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Review Article

An overview of geometrid moths (Lepidoptera: Geometridae) in the Andean Region *s.l.*: A systematic review

Una visión general de las polillas geométridas (Lepidoptera: Geometridae) en la Región Andina *s.l.*: Una revisión sistemática

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ABSTRACT

The Andean Region, spanning from 23° S to 55° S, including the South American Transition Zone, harbours many unique species but faces significant human-induced pressures. It encompasses two biodiversity hotspots, underscoring the importance of understanding its biota for effective conservation. Notably, the Andean Region boasts one of the world's largest concentrations of endemic geometrid moths, vital for ecosystem services and potential as bioindicators. However, limited expertise and comprehensive knowledge hinder their applications. No synthesis of this region's Geometridae exists, unlike well-documented Palearctic and Nearctic regions. Geometridae information in the Andean Region is fragmented, mostly from small-scale studies. Consequently, we conducted a systematic review following the PRISMA protocol, analyzing 151 scientific articles. We assessed topics in five categories: studied taxa, methodologies, evolution, biogeography, and ecology. While evolution and ecology were well-studied, there was a bias towards taxonomic and immature state studies, neglecting other ecological and evolutionary questions. Biogeographic studies were infrequent, often local. Catching methods, morphological analysis, and museological studies were predominant, being cost-effective. Emerging methodologies include genetics, population studies, phylogenetic comparisons, and geometric morphometrics. Keyword analysis revealed common concepts such as taxonomy, Geometridae, immature stages, Chile, Lepidoptera, herbivory, Ecuador, Neotropical Region, Systematics, and Ennominae. In conclusion, we urge prioritizing ecological research on geometrid moths' interactions with other taxa, especially mutualistic and predation interactions. Enhanced efforts are needed for biogeographic patterns, phylogenetic studies, and systematic assessments of *incertae sedis* taxa and those assigned to Palearctic genera.

Keywords: Andean Region, biogeography, ecology, evolution, research trends.

RESUMEN

La Región Andina, que se extiende desde 23° S hasta 55° S, incluida la Zona de Transición de América del Sur, alberga muchas especies únicas, pero enfrenta importantes presiones inducidas por el hombre. Abarca dos puntos críticos de biodiversidad, lo que subraya la importancia de comprender su biota para una conservación eficaz. En particular, la Región Andina cuenta con una de las mayores concentraciones del mundo de polillas geométridas endémicas, vitales para los servicios ecosistémicos y con potencial como bioindicadores. Sin embargo, la experiencia limitada y el conocimiento integral obstaculizan sus aplicaciones. No existe una síntesis de los Geometridae de esta región, a diferencia de las regiones

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Paleártica y Neártica bien documentadas. La información de Geometridae en la Región Andina está fragmentada, en su mayoría proveniente de estudios a pequeña escala. En consecuencia, realizamos una revisión sistemática siguiendo el protocolo PRISMA, analizando 151 artículos científicos. Evaluamos temas en cinco categorías: taxones estudiados, metodologías, evolución, biogeografía y ecología. Si bien la evolución y la ecología están bien estudiadas, hay un sesgo hacia los estudios taxonómicos y de estados inmaduros, descuidando otras cuestiones ecológicas y evolutivas. Los estudios biogeográficos fueron poco frecuentes y a menudo locales. Predominaron los métodos de captura, análisis morfológicos y estudios museológicos, siendo costo-efectivos. Las metodologías emergentes incluyen genética, estudios de población, comparaciones filogenéticas y morfometría geométrica. El análisis de palabras clave reveló conceptos comunes como taxonomía, Geometridae, estadios inmaduros, Chile, Lepidoptera, herbivoría, Ecuador, Región Neotropical, Sistemática y Ennominae. En conclusión, instamos a priorizar la investigación ecológica sobre las interacciones de las polillas geométridas con otros taxones, especialmente las interacciones mutualistas y de depredación. Se necesitan mayores esfuerzos para los patrones biogeográficos, los estudios filogenéticos y las evaluaciones sistemáticas de los taxones *incertae sedis* y aquellos asignados a géneros paleárticos.

Palabras clave: Región Andina, biogeografía, ecología, evolución, tendencias de investigación.

INTRODUCTION

The Andean Region, also known as the Andean-Patagonian, Patagonian, Argentine, Chilean, or Austral Region, encompasses the southern cone of South America that borders the Andes mountain range. It is recognized as a distinct biogeographic unit separate from the Neotropical Region. In a strict sense, the Andean Region covers the Chilean territory, extending from the coast of Antofagasta (23° S) to Cape Horn (55° S), including the eastern slope of the Andes and Argentine Patagonia (Morrone 2015). Additionally, the South American transition zone, which consists of the tropical Andes and the arid diagonal of South America, is also considered part of the Andean Region as a whole (hereafter referred to as the Andean Region *sensu lato*). This is due to its inclusion of both Andean and Neotropical biotic elements, making it a sector belonging to both biogeographic regions (Morrone 2014, 2015).

The climate of the Andean Region *s.l.*, as classified by the Köppen-Geiger system, is highly diverse, encompassing arid (both warm and cold), tropical (monsoon and tropical savannah), temperate (temperate subhumid, Mediterranean, oceanic), and polar (tundra) climates (Peel *et al.* 2007). This climatic diversity is mirrored by its rich array of flora, fauna, soils, and human activities. Notably, it includes two of the 36 recognized biodiversity hotspots: the Valdivian Rainforest and the Tropical Andes. Biodiversity hotspots are defined as areas with exceptional concentrations of endemic species that are experiencing significant habitat loss (Myers *et al.* 2000). Unfortunately, the Valdivian Rainforest hotspot, spanning 641,913 km^2, has only 20.39 % of its area under protection, while the Tropical Andes, covering 1,656,940 km^2, has just 21.78 % protected areas (Habel *et al.* 2019). Over the years, the Tropical Andes hotspot lost 0.29 % of its area between 1992 and 2015, while the Chilean hotspot saw a net area gain of 0.08 %. However, it has become increasingly fragmented (Kong *et al.* 2021), and climate change and agro-economic shifts are expected to have a significant impact by 2050 (Habel *et al.* 2019).

Given these challenges and opportunities, it is essential to consolidate existing knowledge about the various aspects of biodiversity in this region. This will help identify knowledge gaps, discern emerging trends, and propose new avenues for research.

Geometridae, the second most diverse family within Lepidoptera, boasts an impressive diversity of over 23,800 species (Rajaei *et al.* 2022), accounting for 15 % of all species in this insect order (Van Nieukerken *et al.* 2011). The Andean region *s.l.* is home to a significant richness of Geometridae (Gaston *et al*. 1995, Hausmann & Parra 2009, Ramos-González *et al*. 2018, Brehm *et al.* 2019, Rajaei *et al*. 2022). For example, areas within the Tropical Andes exhibit a remarkable diversity of over 1,000 species within just 40 km^2 (Brehm *et al.* 2005). In Chile, although the diversity is lower, with approximately 400 species, endemism exceeds 60 % (Parra & Villagrán-Mella 2008). While several studies have explored various aspects of this group's biology in this region, including ecology, taxonomy, systematics, and biogeography, there has been no systematic review, meta-analysis, or synthesis of knowledge to date. Consequently, information remains

scattered, inconsistent, and primarily focused on small-scale investigations

Hence, a systematic review is warranted to consolidate knowledge about this fauna, pinpoint gaps in the existing literature, and prioritize research needs. This is particularly crucial in an area characterized by high diversity and endemism while facing substantial anthropic pressure.

Given this context, the central question arises: "How many papers have been published in the ecology, biogeography, and evolution of Geometridae from the Andean Region *s.l.*?" The primary objective of this study is to conduct a systematic review of the scientific literature concerning geometrid moths in the Andean Region *s.l.*, to synthesize existing knowledge and enhance its comprehension. The specific objectives include: (1) identifying current research trends in the study of Geometridae in the Andean Region *s.l.*, (2) tracing the evolution of methodologies used across various disciplines to study them, and (3) suggesting future directions and research endeavours to advance our understanding of the ecology, evolution, and biogeography of geometrid moths in the Andean Region *s.l.* To achieve these objectives, we followed the international standard protocol for systematic reviews (PRISMA protocol: https://www.prisma-statement.org/).

The findings from this study will be discussed, and knowledge gaps will be highlighted, providing valuable insights to propel the field's development in the region and its global significance.

MATERIALS AND METHODS

We adhered to the standardized requirements for systematic reviews as specified by the PRISMA protocol (Moher *et al.* 2009, Shamseer *et al.* 2015; details available at https://www.prisma-statement.org). PRISMA defines a systematic review as "a review of a formulated question that uses systematic and explicit methods to identify, select, and critically evaluate relevant research, and to collect and analyze data from studies included in the review". Detailed descriptions of the search methods, inclusion and exclusion criteria, and the information extracted from each article are provided below. The PRISMA checklist is attached in Appendix S1.

