SHILAP Revista de lepidopterología, 54 (213) 30 marzo 2026: 115-134 eISSN: 2340-4078 ISSN: 0300-5267
https://doi.org/10.57065/shilap.1124 https://shilap.org
https://zoobank.org/518E2D6D-2743-4CDA-9A9A-D162F4367DE3

A New Chance: Recovery of Nymphalidae diversity twelve years after mining in a peri-urban Andean Forest of Colombia (Lepidoptera: Papilionoidea)

Oscar Mahecha-J., Vanessa Díaz-S., Alexander García-García, Miguel Gonzalo Andrade-C. & Tomasz W. Pyrcz

Abstract

Various human activities, including mining, have significantly impacted ecosystems in Colombia, leading to a decline in biodiversity. These activities have led to changes in the distribution and diversity of different species, such as Lepidoptera. A study was conducted to analyze the changes in the diversity of Papilionoidea in a peri-urban forest located in Bogotá, twelve years after the cessation of mining activities in the area. Seven study stations were established, and standardized sampling techniques were employed to collect Papilionoidea. The results showed an increase in Nymphalidae diversity compared to studies conducted in the early years after the end of mining in the area. The most common Nymphalidae belonged to the Pronophilina subtribe. This research demonstrates the success of ecological restoration projects implemented in the area after the cessation of mining activities, which allowed for the recolonization of the region by various species, indicating the regeneration of the Andean Mountain Forest. Further studies focused on ecological restoration in the area are recommended, as positive effects on the assemblage of Andean Lepidoptera fauna have been observed.
Keywords: Lepidoptera, Papilionoidea, Nymphalidae, Pronophilina, ecological restoration, synanthropic species, habitat disturbance, Anthropocene, Colombia.

Una nueva oportunidad: Recuperación de la diversidad de Nymphalidae doce años después de la minería en un Bosque Andino periurbano en Colombia (Lepidoptera: Papilionoidea)

Resumen

Diversas actividades humanas, incluida la minería, han impactado significativamente los ecosistemas en Colombia, provocando una disminución de la biodiversidad. Estas actividades han generado cambios en la distribución y diversidad de diferentes especies, como los Lepidoptera. Se realizó un estudio para analizar los cambios en la diversidad de Papilionoidea en un bosque periurbano ubicado en Bogotá, doce años después de haber cesado las actividades mineras en la zona. Se establecieron siete estaciones de estudio, y se emplearon técnicas de muestreo estandarizadas para la recolección de Papilionoidea. Los resultados mostraron un aumento en la diversidad de Nymphalidae en comparación con los estudios realizados en los primeros años después del fin de la minería en la zona. Los Nymphalidae más comunes pertenecían a la subtribu Pronophilina. Esta investigación demuestra el éxito de los proyectos de restauración ecológica implementados en la zona tras el cese de las actividades mineras, que permitieron la recolonización de la región por diversas especies, indicando la regeneración del Bosque Andino de Montaña. Se recomienda realizar más estudios enfocados a la restauración ecológica en la zona, ya que se han observado efectos positivos en el ensamblaje de la fauna

de Lepidoptera andina.
Palabras clave: Lepidoptera, Papilionoidea, Nymphalidae, Pronophilina, restauración ecológica, especies sinantrópicas, perturbación del hábitat, Antropoceno, Colombia.

Introduction

Papilionoidea constitute one of the most diverse insect groups worldwide, with the highest species richness reported in the Neotropical realm, comprising approximately 7,700 species (Lamas, 2000; De-Silva, et al. 2015). Colombia is the second species-rich country after Peru, a total of 3,877 species is reported currently (Garwood et al. 2022). Lepidoptera play a specific and important role in ecosystems (e.g., as pollinators) and serve as valuable conservation bioindicators of habitat health. They frequently contribute to elaborate and carry out of conservation programs (Andrade, 1998). Besides, the Papilionoidea are considering as the umbrella species in biology conservation (New, 1997; Weibull et al. 2000; Díaz-Suárez et al. 2022).

In Colombia, as in other countries around the world, many anthropogenic practices have caused a sharp decline in the total area of ecosystems and many local extinction processes (Mahmoud & Gan, 2017; Murillo-P. et al. 2018; Ouyang et al. 2018; Le Roux et al. 2019; Fowler et al. 2021; Díaz-Suárez et al. 2022; Méndez-Zambrano & Fajardo-Medina, 2024), causing a negative impact on populations of plant and animal native species which may disappear from the face of the planet (Andrade, 1998; Van der Hammen & Andrade, 2003; Le Roux et al. 2019; Fowler et al. 2021). High Andean forests are among the ecosystems most heavily impacted by human population density, agriculture, livestock, and industrial activities that exploit natural resources (Méndez-Zambrano & Fajardo-Medina, 2024). This negative impact is notably reflected on the fauna-flora from the surrounding Andean forests of large cities, such as Bogotá in Colombia (Mahecha-Jiménez et al. 2011; Marín et al. 2014; Ouyang et al. 2018).

Additionally, the urbanization processes have generated the fragmentation of different forest communities, leading to the evolution of secondary forest patches, which in many cases, have lost connectivity between them, reducing the gene flow between populations. As a result, it may reduce the local genetic biodiversity (Van der Hammen & Andrade, 2003; Fahrig, 2003; Mckinney, 2008; While & Whitehead, 2013; Ouyang et al. 2018; Méndez-Zambrano & Fajardo-Medina, 2024). Further, urbanization has been linked to negative effects on biodiversity, which is often greatly reduced by intense urban development but can flourish in suburban and peri-urban areas (Aronson-Myla et al. 2017; Ouyang et al. 2018). The habitat in the peri-urban fragmentation areas allows highlighting many changes that occur between rural and urban ecosystems. It shows that different environmental factors proper to urban areas impact the surrounding ecosystems, by transforming their soil, surface, and groundwater resources (Fahrig, 2003; Mckinney, 2008). Therefore, these peri-urban areas show particularly high ecological fragility due to intensive activities that take place in their proximity and are often described as critical areas for biota (Capel, 1994; Marín et al. 2014).

The Serranía del Zuque is a peri-urban forest that constitutes a source of ecosystem and environmental services for the south-eastern part of Bogotá city. Currently, due to ongoing urban expansion, the natural habitats in this area are under severe anthropogenic pressure, leading to a gradual loss of native vegetation (Aguilar-Garavito, 2010, 2015) and, consequently, a decline in faunal diversity, including Papilionoidea (Mahecha-Jiménez, 2008; Mahecha-Jiménez et al. 2011). The introduction of non-native tree species, including *Acacia decurrens* Willd, *Acacia melanoxylon* Brown, and *Ulex europaeus* L., has disrupted the natural balance of plant and animal communities in the area (Solorza, 2012). This has altered the relationships between different species, changed the functioning of the ecosystem, and displaced native species (Mack et al. 2000; Fahrig, 2003; Mckinney, 2008; Solorza, 2012).

The factors mentioned above increase the likelihood of human-induced land-use disturbances, including erosion, landslides, alterations to hydrological cycles, and changes in the physical and chemical properties of the soil (Solorza, 2012). These disturbances could have impacted the ecological succession dynamics in the Serranía del Zuque (Mahecha-Jiménez et al. 2011; Aguilar-Garavito, 2015). Moreover, the Serranía del Zuque was subject to mining activities from 1960 to 1996, and asphalt production occurred between 1987 and 2006. During this period, frequent avalanches were reported due to the instability of the terrain. Following several slope stabilization efforts, the area was eventually abandoned. In 2009, approximately 35.6 hectares of the Serranía del Zuque were invaded by *U. europaeus* L. (Aguilar-Garavito, 2010, 2015). This invasion resulted in mixed thickets with native vegetation or dense monospecific thickets along the internal road, the network of roads, edges of ravines, in the old mining area, in forest plantations undergrowth, and within native successional bushes (Aguilar-Garavito, 2015).

The Serranía del Zuque is currently threatened by unregulated urban development, contributing to the progressive loss of native vegetation. Mining activities, wildfires, and water pollution caused by human land-use are contributing to high fragmentation in the peri-urban forest (Aguilar-Garavito, 2010, 2015; Mahecha-Jiménez et al. 2011). This promoted the invasion of *U. europaeus* L., causing a displacement of the native plant populations of the Andean forest and possible local extinctions (Aguilar-Garavito, 2010, 2015; Mahecha-Jiménez et al. 2011; Solorza, 2012). In addition, it has triggered forest fires during the dry season, particularly during El Niño events (Aguilar-Garavito, 2015).

However, the Serranía del Zuque was designated as part of the Forest Reserve East of Bogota in 2006. Subsequently, a management plan was established (CAR, 2006a). This resulted in restrictions on human land use (Aguilar-Garavito, 2010, 2015; Mahecha-Jiménez et al. 2011). In addition, the District Environmental Department from Bogotá initiated the ecological restoration of 10.4 hectares invaded by *Ulex europaeus* in the Serranía del Zuque in 2009-2010 (Aguilar-Garavito, 2010, 2015).

This study aimed to analyze the changes in Papilionoidea diversity at the Serranía del Zuque peri-urban Andean forest twelve years after mining operations ceased. We hypothesized that, after the completion of mining operations in the study area, there would be an increase in diversity due to the native vegetation recovery at the Serranía del Zuque, allowing the establishment of host plants for mountain Papilionoidea such as Poaceae and Melastomataceae (Devries, 1987; Pyrcz et al. 2009; Greeney et al. 2009; Montero & Ortiz, 2013; Mahecha et al. 2019). Our results indicate an increase in the diversity of Papilionoidea at the Serranía del Zuque, suggesting that the peri-urban forest is progressively regenerating after mining, contrasting with the findings of Mahecha-Jiménez (2008) and Mahecha-Jiménez et al. (2011).

