie Del Género *Pristimantis* (Anura: Craugastoridae) Del Complejo de Páramos Merchán-Iguaque (Boyacá, Colombia). *Biota Colombiana*, *16*(2), 107–127.

Acosta-Galvis, A. R. (2021, January 3). *Lista de Los Anfibios de Colombia: Referencia En Línea V.09.2019*. 2019. http://www.batrachia.com

Acosta-Galvis, A. R., & Borja-Acosta, K. G. (2021). *Anfibios y reptiles de la expedición en el páramo de Rabanal, Boyacá - Proyecto Boyacá BIO. Version 2.6*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. Occurrence dataset. https://doi.org/10.15472/kvyqph.

Adams, R. J., Smart, P., & Huff, A.S. (2017). Shades of grey: guidelines for working with the grey literature in systematic reviews for management and organizational studies. *International Journal of Management Reviews*, *19*(4), 432–454. https://doi.org/10.1111/ijmr.12102

Agudelo-Hz, W. J., Urbina-Cardona, N., & Armenteras-Pascual, D. (2019). Critical shifts on spatial traits and the risk of extinction of Andean anurans: an assessment of the combined effects of climate and land-use change in Colombia. *Perspectives in Ecology and Conservation*, *17*(4), 206–219. https://doi.org/10.1016/j.pecon.2019.11.002

Alarcón, J. C., Barbosa-Castillo, C., Cruz-Argüello, S., Ramírez-Aguilera, D. P., Salazar, F., Ville, J., Villa, A., Van der Hammen, T., & Alarcón, J. C. (2002). Transformación y cambio en el uso del suelo en los Páramos de Colombia en las últimas décadas. In C. Castaño (Ed.), *Páramos y ecosistemas altoandinos de Colombia en condiciones hotspot & global climatic tensor* (pp. 211 – 333). IDEAM (Instituto de Hidrología, Meteorología y Estudios Ambientales).

Aldana-Domínguez, J., Montes, C., Martínez, M., Medina, N., Hahn, J., & Duque, D. (2017). Biodiversity and ecosystem services knowledge in the Colombian Caribbean: progress and challenges. *Tropical Conservation Science*, *10*. https://doi.org/10.1177/1940082917714229

Anderson, M. J. (2001). A new method for non-parametric multivariate analysis of variance. *Austral Ecology*, *26*(1), 32–46. https://doi.org/10.1111/j.1442-9993.2001.01070.pp.x

Anderson, M. J., Gorley, R. N., & Clarke, K. R. (2008). *PERMANOVA + for PRIMER: Guide to Software and Statistical Methods*. PRIMER-E: Plymouth, UK.

Anthelme, F., & Peyre, G. (2019). Biogeography of South American Highlands. In M. I. Goldstain, & D.A. DellaSala (Eds.), *Encyclopedia of the world's biomes. Volume 1. Mountains (Alpine Systems) - Life at the Top* (pp. 1–12). Elsevier. https://doi.org/10.1016/B978-0-12-409548-9.11811-1

Arbeláez-Cortés, E. (2013a). Describiendo especies: un panorama de la biodiversidad colombiana en el ámbito mundial. *Acta Biológica Colombiana*, *18*(1), 165–178.

Arbeláez-Cortés, E. (2013b). Knowledge of Colombian Biodiversity: Published and Indexed. *Biodiversity and Conservation*, *22*(12), 2875–2906. https://doi.org/10.1007/s10531-013-0560-y

Ardila-Robayo, M. C., & Acosta-Galvis, A. R. (2000). Anfibios. In J.O. Rangel-Ch. (Ed.), *La Región de Vida Paramuna. Colombia Diversidad Biótica III* (pp. 617–628). Universidad Nacional de Colombia, Instituto de Ciencias Naturales.

Arroyo, S., Targino, M., Rueda-Solano, L. A., Daza, J. M., & Grant, T. (2022). A new genus of terraranas (Anura:Brachycephaloidea) from northern South America, with a systematic review of *Tachiramantis*. *Systematics and Biodiversity*, *20*(1), 2123865. https://doi.org/10.1080/14772000.2022.2123865

Barriga, J. C., Diaz-Pulido, A., Santamaría, M., & García, H. (2015). *Catálogo de biodiversidad para las regiones andina, pacífica y piedemonte amazónico. nivel regional.* Volume *2* Tome 1. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt – Ecopetrol S.A.

Barrio-Amorós, C. L. (2004). Amphibians of Venezuela systematic list, distribution and references, an update. *Revista de ecología latinoamericana*, *9*(3), 1–48.

Baxevanis, A. D., & Bateman, A. (2015). The Importance of Biological Databases in Biological Discovery. *Current Protocols in Bioinformatics, Chapter 1*, 1.11.–1.1.6. https://doi.org/10.1002/0471250953.bi0101s50

Becker, C. G., Loyola, R. D., Haddad, C. F. B., & Zamudio, K. R. (2010). Integrating species life-history traits and patterns of deforestation in amphibian conservation planning. *Diversity and Distributions*, *16*(1), 10–19. https://doi.org/10.1111/j.1472-4642.2009.00625.x

Bernal, M. H., & Lynch, J. D. (2008). Review and analysis of altitudinal distribution of the andean anurans in Colombia. *Zootaxa*, *25*, 1–25. https://doi.org/10.11646/zootaxa.1826.1.1

Bickford, D., Lohman, D. J, Sodhi, N. S., Ng, P. K., Meierm, R., Winker, K., Ingram, K. K., & Das, I. (2007). Cryptic species as a window on

diversity and conservation. *Trends in Ecology and Evolution*, *22*, 148–155. https://doi.org/10.1016/j.tree.2006.11.004

Bini, L. M., Diniz-Filho, J. A. F., Rangel, T. F., Bastos, R. P., & Pinto, M. P. (2006). Challenging Wallacean and Linnean shortfalls: knowledge gradients and conservation planning in a biodiversity hotspot. *Diversity and distributions*, *12*(5), 475–482. https://doi.org/10.1111/j.1366-9516.2006.00286.x

Biodiversity Heritage, Library. (2021, January 3). *BHL: Biodiversity Heritage Library.* https://www.biodiversitylibrary.org/

Bock, B. C., & Páez, V. P. (2017). Meta-analysis of the history of the study of the freshwater turtle and tortoise fauna of Colombia. *Acta Biologica Colombiana*, *22*(1), 67–76. https://doi.org/10.15446/abc.v22n1.59876

Borja-Acosta, K. (2022). Colección de Anfibios del Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH-Am). Version 37.5. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. Occurrence dataset. https://doi.org/10.15472/dma300. Accessed June 10, 2022, via GBIF.org.