Search strategy

We conducted a comprehensive search for articles that evaluated various aspects of Geometridae biology in the Andean Region *s.l.* To achieve this, we utilized the search engines of Web of Science and Google Scholar, using the following combination of keywords: "(Geometrid* OR "Geometer moth*") AND (Chile OR Ecuador OR Argentina OR Venezuela OR Colombia OR Peru OR Bolivia OR Andean OR "South America")". Articles were actualized until January 2022. Most of the sources were derived from peer-reviewed publications. Grey literature, including undergraduate, master's, or doctoral theses, books, technical reports, or conference abstracts, was excluded from this review. We assessed the titles, abstracts, and results of the articles identified in our search. For results obtained from the Google Scholar search engine, only the first 20 pages were reviewed (10 results per page, without the "show citations" option), a threshold considered appropriate and employed in other systematic reviews (Razgour *et al.* 2016, Lisón *et al.* 2019). Studies were excluded if they met any of the following criteria: (1) lacked original data published in peer-reviewed journals, (2) did not include an abstract in English for articles written in languages other than English, and (3) were unrelated to geometrid moths in the Andean Region *s.l.* or could not be explicitly associated with a subregion or biogeographic province within this region based on the information provided in the methodology, material examined, or supplementary materials. In addition to English, we included papers in Spanish and Portuguese, the native languages of South American countries, as their exclusion could introduce bias into the results. However, articles were only included if they featured an abstract written in English, ensuring accessibility to the international research community.

Data extraction and synthesis

We conducted a synthesis and qualitative evaluation of the information within the articles that met the aforementioned inclusion criteria. The data extracted from each article were treated as follows:

Publication trends and biogeographic patterns: We gathered information regarding the publication year, the journal of publication, and the biogeographic province corresponding to the studied geometrid moths, based on the localities specified in each work. To determine the distribution by biogeographic province, we plotted the localities of each studied taxon on a high-resolution digital coverage (shapefile) of the provinces of the Andean Region *s.l.* (Romano 2017) and calculated the number of studies per biogeographic province.

Research themes and methodologies: Each article was categorized based on its content into five topics (taxa studied, methodologies employed, evolution, biogeography, and ecology), representing significant combinations of ideas within the study (refer to Appendix S2 for definitions of each topic category and theme). We also extracted the list of keywords provided by each study's authors to identify potential emergent themes in geometrid moths studies. These keywords were standardized for analysis using a word cloud

or "tag cloud". Word clouds visually represent vocabulary usage in texts, with variations in font size, colour, position, or boldness indicating the frequency of use or other variables of interest (Bateman *et al.* 2008). They are valuable for text analysis as they enable the summarization of information. In this context, they allow for the identification of emerging themes and implicit relationships within the articles based on the frequency of keywords used by researchers (Schrammel *et al.* 2009, Koutrika *et al.* 2009). The word cloud was created using the https://www.nubedepalabras.es/ website because its tools support the input of binomials and trinomials without separating their syntactic components (see Appendix S3 for a detailed description of the keyword standardization methods used for word cloud preparation).

RESULTS

We initially identified a total of 325 articles from both search engines. Additionally, we included 20 articles from our library that covered similar topics but did not appear in the original search. These were deemed relevant for a comprehensive understanding of Geometer moths in the Andean Region *s.l.* Out of the total 345 articles, 88 records were identified as duplicates, and two were inaccessible online. Subsequently, we evaluated 255 records and applied the inclusion and exclusion criteria. Among these, 151 studies met the inclusion criteria (as shown in Fig. 1) and were included in this review. A complete list of the included articles can be found in Appendix S4.

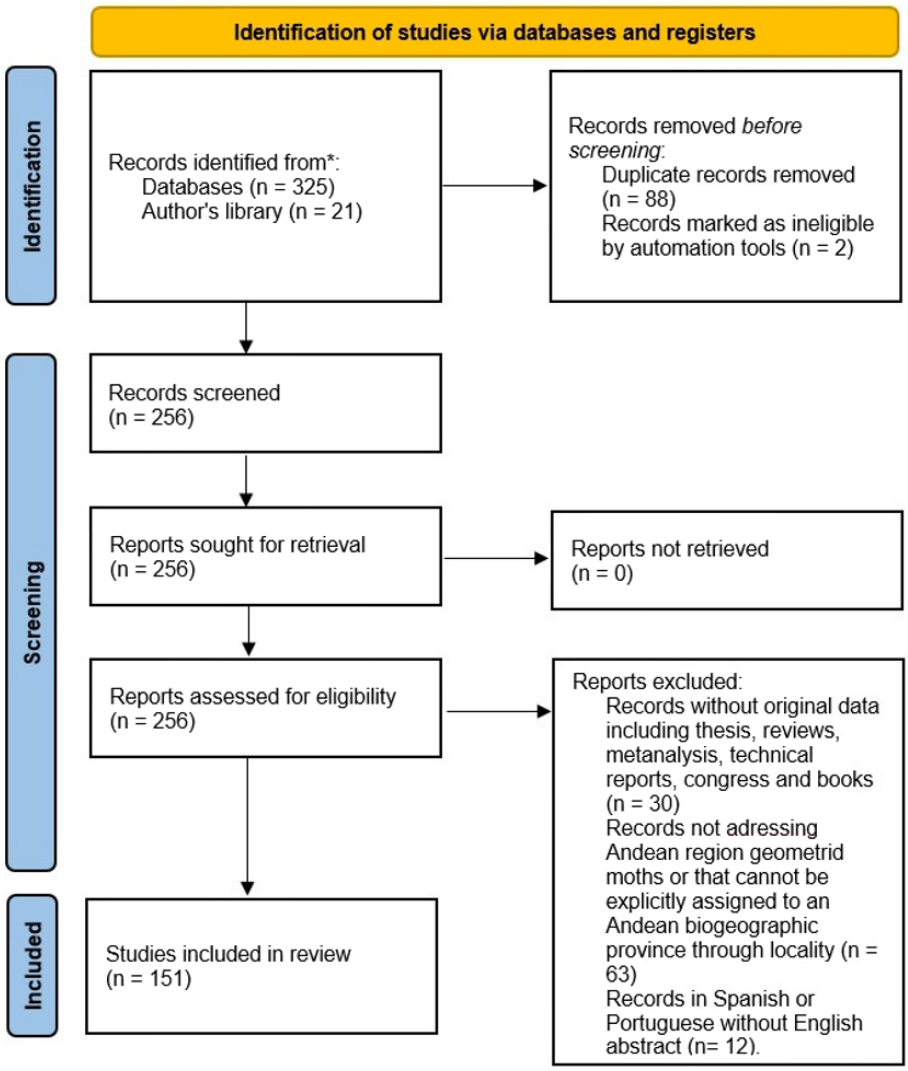

Figure 1. PRISMA flow diagram of literature search followed in this study. / Diagrama de flujo PRISMA de la búsqueda bibliográfica seguida en este estudio.

The remaining 105 documents were excluded for various reasons:

30 records: These did not feature original data published in scientific journals and instead included grey literature, meta-analyses, or reviews.

63 articles: These did not address aspects related to geometrid moths in the Andean Region *s.l.* or presented records that could not be explicitly associated with a biogeographic subregion or province based on the provided locality information.

12 publications in Spanish or Portuguese: Although written in these languages, they were excluded because they did not include an abstract in English, hindering access for the international research community.

Research trends and languages

A total of 151 articles were analyzed, with the majority, 115 articles (76 %), being published from 2000 to 2021. The publication trend over five-year periods (as illustrated in Fig. 2) follows an exponential curve (R^2 = 0.7869).

In terms of the journals that featured these studies, the largest number of articles were published in the Revista Brasileira de Entomología (10.59 %), followed by Zootaxa (6.62 %), and Shilap Revista de Lepidopterología (5.29 %) (as summarized in Table 1).

In terms of the language used in these articles, English dominated, representing approximately 68.2 % of the total. Spanish was the second most commonly used language, accounting for approximately 31.1 % of the articles. Portuguese, with just one article, made up 0.66 % of the papers analyzed.

In terms of the distribution of Geometridae studied by biogeographic province (as depicted in Fig. 3), the research primarily focused on lineages within the Andean Region *s.str.*, accounting for 53.7 % of the total studies, whereas studies in the South American Transition Zone were comparatively fewer.

The province with the highest concentration of articles was Paramo, with 58 studies (21.6 % of the total). This was followed by the Maule province, with 43 articles (16 %), the Atacama province with 35 studies (13 %), the Valdivian Forest province with 31 articles (11.5 %), and the Puna province with 21 records (7.8 %). Biogeographic provinces with the least representation included Juan Fernández and Monte, each with only one article (0.37 % each), followed by the Prepuna province with two articles (0.74 %), and the Patagonian and Magellanic Moorland provinces, each with five articles (1.8 %).