Material and methods

Study location and sampling methods

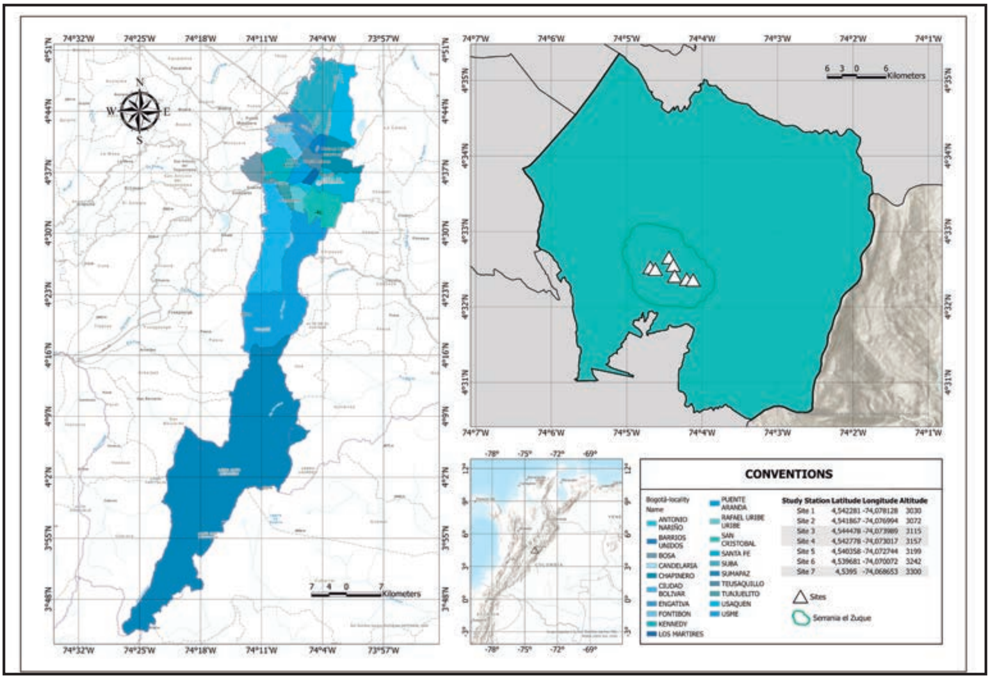
This study took place in the peri-urban Andean forest of Serranía del Zuque, situated in the southeastern part of the eastern hills of Bogotá, on the eastern slopes of the Cordillera Oriental of the Andes in Colombia (4º2’30.38”N and -74º 4’22.40”W; altitude: from 3000 to 3400 m) (Figure 1) (Aguilar-Garavito, 2015). The Serranía del Zuque is an ecotone between high Andean forest and sub-páramo (Mahecha-Jiménez, 2008; Aguilar-Garavito, 2015). The average annual rainfall is 1.500-3.000 mm/year, although this value can vary considerably depending on the ecosystem, with two wet seasons during the year, the first between April and May and the second from October to November (Camelo et al. 2009). The eastern hills have a varied topography in their entirety, where different soil types vary widely in the area since these soils were formed by the interaction between the geological formation, the vegetation cover and the influence of climate. Besides, due to the slow degradation of organic matter and the geological structure results in very acid soils and low fertility (Mahecha, 2000; CAR, 2006b). The climate of the study area is Tropical Mountain, humid with zenithal showers. Its geographical location and the presence of warm and cold currents influence the development of many microclimates. The Eastern Cordillera serves as a barrier against the winds coming from the Llanos and Magdalena Valley that can affect both the rainfall as well as the average temperature of the zones. Temperatures vary between 6 ºC and 13 ºC. (Mahecha, 2000).

The native vegetation from the Serranía del Zuque consists of cloud forests dominated by *Weinmannia tomentosa* L.F, *Bejaria* Mutis, *Clusia* sp., *Drymis granadensis* L.F, *Eugenia* spp., *Macleania rupestris* Kunth A.C. Smith., *Espeletia* sp., *Puya* sp., and *Calamagrostis effuse* Adans. Epiphytic shrubs and vines, such as *Tillandsia* spp., dominate in the sub-canopy, as well as lichens and mosses, and *Chusquea* spp. (Aguilar-Garavito, 2010, 2015). Additionally, the native vegetation has been recovering, the populations of *Chusquea* spp., *W. tomentosa, Espeletia* spp., *Sellaginella* spp., and *Puya* spp. have increased their coverage in comparison to previous years (Aguilar-Garavito, 2010, 2015).

Fieldwork

Fieldwork was performed every 15 days from June 2017 to June 2018 (29 field trips during all study), to cover both rainy and dry season (Freitas et al. 2021; Díaz-Suárez et al. 2022); each sampling consisted of five days of collection (145 days at the end of the fieldwork). Papilionoidea were sampled using 20 × 20 m (400 m²) collecting stations, systematically established at 42-meter intervals, yielding a total of seven stations, covering an altitude between 3000 and 3300 m (Figure 1). These stations were located in areas where Mahecha-Jiménez (2008) and Mahecha-Jiménez et al. (2011) identified significant human impact, including deforestation, the introduction of non-native plant species (e.g. *U. europaeus*), and illegal mining activities. The ecological impact of mining activities during 2006-2007 was reflected in a pronounced decrease in Papilionoidea species richness in the study area (Mahecha-Jiménez, 2008; Mahecha-Jiménez et al. 2011). Following this, Aguilar-Garavito (2010) initiated an ecological restoration project in the affected areas to recover ecological functionality.

Figure 1. Location map of the study stations in the Serrania del Zuque peri-urban Andean forest in Bogotá, Colombia. The white triangles indicate the study stations.



Two collect forms were used: passive and active collect. To passive collect, five Van Someren-Rydon traps baited with dog feces, and decaying fish were placed, as this kind of bait has proven to be very attractive for many groups of cloud forest Lepidoptera (Pyrcz & Wojtusiak, 2002; Pyrcz & Garlacz, 2012; Díaz-Suárez et al. 2022; Cerdeña et al. 2024). Each trap was spaced by 5 m from each other and were located between 1 and 3 m. from the ground surface and at least 100 m altitudinal distance from each other (Freitas et al. 2014; Clavijo-Giraldo et al. 2020). Traps were checked every three hours between 09:00 and 17:00. Active sampling was conducted manually using entomological nets from 08:30 to 17:00. At each study station, four longitudinal transects, spaced 5 meters apart, were established to cover the entire area. Each transect was walked for approximately 30 minutes (Andrade-C et al. 2013; Freitas et al. 2021).

Taxonomic Analysis

The biological material was determined and deposited in the Museum of Natural History at the Universidad Distrital Francisco José de Caldas, Bogotá, Colombia. Taxonomic determination was conducted using an analysis of morphological characters as alar pattern and, the structure of male genitalia. The latter was extracted following the standard procedure and macerated in a warm 10% KOH solution, and subsequently, they were preserved in glycerol vial. Taxonomic arrangement was based on the works of Adams (1985, 1986), Andrade & Amat (1996), Pyrcz (2004a, 2004b), and Pyrcz et al. (2009, 2010, 2013). Comparative material deposited in the Instituto de Ciencias Naturales (ICN) of the Universidad Nacional de Colombia, and the collection of the Nature Education Centre of the Jagiellonian University, Krakow, Poland, was examined. The nomenclature was checked against the checklists of Lamas et al. (2004), Pyrcz et al. (2010, 2013), and Warren et al. (2013). The collected material was covered under the ‘‘Permiso Marco de Recolección de Especímenes de Especies Silvestres de la Diversidad Biológica con Fines de Investigación Científica No Comercial’, granted to the Universidad Distrital Francisco José de Caldas through Resolution 0738 of July 8, 2014, issued by the Autoridad Nacional de Licencias Ambientales – ANLA.

Data analysis

Diversity estimates were calculated in terms of effective species or Hill numbers, which enables a better approach to species richness, incorporates the relative abundance of the same, allowing to give importance to the less abundant and rare species, or taking into account the dominance. That is to say, this method sets a greater emphasis on the most abundant species, thus handling the problem of “abundance”, a subject frequently discussed in different studies on diversity when making comparisons between assemblages and communities (Hill, 1973; Jost, 2006; Moreno et al. 2011; Chao et al. 2014). Likewise, it has been shown that for a better analysis of diversity in an assemblage, the numbers of effective species are best compared with the estimates based on the theory of communication such as the index of Shannon entropy (Ellison, 2010; Moreno et al. 2011; Chao et al. 2014). Therefore, Hill numbers are parameterized by a diversity order q, which determines the measures’ sensitivity to species relative abundances (Hsieh et al. 2016). Hill numbers include the three most widely used species diversity measures: species richness (q = 0), Shannon diversity (q = 1) and Simpson diversity (q = 2) (Moreno et al. 2011; Chao et al. 2014; Hsieh et al. 2016). In addition, a Bootstrap was calculated as estimated in the expected range for the order 0 (0D), the estimate of Chao & Shen (2003) for the expected diversity of order 1 (1D) and the expected diversity of order 2 (2D) the MVUE estimator (*Minimum variance unbiased estimator*) (Gotelli & Colwell, 2011; Moreno et al. 2011; Gotelli & Chao, 2013).

The Relative Abundance Distribution (RAD) was estimated to characterize the sampled community (Chao et al., 2015; Cusack et al., 2015). In this approach, the relative abundance of each species is plotted on the y-axis-often log10-transformed to account for several orders of magnitude-while species are ranked from the most to the least abundant along the x-axis (Chao et al. 2015). The Akaike’s Information Criteria (AIC) was carried out to select the best RAD model for the study area (Cusack et al. 2015).

Coverage-based rarefaction/extrapolation (R/E) sampling curves were generated for each sampling station. The R/E method estimates species diversity (Hill numbers) for both rarefied and extrapolated samples, using sample completeness (measured as sample coverage) up to a coverage value equivalent to twice the reference sample size (Hsieh et al., 2016). However, Hill numbers of any order are influenced by sample size and inventory completeness. To address this, Chao et al. (2014) and Hsieh et al. (2016) proposed a unified framework for estimating species diversity through sample-size- and coverage-based R/E, allowing for statistically robust comparisons across communities. Likewise, a R/E curve can compare sites that have different sizes in their samples (Cleary & Genner, 2006; Gotelli & Colwell, 2011; Chao & Jost, 2012; Chao et al. 2014; Hsieh et al. 2016).

Therefore, when producing an R/E curve, it is possible to evaluate how representative the sampling was at each station, and in general, the whole study area, allowing us to reduce the effect of “sample size” in research (Chao et al. 2014). To determine the similarity between sampling stations according to the abundance and species composition, a cluster analysis was done, using the Bray-Curtis similarity index and as the cluster method the UPGMA (Unweighted Pair Group Method with Arithmetic Mean). Additionally, to support the results of the cluster analysis was conducted by a test ordination Non-Metric Multidimensional Scaling (NMDS) using the similarity Bray-Curtis index (Brehm et al. 2003b; Addo-Fordjour et al. 2015).

To assess significant differences in species abundance and composition between sampling stations, non-parametric statistical tests were used, as the data did not follow a normal distribution according to the Shapiro-Wilk test (p-value= 0.00002, p <0.05). Consequently, a Kruskal–Wallis test (Zar, 1974; Sá, 2007) and an ANOSIM test, based on the Bray–Curtis dissimilarity index with 999 permutations (Binz et al., 2014; Addo-Fordjour et al., 2015; Marín et al., 2015), were performed. Combined both methods (ANOSIM and NMDS) complement visualization of group differences along with significance test (Buttigieg & Ramette, 2014). All analyses were conducted at a 95% significance level. Statistical and diversity analyses were performed in R version 4.2.3 (R Development Core Team, 2023) by iNEXT package (Hsieh et al. 2016), and BiodiversityR (Kindt & Coe, 2005).

Results

A total of 685 individual Lepidoptera were reported, belonging to 4 families, 34 genera and 52 species. The majority (80% of the sample) belonged to the Nymphalidae family, followed by Lycaenidae and Pieridae. Papilionidae was represented by a single species, making it the family with the lowest species richness in the dataset. The most representative subfamilies were Satyrinae (29 species) and Theclinae (10 species). The three most diverse genera in the sample, *Pedaliodes* Butler, *Corades* Doubleday, and *Lymanopoda* Westwood, all belong to the subtribe Pronophilina (Satyrinae) (Table I).