Boulenger, G. A. (1905). Descriptions of new tailless batrachians in the collection of the British Museum. *Annals and Magazine of Natural History, Series 7*, 16, 180–184. https://doi.org/10.1080/03745480509443666

Brito, D. (2010). Overcoming the Linnean shortfall: data deficiency and biological survey priorities. *Basic and Applied Ecology*, *11*(8), 709–713. https://doi.org/10.1016/j.baae.2010.09.007

Buitrago-González, W., López-Guzmán, J., & Vargas-Salinas, F. (2016). Anuros en los complejos paramunos los Nevados, Chilí- Barragán y las Hermosas, Andes Centrales de Colombia. *Biota Colombiana*, *7*(2), 52–76. https://doi.org/10.21068/c2016v17s02a04

Burbano-Girón, J., Molina, M. A., Gutiérrez, C., & Ochoa-Quintero, J. M. (2020). Estado de conservación de los Páramos en Colombia. In L.A. Moreno, G. I. Andrade, G. Didier, & O.L. Hernández-Manrique (Eds.). *Biodiversidad 2020. Estado y tendencias de la biodiversidad continental de Colombia*. (pp 112). Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Cabrera, M. (2014). Los Páramos origen y componentes. origen de los Páramos. In M. Cabrera, & W. Ramírez (Eds.). *Restauración Ecológica de Los Páramos de Colombia: Transformación y Herramientas Para Su Conservación*, (pp 19–20). Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Cadena-Vargas, C. E., & Sarmiento, C. E. (2015). Cambios en las coberturas de Páramo. las amenazas de los Páramos de Colombia. In M. F Gómez, L. A Moreno, G. I Andrade, & C. Rueda (Eds.). *Biodiversidad 2015. Estado y Tendencias de La, Biodiversidad Continental de Colombia*. (pp 204). Investigación de Recursos Biológicos Alexander von Humboldt (IAvH).

Cantillo, M. (2022). Estudios bióticos (Plantas, Fauna Edáfica, Anfibios y Aves) en el Complejo de Páramos Perijá. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. Version 1.6. Occurrence dataset. https://doi.org/10.15472/ej32hn. Accessed June 6, 2022, via GBIF.org.

Carrot Search Foam Tree. (2019). Retrieved from https://carrotsearch.com/foamtree/

Carvajal-C, J. E., Aponte-G, A. F., Lynch, J. D., & Rangel-Ch, J. O. (2019). Ecosistemas de la Serranía de Perijá. En Rangel-Ch. In J.O. Andrade-C. M. G. Jarro-F. C. Santos-C. G. (Eds.), *Colombia Diversidad Biótica XVIII. Biodiversidad y territorio de la serranía de Perijá (Cesar-Colombia): 369-378*. Bogotá D.C: Universidad Nacional de Colombia - Instituto de Ciencias Naturales.

Carvajalino-Fernández, J. M., Bonilla, M., & Navas, C. A. (2011). Freezing risk in tropical high-elevation anurans: an assessment based on the Andean frog *Pristimantis nervicus* (Strobomantidae). *South American Journal of Herpetology*, *6*(2), 73–78. https://doi.org/10.2994/057.006.0205

Catenazzi, A., & Von May, R. (2014). Conservation Status of Amphibians in Peru. *Herpetological Monographs*, *28*(1), 1–23. https://doi.org/10.1655/HERPMONOGRAPHS-D-13-00003

Catenazzi, A. (2015). State of the world's amphibians. *Annual Review of Environment and Resources*, *40*, 91–119. https://doi.org/10.1146/annurev-environ-102014-021358

Christie, A. P., Abecasis, D., Adjeroud, M., Alonso, J. C., Amano, T., Anton, A., Baldigo, B. P., Barrientos, R., Bicknell, J. E., Buhl, D. A., Cebrian, J., Ceia, R. S., Cibils-Martina, L., Clarke, S., Claudet, J., Craig, M. D., Davoult, D., De Backer, A., Donovan, M. K., Eddy, T. D., França, F. M., Gardner, J. P. A., Harris, B. P., Huusko, A., Jones, I. L., Kelaher, B. P., Kotiaho, J. S., López-Baucells, A., Major, H. L., Mäki-Petäys, A., Martín, B., Martín, C. A., Martin, P. A., Mateos-Molina, D., McConnaughey, R. A., Meroni, M., Meyer, C. F. J., Mills, K., Montefalcone, M., Noreika, N., Palacín, C., Pande, A., Pitcher, C. R., Ponce, C., Rinella, M., Rocha, R., Ruiz-Delgado, M. C., Schmitter-Soto, J. J., Shaffer, J. A., Sharma, S., Sher, A. A., Stagnol, D., Stanley, T. R., Stokesbury, K. D. E., Torres, A., Tully, O., Vehanen, T., Watts, C., Zhao, Q., & Sutherland, W. J. (2020). Quantifying and addressing the prevalence and bias of study designs in the environmental and social sciences. *Nature Communications*, *11*(1), 6377. https://doi.org/10.1038/s41467-020-20142-y

Christie, A. P., White, T. B., Martin, P. A., Petrovan, S. O., Bladon, A. J., Bowkett, A. E., Littlewood, N. A., Mupepele, A., Rocha, R., Sainsbury, K. A., Smith, R. K., Taylor, N. G., & Sutherland, W. J. (2021). Reducing publication delay to improve the efficiency and impact of conservation science. *PeerJ*, *9*, e12245. https://doi.org/10.7717/peerj.12245

Christmann, T., & Oliveras, I. (2020). Nature of alpine ecosystems in tropical mountains of South America. In M. I. Goldstain, & D.A. DellaSala (Eds.), *Encyclopedia of the world's biomes. Volume 1. Mountains (Alpine Systems) - Life at the Top* (pp.282–290). Elsevier. https://doi.org/10.1016/b978-0-12-409548-9.12481-9

Cisneros-Heredia, D. F., & Gluesenkamp, A.G. (2010). A new Andean toad of the genus *Osornophryne* (Amphibia: Anura: Bufonidae) from northwestern Ecuador, with taxonomic remarks on the genus. *Avances En Ciencias e Ingenierias*, *2*(3): B64–B73.