Notably, the Falkland Islands' biogeographic province was not considered in this review due to the absence of articles specifically related to geometrid moths in that region in the search results.

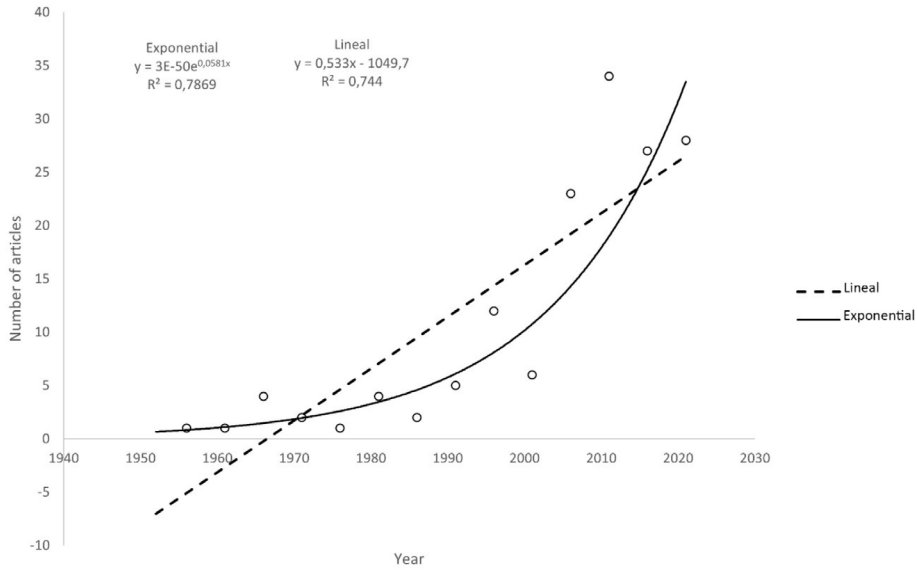

Figure 2. Frequency of publication per five-year period of scientific articles about the Geometridae of the Andean Region *s.l.* included in this review. / Frecuencia de publicación por quinquenio de artículos científicos sobre los Geometridae de la Región Andina s.l. incluido en esta revisión.

Table 1. Ranking journals (top 12) with the highest number of articles published on the Andean Geometridae (until January 2022). / Ranking de revistas (top 12) con mayor número de artículos publicados sobre los Geometridae andinos (hasta enero de 2022).

Magazine	Nº Articles	Editorial	Country
Brazilian Journal of Entomology	16	Sociedade Entomológica do Brasil	Brazil
Zootaxa	10	Magnolia Press	New Zealand
Shilap-Revista de lepidopterología	8	Sociedad Hispano-Luso-Americana de Lepidopterología	Spain
Neotropical Entomology	7	Sociedade Entomológica do Brasil	Brazil
Bulletin of the American Museum of Natural History	6	American Museum of Natural History	USA
Gayana	6	Ediciones Universidad de Concepción	Chile
Journal of the Lepidopterists Society	6	The Lepidopterists' Society	USA
Revista Chilena de Historia Natural	6	Sociedad de Biología de Chile	Chile
Acta Zológica Lilloana	5	Fundación Miguel Lillo	Argentina
Boletín de la Sociedad de Biología de Concepción (*)	4	Sociedad de Biología de Concepción	Chile
Journal of Insect Science	4	Oxford University Press	USA
Zookeys	4	Pensoft Publishers	Bulgaria

(*) Publication discontinued since 2009.

Keyword cloud analysis (as shown in Fig. 5) revealed that the most frequently used concepts in the analyzed articles were Chile, Ecuador, Neotropical Region, Andean Region, and Argentina.

Taxa studied

In terms of taxonomic groups, the majority of research predominantly centred on the species level or communities/assemblages of geometrid moths (60 %). Conversely, a smaller portion of the studies delved into higher taxonomic levels. These higher-level investigations primarily encompassed taxonomic reviews or assessments of phylogenetic relationships (as illustrated in Fig. 4).

Furthermore, a keyword cloud analysis (as demonstrated in Fig. 5) highlighted the various taxonomic groups that were the subject of the study. These included Ennominae, Larentiinae, *Eupithecia*, *Hoplosauris*, *Syncirsodes*, and Trichopterygini. It is worth noting that several articles from the Paramo province focus on elucidating various aspects within the genus *Eois*.

Methodologies used

In the studies of Geometridae in the Andean Region *s.l.*, a variety of methodologies were employed (as illustrated in Fig. 6a). The most commonly used method was catching, accounting for 73.5 % of the studies, followed by the examination of museum specimens (37 %). It's noteworthy that in museum specimen studies, researchers generally did not conduct the sampling themselves. Morphological analysis emerged as the dominant methodology, utilized in 60.2 % of the studies. However, the integration of genetic analysis, either in conjunction with morphological analysis or independently, gained prominence starting in 2008 and currently represents 16.5 % of the studies conducted up to 2021.

Another widely adopted methodology involved the investigation of immature stages, employed in 30.4 % of the studies. Most researchers combined various methods to gather comprehensive data. Conversely, a limited number of studies leveraged population analysis or geometric morphometrics statistics to test their hypotheses.

In the keyword cloud analysis (as depicted in Fig. 5), specific keywords related to methodologies emerged, including DNA, and geometric morphometrics.

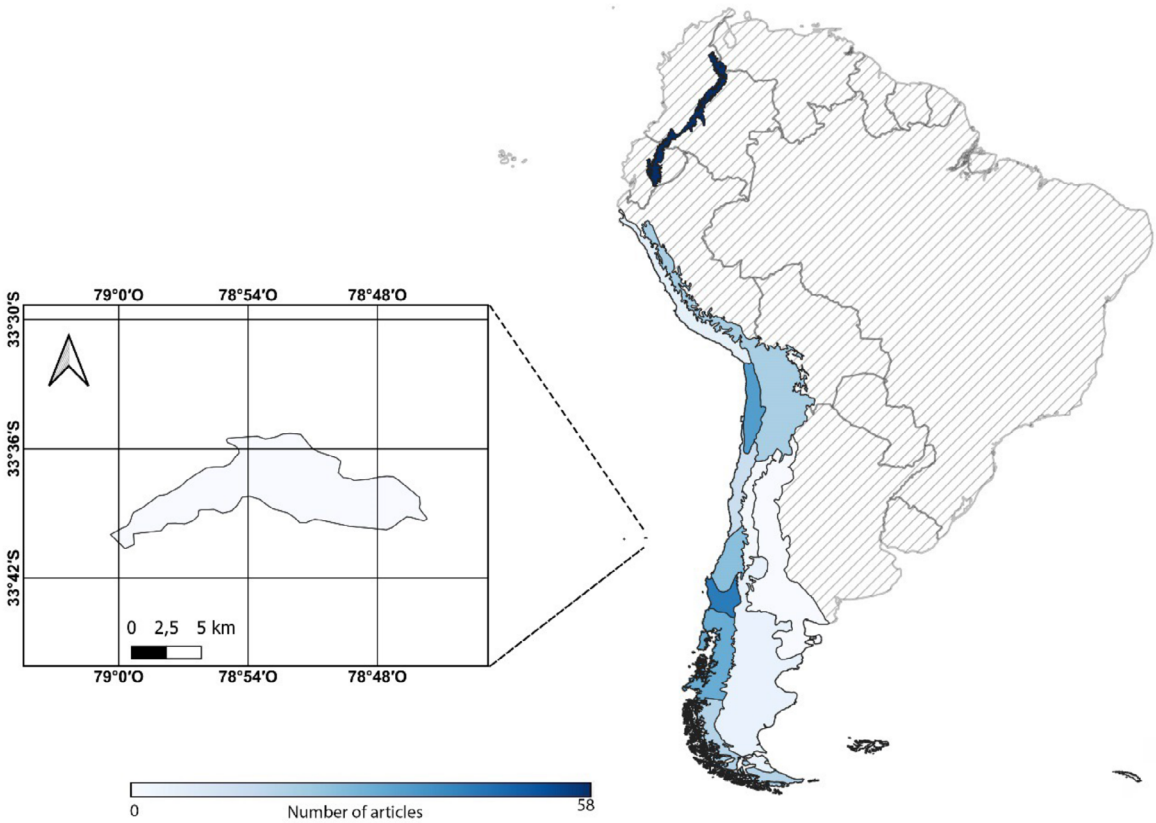

Figure 3. Distribution of Geometridae articles analysed in this study according to the biogeographic province of the species included. Each paper may contain species present in more than one single biogeographic province. The diagonal lines area represents Neotropical Region *s.str.*, and the zoomed area corresponds to Juan Fernández province. / Distribución de los artículos de Geometridae analizados en este estudio según la provincia biogeográfica de las especies incluidas. Cada artículo puede contener especies presentes en más de una única provincia biogeográfica. El área de las líneas diagonales representa la Región Neotropical *s.str.*, y el área ampliada corresponde a la provincia de Juan Fernández.