Considering the abundance for each species, *Pedaliodes ochrotaenia* (C. Felder & R. Felder) and *Pedaliodes polla* Thieme had a higher abundance than other species registered in the zone and were the co-dominants species for each sampling station. However, species such as *Colias dimera* Doubleday, *Pedaliodes cocytia* (C. Felder & R. Felder), *Lymanopoda samius* Westwood, *Viloriodes manis* (C. Felder & R. Felder), and *Pedaliodes phoenissa* (Hewitson) presented a high abundance in the study area in comparison to other species as *Junea doraete* (Hewitson), *Cyanophrys agricolor* (Butler & H. Druce) and *Papilio polyxenes* Fabricius. Sequentially, three of the less abundant species correspond to Lycaenidae: *Salazaria sala* (Hewitson), *Marachina maraches* (H. Druce), and *Lamprospilus* sp. Geyer. Nevertheless, something to highlight in the results is that several species of Lycaenidae are reported, although they presented a low abundance.

Table II. RAD models with AIC values at the Serrania del Zuque peri-urban forest.

Model	Serrania del Zuque
Null	304.2
Preemption	233.9
Log-normal	**226.4**
Zipf	263.2
Zipf-Mandelbrot	**226.9**

Table III. The observed and estimated Hill numbers diversity values (effective species) obtained for each study station.

	Observed			Estimated		
Study Station	**0D**	**1D**	**2D**	**0D**	**1D**	**2D**
Station 1	33	30.45	28.09	35	32.23	29.86
Station 2	42	38.33	35.34	46	39.16	36.23
Station 3	40	36.25	33.15	42	38.02	34.12
Station 4	36	33.3	31.39	39	35.23	32.67
Station 5	32	29.74	27.92	35	31.12	29.3
Station 6	30	27.46	25.33	33	29.56	27.02
Station 7	27	23.8	21.18	30	25.34	23.36

* Kruskal-Wallis test: *p-value* = 0.169. There isn't significant difference between observed and estimated Hills numbers values.

Five models of RAD were tested (null, preemption, lognormal, Zipf and Zipf-Mandelbrot models) and according to the AIC criterion, the best adjustment for the Alto del Zuque turned out to be the lognormal and Zipf-Mandelbrot distribution models, as a kind mix model (Table II). This result provides evidence of a similar pattern in the abundance distribution between dominant and rare Papilionoidea species in the study area.

Figure 2. Sample Coverage curve based on R/E analysis.

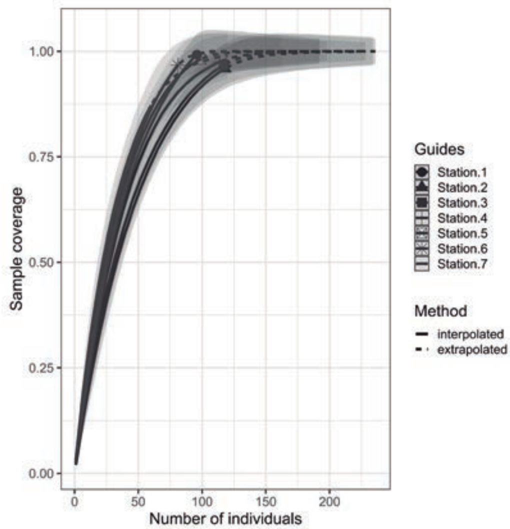
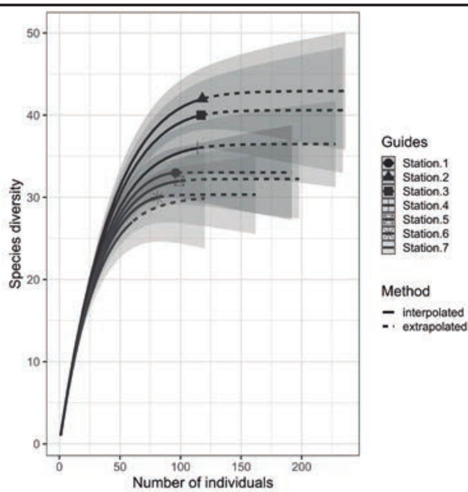


Figure 3. Species diversity curve according to R/E analysis.



The observed and estimated Hill numbers of diversity (0D, 1D, and 2D) were similar, showing no significant differences between them (Table III), so that we can infer to the community is homogeneous among all the stations in the study area. Moreover, the analysis of the sample Coverage-R/E curve (Figure 2) indicates that the sampling effort was appropriate for all the established stations, although it is noteworthy that no curve reached an asymptote, this suggests that a more extensive sampling could potentially increase the number of species in the study area. However, when comparing the 0D, 1D, and 2D diversity values (Table III) with the species diversity curve based on the R/E analysis (Figure 3), it can be inferred that the sampling effort was adequate. The number of species observed closely matched the number of species expected at each sampling station, supporting the validity of the R/E curve results.

Figure 4. Cluster analysis with the Bray- Curtis index and UPGMA.

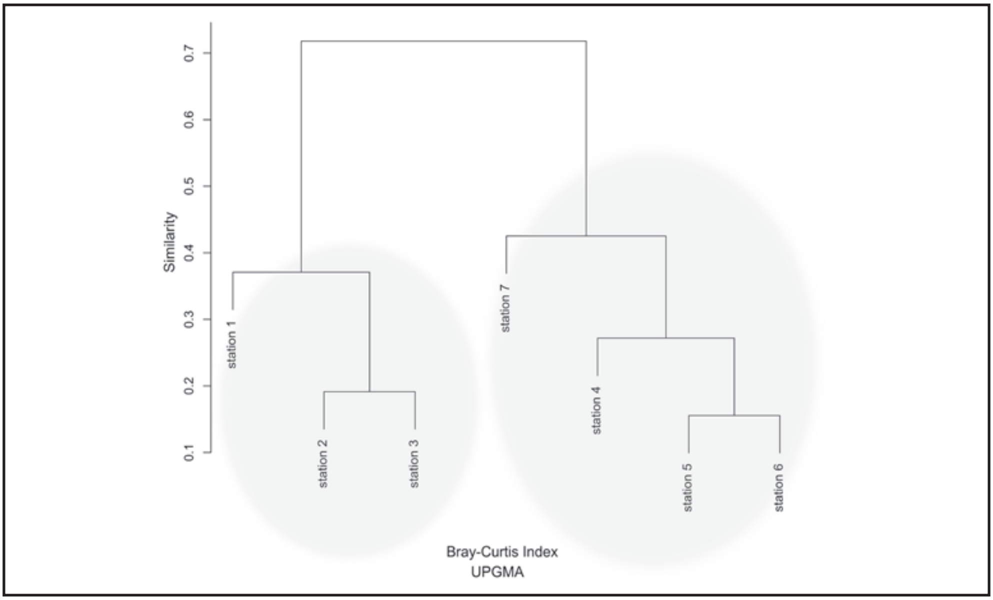
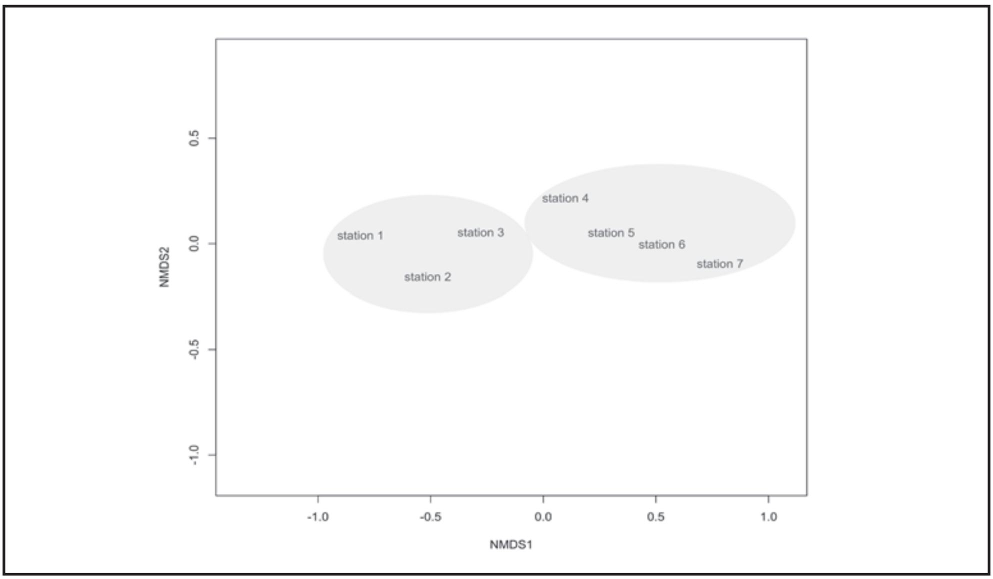


Figure 5. NMDS analysis using the similarity Bray-Curtis index.



On the other hand, based on the similarity analysis, a clear difference in species turnover is uncovered and grouping into two groups, the first group had stations 1, 2, and 3 (72.3% similarity), and the second group contained stations from 4 to 7 (68.8% similarity). Also, there is a high degree of similarity between station 2 and 3 (84.4% similarity), and between station 5 and 6 (85.8% similarity) (Figure 4). The NDMS ordination analysis results (*Kruskal stress = 0, R= 1*) corroborated these results (Figure 5). Therefore, there was a significant difference in the composition of species among sampling units (*ANOSIM test: R=0.346*, *p-value= 0.001*).

We compared the species diversity data (effective number of species) for Papilionoidea reported by Mahecha-Jiménez (2008) (Table IV) and for Pronophilina by Mahecha-Jiménez et al. (2011) (Table V) at the Serranía del Zuque. Our current observations revealed a significant increase in both abundance and species richness. The number of Papilionoidea species increased from 26 to 52, while Pronophilina species rose from 13 to 30, reflecting a substantial enrichment of the butterfly community in the study area. Finally, it is noteworthy that a newly identified species in the genus *Eretris* Thieme, 1905 has been reported. It will be described in an upcoming monograph (Pyrcz et al. in prep.) (see Table I).

Table IV. Comparison of Hill numbers values (numbers of effective species) observed in Mahecha-Jiménez (2008) and the results from the current study for Papilionoidea at the Serrania del Zuque.

	Hill Numbers values		
Study	**0D**	**1D**	**2D**
Mahecha-Jiménez (2008)	26	24.7	21.2
Mahecha-J. et al. current one	52	50.4	47.3

Table V. Comparison of Hill numbers values (numbers of effective species) observed in Mahecha-Jiménez et al. (2011) and the results from the current study for Pronophilina at the Serrania del Zuque.