Clarke, K. R., & Gorley, R. N. (2006) *PRIMER v6: User Manual/Tutorial*. PRIMER-E, Plymouth.

Clarke, K. R., Somerfield, P. J., & Gorley, R. N. (2008). Testing of null hypotheses in exploratory community analyses: similarity profiles and biota-environment linkage. *Journal of Experimental Marine Biology and Ecology*, *366*(1-2), 56–69. https://doi.org/10.1016/j.jembe.2008.07.009

Clarke, K. R., & Gorley, R. N. (2015). *Primer v7: User Manual/Tutorial*. PRIMER-E. Plymouth.

Cochran, D. M., & Goin, C. J. (1970). Frogs of Colombia. *Bulletin of the United States National Museum*, *288*, 1–655. https://doi.org/10.5479/si.03629236.288.1

Cortés-Duque, J., Sarmiento, C., Baptiste, B., Cortés-Duque, J., & Sarmiento, C. (2013). *Visión Socioecosistémica de Los Páramos de Alta Montaña Colombiana: Memorias Del Proceso de Definición de Criterios Para La Delimitación de Páramos*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Coloma, L.A., Lötters, S., & Salas, A. W. (2000). Taxonomy of the *Atelopus ignescens* complex (Anura: Bufonidae): designation of a neotype of *Atelopus ignescens* and recognition of *Atelopus exiguus*. *Herpetologica*, *56*(3):303–324.

Cope, E. D. (1899). Contributions to the herpetology of New Granada and Argentina, with descriptions of new forms, by Edward D. Cope; a posthumous paper edited by J. Percy Moore. *Philadelphia Museums. Science Bulletin*, *1*, 1–22.

Cuatrecasas, J. (1958). Aspectos de La Vegetación Natural de Colombia. *Revista de La Academia Colombiana de Ciencias Exactas, Físicas y Naturales*, *10*(40), 221–268.

de Magalhães, R., Rocha, P., Santos, F., Strüssmann, C., & Ariovaldo, G. (2018). Integrative taxonomy helps to assess the extinction risk of anuran species. *Journal for Nature Conservation*, *45*, 1–10. https://doi.org/10.1016/j.jnc.2018.07.001

Doan, T. M. (2003). A South-to-North Biogeographic Hypothesis for Andean Speciation: Evidence from the Lizard Genus *Proctoporus* (Reptilia, Gymnophthalmidae). *Journal of Biogeography*, *30*(3), 361–374. https://doi.org/10.1046/j.1365-2699.2003.00833.x

Duarte-Ballesteros, L., Urbina-Cardona, J. N., & Saboyá-Acosta, L. P. (2021). Ensamblajes de anuros y heterogeneidad espacial en un ecosistema de Páramo de Colombia. *Caldasia*, *43*(1), 126–137. https://doi.org/10.15446/caldasia.v43n1.84860

Duellman, W. E., & Hillis, D. M. (1987). Marsupial frogs (Anura: Hylidae: Gastrotheca) of the Ecuadorian Andes: Resolution of taxonomic problems and phylogenetic relationships. *Herpetologica*. *43*(2):141–173.

Duellman, W. E., Marion, A. B., & Hedges, S. B. (2016). Phylogenetics, classification, and biogeography of the treefrogs (Amphibia: Anura:Arboranae). *Zootaxa*, *4104*(1): 001–109. https://doi.org/10.11646/zootaxa.4104.1.1

Espíndola, A., Ruffley, M., Smith, M. L., Carstens, B. C., Tank, D. C., & Sullivan, J. (2016). Identifying cryptic diversity with predictive phylogeography. *Proceedings of the Royal Society*, *283*(1841), 20161529. https://doi.org/10.1098/rspb.2016.1529

Estela, F. A., López-Victoria, M., Castillo, L. F., & Naranjo, L. G. (2010). Estado del conocimiento sobre aves marinas en Colombia, después de 110 años de investigación." *Boletín SAO*, *20*, 2–21.

Etter, A., & Van Wyngaarden, W. (2000). Patterns of landscape transformation in Colombia, with emphasis in the Andean region. *Ambio*, *29*(7), 432–439. https://doi.org/10.1579/0044-7447-29.7.432

Etter, A., McAlpine, C., & Possingham, H. (2008). Historical patterns and drivers of landscape change in Colombia since 1500: a regionalized spatial approach. *Annals of the Association of American Geographers*, *98*(1), 2–23. https://doi.org/10.1080/00045600701733911

Etter, A., Andrade, A., Saavedra, K., & Cortés, J. (2018). Actualización de la lista roja de los ecosistemas terrestres de Colombia: herramienta para la gestión de los ecosistemas. In L. A. Moreno, C. Rueda, & G. I. Andrade (Eds.). *Biodiversidad 2017. Estado y tendencias de la biodiversidad continental de Colombia*. (pp. 204) Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Estupiñán, R. A., Ferrari, S. F., Concalves, E. C., Barbosa, M. S., Vallinoto, M., & Schneider, M. P. (2016). Evaluating the diversity of Neotropical anurans using DNA barcodes. *Zookeys*, *637*, 89–106. https://doi.org/10.3897/zookeys.637.8637