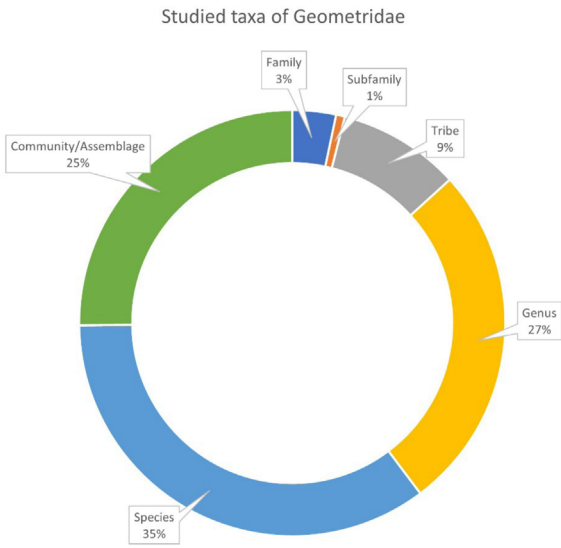

Figure 4. Classification of articles included in this review, according to the taxa studied. Each article can belong to only one category. / Clasificación de los artículos incluidos en esta revisión, según los taxones estudiados. Cada artículo puede pertenecer a una sola categoría.

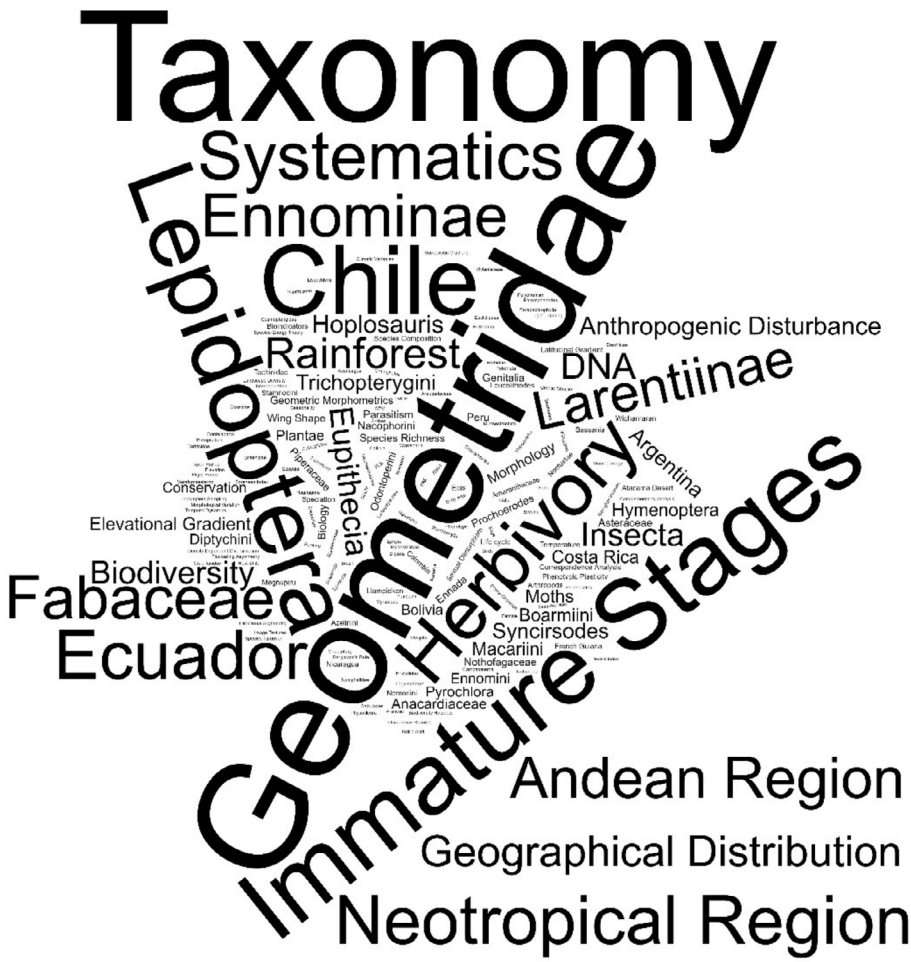

Figure 5. Word cloud of the 664 keywords collected from the articles included in this review (previously homogenised). / Nube de palabras de las 664 palabras clave recogidas de los artículos incluidos en esta revisión (previamente homogeneizadas).

Evolution

In the realm of evolutionary inquiries (as demonstrated in Fig. 6b), the majority of studies focused on taxonomic aspects, comprising 58 % of the total. These studies primarily dealt with classification and species description. However, a smaller portion of studies explicitly reconstructed phylogenetic relationships to construct or evaluate existing classifications (11.2 %). Such studies often favoured congruent morphological characters (particularly genitalia and wing venation) or genetic distance methods (4.6 %).

A limited number of studies delved into investigating the pace and mode of diversification (1.3 %) or addressed microevolutionary questions (0.6 %) through haplotype networks. Similarly, only a few studies employed phylogenetic comparative methods, representing only 2.6 % of the analyzed studies, with a particular focus on the genus *Eois* Hübner.

In the context of strictly evolutionary studies, there has been a noticeable shift in methodologies from relying on morphological characters to the utilization of multiple molecular markers (see Table 2). The keyword cloud analysis emphasized terms such as taxonomy and systematics, which characterize this area of research (Fig. 5).

Furthermore, the discipline of evolutionary research exhibited an exponential publication trend (R^2 = 0.76), with an acceleration in the publication rate observed from the year 2000 (as illustrated in Fig. 7).

Table 2. Summary of the studies that evaluated or reconstructed hypotheses and explicit evolutionary mechanisms on the Geometridae of the Andean Region *s.l.* analysed in this review. / Resumen de los estudios que evaluaron o reconstruyeron hipótesis y mecanismos de evolución explícitos sobre los Geometridae de la Región Andina *s.l.* analizados en esta revisión.

Study	Taxonomic resolution	Methodology used	Key findings	Tribe
Parra (1991)	Tribe	Morphological phylogeny (genitalia + external features + wing venation) using the parsimony method	The genus *Pachrophylla* is found to be a polyphyletic taxon, necessitating the description of four new genera within the Trichopterygini tribe to ensure monophyly.	Trichopterygini
Parra & Hormazabal (1993)	Genus	Morphological phylogeny (genitalia + external features) using the parsimony method	The genus Leucolithodes is a monophyletic taxon comprising three species, which are supported by five synapomorphies.	Nacophorini
Canfield *et al.* (2008)	Genus	Calibrated molecular phylogeny (COI+COII+Ef-1alpha) using maximum parsimony, maximum likelihood and Bayesian inference + phylogenetic comparative method (ancestral reconstruction)	*Nemoria* constitutes a monophyletic taxon with an estimated origin approximately 7.5 ± 0.06 million years ago. Ancestral state reconstructions indicate that the presence of phenotypic plasticity in both larvae and adults is a trait that has emerged independently multiple times throughout the phylogenetic history.	Nemoriini
Hausmann & Parra (2009)	Family	Molecular phylogeny (COI) using Neighbour-Joining and K2P model	Numerous Chilean taxa are potentially para- or polyphyletic, especially those assigned to Palaearctic genera, which require further revision. In light of this, three new combinations were proposed.	Cidariini, Nacophorini, Diptychini, Euphyini, Trichopterygini, Ennomini, Eupithecini, Perizomini, Xanthorhoini, Rheumapterini, Euangeronini and Ennadini
Parra *et al.* (2009)	Genus	Morphological phylogeny (genitalia + external features) using the parsimony method	*Oratha* forms a monophyletic taxon encompassing four species, which are supported by four synapomorphies. In contrast, *Euclidiodes* constitute a monophyletic taxon consisting of six species and supported by a single synapomorphy.	Nacophorini and Diptychini
Strutzenberger *et al.* (2010)	Genus	Molecular phylogeny (COI + Ef-1alpha) using maximum likelihood and Bayesian inference + Phylogenetic comparative method (reconstruction of ancestral states)	The monophyly of *Eois* is confirmed, and reconstruction indicates that Piper served as the ancestral host plant for this lineage, with multiple parallel host shifts to other Piperaceae plants.	Asthenini

Continuation Table 2.