	Hill Numbers values		
Study	**0D**	**1D**	**2D**
Mahecha-Jiménez et al. (2011)	13	10.07	9.40
Mahecha-J. et al. current one	30	27.46	25.33

Discussion

A total of 52 species of Papilionoidea were identified, representing a significant increase compared to the 26 species previously reported by Mahecha-Jiménez (2008). Likewise, 30 species of Pronophilina were recorded, exceeding the 13 species reported by Mahecha-Jiménez et al. (2011) for the Serranía del Zuque. An ecological restoration process was implemented in the study area between 2009 and 2010 to facilitate the regeneration of natural habitats (Aguilar-Garavito, 2010, 2015), this restoration process appears to have played a key role in enhancing Papilionoidea diversity in the area. Additionally, the area is undergoing ecological succession from a mix of pasture and forest to a closed forest (Aguilar-Garavito, 2015). This transition is leading to changes in the habitats and the composition of Lepidoptera communities in the area (Waltz & Wallace, 2004; De Souza et al. 2013), because we reported a high increase in the diversity values compared to previous diversity study data reported in the same zone by Mahecha-Jiménez (2008) and Mahecha-Jiménez et al. (2011). Some species related to cloud forests in good conditions previously not recorded in the Serranía del Zuque (Mahecha-Jiménez, 2008; Mahecha-Jiménez et al. 2011) have colonized the area, such as Pronophilina Satyrinae: *Daedalma dinias* Hewitson, 1858, *Manerebia levana* (Godman, 1905), *Lymanopoda lebbaea* C. Felder & R. Felder, [1867] and Lycaenidae: *Salazaria sala* (Hewitson, 1867).

There was an increase in Lycaenidae species in the study area, and we found abundant species in forest edge areas and clearings with varying levels of human disturbance such as *Rhamma comstocki* Johnson, 1992, *Hemiargus hanno bogotana* Draudt, 1921 and *Penaincisalia loxurina* (C. Felder & R. Felder, 1865) (Pulido & Parrales, 2011; Henao-P & Stiles, 2018; Henao-Bañol et al. 2018). However, we reported rare and endemic species of Papilionoidea at the Serranía del Zuque, for example, Nymphalidae: *Daedalma dinias* Hewitson, 1858, *Lymanopoda samius* Westwood, *Lymanopoda lebbaea* C. Felder & R. Felder, 1867, *Idioneurula erebioides* Felder, 1867, *Manerebia levana* (Godman, 1905), and *Manerebia apiculata* (C. Felder & R. Felder, 1867); Lycaenidae: *Salazaria sala* (Hewitson, 1867) and *R. comstocki* Johnson, 1992; Pieridae: *Catasticta semiramis* (Lucas, 1852) and *Catasticta chrysolopha* (Kollar, 1850); Papilionidae: *Papilio polyxenes* Fabricius, 1775 (Henao-Bañol et al. 2018b). Moreover, *Junea doraete* Hewitson, 1858, is considered a bioindicator of natural forests in a state of good conservation (Duran-Prieto & Molina-Fonseca, 2020).

On the other hand, species such as *Pedaliodes polla* Thieme, *Viloriodes manis* (C. Felder & R. Felder), *Pedaliodes ochrotaenia* (C. Felder & R. Felder), *Pedaliodes phoenissa* (Hewitson, 1862), *Corades chelonis* Hewitson, 1863, *Lasiophila circe* C. Felder & R. Felder, 1859, *Pedaliodes empusa* C. Felder & R. Felder, 1867, and *L. samius* Westwood are often associated with Andean secondary forests. These species may be considered potential generalists capable of colonizing early stages of ecological succession in montane habitats (Díaz-Suárez et al., 2022). Henao-Bañol et al. (2018) also found that several Pronophilina species are associated with forest edges and clearings with varying degrees of human disturbance, and tend to be more abundant in moderately disturbed areas.

Furthermore, the genus *Chusquea* serves primarily as a host plant for several Pronophilina species in the Neotropical region (Pyrcz, 2004a, 2004b; Pyrcz & Viloria, 2005; Greeney et al., 2009; Pyrcz et al., 2009; Montero & Ortiz, 2013; Mahecha et al., 2019; Díaz-Suárez et al., 2022). Most *Chusquea* species readily colonize disturbed sites (Judziewicz et al., 1999; Fisher et al., 2014), exerting long-term influence on the structure and diversity of dynamic plant communities and contributing to habitat resilience (Beckage et al., 2000; Holz & Veblen, 2006; Raffaele et al., 2007; Giordano et al., 2009; Muñoz & González, 2009; Muñoz et al., 2012). As pioneer species in forest succession, *Chusquea* plays an ecologically important role in facilitating tree cover regeneration (González et al., 2002; Pacheco, 2013). This ecological context may help explain the observed increase in Pronophilina species in the study area.

Three lines of evidence support the recovery of Papilionoidea diversity in the Serranía del Zuque: (1) an increase in the total number of species; (2) the recolonization by forest specialist species typically found in undisturbed habitats; and (3) a shift in the proportion of synanthropic species within the sample. For instance, species such as *Viloriodes manis* (C. Felder & R. Felder), *Pedaliodes polla* Thieme, *Panyapedaliodes drymaea* Forster, and *Colias dimera* Doubleday & Hewitson, 1847, exhibited lower abundances compared to previous studies.

The RAD analysis for the study area fits a log-normal and Zipf-Mandelbrot distribution model, which indicates that a natural community is extensive, varied and mature (Magurran, 1988), and complies with most of the ecological requirements of a community (May, 1975). It is important to highlight that this result reveals a similar pattern in the abundance distribution between dominant and rare Papilionoidea species in the study area. This pattern may suggest a community structure characterized by hierarchical niche subdivision, in which a small fraction of species exploits a large portion of the available resources. In turn, under as proposed by Hill & Hamer (1998) and Marín et al. (2014) communities that compose log-normal series of distribution models present some level of disturbance (Mouillot & Lepretre, 2000; Matthews & Whittaker, 2015; Nallis, 2021; Cerdeña et al. 2024). According to Wilson (1991), species presence is influenced by initial physical conditions and the presence of other species, which represent ecological 'costs.' In this framework, pioneer species require minimal preconditions and thus incur low costs, whereas late-successional species face higher costs –such as greater energy expenditure, longer establishment times, and dependence on ecosystem organization– before they can successfully colonize an area. These temporal and ecological differences among species can result in a Zipf-Mandelbrot distribution pattern. Whereas a log-normal model may result from many factors acting simultaneously, a Zipf-Mandelbrot model is indicative of many factors acting sequentially (Wilson, 1991; Marimon et al. 2015; Nallis, 2021; Cerdeña et al. 2024).

The RAD described by Mahecha-Jiménez (2008) in the same region followed a log-normal distribution, suggesting that the butterfly community at that time was subject to substantial environmental disturbance, causing a rise up in the heterogeneous environment that benefits several times the most dominant species, which causes an increase in the dominance of some species about others, observing a low diversity in the community (Matthews & Whittaker, 2015). We have to point out, however, that these models have been widely debated (Mouillot & Lepretre, 2000; Williamson & Gaston, 2005; Ferreira & Petrere, 2008; Matthews & Whittake, 2015; Nallis, 2021; Cerdeña et al. 2024).

As the study area undergoes ecological succession, the formation of diverse ecotones may facilitate increased species richness and expanded distribution patterns (Uehara-Prado et al. 2005; Weyland & Zaccagnini, 2008; Uehara-Prado & Freitas, 2009; Urbano et al. 2014). Similar diversity estimates across the stations in the Serranía del Zuque may, at least partially, be attributed to the Intermediate Disturbance Hypothesis, which posits that species richness is highest at intermediate levels of disturbance (Townsend et al. 1997; Kershaw & Mallik, 2013), or by the mass ratio hypothesis, which proposes that the biological traits of the dominant species are the critical drivers of ecosystem function and that these species increase in biomass rapidly after disturbance then stabilize. Consequently, species diversity first peaks then decline after a disturbance as a few species dominate the site. Both hypotheses provide a conceptual link among disturbance, species diversity, and productivity (Kershaw & Mallik, 2013). The highest level of species richness often occurs at moderate altitudes due to species turnover between lowland and highland areas. This intermediate zone tends to have greater diversity, a phenomenon known as the mid-domain effect. This may explain why stations 2 and 3 exhibited higher diversity values compared to the other stations and were more similar to each other (Colwell & Lees, 2000; Sanders, 2002; Colwell et al. 2004; Guerrero & Sarmiento, 2010; Giraldo-Cañas, 2021).

Some studies of Papilionoidea in other Colombian Andean forests have reported higher overall species richness, particularly within the subtribe Pronophilina, which was the most representative taxon in our sample. For example, Pyrcz & Wojtusiak (1999) reported 44 species for Pronophilina in the Tambito Reserve in the Western Cordillera of Colombia, whereas Prieto (2003) reported richness of 40 species in the nearby Cerro Munchique. Pyrcz & Rodríguez (2007) found 85 species in the Páramo de Tatamá, Farallones de Citará Cerro Frontino massifs in the Western Cordillera. Pyrcz & Viloria (2007) found 54 species of Pronophilina in the Serranía del Tamá, on the Colombian-Venezuelan border. Montero & Ortíz (2013) reported 60 species of Papilionoidea (Papilionoidea + Hesperioidea), including 32 species of Pronophilina, for El Tablazo Andean forest in the Subachoque-Cundinamarca in East Cordillera. Marín et al. (2014) found 75 species of Papilionoidea (Papilionoidea + Hesperioidea), including 38 species of Pronophilina, at the Romeral peri-urban forest of the Central Cordillera in Medellín, southwest of the Aburrá Valley. Olarte-Quiñonez et al. (2016) reported 69 Papilionoidea in the East Cordillera on the Norte de Santander and Santander border. Pyrcz et al. (2016) identified 48 species of Pronophilina on the Páramo de Belmira on the Central Cordillera. Clavijo-Giraldo et al. (2020) found 69 species of Papilionoidea (Papilionoidea + Hesperioidea) but they did not find any representative of Papilionidae. Clavijo-Giraldo et al. (2024) reported 108 Papilionoidea species in high-montane ecosystems of the Central Cordillera in Antioquia.

However, some studies have reported a lower richness compared to our research in other Colombian Andean forests, for example, Pérez et al. (2017) reported 31 Papilionoidea species (12 Pronophilina species) for Andean forest at the Santa Rosa de Viterbo in Boyacá-Colombia. Henao-B & Stilles (2018) reported 55 species of Papilionoidea (Papilionoidea + Hesperioidea) in Tabio in East Cordillera on Cundinamarca, where 13 species were Pronophilina. Murillo-P. et al. (2018) identified only eight species of Papilionoidea in Neuta, San Isidro, and Tierra Blanca wetlands in Soacha municipality in East Cordillera. Duran-Prieto & Molina-Fonseca (2020) reported 45 Papilionoidea species, including 18 Pronophilina species, in the Bogotá region of the East Cordillera in Cundinamarca. Olarte-Quiñonez et al. (2021) found 25 Pronophilina species in Cerro de Tierra Negra in the East Cordillera on the Norte de Santander and Santander border. Díaz-Suárez et al. (2022) reported 23 species of Pronophilina in the Frailejonal Andean forest in the East Cordillera in Cundinamarca. Nonetheless, the results obtained in these studies cannot be immediately compared due to different sampling methodologies applied, sampling time effort, and the area size.