Fandiño, M. C., & Amézquita, A. (1997). Vocalization and larval transportation of male *Colostethus subpunctatus* (Anura: Dendrobatidae). *Amphibia-Reptilia*, *18*(1), 39–48. https://doi.org/10.1163/156853897x00297

Fleishman, E., Noss, R. F., & Noon, B. R. (2006). Utility and limitations of species richness metrics for conservation planning. *Ecological Indicators*, *6*(3), 543–553. https://doi.org/10.1016/j.ecolind.2005.07.005

Frost, D. R. (2021). Amphibian Species of the World: An Online Reference. Version 6.1. American Museum of Natural History. 2021. https://doi.org/10.5531/db.vz.0001

García-R, J. C., Crawford, A. J., Mendoza, Á. M., Ospina, O., Cardenas, H., & Castro, F. (2012). Comparative Phylogeography of Direct-Developing Frogs (Anura: Craugastoridae: *Pristimantis*) in the Southern Andes of Colombia. *PloS one*, *7*(9), e46077. https://doi.org/10.1371/journal.pone.0046077

Garnett, S., & Christidis, L. (2017). Taxonomy anarchy hampers conservation. *Nature*, *546*(7656), 25–27. https://doi.org/10.1038/546025a

Gómez, M. F., Moreno, L. A., Andrade, G. I., & Rueda, C. (2015). *Biodiversidad 2015. Estado y Tendencias de La Biodiversidad Continental de Colombia*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH). https://doi.org/10.1017/CBO9781107415324.004

González-Durán, G. A., Targino, M., Rada, M., & Grant, T. (2017). Phylogenetic relationships and morphology of the *Pristimantis leptolophus* species group (Amphibia: Anura: Brachycephaloidea), with the Recognition of a new species group in *Pristimantis* Jiménez de La Espada, 1870. *Zootaxa*, *4243*(1), 42–74. https://doi.org/10.11646/zootaxa.4243.1.2

Gradstein, S. R., Homeier, J., & Gansert, D. (2008). *The tropical mountain forest. patterns and processes in a biodiversity hotspot. Biodiversity and Ecology Series* Vol. 2. Göttingen Centre for Biodiversity and Ecology.

Gregory-Wodzicki, K. M. (2000). Uplift history of the central and northern Andes: a review. *Geological Society of America Bulletin*, *112*(7), 1091–1105. https://doi.org/10.1130/0016-7606(2000)112<1091:uhotca>2.0.co;2

Guarnizo, C. E., & Cannatella, D. C. (2014). Geographic determinants of gene flow in two sister species of tropical Andean frogs. *Journal of Heredity*, *105*(2), 216–225. https://doi.org/10.1093/jhered/est092

Guayasamin, J. M., Almeida-Reinoso, D., & Nogales-Sornosa, F. (2004). Two new species of frogs (Leptodactylidae: *Eleutherodactylus*) from the high Andes of northern Ecuador. *Herpetological Monographs*, *18*(1), 127–141. https://doi.org/10.1655/0733-1347(2004)018[0127:tnsofl]2.0.co;2

Guevara, A. (2021). Inversión en actividades de ciencia tecnología e innovación - ACTI en Colombia. In M. A Muñoz (Ed.). *Informe de Indicadores de Ciencia y Tecnología Colombia 2020*. Observatorio Colombiano de Ciencia y tecnología.

Gutiérrez, G., & Lüddecke, H. (2002). Mating pattern and hatching success in a population of the Andean frog *Hyla labialis*. *Amphibia Reptilia*, *23*(3), 281–292, https://doi.org/10.1163/15685380260449162

Gutiérrez-Lamus, D. L., Serrano, V. H., & Ramírez-Pinilla, M. P. (2004). Composition and abundance of Anura in two forest types (natural and planted) in the Eastern Cordillera of Colombia. *Caldasia*, *26*(1), 245–264.

Hedges, S. B., Duellman, W. E., & Heinicke, M. P. (2008). New World direct developing frogs (Anura: Terrarana): molecular phylogeny, classification, biogeography, and conservation. *Zootaxa*, *1737*(1): 3–179. https://doi.org/10.11646/zootaxa.1737.1.1

Henao, F., Arroyo, S., Cárdenas-Posada, G., Fernández, M., López, J. P., Martínez, D.C., Mendoza, J. S., Mondragón-Botero, A., León, O., Pulido-Herrera, K. L., Rodríguez-Cerón, N., & Madriñán, S. (2019). Caracterización biológica en la zona de transición bosque-Páramo del complejo de Páramos Chingaza, Colombia. *Biota Colombiana*, *20*(1): 132–145. https://doi.org/10.21068/c2019.v20n01a10

Hess, C. G. (1990). Moving up-Moving down": Agro-Pastoral Land-Use Patterns in the Ecuadorian Paramos. *Mountain Research and Development*, *10*(4), 333–342, https://doi.org/10.2307/3673495

Hofstede, R. (2013). Lo mucho que sabemos del Páramo. apuntes sobre el conocimiento actual de la integridad, la transformación y la conservación del Páramo. In J. Cortés-Duque, & C Sarmiento (Eds.). *Visión socio ecosistémica de los Páramos y la alta montaña colombiana: memorias del proceso de definición de criterios para la delimitación de Páramos* (pp. 113–126). Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH).

Hofstede, R, Segarra, P., & Mena, P. (2003). *Los Páramos Del Mundo. Proyecto Atlas Mundial de Los Páramos*. Global Peatland Initiative/NC-IUCN/EcoCiencia.

Hofstede, R., Calles, J., López, V., Polanco, R., Torres, F., Ulloa, J., Vásquez, A., & Cerra, M. (2014). *Los Páramos andinos ¿qué sabemos? estado de conocimiento sobre el impacto del cambio climático en el ecosistema Páramo*. Unión Internacional para la Conservación de la Naturaleza (UICN).

Hofstede, R. G. M., & Llambí, L. D. (2020). Plant Diversity in PáramodNeotropical High Mountain Humid Grasslands. In M. I. Goldstein, & D. A. DellaSala (Eds), *Encyclopedia of the World's Biomes*. Vol. *1*. Elsevier.