Study	Taxonomic resolution	Methodology used	Key findings	Tribe
Parra *et al.* (2010)	Genus	Morphological phylogeny (genitalia + external features) using the methods of parsimony and Bayesian inference (M2P).	*Psilaspilates* constitutes a morphologically homogeneous group; however, they exhibit poorly supported clades and limited congruence between different analytical approaches.	Diptychini
Parra & Hernández (2010)	Tribe	Morphological phylogeny (genitalia + external features) using the methods of parsimony and Bayesian inference (M2P). Bayesian consensus network of reticulated evolution.	The "Lithinini" in the southern cone of South America form a monophyletic group supported by four synapomorphies. Five genera have been included in the tribe, with four of them being revalidated.	Diptychini
Strutzenberger & Fiedler (2011)	Genus	Calibrated molecular phylogeny (COI + Ef-1alpha) using Bayesian inference + Phylogenetic comparative method (estimation of speciation rate)	The origin of Neotropical *Eois* was estimated to have occurred during the Miocene, approximately 30.96 million years ago, with a confidence interval of 4.94 to 5.17 million years. This diversification pattern can be explained by a DDL model. Importantly, the diversification of this taxon coincided with the rising elevation of the Andes Mountain range and the diversification of its host plants, specifically *Piper* spp.	Asthenini
Brehm (2015)	Genus	Molecular phylogeny (COI) using Neighbour-Joining and K2P model	The genus *Hagnagora* is found to be a polyphyletic taxon. To establish monophyly, four species have been excluded.	Cophocerotini
Rivera-Cabello *et al.* (2015)	Species	Haplotype network using the Medial Junction Network (MJNs) and molecular phylogeny (COI) method using the Neighbour-Joining and Maximum Likelihood method	There is no genetic differentiation among haplotypes based on host plants. Larvae collected from both host plants belong to the same taxon, identified as *Macaria mirthae.*	Macariini
Bocaz *et al.* (2016)	Genus	Morphological phylogeny (genitalia + metafurcasternum) using the parsimony method	The genus *Syncirsodes* is a monophyletic taxon consisting of four species, and its monophyly is supported by seven synapomorphies.	Ennomini

Continuation Table 2.

Study	Taxonomic resolution	Methodology used	Key findings	Tribe
Strutzenberger *et al.* (2017)	Genus	Calibrated molecular phylogeny (COI + Ef-1alpha) using maximum likelihood and Bayesian inference + Phylogenetic comparative method (estimation of speciation rate)	The monophyly of *Eois* has been confirmed. The origin of tropical *Eois* was estimated to have occurred during the Miocene, approximately 24.2 million years ago, with a confidence interval ranging from 20.3 to 28.4 million years ago. This diversification pattern is generally explained by a yule3rate model, although different clades diversified under a DDL model. Ancestral state reconstructions indicate that the ancestral host plant of this lineage was likely from the genus *Piper*. Host plant associations showed a strong phylogenetic signal, with seven host changes observed.	Asthenini
Parra *et al.* (2017)	Tribe	Morphological phylogeny (genitalia + external features + wing venation) using the methods of parsimony and Bayesian inference (M2P).	The Trichopterygini of the southern cone of South America is a monophyletic group supported by four synapomorphies. Within this tribe, one genus was incorporated, and four synonyms and three new generic combinations were proposed.	Trichopterygini
Brehm (2018)	Genus	Molecular phylogeny (COI) using Neighbour-Joining and K2P model	The species of the genus *Callipia* cluster together, forming a distinct group characterized by the presence of four discernible clades.	Stamnodini
Brehm *et al.* (2019)	Family	Molecular phylogeny (COI+Wingless+ ArgK+MDH+RpS5+GAPDH+IDH+Ca-ATPase+Nex9+Ef-1alpha+CAD) using maximum likelihood	Many of the South American Geometridae taxa are paraphyletic or polyphyletic. In response, 11 new tribes have been established, and 27 genera have been assigned to specific tribes. Additionally, 26 new combinations and eight new synonyms were proposed and 119 taxa have been designated as *incertae sedis*.	For details of the 80 tribes analysed see Brehm *et al.* 2019
Murillo-Ramos *et al.* (2019)	Family	Molecular phylogeny (COI+Wingless+ ArgK+MDH+RpS5+GAPDH+IDH+Ca-ATPase+Nex9+Ef-1alpha+CAD) using maximum likelihood	The family Geometridae has been confirmed as a monophyletic taxon. However, some of the less diverse subfamilies were found to be paraphyletic or polyphyletic. To address these issues, subfamilies have been redefined to ensure the monophyly of these groups. Additionally, a new subfamily has been described, and several taxonomic changes at the tribe level have been implemented.	For details of the 80 tribes analysed, see Murillo-Ramos *et al.* 2019
Moraes *et al.* (2021)	Genus	Molecular phylogeny (COI) using maximum likelihood and species delimitation by ABGD, bPTP and mPTP	Phylogenetic relationships were not analyzed in this study due to concerns about their reliability, as indicated by the authors. However, it is noteworthy that there has been a significant increase in the diversity of Neotropical *Eois*, with a remarkable 176 % rise, suggesting the presence of numerous undescribed cryptic species within this group.	Asthenini

Biogeography

Studies falling under the "biogeography" category (Fig. 6c) constitute less than 4 % of the total analysis. These investigations addressed various topics, including ecogeographic patterns, the determination of factors influencing current species distribution, as well as the identification of ancestral areas for species and the estimation of areas with high endemism. Most of these studies were conducted at the local scale within the Paramo province (as outlined in Table 3). A few prominent terms emerged from the keyword analysis, with "distribution" being the most frequently encountered, followed by concepts associated with methodologies or patterns such as "endemism" and "Bergmann's rule" (see Fig. 5). In terms of publication trends, the data better align with a polynomial model (R^2 = 0.619), revealing a peak in publications during the five years represented by 2006-2011 (Fig. 7).

Ecology

Within the category of "ecology" topics (Fig. 6d), studies primarily focused on establishing biotic interactions, notably larval host plants, and to a lesser extent on the description of Hymenoptera and parasitic Diptera of Geometridae (33.7 %). Studies related to diversity, abundance, and species richness had relatively lower representation (7.95 %, 7.95 %, and 9.93 %, respectively), with a predominant emphasis on the equatorial Andes (Paramo province). These studies often evaluated beta diversity in altitudinal transects. Research about the influence of environmental variables, seasonality, and ecoimmunology was less prevalent in the studies analyzed.

Keyword analysis highlighted several prominent concepts, including immature stages, herbivory, anthropogenic disturbance, biodiversity and species richness. Notably, terms associated with specific plant species such as Fabaceae, Anacardiaceae, Plantae, Asteraceae, and Piperaceae were also prominent (see Fig. 5). In terms of publication trends, there has been a decline in the last five years, exhibiting a curve with limited fit to a polynomial model (R^2 = 0.4669). However, there was a peak in publications during the five years represented by 2003-2016 (Fig. 7).