The relatively low species diversity in the study area is likely a consequence of the long-term habitat degradation resulting from past mining operations (Aguilar-Garavito, 2010). This disturbance led to the formation of forest patches that hindered gene flow between subpopulations, resulting in a reduction in the diversity of various animal and plant taxa (Murillo-P. et al. 2018). Although nearly eight years have passed since the beginning of the ecological restoration process and twelve years since the cessation of mining activities (see Aguilar-Garavito, 2010; 2015), complete recovery of the habitat in the study area has not been observed. However, vegetal coverage has been gradually regenerating. For instance, the cover by the species of Poaceae and Melastomataceae has been increasing (Aguilar-Garavito, 2015). This has allowed for the growth of different plants that serve as hosts for many Papilionoidea species, leading to a gradual recovery of the diversity of Papilionoidea, particularly Pronophilina, in the Serranía del Zuque after the mining activity. Finally, these findings reinforce the need for ongoing ecological restoration initiatives aimed at preserving native montane ecosystems in peri-urban regions of Colombia.

Acknowledgments

The authors would like to express their gratitude to the Universidad Distrital Francisco José de Caldas in Bogotá, Colombia and Instituto de Ciencias Naturales ICN at the Universidad Nacional de Colombia for its logistical support. We thank the Instituto de Ciencias Naturales ICN at the Universidad Nacional de Colombia and the Nature Education Center at Jagiellonian University in Poland for granting access to reference materials. This research was partially funded by the Project NCN grant Harmonia-10 (2018/30/M/NZ8/00293), titled *"Evolutionary biogeography and diversification of the predominantly Andean butterfly subtribe Pronophilina (Nymphalidae, Satyrinae) based on phylogenetic data generated using modern molecular methods*." Additionally, O. Mahecha-J.'s research trip to Poland was supported by the PROM-International Scholarship Exchange Program for Doctoral Students and Scholars of Jagiellonian University and the Polish National Academic Exchange Agency, under agreement number PPI/PRO/2018/1/00001/U/001.

Conflict of Interest

The authors declare that there is no known financial interest or personal relationship that could have influence the work presented in this article.

References

Adams, M. J. (1985). Speciation in the Pronophiline butterflies (Satyridae) of the northern Andes. *Journal of Research on the Lepidoptera Supplement, 1*, 33-49.

Adams, M. J. (1986). Pronophiline butterflies (Satyridae) of the three Andean Cordilleras of Colombia. *Zoological Journal of the Linnean Society, 87*(3), 235-320. https://doi.org/10.1111/j.1096-3642.1986.tb01338.x

Addo-Fordjour, P., Osei, B. A., & Kpontsu, E. A. (2015). Butterfly community assemblages in relation to human disturbance in a tropical upland forest in Ghana, and implications for conservation. *Journal of Insect Biodiversity, 3*(6), 1-18. https://doi.org/10.12976/jib/2015.3.6

Aguilar-Garavito, M. (2010). *Restauración ecológica de áreas afectadas por Ulex europaeus L. Serranía El Zuque, Reserva Forestal Bosque Oriental de Bogotá, localidad 4 San Cristóbal, Bogotá D. C., Colombia* (Tesis de Master). Universidad de Alcalá.

Aguilar-Garavito, M. (2015). Restauración ecológica de ecosistemas andinos afectados por plantas invasoras en áreas naturales Protegidas: el caso de *Ulex europaeus* L. en la Reserva Forestal Bosque oriental de Bogotá y de *Hedychium coronarium* J. König, en la cuenca alta del río Otún. In T. J. Cárdenas, M. P. Baptiste, W. Ramírez & G. M. Aguilar (Eds.). *Herramienta de decisión para la gestión de áreas afectadas por invasiones biológicas en Colombia* (Caso 4, pp. 118-129). Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Andrade, M. G. (1998). Utilización de las mariposas como bioindicadoras del tipo de hábitat y su biodiversidad en Colombia. *Revista Academia Colombiana Ciencias Exactas, Física, Natuarles, 22*(84), 407-421. https://doi.org/10.18257/raccefyn.22(84).1998.2933

Andrade-C, M. G., & Amat, G. (1996). Un estudio regional de las mariposas altoandinas en la Cordillera Oriental de Colombia. In M. G. Andrade-C, G. Amat, G. & F. Fernández (eds.). *Insectos de Colombia, estudios escogidos* (pp. 149-180). Academia Colombiana de Ciencias Exactas, Físicas y Naturales Colección Jorge Álvarez Lleras No. 10 Coeditado con el Centro Editorial Javeriano.

Beckage, B., Clark, J. S., Clinton, B. D., & Haines, B. L. (2000). A long-term study of tree seedling recruitment in Southern Appalachian forests: the effects of canopy gaps y shrub understories. *Canadian Journal of Forest Research, 30*, 1617-1631. https://doi.org/10.1139/x00-075

Binz, H., Schulze, C., & Linsenmair, K. (2014). Effects of topography on forest butterfly assemblages in the pacific lowlands of Costa Rica. *Ecotropica, 20*, 1-14.

Brehm, G., Süssenbach, D. & Fiedler, K. (2003b). Unique elevational diversity patterns of geometrid moths in an Andean montane rainforest. *Ecography, 26*, 456-466. https://doi.org/10.1034/j.1600-0587.2003.03498.x

Buttigieg, P., & Ramette, A. (2014). A guide to statistical analysis in microbial ecology: a community-focused, living review of multivariate data analyses. *FEMS Microbiology Ecology, 90*(3), 543-550. https://doi.org/10.1111/1574-6941.12437 PMid:25314312

Camelo, D., Pineda, J., Vicente, J., López, J., Jiménez, M., Muñoz, Y., Suárez, A., & Vivas, N. (2009). *Reserva forestal protectora bosque oriental de Bogotá. Inventario de fauna*. CAR.

Capel, H. (1994). Las periferias urbanas y la geografía. Reflexiones para arquitectos. *Anthropos, 43*, 136-143.

CAR (2006a). *Resolución No. 1141 de la Corporación Autónoma Regional de Cundinamarca*. http://www.alcaldiabogota.gov.co/sisjur/normas/Norma1.jsp?i=20128

CAR (2006b). *Plan de manejo ambiental de la zona de reserva forestal protectora Bosque oriental de Bogotá*. http://ambientebogota.gov.co/cerros-orientales

Casas-Pinilla, L. C., Mahecha-J., O., Dumar, J. C., & Ríos-Málaver, I. C. (2017). Diversidad de mariposas en un paisaje de bosque seco tropical, en la Mesa de Los Santos, Santander, Colombia (Lepidoptera: Papilionoidea). *SHILAP Revista de lepidopterología, 45*(177), 83-108. https://doi.org/10.57065/shilap.974

Cerdeña, J., Mahecha-J., O., Garlacz, R., Arivilca-Pari, J., Farfán, J., Delgado-Coila, M., Florczyk, K., Díaz-S., V., & Pyrcz, T. W. (2024). A Rapid Assessment of Pronophilina Reuter, 1896 community structure and diversity in the uppermost cloud forests near timberline in Manu National Park, Peru (Lepidoptera: Nymphalidae, Satyrinae). *SHILAP Revista de lepidopterología, 52*(206), 235-250. https://doi.org/10.57065/shilap.899

Chao, A., & Shen, T. J. (2003). Nonparametric estimation of Shannon's index of diversity when there are unseen species in the sample. *Environmental and Ecological Statistics, 10,* 429-433. https://doi.org/10.1023/A:1026096204727

Chao, A., & Jost, L. (2012). Coverage-based rarefaction and extrapolation: standardizing samples by completeness rather than size. *Ecology, 93*, 2533-2547. https://doi.org/10.1890/11-1952.1 PMid:23431585

Chao, A., Gotelli, N. J., Hsieh, T. C., Sander, E. L., Ma, K. H., Colwell, R. K., & Ellison, A. M. (2014). Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. *Ecological Monographs, 84*(1), 45-67. https://doi.org/10.1890/13-0133.1

Chao, A., Hsieh, T. C., Chazdon, R. L., Colwell, R. K., & Gotelli, N. J. (2015). Unveiling the species-rank abundance distribution by generalizing the Good-Turing sample coverage theory. *Ecology, 96*(5), 1189-1201. https://doi.org/10.1890/14-0550.1 PMid:26236834

Clavijo-Giraldo, A., Álvarez-Hincapié, C. F., & Colorado, G. (2024). Habitat structure influences the diversity of diurnal butterflies (Lepidoptera: Papilionoidea) in high-montane ecosystems in Colombia. *Revista De Biología Tropical*, *72*(1), https://doi.org/10.15517/rev.biol.trop.v72i1.57968

Clavijo-Giraldo, A., Areiza-Restrepo, L., Álvarez-Hincapié, C. F., Parrales-Ramírez, D. A., Borja-Acosta, K. G., Uribe-Soto, S. I., & Medina-Uribe, C. A. (2020). Mariposas diurnas (Lepidoptera: Papilionoidea) en la Reserva Forestal El Romeral, Cordillera Central, Antioquia, Colombia. *Biota,* (2), 142-155. https://doi.org/10.21068/c2020.v21n02a10

Cleary, D. F. R., & Genner, M. J. (2006). Diversity patterns of Bornean butterfly assemblages. *Biodiversity and Conservation, 15*, 503-524. https://doi.org/10.1007/978-1-4020-5204-0_31

Colwell, R. K., & Lees, D. C. (2000). The mid-domain effect: geometric constraints on the geography of species richness. *Trends in Ecology and Evolution, 15*, 70-76. https://doi.org/10.1016/S0169-5347(99)01767-X PMid:10652559

Colwell, R. K., Rahbek, C., & Gotelli, N. J. (2004). The mid–domain effect and species richness patterns: what have we learned so far? *The American Naturalist, 163*, E1-E23. https://doi.org/10.1086/382056 PMid:15026983

Cusack, J. J., Dickman, A. J., Rowcliffe, J. M., Carbone, C., Macdonald, D. W., & Coulson, T. (2015). Random versus game trail-based camera trap placement strategy for monitoring terrestrial mammal communities. *PloS one, 10* (5): e0126373. https://doi.org/10.1371/journal.pone.0126373 PMid:25950183 PMCid:PMC4423779

Devries, P. (1987). *The Butterflies of Costa Rica and their natural history, Papilionidae, Pieridae, Nymphalidae*. Princenton University Press.