Hortal, J., de Bello, F., Diniz-Filho, J. A. F., Lewinsohn, T. M., Lobo, J. M., & Ladle, R. J. (2015). Seven shortfalls that beset large-scale knowledge of biodiversity. *Annual Review of Ecology, Evolution, and Systematics*, *46*(1), 523–549. https://doi.org/10.1146/annurev-ecolsys-112414-054400

Hoyos, J. M., Medina, P., & Schoch, P. (2015). Osteology of *Atelopus muisca* (Anura, Bufonidae) from Colombia. *Zootaxa*, *3905*(1), 119–130. https://doi.org/10.11646/zootaxa.3905.1.7

Huang, X., Hawkins, B. A., & Qiao, G. (2013). Biodiversity Data Sharing: Will Peer-Reviewed Data Papers Work?, *BioScience*, *63*(1), 5–6. https://doi.org/10.1525/bio.2013.63.1.2

Instituto de Investigación de Recursos Biológicos Alexander von Humboldt - IAvH. (2012). *Cartografía de Páramos de Colombia Esc 1:100.000." Bogotá D.C. Colombia*. Instituto Humboldt y Ministerio de Ambiente y Desarrollo Sostenible.

Instituto de Investigación de Recursos Biológicos Alexander von Humboldt - IAvH. (2019). *Humboldt Institutional Repository.* http://repository.humboldt.org.co/

IUCN. (2021). *IUCN Red List*. http://www.iucnredlist.org/initiatives/amphibians/analysis/red-list-status

Jiao, C., & Darch, P. T. (2020). The role of the data paper in scholarly communication. *Proceedings of the Association for Information Science and Technology*, *57*(1), e316. https://doi.org/10.1002/pra2.316

Jiménez de la Espada, M. (1875). *Vertebrados del Viaje al Pacífico Verificado de 1862 a 1865 por una Comisión de Naturalistas Enviada por el Gobierno Español. Batracios*. Madrid: A. Miguel Ginesta.

Kappelle, M., & Savage, J. M. (2005). Anfibios y reptiles de los Páramos y sus alrededores en costa rica. In M. Kappelle, S. Horn, & C. R. Heredia (Eds.). *Páramos de Costa Rica* (pp. 513–519). Editorial INBio.

Lacher, T. E., Boitani, L., & da Fonseca, G. A. B. (2012). The IUCN Global assessments: partnerships, collaboration and data sharing for biodiversity science and policy. *Conservation Letters*, *5*, 327–333. https://doi.org/10.1111/j.1755-263X.2012.00249.x

La Marca, E., García-Pérez, J. E., & Renjifo, J. M. (1990). Una nueva especie de Atelopus (Amphibia: Anura: Bufonidae) del páramo de Tamá, Estado Apure, Venezuela. *Caldasia*, *16*, 97–104.

Lauer, W. (1981). Ecoclimatological conditions of the paramo belt in the tropical high mountains. *Mountain Research and Development*, *1*(3/4), 209–221, https://doi.org/10.2307/3673058

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health

care interventions: explanation and elaboration. *PLoS Medicine*, *6*(7), e1000100. https://doi.org/10.1371/journal.pmed.1000100

Londoño, M. C., Saboyá, L. P., & Urbina-Cardona, N. (2019). Conocimiento científico de los efectos del cambio climático sobre la biodiversidad continental: productividad de las instituciones colombianas y propuesta para un análisis integral. *Biodiversidad En La Práctica*, *4*(1), 86–110. http://hdl.handle.net/20.500.11761/35255

López, J. H. (2017). *Estudios bióticos (plantas, fauna edáfica, anfibios y aves) en los complejos de Páramos Las Hermosas y Chilí-Barragán*. Version 4.2. Occurrence Dataset. https://doi.org/10.15472/zav8dr

Lynch, J. D. (1976). New species of frogs (Leptodactylidae: Eleutherodactylus) from the Pacific versant of Ecuador. *Occasional Papers of the Museum of Natural History*, University of Kansas, *55*, 1–33.

Lynch, J.D. (1998). New Species of *Eleutherodactylus* from The Cordillera Occidental of western Colombia with synopsis of the distribution of species in Western Colombia. *Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales*. *22*(82):117–148.

Lynch, J. D. (2000). A new species of frog, genus *Eleutherodactylus* (Leptodactylidae), from the Sabana de Bogotá. *Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales*, *24*(92):435–439.

Lynch, J. D. (2001). A Small Amphibian Fauna from a Previously Unexplored Paramo of the Cordillera Occidental in Western Colombia. *Journal of Herpetology*, *35*(2), 226–231, https://doi.org/10.2307/1566112

Lynch, J. D., & Ruiz-Carranza, P. M. (1985). A synopsis of the frogs of the genus *Eleutherodactylus* from the Sierra Nevada de Santa Marta. *Occasional Papers of the Museum of Zoology, University of Michigan*, *7*(11), 1-59.

Lynch, J. D., & Suárez, Á. (2002). Biogeographic analysis of the amphibian fauna of the paramos. *Caldasia*, *24*(2), 471–480.

Lynch, J. D. (2003). Two new frogs (*Eleutherodactylus*) from the Serranía de Perija, Colombia. Revista de la Academia Colombiana de Ciencias Exactas, *Físicas y Naturales*, *27*, 613–617.

Machuca-Martínez, F. (2020). Importance of scientific data and its publication as data paper. *Ingeniería y competitividad*, *22*(1), 8843.

Madriñán, S., Cortés, A. J., & Richardson, J. E. (2013). Páramo is the world's fastest evolving and coolest biodiversity hotspot. *Frontiers in Genetics*, *4*(191), 1–7. https://doi.org/10.3389/fgene.2013.00192

Mahood, Q., Van Eerd, D., & Irvin, E. (2013). Searching for grey literature for systematic reviews: challenges and benefits. *Research Synthesis Methods*, *5*(3), 221–234, https://doi.org/10.1002/jrsm.1106

Medina, C.A., Arbeláez-Cortés, E., Borja, K., González, C., DoNascimiento, F.A., Acosta, A.R., Mendoza, H., & Espitia-Reina, D. (2016). Las colecciones biológicas del instituto Humboldt. In M.F. Gómez, L.A. Moreno, G.I. Andrade, & C. Rueda (Eds.). *Biodiversidad 2015. Estado y Tendencias de La Biodiversidad Continental de Colombia*, Instituto Alexander von Humboldt.