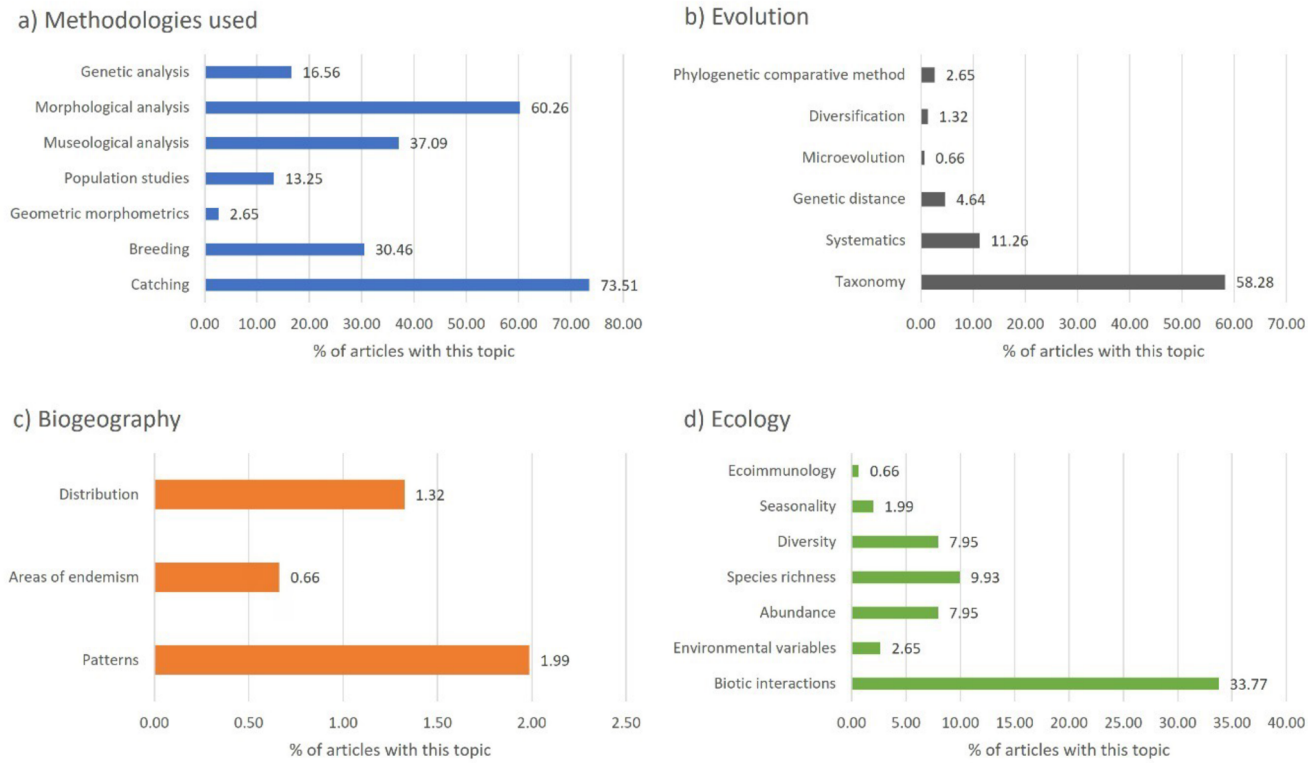

Figure 6. Study topics and percentage of the 151 studies of geometrid moths of the Andean Region *s.l.* that were included in this review: a) methodologies used, b) evolution, c) biogeography, and d) ecology. Each article was classified into one or more of these subject categories. / Temas de estudio y porcentaje de los 151 estudios de polillas geometridas de la Región Andina *s.l.* que se incluyeron en esta revisión: a) metodologías utilizadas, b) evolución, c) biogeografía y d) ecología. Cada artículo se clasificó en una o más de estas categorías temáticas.

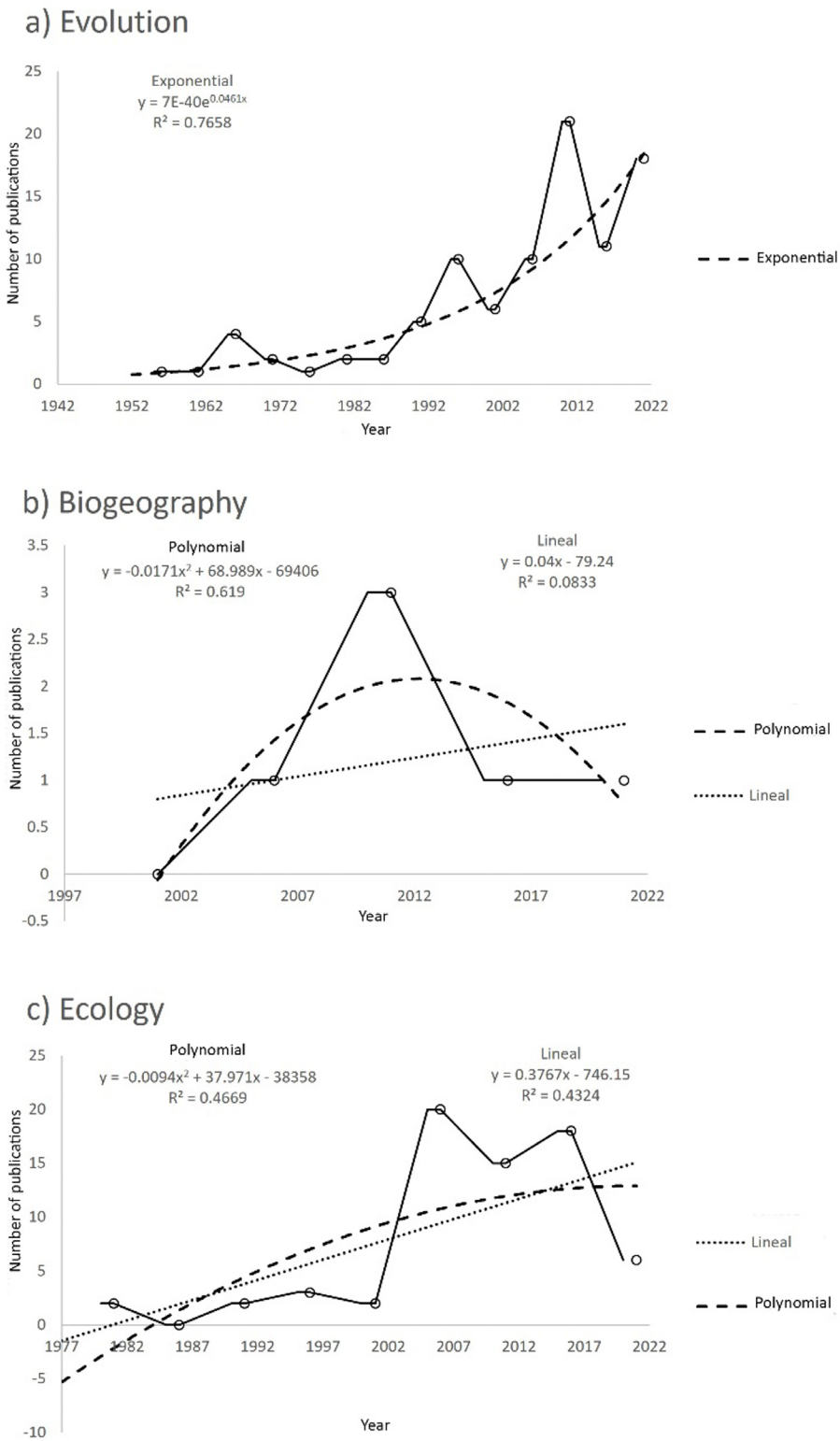

Figure 7. Publication trends by quinquennium in: a) evolution, b) biogeography, and c) ecology of the geometrid moths of the Andean Region *s.l.* according to the 151 articles analysed in this review. / Tendencias de publicación por quinquenio en: a) evolución, b) biogeografía, y c) ecología de las polillas geométridas de la Región Andina *s.l.* según los 151 artículos analizados en esta revisión.

Table 3. Summary of the studies that evaluated biogeographic or ecogeographic aspects of the Geometridae of the Andean Region *s.l.* analysed in this review. / Resumen de los estudios que evaluaron aspectos biogeográficos o ecogeográficos de los Geometridae de la Región Andina *s.l.* analizados en esta revision.

Study	Objective	Methodology	Key findings	Biogeographic province
Brehm & Fiedler (2004)	Evaluation of Bergmann's rule in an altitudinal gradient	Correspondence analysis + linear correlation	The wing expansion exhibited a negative correlation with altitude, indicating that Bergmann's Rule's prediction does not apply in this context.	Paramo
Canfield *et al.* (2008)	Determination of historical geographic range through phylogeny	Dispersion-Vicariance analysis using a likelihood approach (LAGRANGE)	It is suggested that *Nemoria* originated in Central and South America (Neotropical) and subsequently radiated towards North America through seven distinct colonization events.	Paramo and Puna
Rodríguez-Castañeda *et al.* (2010)	Evaluation of Species Turnover in Altitudinal Gradient	Comparisons of multistage communities with the Morisita index, ANOVA, and randomisation.	The diversity of *Eois* and its host plants exhibits a covariation pattern along the elevation gradient.	Paramo
Zamora-Manzur *et al.* (2011)	Recognition of areas of endemism	PAE and complementarity analysis	The Biobio Region (current regions of Ñuble and Biobio in Chile) holds a significant portion of the Geometridae diversity in the country, accounting for 37.5 %. This diversity is distributed across six areas of endemism, and based on this, five priority conservation sites are recommended.	Maule
Pyrcz *et al.* (2013)	Assessment of latitudinal species richness gradient	Multiple regression (MCO) between richness vs area and richness vs climate variables + Spearman's correlation coefficient	The diversity of *Erateina* is distributed unevenly along the latitudinal gradient within the Andes, with a peak occurring between 3-11° S. This particular pattern can be attributed to seasonality.	Paramo and Puna
Strutzenberger *et al.* (2017)	Recognise mechanisms involved in the origin of diversity	Evaluation of origin hypotheses in BiogeoBEARS	According to a DEC+J model, the ancestral range of Eois was in tropical Asia.	Paramo

DISCUSSION

Research trends and languages

This review reveals a growing interest in Geometridae inhabiting the Andean Region *s.l.*, reflected in an increasing number of publications across all analyzed topics over the past two decades. This upsurge aligns with broader trends observed in many scientific disciplines (Manzano-Agugliaro *et al.* 2013, Wojciechowski *et al.* 2017, Emmer 2018, Torres *et al.* 2020). Notably, there is a substantial emphasis on taxonomy, particularly the description of new taxa, while studies addressing ecological and biogeographical aspects remain comparatively scarce. A significant portion of ecological research focuses on interspecific interactions, such as those involving host plants and parasites. Furthermore, conservation concerns have been directly addressed in only a single study proposing priority sites.