De-Silva, D. L., Elias, M., Willmott, K., Mallet, J., & Day, J. J. (2015). Diversification of clearwing butterflies with the rise of the Andes. *Journal of Biogeography, 43,* 44-58. https://doi.org/10.1111/jbi.12611 PMid:27546953 PMCid:PMC4973677

De-Souza, L. M., Tambosi, L. R., Romitelli, I., & Metzger, J. P. (2013). Landscape ecology perspective in restoration projects for biodiversity conservation: a review. *Natureza & Conservação, 11*, 108-118. https://doi.org/10.4322/natcon.2013.019

Díaz-Suárez, V., Mahecha, O., Andrade, M. G., & Pyrcz, T. W. (2022). Perturbación antrópica afectando a los patrones de diversidad en Satyrinae de montaña Pronophilina Reuter, 1896 en un bosque altoandino en Colombia (Lepidoptera: Nymphalidae). *SHILAP Revista de lepidopterología, 50*(200), 709-728. https://doi.org/10.57065/shilap.263

Duran-Prieto, J., & Molina-Fonseca, A. G. (2020). Colores urbanos: Mariposas (Lepidoptera: Papilionoidea) de Bogotá Región (Colombia). *Biota colombiana, 21*(2), 21-39. https://doi.org/10.21068/c2020.v21n02a02

Ellison, A. M. (2010). Partitioning diversity. *Ecology, 91*, 1962-1963. https://doi.org/10.1890/09-1692.1 PMid:20715615

Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology, Evolution and Systematic, 34,* 487-515. https://doi.org/10.1146/annurev.ecolsys.34.011802.132419

Ferreira, F. C., & Petrere, M. J. R. (2008). Comments about some species abundance patterns: classic, neutral, and niche partitioning models. *Brazilian Journal of Biology, 68,* 1003-1012. https://doi.org/10.1590/S1519-

69842008000500008 PMid:19197471

Fisher, A. E., Clark, L. G., & Kelchner, S. A. (2014). Molecular Phylogeny Estimation of the Bamboo Genus *Chusquea* (Poaceae: Bambusoideae: Bambuseae) and Description of Two New Subgenera. *Systematic Botany, 39*(3), 829-844. https://doi.org/10.1600/036364414X681554

Fowler, H. J., Lenderink, G., Prein, A. F., Weatra, S., Allan, R. P., Ban, N., Barbero, R., Berg, P., Blenkinsop, S., Do, H. X., Guerreiro, Haeter, J. O., Kendon, E. J., Lewsi, E., Schaer, Ch., Sharma, A., Wasko, C., & Zhang, X. (2021). Anthropogenic intensification of short-duration rainfall extremes. *Nature Reviews Earth Environment, 2*, 107-122. https://doi.org/10.1038/s43017-020-00128-6

Freitas, A. V., Agra Iserhard, C., Pereira Santos, J., Oliveira Carreira, I, J. Y., Bandini Ribeiro, D., Alves Melo, D. H., Batista Rosa1, A. H., Marini-filho, O. J., Mattos Accacio, G., & Uehara-Prado, M. (2014). Studies with butterfly bait traps: an overview. *Revista Colombiana de Entomología, 40*(2), 203-212.

Freitas, A. V., Santos, J. P., Rosa, A. H., Iserhard, C. A., Richter, A., Siewert, R. R., Gueratto, P. E., Carreira, J. Y. O., & Lourenço, G. M. (2021). Sampling methods for butterflies (Lepidoptera). *Measuring arthropod biodiversity: a handbook of sampling methods* (pp. 101-123). https://doi.org/10.1007/978-3-030-53226-0_5

Garwood, K., Huertas, B., Ríos-Málaver I. C., & Jaramillo, J. G. (2022). *Checklist of Colombian Butterflies (Lepidoptera: Papilionoidea) / Mariposas de Colombia Lista de chequeo (Lepidoptera: Papilionoidea)*. BioButterfly Database (2da Edición).

Giordano, C., Sánchez, R., & Austin, A. (2009). Gregarious bamboo flowering opens a window of opportunity for regeneration in a temperate forest of Patagonia. *New Phytologist,* 181, 880-889. https://doi.org/10.1111/j.1469-8137.2008.02708.x PMid:19076297

Giraldo-Cañas, D. (2021). Malpighiaceae de Colombia: Patrones de distribución, riqueza, endemismo y diversidad filogenética. *Darwiniana, 9*(1), 39-54. https://doi.org/10.14522/darwiniana.2021.91.923

Gotelli, N. J., & Chao, A. (2013). Measuring and estimating species richness, species diversity, and biotic similarity from sampling data. In S. A. Levin (eds.). *The encyclopedia of biodiversity* (Vol. 5, second edition, (pp. 195-211). Academic Press. https://doi.org/10.1016/B978-0-12-384719-5.00424-X

Gotelli, N. J., & Colwell, R. K. (2011). Estimating species richness. In A. E. Magurran & B. J. Mcgill (eds.). *Biological diversity: frontiers in measurement and assessment* (pp. 39-54). Oxford University Press.

González, M. E., Veblen, T. T., Donoso, C., & Valeria, L. (2002). Tree regeneration responses in a lowland *Nothofagus*-dominated Forest after bamboo dieback in South-Central Chile. *Plant Ecology, 161*, 59-73. https://doi.org/10.1023/A:1020378822847

Greeney, H. F., Pyrcz, T. W., Devries, P. J., & Dyer, L. A. (2009). The early stages of *Pedaliodes poesia* (Hewitson, 1862) in eastern Ecuador (Lepidoptera: Satyrinae: Pronophilini). *Journal of Insect Science, 9,* 1-8. https://doi.org/10.1673/031.009.3501 PMid:19619012 PMCid:PMC3011897

Guerrero, R., & Sarmiento, C. (2010). Distribución altitudinal de hormigas (Hymenoptera, Formicidae) en la vertiente noroccidental de la Sierra Nevada de Santa Marta (Colombia). *Acta Zoológica Mexicana, 26*(2), 279-302. https://doi.org/10.21829/azm.2010.262699

Henao-Bañol, E. R., Páez, A., & Rodríguez-M., J. V. (2018). Inventario de mariposas diurnas (Lepidoptera: Hesperioidea-Papilionoidea) de la Reserva Forestal Productora Protectora de la cuenca alta del río Bogotá (RFPP-CARB). *Boletín Científico. Centro de Museos. Museo de Historia Natural, 22*(2), 144-171. https://doi.org/10.17151/bccm.2018.22.2.11

Henao-P., E., & Stiles, F. (2018). Un inventario de las mariposas diurnas (Lepidoptera: Hesperioidea-Papilionoidea) de dos reservas altoandinas de la cordillera oriental de Colombia. *Revista de la Facultad de Ciencias, 7*(1), 71-87. https://doi.org/10.15446/rev.fac.cienc.v7n1.67837

Hill, M. O. (1973). Diversity and evenness: a unifying notation and its consequences. *Ecology, 54*, 427-432. https://doi.org/10.2307/1934352

Holz, C. A., & Veblen, T. T. (2006). Tree regeneration responses to *Chusquea montana* bamboo die-off in a subalpine *Nothofagus* Forest in the southern Andes. *Journal of Vegetation Science, 17,* 19-28. https://doi.org/10.1111/j.1654-1103.2006.tb02419.x

Hsieh, T. C., Ma, K. H., & Chao, A. (2016). iNEXT: An R package for rarefaction and extrapolation of species diversity (Hill numbers). *Methods in Ecology and Evolution, 7*, 1451-1456. https://doi.org/10.1111/2041-210X.12613

Jost, L. (2006), Entropy and diversity. *Oikos, 113*, 363-375. https://doi.org/10.1111/j.2006.0030-1299.14714.x

Judziewicz, E. J., Clark, L. G., Londoño, X., & Stern, M. J. (1999). *American bamboos*. Smithsonian Institution.

Kershaw, H. M., & Mallik, A. U. (2013). Predicting plant diversity response to disturbance: applicability of the intermediate disturbance hypothesis and mass ratio hypothesis. *Critical reviews in plant sciences, 32*(6), 383-395. https://doi.org/10.1080/07352689.2013.791501

Kindt, R., & Coe, R. (2005). *Tree diversity analysis. A manual and software for common statistical methods for* *ecological and biodiversity studies*. World Agroforestry Centre (ICRAF). http://www.worldagroforestry.org/output/tree-diversity-analysis.

Lamas, G. (2000). Estado actual del conocimiento de la sistemática de los lepidópteros, con especial referencia a la región Neotropical. In F. Martín-Piera, J. J. Morronem & A. Melic (eds.). *Hacia un Proyecto CYTED para el inventario y estimación de la Universidad entomológica en Iberoamérica: PrIBES* (pp. 253-260). Sociedad Entomológica Aragonesa, Monografías Tercer Milenio 1.

Lamas, G., Viloria, A. L., & Pyrcz, T. W. (2004). Subtribe Pronophilini. In G. Lamas (eds.). *Atlas of Neotropical Lepidoptera, Checklist: Part 4A, Hesperioidea-Papilionoidea* (pp. 206-215). Association for Tropical Lepidoptera.

Le Roux, J. J., Hui, C., Castillo, M. L., Iriondo, J. M., Keet, J. H., Khapugin, A. A., Médil, F., Rejmánek, M., Theron, G., Yannelli, F., & Hirsch, H. (2019). Recent anthropogenic plant extinctions differ in biodiversity hotspots and coldspots. *Current Biology, 29*(17), 2912-2918. https://doi.org/10.1016/j.cub.2019.07.063 PMid:31447372

Mack, R., Simberloff, D., & Lonsdale, M. (2000). Invasiones biológicas: causas, epidemiología, consecuencias globales y control. *Tópicos en Ecología, 5*, 1-19.

Magurran, A. E. (1988). *Ecological diversity and its measurement*. Princenton University Press. https://doi.org/10.1007/978-94-015-7358-0

Mahecha, G. (2000). *Cerros de Bogotá*. Villegas Editores.

Mahecha-Jiménez, O. J. (2008). *Diversidad de lepidópteros (Papilionoidea) a lo largo de un gradiente altitudinal en la Serranía Alto el Zuque, Reserva Forestal Bosque Oriental de Bogotá, Cundinamarca* (Bachelor's degree dissertation unpublished). Universidad Distrital Francisco José de Caldas.

Mahecha-Jiménez, O. J., Dumar-Rodríguez, J. C., & Pyrcz, T. W. (2011). Efecto de la fragmentación del hábitat sobre las comunidades de Lepidoptera de la tribu Pronophilini a lo largo de un gradiente altitudinal en un bosque andino en Bogotá (Colombia) (Lepidoptera: Nymphalidae, Satyrinae). *SHILAP Revista de lepidopterología, 39*(153), 117-126.

Mahecha, O., Garlacz, R., Andrade-C, M. G., Prieto, C., & Pyrcz, T. W. (2019). Island biogeography in continental areas inferring dispersal based on distributional patterns of Pronophilina butterflies (Nymphalidae: Satyrinae) in the north Andean massifs. *Revista Mexicana de Biodiversidad, 90*(3), 1-19.

Marín, M. A., Álvarez, C. F., Giraldo, C. E., Pyrcz, T. W., Uribe, S. I., & Vila, R. (2014). Mariposas en un bosque de niebla andino periurbano en el valle de Aburrá, Colombia. *Revista Mexicana de Biodiversidad, 85*, 200-208. https://doi.org/10.22201/ib.20078706e.2019.90.2796

Marín, M., Giraldo, C., Marín, A., Álvarez, C., & Pyrcz, T. (2015). Differences in butterfly (Nymphalidae) diversity between hillsides and hilltop forest patches in the northern Andes. *Studies on Neotropical Fauna and Environment, 50*(3), 194-203. https://doi.org/10.1080/01650521.2015.1099379

Marimon, B. S., Colli, G. R., Marimon-Junior, B. H., Mews, H. A., Eisenlohr, P. V., Feldpausch, T. R., & Phillips, O. L. (2015). Ecology of floodplain campos de murundus savanna in southern Amazonia. *International Journal of Plant Sciences, 176*(7), 670-681. https://doi.org/10.1086/682079

Matthews, T. J., & Whittaker, R. J. (2015). On the species abundance distribution in applied ecology and biodiversity management. *Journal of Applied Ecology, 52*(2), 443-454. https://doi.org/10.1111/1365-2664.12380

May, R. M. (1975). Patterns of species abundance and diversity. In M. L. Cody & J. M. Diamond (eds.). *Ecology and evolution of communities* (pp. 81-120). Harvard University Press.