Mendoza, A. M., Ospina, O. E., Cárdenas-Henao, H., & García-R, J. C. (2015). A likelihood inference of historical biogeography in the world's most diverse terrestrial vertebrate genus: Diversification of direct-developing frogs (Craugastoridae: *Pristimantis*) across the Neotropics. *Molecular Phylogenetics and Evolution*, *85*, 50–58. https://doi.org/10.1016/j.ympev.2015.02.001

Mendoza-Henao, A. M., Cortes-Gomez, Á. M., González, M. A., Hernández-Córdoba, Andrés, R. O. D., Daza, J. M., Hoyos, J. M., Ramírez-Pinilla, M. P., Urbina-Cardona, N., & Salgado-Negret, B. (2019). A Morphological database for Colombian anuran species from conservation-priority ecosystems. *Ecology*, *100*(5), 2685. https://doi.org/10.1002/ecy.2685

Meza-Joya, F. L., & Torres, M. (2016). Spatial Diversity Patterns of *Pristimantis* Frogs in the Tropical Andes. *Ecology and Evolution*, *6*(7), 1901–1913. https://doi.org/10.1002/ece3.1968

Michaels, C., Beatrice, G., & Richard, P. (2014). The importance of natural history and species-specific approaches in amphibian *ex-situ* conservation. *The Herpetological Journal*. *24*, 135–145.

Ministerio de Ciencia, Tecnología e Innovación de Colombia. (2018). Clasificación de revistas Publindex. [Web page]. Retrieved from https://scienti.minciencias.gov.co/publindex/#/revistasPublindex/clasificacion

Morales, M, J., Otero, T., Van der Hammen, A., Torres, C., Cadena, C., Pedraza, N., Rodríguez Franco, C. A., Betancourth, J. C., Olaya, E., Posada, E., & Cárdenas, L. (2007). *Atlas de Páramos de Colombia*. Instituto de Investigación de Recursos Biológicos.

Moreno-Arias, R.A., Medina-Rangel, G.F., Carvajal-Cogollo, J.E., & Castaño-Mora, O.V. (2007). Ecosistemas de la Serranía de Perijá. In J.O. Rangel-Ch. (Eds.), *Colombia Diversidad Biótica VIII. Medina y baja montaña de la Serranía de Perijá: 449-470*. Bogotá D.C.: Universidad Nacional de Colombia - Instituto de Ciencias Naturales.

Moreno, L. A., Andrade, G. I., Didier, G., & Hernández-Manrique, O. L. (Eds.). (2020). Biodiversidad 2020. *Estado y tendencias de la biodiversidad continental de Colombia*. Bogotá, D. C., Colombia: Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Navas, C. A. (1996a). Implications of microhabitat selection and patterns of activity on the thermal ecology of high elevation neotropical anurans. *Oecologia*, *108*(4), 617–626. https://doi.org/10.1007/BF00329034

Navas, C. A. (1996b). Metabolic locomotor performance, physiology, and thermal in neotropical niche breadth anurans. *Physiological Zoology*, *69*(6), 1481–1501. https://doi.org/10.1086/physzool.69.6.30164271

Navas, C. A. (1999). Biodiversidad de anfibios y reptiles en el Páramo: una visión eco-fisiológica. *Revista de La Academia Colombiana de Ciencias Exactas, Físicas y Naturales 23* (Suplemento especial): 465–474.

Navas, C. A. (2002). Herpetological diversity along Andean elevational gradients: links with physiological ecology and evolutionary physiology. *Comparative Biochemistry and Physiology - A Molecular and Integrative Physiology*, *133*(3), 469–485. https://doi.org/10.1016/S1095-6433(02)00207-6

Navas, C. A. (2006). patterns of distribution of anurans in high Andean tropical elevations: insights from integrating biogeography and evolutionary physiology. *Integrative and Comparative Biology*, *46*(1), 82–91. https://doi.org/10.1093/icb/icj001

Navas, C. A., Carvajalino-Fernández, J. M., Saboyá-Acosta, L. P., Rueda-Solano, L. A., & Carvajalino-Fernández, M. A. (2013). The body temperature of active amphibians along a tropical elevation gradient: patterns of mean and variance and inference from environmental data. *Functional Ecology*, *27*(5), 1145–1154. https://doi.org/10.1111/1365-2435.12106

Nori, J., Lemes, P., Urbina-Cardona, N., Baldo, D., Lescano, J., & Loyola, R. (2015). Amphibian conservation, land-use changes and protected areas: A global overview. *Biological Conservation*, *191*, 367–374. https://doi.org/10.1016/j.biocon.2015.07.028

Nowakowski, A. J., Thompson, M. E., Donnelly, M. A., & Todd, B. D. (2017). Amphibian sensitivity to habitat modification is associated with population trends and species traits. *Global Ecology and Biogeography*, *26*(9), 1020–1032. https://doi.org/10.1111/geb.12571

Oliveira, B., São-Pedro, V., Santos-Barrera, G., Penone, C., & Costa, G. (2017). AmphiBIO, a global database for amphibian ecological traits. *Scientific Data*, *4*, 170123. https://doi.org/10.1038/sdata.2017.123

Páez-Moscoso, D. J., Guayasamin, J. M., & Yánez-Muñoz, M. H. (2011). A new species of Andean toad (Bufonidae, *Osornophryne*) discovered using molecular and morphological data, with a taxonomic key for the genus. *ZooKeys*, *108*, 73–97. https://doi.org/10.3897/zookeys.108.1129

Peters, W. C. H. (1863). Über eine neue Schlangen-Gattung, Styporhynchus, und verschiedene andere Amphibien des zoologischen Museum. *Monatsberichte der Königlichen Preussische Akademie des Wissenschaften zu Berlin*, *1863*, 399–413.