While Spanish serves as the official language in the countries within the scope of this review, the majority of articles have been published in English. This underscores the aspiration to engage with the international scientific community, given that publications in English tend to garner greater impact, as measured by citation frequency. Nevertheless, Spanish-language publications still comprise a substantial body of knowledge, with studies featured in locally impactful journals. Until a few years ago, many of these journals were solely available in print format, posing accessibility challenges for English-speaking researchers interested in the study and conservation of Geometridae in this region.

Regarding the most studied biogeographic provinces, research across all analyzed areas predominantly concentrates on the South American Transition Zone. Specifically, considerable attention is given to the equatorial Andes within the Paramo province, where studies encompass both evolutionary and biogeographical perspectives. In contrast, the province of Atacama in the extreme north of Chile serves as the focal point for ecological investigations concerning interactions. This distribution of research efforts highlights a disproportion in the number of studies on geometrid moths relative to the surface area of these regions on the continent.

Within the Andean Region *s.str.*, Geometridae studies are chiefly concentrated in the Maule biogeographic province. This observation suggests a bias in research toward species found in the biogeographic provinces where the primary authors' research centres are located. Conversely, provinces such as Desert, Monte, Prepuna, Patagonian, Magellanic Moorland, Juan Fernández, and the Falkland Islands, despite harbouring high diversity and/or endemism across various taxa, account for only a minor portion (7.5 %) of published studies. Consequently, there is a need to allocate efforts towards enhancing knowledge of the Geometridae fauna in these underrepresented areas.

Taxa studied

The results indicate that research on geometrid moths frequently revolves around single species or genera, with few investigations extending to encompass broader communities or taxa. Studies focused on individual species often contribute novel insights into host associations (e.g., Mendez-Abarca *et al.* 2014), new species descriptions (e.g., Parra & Ibarra-Vidal 2002), or the immature stages of previously described species (e.g., Vargas & Parra 2013).

In contrast, research at higher taxonomic levels (genus, tribe, subfamily, family) tends to prioritize descriptions (e.g., Parra *et al.* 2018) or taxonomic revisions, often lacking phylogenetic underpinnings (e.g., Parra *et al.* 2009). However, investigations centred on entire Geometridae communities primarily emphasize ecological aspects, particularly comparisons of communities along altitudinal gradients (beta diversity) (e.g., Beck *et al.* 2011).

The preponderance of research efforts in Ecuador and Chile may be attributed to the presence of research hubs in these regions. Conversely, other countries such as Bolivia and Peru face limitations in Geometridae research due to a scarcity of dedicated researchers in this field. Notably, the keyword cloud analysis highlights Ennominae as the most frequently studied taxon which can be explained by being the most diverse subfamily (Gaston *et al.* 1995, Scoble 1999, Pitkin 2002, Scoble & Hausmann 2007, Rajaei *et al.* 2022) and the most extensively studied from a taxonomic perspective, based on the large-scale reviews by Rindge (e.g., Rindge 1973, 1983, 1986) and Pitkin (i.e., Pitkin 2002), in contrast to what occurs in other subfamilies with lower diversity such as Geometrinae (e.g., Pitkin 1996) or with greater taxonomic challenges and lacking large-scale revisions like Larentiinae (Brehm *et al.* 2019). In the Andean region *s.str.*, the taxa of Larentiinae best studied from a taxonomic standpoint are the genus *Eupithecia* (e.g., Rindge 1987, Vojnits 1985, Parra & Ibarra-Vidal 2002, Vargas & Parra 2002, 2004) and the tribe Trichopterygini (e.g., Parra *et al.* 2017, Ramos-González *et al.* 2019), comprising approximately half of the larentines in this region; however, biological backgrounds of most species remain unknown.

According to Rajaei *et al.* (2022), the diversity of Geometridae in the countries that make up the Andean Region *s.l.* corresponds to approximately 4511 species, with 407 species described in Chile, 1314 species described in Peru, 410 species described in Bolivia, 904 species described in Ecuador, 890 species described in Colombia, and according

to Chalup (2019), 586 species distributed in Argentina. The studies analyzed have only covered approximately 15 % of the estimated total diversity in terms of evolutionary, ecological or biogeographical themes.

Methodologies used

This review demonstrates that researchers typically gather data from specimens captured using UV light traps, nets, and entomological umbrellas (larvae). Additionally, they often rely on museum collections, particularly for morphological analyses involving genitalia, external features, and wing venation. This practice is widespread in Geometridae studies throughout the analyzed region. Notably, a significant proportion of studies making use of museum collections are centred in the Andean Region *s.str.* Local museums like the Museum of Zoology at the University of Concepción (MZUC-UCCC), as well as European museums such as the Zoologische Staatssammlung München (ZSM) and the British Museum of Natural History (BMNH), play a pivotal role in housing extensive collections. The BMNH, influenced by European naturalists who conducted expeditions in the nineteenth century (e.g., Felder & Rogenhofer 1875, Butler 1882), boasts the largest collection of Geometridae species types described for the Andean Region *s.str.*

While geometric morphometrics represents an actively developing field for assessing various evolutionary and ecological hypotheses regarding organismal shape (Villalobos-Leiva & Benítez 2020), its application in the study of Andean geometrids is still emerging.

Despite being one of the most commonly employed methodologies in ecological studies of Lepidoptera, larval breeding, which involves relatively low monetary investment, is yet to reveal associations with host plants for over 95 % of Geometridae species in the Andean Region *s.l.* Recent decades have witnessed a heightened global interest in the study of insect-plant interactions (Kergoat *et al.* 2017, Pincebourde *et al.* 2017). Nevertheless, knowledge of these interactions within the Geometridae in the Andean Region remains primarily limited to *Eois* of the Paramo and a few taxa in the Atacama and Maule provinces. This dearth of ecological studies and interspecific associations among geometrid moths restricts their potential application as bioindicators and impedes their inclusion in conservation initiatives.

Many countries within the Andean Region *s.l.* grapple with severe funding constraints for non-applied biological research, particularly concerning less charismatic taxa. Consequently, easily accessible methodologies, such as breeding and utilizing museum collections, hold particular importance in a context where resources and funding are scarce. Thus, supporting researchers in documenting and studying the natural history of species and fostering international collaborations is crucial.

Evolution

Studies on evolutionary topics within Geometridae have predominantly centred on taxonomic aspects, involving the description of new genera and species, leveraging both genetic (distance) and morphological data. These investigations have highlighted the ongoing uncertainty regarding the taxonomic classification of numerous taxa. However, relatively few studies have embraced an explicit evolutionary approach to substantiate proposed taxonomic revisions, recognizing the monophyletic nature of the taxa underscores the importance of species delimitation and maintaining monophyly in taxonomic classifications, which aids in conservation efforts and evolutionary studies.

The methodologies for reconstructing phylogenies have evolved. Initially, parsimony analysis based on morphological characters held sway. Presently, molecular phylogenies, reconstructed using grouping algorithms founded on distances (e.g., Neighbour Joining) or optimization criteria grounded in statistics (e.g., Maximum Likelihood and Bayesian Inference), have gained prominence. Notably, the application of molecular markers in building robust phylogenies has been particularly focused on taxa within the South American Transition Zone. In contrast, morphological phylogenies continue to find use in the Andean Region *s.str.*, albeit now within a Bayesian framework.

The 658 bp COI fragment, known as the "genetic barcode," is the most frequently employed molecular marker. Its popularity arises from its ease of amplification and its robust phylogenetic signal for detecting cryptic species (Hebert *et al.* 2003). However, despite its utility, COI has been employed for species delimitation analysis in only one recent study of Geometridae in this region (Moraes *et al.* 2021). Currently, an approach based on the quantity of sequences appears to take precedence over their quality. This approach is not consistently reported in the phylogenetic studies conducted to date within Geometridae, despite the recognized importance of adhering to non-saturation and neutrality criteria (Xia *et al.* 2003).

In cases where sequencing numerous molecular markers remains unfeasible, adopting a focused approach on a select few genes, or even a single molecular marker, merits consideration. This approach should be preceded by confirmation that the chosen marker is not saturated and exhibits a linear rate of change over time (Xia *et al.* 2003). This strategy has yielded results that align with those derived from published multigenic phylogenies, particularly when supplemented with morphological evidence.

Within the genera *Eois* and *Nemoria*, ecological and evolutionary approaches grounded in phylogenies have been

employed (e.g., Strutzenberger *et al.* 2017), particularly utilizing the phylogenetic comparative method. Understanding the estimated origin of *Nemoria* and the independent emergence of phenotypic plasticity provides insights into the evolutionary dynamics of adaptive traits and their ecological significance within Geometridae. However, further endeavours are needed to explore new macroevolutionary processes and the evolution of traits, both discrete and continuous, in light of newly constructed phylogenies and those already established. Investigating the ancestral host plant of Geometridae species and its association with the diversification of the lineage suggests potential co-evolutionary dynamics between Geometridae and their host plants, with implications for understanding ecological interactions and diversification patterns.