Mckinney, M. L. (2008). Effects of urbanization on species richness: A review of plants and animals. *Urban Ecosystem, 11*, 161-176. https://doi.org/10.1007/s11252-007-0045-4

Mcgill, B. J., Etienne, R. S., Gray, J. S., Alonso, D., Anderson, M. J., Benecha, H. K., & Hurlbert, A. H. (2007). Species abundance distributions: moving beyond single prediction theories to integration within an ecological framework. *Ecology letters, 10*(10), 995-1015. https://doi.org/10.1111/j.1461-0248.2007.01094.x PMid:17845298

Mahmoud, S. H., & Gan, T. Y. (2018). Impact of anthropogenic climate change and human activities on environment and ecosystem services in arid regions. *Science of the Total Environment, 633*, 1329-1344. https://doi.org/10.1016/j.scitotenv.2018.03.290 PMid:29758885

Méndez-Zambrano, M. A., & Fajardo-Medina, G. E. (2024). Habitat Suitability in High Andean Butterflies: The Role of Land Cover in the Occurrence and Conservation of Species. *Neotropical Entomology, 53*(4), 759-772. https://doi.org/10.1007/s13744-024-01178-x PMid:38980501

Montero, F., & Ortíz, M. (2013). Aporte al conocimiento para la conservación de las mariposas (Hesperioidea y Papilionoidea) en el páramo del Tablazo, Cundinamarca (Colombia). *Boletín Científico Museo Historia Natural, 17*(2), 197-226.

Moreno, C. E., Barragán, F., Pineda, E., & Pavón, N. P. (2011). Reanalizando la diversidad alfa: alternativas para interpretar y comparar información sobre comunidades ecológicas. *Revista Mexicana de Biodiversidad, 82*, 1249-1261. https://doi.org/10.22201/ib.20078706e.2011.4.745

Mouillot, D., & Lepretre, A. (2000). Introduction of relative abundance distribution (RAD) indices, estimated from the rank-frequency diagrams (RFD), to assess changes in community diversity. *Environmental Monitoring and Assessment, 63*, 279-295. https://doi.org/10.1023/A:1006297211561

Muñoz, A. A., & González, M. E. (2009). Patrones de regeneración arbórea en claros a una década de la floración y muerte masiva de *Chusquea quila* (Poaceae) en un remanente de bosque antiguo del valle central en el centro-sur de Chile. *Revista Chilena de Historia Natural, 82,* 185-198. https://doi.org/10.4067/S0716-078X2009000200002

Muñoz, A., González, M., Celedón, C., & Veblen, T. T. (2012). Respuesta inicial de la regeneración arbórea luego de la floración y muerte de *Chusquea culeou* (Poaceae) en bosques andinos del centro-sur de Chile. *Bosque, 33*(2), 153-162. ttps://doi.org/10.4067/S0717-92002012000200005

Murillo-P., A., Robayo-CH, G., & Mahecha-J., O. (2018). Mariposas asociadas a humedales en el municipio de Soacha, Cundinamarca, Colombia (Lepidoptera: Papilionoidea). *SHILAP Revista de lepidopterología, 46*(182), 207-219. https://doi.org/10.57065/shilap.825

Nallis, B. G. (2021). *Fatores que estruturam metacomunidades em fitotelmos de restinga. (Defesa de Dissertação de Mestrado)*. Universidade Federal de São Carlos.

New, T. R. (1997). Are Lepidoptera an effective ‘‘umbrella group’’ for biodiversity conservation? *Journal Insect Conservation, 1*, 5-12.

Olarte-Quiñonez, C. A., Acevedo-Rincón, A. A., Ríos-Málaver, I. C., & Carrero-Sarmiento, D. A. (2016). Diversidad de mariposas (Lepidoptera, Papilionoidea) y su relación con el paisaje de alta montaña en los Andes nororientales de Colombia. *Arxius de Miscel·lània Zoològica, 14*, 233-255. https://doi.org/10.32800/amz.2016.14.0233

Olarte-Quiñonez, C. A., Carrero-Sarmiento, D., Viloria, Á. L., & Ríos-Málaver, I. C. (2021). Patrones de diversidad de las mariposas de la subtribu Pronophilina (Lepidoptera: Nymphalidae: Satyrinae) en un gradiente altitudinal del Cerro de Tierra Negra, Cordillera Oriental, Norte de Santander, Colombia. *Boletín Científico. Centro de Museos. Museo de Historia Natural, 25*(2), 197-218. https://doi.org/10.17151/bccm.2021.25.2.12

Ouyang, J. Q., Isaksson, C., Schmidt, C., Hutton, P., Bonier, F., & Dominoni, D. (2018). A new framework for urban ecology: an integration of proximate and ultimate responses to anthropogenic change. *Integrative and comparative biology, 58*(5), 915-928. https://doi.org/10.1093/icb/icy110 PMid:30376106 PMCid:PMC6204990

Pacheco, N. (2013). *Chusquea* (Poaceae) en el Parque Nacional Puyehue, Región de los Lagos, Chile. *Chloris Chilensis, 16*(1). http://www.chlorischile.cl.

Pérez, J. H., Sánchez, R. E., & Salcedo, D. J. (2017). Diversidad de mariposas presentes en la Escuela de Policía Rafael Reyes de Santa Rosa de Viterbo, Boyacá, Colombia (Lepidoptera: Papilionoidea). *SHILAP Revista de lepidopterología, 45*(178), 343-352. https://doi.org/10.57065/shilap.1007

Prieto, C. H. (2003). Satírinos (Lepidoptera, Nymphalidae, Satyrinae) del Parque Nacional Natural Munchique. Diversidad de especies y distribución altitudinal. *Revista Colombiana de Entomología, 29*, 203-210. https://doi.org/10.25100/socolen.v29i2.9606

Pulido, H., & Parrales, D. A. (2011). Listado de especies de las mariposas diurnas (Hesperioidea y Papilionoidea) de Arcabuco (Boyacá, Colombia). *Boletín Científico. Centro de Museos. Museo de Historia Natural, 15*(2), 191-200.

Pyrcz, T. W. (2004a). Notas taxonómicas sobre el género *Pronophila* Doubleday con la descripción de cuatro nuevas subespecies de *Pronophila unifasciata* Lathy (Nymphalidae: Satyrinae: Pronophilina). *Boletín Científico Museo de Historia Natural de Caldas, 8*, 233-244.

Pyrcz, T. W. (2004b). Pronophiline butterflies of the highlands of Chachapoyas in northern Peru: faunal survey, diversity and distribution patterns (Lepidoptera, Nymphalidae, Satyrinae). *Genus, 15*, 455-622.

Pyrcz, T. W., Clavijo, A., Uribe, S., Marin, M. A., Alvarez, C. F., & Zubek, A. (2016). Páramo de Belmira as an important centre of endemism in the northern Colombian Andes: New evidence from Pronophilina butterflies (Lepidoptera: Nymphalidae, Satyrinae, Satyrini). *Zootaxa, 4179*(1), 77-102. https://doi.org/10.11646/zootaxa.4179.1.3 PMid:27811691

Pyrcz, T. W., & Garlacz, R. (2012). The presence-absence situation and its impact on the assemblage structure and interspecific relations of Pronophilina butterflies in the Venezuelan Andes (Lepidoptera: Nymphalidae). *Neotropical entomology, 41*(3), 186-195. https://doi.org/10.1007/s13744-012-0031-2 PMid:23950042 PMCid:PMC3380249

Pyrcz, T. W., Prieto, C., Viloria, A. L., & Andrade-C., M. G. (2013). New species of high elevation cloud forest butterflies of the genus *Pedaliodes* Butler from the northern Colombian Andes (Lepidoptera, Nymphalidae, Satyrinae). *Zootaxa, 3716*(4), 528-538. https://doi.org/10.11646/zootaxa.3716.4.2 PMid:26106789

Pyrcz, T. W., & Rodríguez, G. (2007). Mariposas de la Tribu Pronophilini en la cordillera occidental de Los Andes Colombia (Lepidoptera: Nymphalidae, Satyrinae). *SHILAP Revista de lepidopterología, 35*(140), 455-489.

Pyrcz, T. W., & Viloria, A. L. (2005). Adiciones a la fauna de mariposas de la reserva forestal de Tambito (Colombia): descripción de cuatro subespecies nuevas de la subtribu Pronophilina (Nymphalidae, Satyrinae). *Boletín del Museo de Historia Natural de la Universidad de Caldas*, *9*, 258-277.

Pyrcz, T. W., & Viloria, A. L. (2007). Erebiine and pronophiline butterflies of the Serranía del Tamá, Venezuela-Colombia border. *Tropical Lepidoptera, 15*(1-2), 18-52.

Pyrcz, T. W., Viloria, A. L., & Boyer, P. (2010). The *obsoleta* clade of the genus *Lymanopoda* Westwood (Lepidoptera, Nymphalidae: Satyrinae). *Folia Entomologica Hungarica, 71*, 161-195. https://doi.org/10.1007/s13744-012-0031-2 PMid:23950042 PMCid:PMC3380249

Pyrcz, T. W., & Wojtusiak, J. (1999). Mariposas de la tribu Pronophilini de la Reserva Forestal Tambito, Cordillera Occcidental, Colombia. Segunda parte. Patrones de distribución altitudinal (Lepidoptera: Nymphalidae: Satyrinae). *SHILAP Revista de lepidopterología, 27*(106), 203-213.

Pyrcz, T. W., & Wojtusiak, J. (2002). The vertical distribution of pronophiline butterflies (Nymphalidae: Satyrinae) along and elevational transect in Monte Zerpa (Cordillera de Mérida, Venezuela) with remarks on their diversity and parapatric distribution. *Global Ecological biogeography, 11*, 211-221. https://doi.org/10.1046/j.1466-822X.2002.00285.x

Pyrcz, T. W., Wojtusiak, J., & Garlacz, R. (2009). Diversity and Distribution Patterns of Pronophilini Butterflies (Lepidoptera: Nymphalidae: Satyrinae) along an Altitudinal Transect in North-Western Ecuador. *Neotropical Entomology, 38*(6), 716-726. https://doi.org/10.1590/S1519-566X2009000600003 PMid:20098916

R Development Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. http://www.R-project.org/

Raffaele, E., Kitzberger, T., & Veblen, T. (2007). Interactive effects of introduced herbivores and post-flowering die-off of bamboos in Patagonian *Nothofagus* forests. *Journal of Vegetation Science, 18*(3), 371-378. https://doi.org/10.1111/j.1654-1103.2007.tb02549.x

Sanders, N. J. (2002). Elevational gradients in ant species richness: Area, geometry and Rapaport's rule. *Ecography, 25,* 25-32. https://doi.org/10.1034/j.1600-0587.2002.250104.x

Solorza, J. (2012). Evaluación de la Regeneración de *Acacia decurrens, Acacia melanoxylon* y *Ulex europaeus* en áreas en proceso de restauración ecológica. *Revista Luna Azul, 34*, 66-80.