Rangel-Ch, O. (2019). *Colombia Diversidad Biótica*. www.colombiadiversidadbiotica.com%0A

Rangel, O., & Rangel -Ch, O. (2000). La región paramuna y franja aledaña en Colombia. In O Rangel -Ch (Ed.). *Colombia diversidad biótica III. La Región de Vida Paramuna*. Universidad Nacional de Colombia and Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Ravelo, J. V., & Martínez, M. M. (2019). *Caracterización biológica de la ventana de biodiversidad Río Guamués, Corregimiento El Encano, Municipio de Pasto, Nariño, Colombia*. Version 2.2. https://doi.org/10.15472/7tk1wz. Accessed via GBIF.org.

Riddler, B. R., & Hafner, D. J. (1999). Species as units of analysis in ecology and biogeography: time to take the blinders off. *Global Ecology Biogeography*, *8*(6), 433–441. https://doi.org/10.1046/j.1365-2699.1999.00170.x

Rivera Ospina, D., & Rodríguez, C. (2011). *Guía Divulgativa de Criterios Para La Delimitación de Páramos de Colombia*. Ministerio de Ambiente, Vivienda y Desarrollo Territorial e Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Rivera-Correa, M., Jiménez-Rivillas, C., & Daza, J. M. (2017). Phylogenetic analysis of the Neotropical *Pristimantis leptolophus* species group (Anura: Craugastoridae): molecular approach and description of a new polymorphic species. *Zootaxa*, *4242*(2): 313–344. https://doi.org/10.11646/zootaxa.4242.2.6

Rivero, J. A. (1984). Los Eleutherodactylus (Amphibia, Salientia) de los Andes Venezolanos. II, Especies sub-parameras. Memoria. *Sociedad de Ciencias Naturales La Salle*, *42*, 57–132.

Roach, N. S., Urbina-Cardona, N., & Lacher, T. E. Jr. (2020). Land cover drives amphibian diversity across steep elevational gradients in an isolated neotropical mountain range: Implications for community conservation. *Global Ecology and Conservation*, *22*, e00968. https://doi.org/10.1016/j.gecco.2020.e00968

Roche, D. G., Kruuk, L. E. B., Lanfear, R., & Binning, S. A. (2015). Public Data Archiving in Ecology and Evolution: How Well Are We Doing? *PLoS Biol*, *13*(11): e1002295. https://doi.org/10.1371/journal.pbio.1002295

Rodríguez, N., Armenteras, D., Morales, M., & Romero, M. (2006). *Ecosistemas de los andes colombianos*. Instituto de Investigación de Recursos Biológicos Alexander Von Humbolt.

Ron, S. R., Merino-Viteri, A., & Ortiz, D. A. (2020). *Anfibios Del Ecuador*. Versión 2019.0. 2020. https://bioweb.bio/faunaweb/amphibiaweb

Rueda-Almonacid, J. V., & Hoyos, J. M. (1991). *Atelopus muisca*, Nueva Especie de Anfibio (Anura: Bufonidae) Para El Parque Nacional Natural Chingaza, Colombia. *Trianea Acta Científica y Tecnológica*, 471–480.

Rueda-Almonacid, J. V., Lynch, J. D., & Galvis-Peñuela, P. A. (2003). Una nueva especie de anfibio (Anura: Leptodactylidae) de los alrededores de La Sabana de Bogotá, Colombia. (*27*, pp. 461–466). Revista de la Academia Colombiana de Ciencias Exactas Físicas y Naturales.

Rueda-Almonacid, J. V., Lynch, J. D., & Amézquita, A. (2004). Libro rojo de anfibios de Colombia. Serie Libros Rojos de Especies Amenazadas de Colombia. *Conservación Internacional Colombia*, Instituto de Ciencias Naturales – Universidad Nacional de Colombia, Ministerio del Medio Ambiente.

Rueda-Almonacid, J. V., Rodríguez-Maecha, J. V., Lötters, S., La Marca, E., Kahn, T., & Angulo, A. (2005). *Ranas Arlequines*. Conservación Internacional Serie Libretas de Campo.

Ruiz, D., Moreno, H. A., Gutiérrez, M. E., & Zapata, P. A. (2008). Changing climate and endangered high mountain ecosystems in Colombia. *Science of the Total Environment*, *398*(1–3), 122–132. https://doi.org/10.1016/j.scitotenv.2008.02.038

Ruiz-Carranza, P. M., & Lynch, J. D. (1991). Ranas Centrolenidae de Colombia II. Nuevas especies de *Centrolene* de la

Cordillera Oriental y Sierra Nevada de Santa Marta. *Lozania*. *58*, 1–26.

Ruthven, A. G. (1916). Description of a new species of *Atelopus* from the Santa Marta Mountains, Colombia. *Occasional Papers of the Museum of Zoology*, University of Michigan, *28*, 1–3.

Ruthven, A. G. (1917). Two new species of *Eleutherodactylus* from Colombia. *Occasional Papers of the Museum of Zoology*, University of Michigan *39*: 1–6.

Santos, J.C., Coloma, L.A., Summers, K., Caldwell, J.P., Ree, R., & Cannatella, D.C. (2009). Amazonian amphibian diversity is primarily derived from late Miocene Andean lineages. *PLoS Biology*, *8*(9), https://doi.org/10.1371/annotation/18e722e3-05db-4e40-86a0-bedfc4934a5a

Sarmiento, C., Cadena, C., Sarmiento, M., Zapata, J., & León, O. (2013). *Aportes a la conservación estratégica de los Páramos de Colombia: actualización de la cartografía de los complejos de Páramo a escala 1:100.000*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Sarmiento, C., & Ungar, P. (2014). *Aportes a la delimitación del Páramo mediante la identificación de los límites inferiores del ecosistema a escala 1:25.000 y análisis del sistema social asociado al territorio: complejo de Páramos Jurisdicciones – Santurbán – Berlín departamentos de Santander y Norte de Santander*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Sarmiento, C., & León, O. (2015). *Transición bosque–Páramo: bases conceptuales y métodos para su identificación en los andes colombianos*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH).