The significant increase in the diversity of Neotropical diverse genus *Eois* underscores the presence of cryptic species and the need for thorough taxonomic and evolutionary studies to uncover and conserve hidden biodiversity within Geometridae. Overall, these findings contribute to our understanding of the evolutionary history, biodiversity patterns, and ecological dynamics within Geometridae, with implications for taxonomy, conservation, and evolutionary biology.

Recent efforts have contributed to clarifying the systematic position of South American taxa within a global context (e.g., Brehm *et al.* 2019, Murillo-Ramos *et al.* 2019, Sivhonen *et al*. 2020). A significant outcome of these proposals is the confirmation that taxa within the Andean Region *s.str.* diversified independently from the rest of South American lineages, owing to the region's historical isolation due to various processes. Consequently, new tribes, including Odontoperini, Ennadini, and Euangeronini, primarily composed of species from this geographical area, have been proposed (Brehm *et al.* 2019). Expanding these large-scale efforts to encompass a greater number of species and genera is essential for elucidating the systematic position of numerous remaining *incertae sedis* species that persist.

Biogeography

Biogeography and macroecology have received relatively little attention in the study of Geometridae in the Andean Region *s.l.* Despite being disciplines with a long historical development, the biogeography of Geometridae in this region was not explored systematically until the last two decades. Publications on local biogeographic patterns have been sporadic. Although information on species distribution, including georeferenced data and presence/absence records, is well-documented in various taxa (Maciel-Mata *et al.* 2015), there remains untapped potential for research on different biogeographic patterns and processes within the Geometridae family. This underdevelopment may, in part, be attributed to incomplete biodiversity inventories in the region, which is exacerbated by the scarcity of Geometridae specialists in Latin America. Recent initiatives have attempted to compile information in the form of catalogues or species listings for geometrids in countries such as Colombia (Murillo-Ramos *et al.* 2021), Chile (Ramos-González *et al.* 2018), and Argentina (Chalup 2019).

In light of the biogeographic studies of Andean geometrid moths, the negative correlation observed between wing expansion and altitude challenges the applicability of Bergmann's Rule, which posits that organisms tend to be larger in colder climates. This suggests that factors other than temperature, such as temperature fluctuations or resource availability, may exert a stronger influence on wing size variation within this population of geometrids, which warrants further investigation into altitudinal and latitudinal patterns. The reconstruction of the ancestral range of *Eois* in tropical Asia implies a historical connection between tropical Asian and Neotropical regions. This suggests that dispersal events and historical biogeographic processes played pivotal roles in shaping the distribution and diversification of *Eois* moths across different continents, particularly in the Neotropics, where *Eois* diversity is highest (Brehm *et al*., 2011).

Ecology

The results highlight that ecological aspects of Geometridae are relatively underrepresented in research conducted within the provinces encompassing the Andean Region *s.str.* A significant proportion of articles focus on associations with host plants (e.g., Bodner *et al.* 2010, Vargas & Parra 2009, Vargas *et al.* 2015) and parasites (e.g., Vargas *et al.* 2014, Seifert *et al.* 2015). However, other critical biotic interactions, such as pollination and predation, remain understudied in this geographic area although there are indications that the contribution to pollination by nocturnal moths may be greater than the contribution of diurnal pollinating insects (Anderson *et al*. 2023). It is necessary to conduct research to better understand the specific interactions between plants and geometrids, including studies on ecology and behavior, to inform conservation and management decisions. It is crucial to promote the conservation and use of native pollinators, which are generally declining worldwide (Potts *et al*. 2010).

Although certain species of Geometridae are or potentially represent economic interest due to their association with commercially or ornamentally important plant species (e.g., *Eois* spp. on *Piper* spp.; *Oxydia trychiata* on *Pinus* spp. *Cupresus* spp. and *Eucaliptus* spp.; *Erosina hyberniata* Guenée, 1858 on *Tecoma stans* (L.) Juss. ex Kunth; *Eupithecia tamarugalis* Vargas

& Parra, 2005 on *Prosopis tamarugo* Phil.; *Eupithecia atacama* (Vojnits, 1985) and *Perizoma sordescens* Dognin, 1908 on *Chenopodium quinoa* Willd; *Eupithecia horismoides* Rindge, 1987 on *Gunnera tinctoria* (Mol.); *Cyclophora nanaria* (Walker, 1861) on *Olea europaea* L.; *Sabulodes* sp. on *Persea americana* Mill.; *Oxydia vesulia* (Cramer, 1779) on *Persea americana*, *Eucaliptus* sp. and *Vitis vinifera* L.; *Disclisioprocta edmondsii* Butler, 1882 on *Bougainvillea glabra* Choisy), the majority of Geometridae species would represent taxa with association to native or endemic vegetation. Geometrid moths would have great potential as bioindicators due to their extensive distribution, limited mobility, high diversity, ease of sampling, and close association with the vegetation they inhabit (Scoble 1995, Minet & Scoble 1999, Brehm & Fiedler 2005, Bodner *et al.* 2010). They also exhibit remarkable sensitivity, evident through morphological, genetic, and phenological changes in response to external disturbances such as global warming or alterations in their host plants (Virtanen *et al.* 2002, Benítez *et al.* 2015, Hill *et al.* 2021). However, unlike other Lepidoptera taxa, such as butterflies (Papilionoidea) and Erebidae or Notodontidae (Gerlach *et al.* 2013), the utilization of Geometridae as bioindicators has been limited worldwide and has only been used in one study in the Andean region *s.str.* (see Rojas *et al.* 2015). This deficiency can be attributed to a lack of knowledge about their natural history and a scarcity of specialists (Hausmann 2001).

Understanding how the biota of Andean landscapes responds to environmental changes is of paramount importance, particularly in the context of ongoing climate change, given the region's status as a biodiversity hotspot (Tropical Andes and Valdivian Rainforest). Surprisingly, knowledge regarding the responses of geometrid moths to environmental changes has been explored in only one study, with an emphasis on Papilionoidea (Pyrcz *et al.* 2014). Conservation-related issues have received limited attention identifying important areas for conservation of Geometridae in ecotonal zones on Maule biogeographic province (Zamora-Manzur *et al.* 2011) but without impact on public policies. Therefore, there is a pressing need for further research efforts into the ecology of Andean geometer moths, as they offer an excellent opportunity to enhance our understanding of Lepidoptera diversity responses to climate change and environmental shifts.

Future research

This systematic review of the evolution, biogeography, and ecology of geometrid moths in the Andean Region *s.l.* has identified several critical knowledge gaps that should be addressed in future research:

1. Taxonomic and Systematic Studies: Future research should prioritize the development of new taxonomic and systematic studies, with a particular emphasis on the less-studied biogeographic provinces such as Desert, Monte, Prepuna, Patagonian, Magellanic Moorland, Juan Fernández, and the Falkland Islands. This will contribute to a more comprehensive understanding of the diversity and distribution of Geometridae species in these regions.
2. Inventory Lists and Illustrated Catalogues: Efforts should be increased to create inventory lists of local Geometridae diversity and produce illustrated catalogues summarizing known biological data for Geometridae species. These resources will serve as valuable references for researchers and enthusiasts alike.
3. Evolutionary Studies: There should be a greater number of explicit evolutionary studies aimed at understanding ancestor-descent relationships among higher taxonomic categories (tribe, subfamily, family) and South American species attributed to Palearctic genera. Additionally, research should explore micro- and macroevolutionary questions, employing appropriate methodologies such as phylogeography, geometric morphometrics, and the phylogenetic comparative method.
4. Biogeographic Patterns and Processes: Research efforts should be increased to evaluate biogeographic patterns and processes, taking into account the historical factors that have shaped the fauna of the region. This includes identifying and protecting refuges and high-diversity habitats that are rich in Geometridae species. Initiatives like citizen science programs could be valuable for collecting data and raising public awareness about the region's biodiversity.
5. Ecological Research: There is a need for expanded ecological research, especially investigations into the impact of environmental variables on Geometridae fauna and diversity at multiple scales, particularly in less-studied areas like the southern cone of South America. Research should also delve into interspecific relationships, exploring not only new host plant associations but also mutualistic interactions.
6. Language Accessibility: While increasing the number of articles available in English is important for sharing knowledge with the broader scientific community, it is also essential to ensure that scientific evidence is accessible to local communities in their native language. Therefore, efforts should be made to disseminate knowledge in the local language through various media outlets.

Addressing these research priorities will contribute significantly to our understanding of Geometridae moths in

the Andean Region *s.l.* and help advance scientific knowledge and conservation efforts in this biogeographically important area.

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