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Joxual J. Araque Pérez[1] & Jaime Navarrete-Rivas[2].

RESUMEN

Este estudio documenta la diversidad de polillas Saturniidae y Sphingidae en los bosques de transición pre-montanos del Cerro Quizaltepe, San Lorenzo, Boaco, Nicaragua, una zona previamente inexplorada. Durante la estación seca, se registraron 70 individuos de 25 especies, siendo *Manduca lefeburii* y *Dysdaemonia boreas* las más abundantes. Los análisis de uso de suelo identificaron amenazas de expansión agrícola, subrayando el valor de conservación de este sitio, que actúa como un refugio para especies de tierras bajas y de montaña. Estos resultados iniciales apuntan a que la temporada de lluvias podría incrementar la diversidad y abundancia de especies, destacando la necesidad de investigaciones estacionales y la relevancia del área como corredor ecológico y refugio para la conservación de especies.

Palabras clave: Diversidad de Lepidoptera, Saturniidae, Sphingidae, bosque premontano, Quizaltepe-Boaco.

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ABSTRACT

This study documents the diversity of Saturniidae and Sphingidae moths in the transitional premontane forests of Quizaltepe Hill, San Lorenzo, Boaco, Nicaragua, a previously unexplored area. During the dry season, 70 individuals representing 25 species were recorded, with *Manduca lefeburii* and *Dysdaemonia boreas* being the most abundant. Land-use analysis identified threats from agricultural expansion, underscoring the conservation value of this site, which serves as a refuge for both lowland and montane species. These preliminary results suggest that the rainy season could increase species diversity and abundance, highlighting the need for seasonal research and the importance of the area as an ecological corridor and refuge for species conservation.

Key Words: Moth diversity, Saturniidae, Sphingidae, premontane forest, Quizaltepe Boaco.

INTRODUCTION

The group commonly referred to as "Heterocera" encompasses approximately 147,415 species of nocturnal Lepidoptera (Amarillo, 2000), including the Saturniidae family, which is characterized by large-sized moths with an estimated 1,200–1,300 species worldwide (Heppner, 1991), 850 of which are found in the Neotropics (Scoble, 1992). Conversely, the Sphingidae family includes around 1,400 species across 200 genera, with members distributed across most continents (Kitching & Cadiou, 2000).

In tropical regions, data on moths are scarce, with assessments in Central America indicating a significant decline in macrolepidopteran species and abundances (Jansen & Hallwachs, 2021; Salcido *et al*., 2020). Moths respond to successional processes and habitat changes and function as ecological indicators (Lomov *et al*., 2006). They play a key role in food webs, supporting birds, bats, parasitoids, and parasites. Sphingids are essential pollinators, exhibiting seasonal patterns aligned with local flora (Haber & Frankie, 1989), while adult Saturniids do not feed (Janzen, 1984). These families serve as bioindicators of ecosystem health (Highland *et al*., 2013), highlighting their importance for understanding and preserving tropical biodiversity (Novotny *et al*., 2010).

In Nicaragua, moth research remains scarce. However, pioneering studies such as Maes (1998) provide a crucial foundation for further investigations and the documentation of new species records. The most comprehensive studies on Saturniidae and Sphingidae were conducted by Maes *et al*. (2001), whose species list could be expanded with new findings. As bioindicators, Tórrez *et al*. (2007) utilized the Sphingidae and Saturniidae families to assess

different habitat types, emphasizing the need for further research and conservation efforts. Studies on Saturniidae and Sphingidae remain limited, with little information available on their current status and conservation needs (Santos *et al.*, 2015)

Additionally, as one of the few remaining forest remnants in the San Lorenzo area, it may serve as a crucial refuge for numerous species, underscoring its ecological importance for conservation. The significance of these forest fragments, along with their shape and structure, is essential for preserving areas that serve as habitats for many endangered or at-risk species (Araque, 2023).

The primary objective is to document moth species in Quizaltepe Hill, an area that has not been previously sampled for faunal diversity. The site's unique orographic and climatic characteristics offer promising opportunities to identify and potentially discover moth species that are rare or absent in the department of Boaco. As a transitional zone between the Pacific and Caribbean regions of Nicaragua, it exhibits climatic conditions not found in other areas. However, the fragmentation of this zone, caused by livestock farming and agricultural boundaries, has resulted in the loss of its remaining forested areas.

MATERIALS AND METHODS

Location of the Study Area

The municipality of San Lorenzo, located in the department of Boaco, Nicaragua, is situated in the Central North region of the country. Between the coordinates 12.0340 and 12.4700 north latitude, and -84.5220 and -85.5912. Geographically, it forms part of the sub-basins of the Tecolostote and Malacatoya rivers, which drain their waters into Lake Nicaragua (Cocibolca), within basin 69, according to PREVDA, 2010.