Sarmiento, C., Osejo, A., Ungar, P., & Zapata, J. (2017). *Páramos habitados: desafíos para la gobernanza ambiental de la alta montaña en Colombia. biodiversidad en la práctica*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Schmidt, O. (1857). Diagnosen neuer Frösche des zoologischen Cabinets zu Krakau. Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche *Classe*, *24*, 10–15.

Shamseer, L., Moher, D., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., & Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ*, *349*, g7647. https://doi.org/10.1136/bmj.g7647

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to do a systematic review: a best practice guide for conducting and reporting narrative reviews, meta-analyses, and meta-syntheses. *Annual review of psychology*, *70*, 747–770, https://doi.org/10.1146/annurev-psych-010418-102803

Solarte Cruz, M. E. (2021). E*studios bióticos (Plantas, Fauna Edáfica, Anfibios y Aves) en los Complejos de páramos Chiles-Cumbal, La Cocha-Patascoy y Doña Juana Chimayoy*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. Occurrence dataset. https://doi.org/10.15472/zmnvox. Accessed June 6, 2022, via GBIF.org.

Somerfield, P. J., & Clarke, K. R. (2013). Inverse analysis in non-parametric multivariate analyses: distinguishing groups of associated species which covary coherently across samples. *Journal of Experimental Marine Biology and Ecology*, *449*, 261–273, https://doi.org/10.1016/j.jembe.2013.10.002

Stuart, S. N., Hoffmann, M., Chanson, J. S., Cox, N. A., Berridge, R. J., Ramani, P., & Young, B. E. (2008). *Threatened Amphibians of the World*. IUCN, Gland, Switzerland; and Conservation International.

Sutherland, W. J., Taylor, N. G., MacFarlane, D., Amano, T., Christie, A. P., Dicks, L. V., Lemasson, A. J., Littlewood, N. A., Martin, P. A., Ockendon, N., Petrovan, S. O., Robertson, R. J., Rocha, R., Shackelford, G. E., Smith, R. K., Tyler, E. H. M., & Wordley, C. F. R. (2019). Building a tool to overcome barriers in research-implementation spaces: The Conservation Evidence database. *Biological Conservation*, *238*, 108199. https://doi.org/10.1016/j.biocon.2019.108199

The World Bank. (2018). Data: Research and Development Expenditure (% of GDP). 2018. https://data.worldbank.org/topic/science-and-technology?locations=CO

Theodoridis, S., Nogués-Bravo, D., & Conti, E. (2019). The role of cryptic diversity and its environmental correlates in global conservation status assessments: Insights from the threatened bird's-eye primrose (*Primula farinosa* L.). *Diversity and distributions*, *25*, 1457–1471. https://doi.org/10.1111/ddi.12953

Thompson, M. E., Medina-Rangel, G. F., & Ruiz-Valderrama, D. H. (2018). First record and massive range extension of *Hyalinobatrachium cappellei* (Van Lidth de Jeude, 1904) (Anura, Centrolenidae) in Colombia. *Check List*, *14*(6), 945–949. https://doi.org/10.15560/14.6.945.

Trueb, L. (1971). Phylogenetic relationships of certain neotropical toads with the description of a new genus (Anura: Bufonidae). *Contributions in Science Natural History Museum of Los Angeles County*, *216*, 1–40, https://doi.org/10.5962/p.241202

Urbina-Cardona, J. N., Saboyá-Acosta, L. P., Camacho-Rozo, C. P., Acosta-Peña, A. R., Arenas-Rodríguez, A., Albarracín-Caro, J. F., Moreno, A. M., Novoa-Salamanca, N. M., Camacho-Durán, M. J., Giraldo, N., Hernández-Gallego, M. J., Pirateque, L., Aldana, V., Echeverry, D., Morales-Devia, H., & Zabala-Forero, F. A. (2023). Producción científica sobre la herpetología en Colombia: perspectivas desde los temas de investigación hacia la conservación biológica *Caldasia 12* (40) *in press*. https://doi.org/10.1177/1940082919854058

Vásquez-Restrepo, J. D. (2021). Inclusion is not representativeness: the context of Colombian samples in the taxonomic and systematic mid-large herpetological literature. *Revista Latinoamericana De Herpetología*, *4*(2), 236–247. https://doi.org/10.22201/fc.25942158e.2021.02.281

Velásquez-Tibatá, J., Olaya-Rodríguez, M. H., López-Lozano, D., Gutiérrez, C., González, I., & Londoño-Murcia, M. C. (2019). BioModelos: A collaborative online system to map species distributions. *PloS one*,*14*(3), e0214522, https://doi.org/10.1371/journal.pone.0214522

Vuilleumier, F. (1970). Insular Biogeography in Continental Regions. I. The Northern Andes of South. *The American Naturalist*, *104*(938), 373–388, https://doi.org/10.1086/282671

Walters, A. D., Cannizzaro, A. G., Trujillo, D. A., & Berg, D. J. (2021). Addressing the Linnean shortfall in a cryptic species complex. *Zoological Journal of the Linnean Society*, *192*(2), 277–305. https://doi.org/10.1093/zoolinnean/zlaa099

Werner, F. (1899). Ueber Reptilien und Batrachier aus Columbien und Trinidad. *Verhandlungen des Zoologisch-Botanischen Vereins in Wien*, *49*, 470–474, https://doi.org/10.5962/bhl.part.24106

Whittaker, R. H. (1952). A study of summer foliage insect communities in the great smoky mountains. *Ecological Monographs*, *22*(1), 1–44. https://doi.org/10.2307/1948527

Wicherts, J. M., Bakker, M., & Molenaar, D. (2011). Willingness to Share Research Data Is Related to the Strength of the Evidence and the Quality of Reporting of Statistical Results. *PLoS One*, *6*(11), e26828. https://doi.org/10.1371/journal.pone.0026828