Townsend, C. R., Scarsbrook, M. R., & Dolédec, S. (1997). The intermediate disturbance hypothesis, refugia, and biodiversity in streams. *Limnology and Oceanography, 42*(5), 938-949. https://doi.org/10.4319/lo.1997.42.5.0938

Uehara-Prado, M., Brown, K., & Freitas, A. (2005). Biological Traits of Frugivorous Butterflies in a Fragmented and a Continuous Landscape in the South Brazilian Atlantic Forest. *Journal of the Lepidopterists' Society, 59*(2), 96-106.

Uehara-Prado, M., & Freitas, A. (2009). The effect of rainforest fragmentation on species diversity and mimicry ring composition of Ithomiini butterflies. *Insect Conservation and Diversity, 2*, 23-28. https://doi.org/10.1111/j.1752-4598.2008.00025.x

Urbano, P., Munevar, J., Mahecha-J., O., & Hincapié, E. (2014). Diversidad y estructura de las comunidades de Lepidoptera en la zona del ecotono entre el piedemonte llanero y sabana inundable en Casanare-Colombia (Lepidoptera: Papilionoidea). *SHILAP Revista de lepidopterología, 42*(167), 433-437.

Urbano, P., Mahecha-J., O., Suárez, E., Izquierdo, V., & Díaz-S., V. (2018). Variación temporal del ensamblaje de mariposas asociadas a la Cuenca de la Calaboza, Yopal, Casanare, Colombia (Lepidoptera: Papilionoidea). *SHILAP Revista de lepidopterologia, 46*(184), 533-550. https://doi.org/10.57065/shilap.745

Van Der Hammen, T., & Andrade-C., M. G. (2003). *Estructura Ecológica Principal de Colombia (Primera aproximación)*. Ministerio de Ambiente e Ideam.

Waltz, A. E., & Wallace-Covington, W. (2004). Ecological restoration treatments increase butterfly richness and abundance: mechanisms of response. *Restoration Ecology, 12*(1), 85-96. https://doi.org/10.1111/j.1061-2971.2004.00262.x

Warren, A. D., Davis, K. J., Stangeland, E. M., Pelham, J. P., & Grishin, N. V. (2013). *Illustrated Lists of American Butterflies*. http://www.butterfliesofamerica.com/

Weibull, A. C., Bengtsson, J., & Nohlgren, E. (2000). Diversity of butterflies in the agricultural landscape: the role of farming system and landscape heterogeneity. *Ecography, 23*, 743-750. https://doi.org/10.1034/j.1600-0587.2000.230611.x

Weyland, F., & Zaccagnini, M. (2008). Efecto de las terrazas sobre la diversidad de artrópodos caminadores en cultivos de soja. *Ecología Austral, 8,* 357-366.

While, A., & Whitehead, M. (2013). Cities, urbanisation and climate change. *Urban Studies, 50,* 1325-1331. https://doi.org/10.1177/0042098013480963

Williamson, M., & Gaston, K. J. (2005). The lognormal distribution is not an appropriate null hypothesis for the

species-abundance distribution. *Journal of Animal Ecology, 74,* 409-422. https://doi.org/10.1111/j.1365-2656.2005.00936.x
Wilson, J. B. (1991). Methods for fitting dominance-diversity curves. *Journal of Vegetation Science, 2*, 35-46. https://doi.org/10.2307/3235896
Zar, J. H. (1974). *Biostatistical Analysis*. Prentice Hall Inc.

*Oscar Mahecha-J.
Programa Académico de Biología
Facultad de Ciencias Matemáticas y Naturales
Universidad Distrital Francisco José de Caldas
Carrera 4 # 26 D – 31
Bogotá
COLOMBIA / *COLOMBIA*
E-mail: ojmahechaj@udistrital.edu.co
https://orcid.org/0000-0002-8682-0020

Vanessa Díaz-S.
Biogeografía y Ecología Evolutiva Neotropical BEEN
Universidad Distrital Francisco José de Caldas
Carrera 3 Nº 26A-40
Bogotá
COLOMBIA / *COLOMBIA*
E-mail: diazsvane@gmail.com
https://orcid.org/0000-0003-2938-2324

Alexander García-García
Grupo de Investigación en Artrópodos Kumangui
Universidad Distrital Francisco José de Caldas
Carrera 3 Nº 26A-40
Bogotá
COLOMBIA / *COLOMBIA*
E-mail: agarciag@udistrital.edu.co
https://orcid.org/0000-0001-9905-003X

Miguel Gonzalo Andrade-C.
Instituto de Ciencias Naturales ICN
Universidad Nacional de Colombia
Carrera 30, No. 45-03
Bogotá
COLOMBIA / *COLOMBIA*
E-mail: mgandradec@unal.edu.co
https://orcid.org/0000-0002-9181-4653

Tomasz W. Pyrcz
Department of Evolution of Invertebrates
Institute of Zoology and Biomedical Research
Jagiellonian University
Gronostajowa, 9
PL-30-387 Kraków
POLONIA / *POLAND*
E-mail: tomasz.pyrcz@uj.edu.pl
https://orcid.org/0000-0003-4822-0670

*Autor para la correspondencia / *Corresponding author*

(Recibido para publicación / *Received for publication* 14-XI-2024)
(Revisado y aceptado / *Revised and accepted* 5-V-2025)
(Publicado / *Published* 30-III-2026)

Table I. List of species of Papilionoidea butterflies found at the Serrania del Zuque with their respective abundances for each study station and the abundance total at the study area.

Family/ Subfamily	Species/Subspecies	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Abundance Total
Nymphalidae/ Satyrinae	*Corades chelonis* Hewitson, 1863*□	2	4	3	4	3	2	2	20
	Corades chirone Hewitson, 1863	0	0	0	2	2	3	1	8
	Corades cybele Butler, 1866	0	2	2	3	2	2	1	18
	Corades dymantis Thieme, 1907*□	4	3	3	2	2	1	0	15
	Corades medeba columbina Hewitson, 1850	1	2	2	3	2	1	1	12
	Daedalma dinias Hewitson, 1858	0	0	0	3	3	2	2	10
	Daedalma drusilla Hewitson, 1858	0	0	0	0	0	3	4	7
	Eretris apuleja bogotana E. Krüger, 1924*□	4	3	1	0	0	0	0	8
	Eretris n. sp.	0	0	3	4	3	2	2	14
	Forsterinaria difficilis (Forster, 1964)	2	3	2	3	1	0	0	11
	Idioneurula erebioides Felder, 1867*□	2	2	3	4	3	4	3	21
	Junea doraete (Hewitson 1858)	0	0	0	0	3	2	2	7
	Lasiophila circe C. Felder & R. Felder, 1859*□	0	3	3	4	3	2	1	16
	Lymanopoda ionius Westwood, 1851*□	0	3	3	2	3	2	2	15
	Lymanopoda lebbaea C. Felder & R. Felder, 1867	0	1	2	2	3	1	1	10
	Lymanopoda obsoleta Westwood, 1851	2	3	3	4	3	2	1	18
	Lymanopoda samius Westwood, 1851*□	4	3	4	5	4	3	2	25
	Manerebia apiculata (C. Felder & R. Felder, 1867)	0	2	3	2	3	2	1	13
	Manerebia levana (Godman, 1905)	0	0	0	2	3	3	4	12
	Panyapedaliodes drymaea Forster, 1964*□	0	3	4	4	4	3	2	20
	Pedaliodes polla Thieme, 1905* □	6	7	6	5	5	4	3	36
	Pedaliodes empusa C. Felder & R. Felder, 1867	2	3	5	4	2	2	0	18
	Pedaliodes cocytia (C. Felder & R. Felder, 1867) *□	0	1	2	4	6	6	6	25
	Pedaliodes ochrotaenia (C. Felder & R. Felder, 1867) *□	6	5	7	6	5	5	3	37
	Pedaliodes phoenissa (Hewitson, 1862)	3	5	5	4	4	3	2	26
	Pedaliodes polusca (Hewitson, 1862)	0	3	3	3	2	2	0	13

	Pronophila unifasciata bogotensis Lathy, 1906	2	3	0	0	0	0	0	5
	Steremnia pronophilia (C. Felder & R. Felder, 1867) *□	0	0	3	3	5	4	3	18
	Steroma bega andensis Westwood, [1851]	0	0	4	4	3	3	2	16
	Viloriodes manis (C. Felder & R. Felder, 1867) *□	0	4	5	4	5	4	3	25
Nymphalidae/ Nymphalinae	*Hypanartia kefersteini* (E. Doubleday, [1847])	2	3	2	2	1	0	0	10
	Vanessa virginiensis (Drury, 1773) *	2	4	2	3	2	2	2	17
Nymphalidae/ Heliconinae	*Altinote tinacria* (C. Felder & R. Felder, 1862 *	5	4	4	3	2	0	0	18
	Dione glycera (C. Felder & R. Felder, 1861) *	3	4	3	4	3	2	1	20
Pieridae/ Pierinae	*Catasticta chrysolopha* (Kollar, 1850) *	3	2	2	0	0	0	0	7
	Catasticta semiramis (Lucas, 1852) *	3	4	2	2	0	0	0	11
	Phulia xanthodice (Lucas, 1852) *	3	3	2	1	0	0	0	9
	Leodonta zenobia (C. Felder & R. Felder, 1865)	2	2	3	1	0	0	0	8
	Leptophobia eleone (E. Doubleday, 1847) *	4	2	2	2	0	0	0	10
Pieridae/ Coliadinae	*Colias dimera* Doubleday, 1847 *	5	4	4	5	4	4	3	29
Lycaenidae/ Theclinae	*Atlides havila* (Hewitson, 1865)	2	2	2	0	0	0	0	6
	Cyanophrys pseudolongula (Clench, 1944)	2	1	1	0	0	0	0	4
	Cyanophrys agricolor (Butler & H. Druce, 1872)	2	1	0	0	0	0	0	3
	Lamprospilus sp. Geyer, 1832	2	0	0	0	0	0	0	2
	Micandra aegides (C. Felder & R. Felder, 1865)	3	2	1	0	0	0	0	6
	Marachina maraches (H. Druce, 1912)	3	1	0	0	0	0	0	4
	Penaincisalia loxurina (C. Felder & R. Felder, 1865) *	4	3	3	0	0	0	0	10
	Rhamma commodus (C. Felder & R. Felder, 1865)	3	2	1	1	0	0	0	7
	Rhamma comstocki Johnson, 1992 *	2	3	1	0	0	0	0	6
	Salazaria sala (Hewitson, 1867)	2	2	0	0	0	0	0	4
Lycaenidae/ Polyommatinae	*Hemiargus hanno bogotana* Draudt, 1921*	3	2	0	0	0	0	0	5
Papilionidae/ Papilioninae	*Papilio polyxenes* Fabricius, 1775 *	0	2	2	0	0	0	0	4

* Mahecha-Jiménez (2008) also reported these species of Papilionoidea butterflies.

□ Mahecha-Jiménez et al. (2011) also documented these species of Pronophilina butterflies.