Figure 1. Aerial view of Quizaltepe Hill, San Lorenzo – Boaco (Nicaragua) (photo © Milton Ñamendy).

The Quizaltepe hill area is located within the municipality of San Lorenzo, Boaco (Figure 1). This region is characterized by a diverse climate that ranges from very humid to semi-arid conditions, contributing to the variability in species abundance and diversity (PREVDA, 2010). The area is classified as a pre-montane zone with dry to semi-humid forest characteristics, as it serves as a transitional region between the drier Pacific side of Nicaragua and the wetter, more humid Caribbean side.

To characterize the area, meteorological data from NASA-Power, were utilized (https://power.larc.nasa.gov/), covering a 21-year period (2001-2022). The data indicate that average temperatures in the area range from 15°C to 26°C. This temperature variation is significantly influenced by trade winds from the Caribbean and Pacific regions of Nicaragua, shaping the microclimatic conditions observed in the study area (Figure 2).

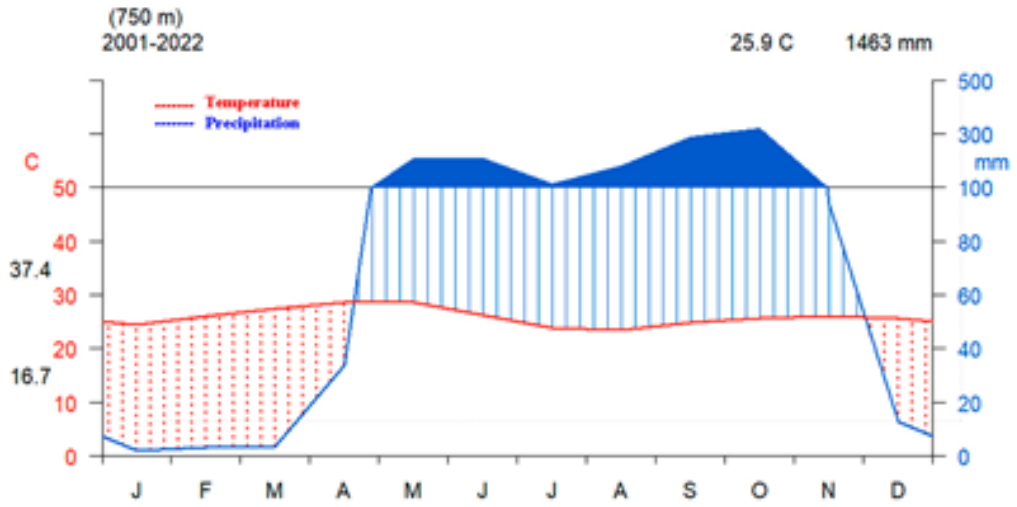

Figure 2. Climograph of Quizaltepe: Temperature and Precipitation Trends (2001-2022), showing the mean annual temperature (red line) and total annual precipitation (blue bars). The annual precipitation is 1463 mm, with significant monthly fluctuations, reaching up to 500 mm in some months (authors elaboration)

In figures 3, Finca Hilario highlights two distinct life zones according to Holdridge's classification: the Subtropical Moist Forest (Dry), shown in light brown, characterized by moderate humidity and a distinct dry season, and the Tropical Dry Forest (Cool), indicated in blue, which features cooler and drier conditions typically found in elevated tropical areas (Holdridge, 1967).

Maps and Graphs: All maps were created (Figure 3, 4) using QGIS software, version 3.28 (Firenze), The DEM/Elevation data were derived from the file n12_w086_1arc_v3 - DEM30M, downloaded from Earth Explorer. Graphs generated from the species collections were produced using R-Studio (R-Core Team, 2024).

Supervised Classification: Satellite images from Planet.com for December 2023, code (L15-0533E-1093N), were downloaded. The raster resolution is 4.7m per pixel. A virtual raster was created in QGIS with bands R:2, G:1, and B:3 to perform supervised classification and generate a land use cover map, (Figure, 4). The virtual raster (band combination) and the output model were used for classification using Random Forest through the Dzetsaka classification plugin in QGIS (Pollini, 2021).

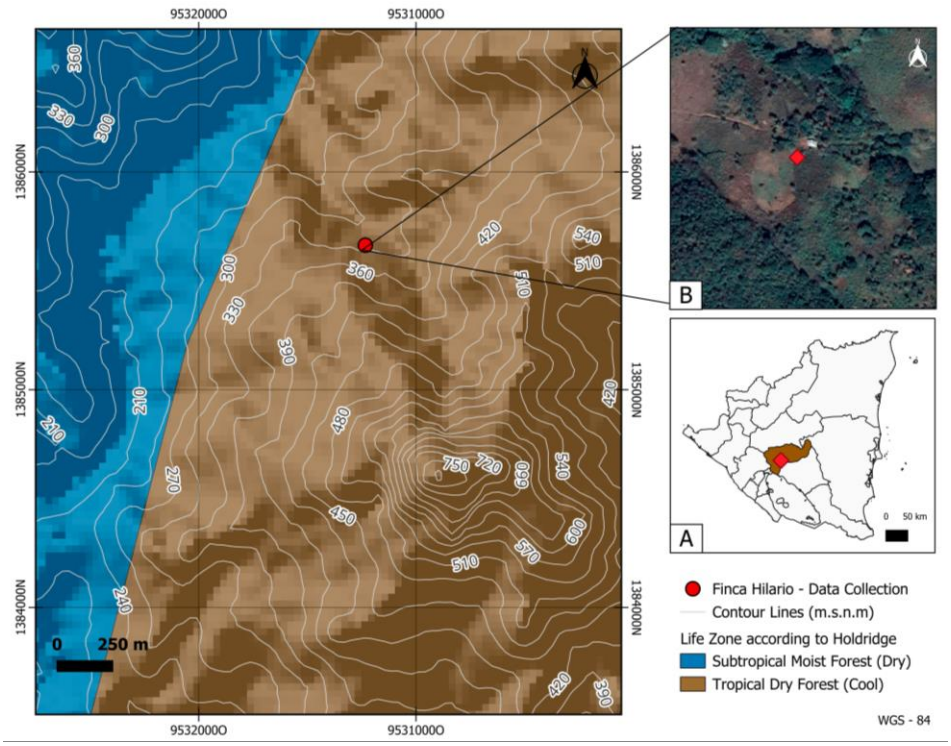

Figure 3. Topographic map of Finca Hilario with Life Zones According to Holdridge Classification. Source: authors elaboration based on WMS data from SIGportal (sica.int).

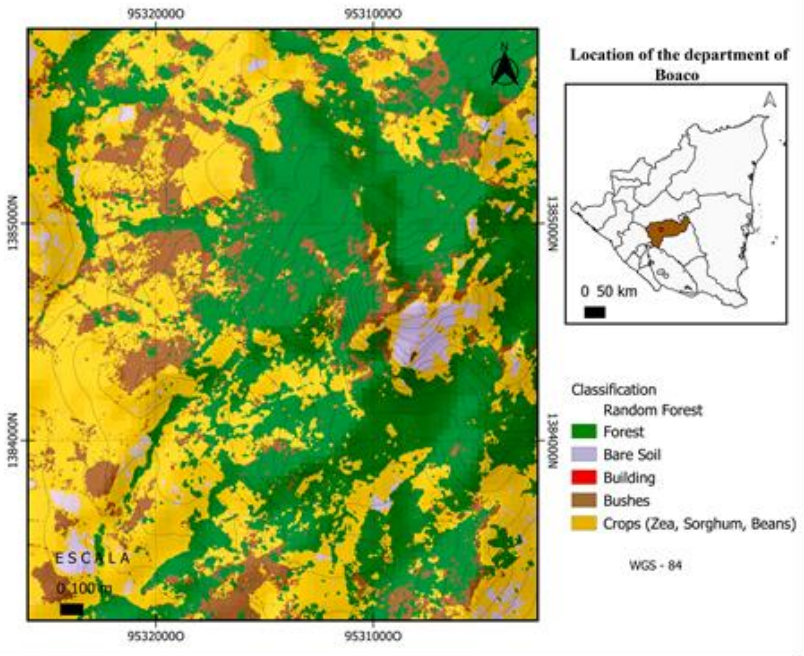

Figure 4. Land use classification from planet images. The green areas highlight that the surrounding area of the hill preserves the most vegetation, which could potentially harbor new species records.

Specimen capture: was conducted during the dry season in April and May 2024, with two sampling nights per month, each lasting 6 hours (four nights in total), for a total of 24 hours of sampling effort. Two light traps, each equipped with a 250W mercury bulb (MED), were used, powered by a transformer during the 6-hour nightly sessions over a square-shaped white cloth. The traps were set at coordinates 12.34947, -85.61934, at an elevation of 330 meters above sea level. Moths were euthanized using ethyl alcohol injected into the thorax with a 3-cc syringe and were subsequently stored in labeled paper triangles (Figure 5).

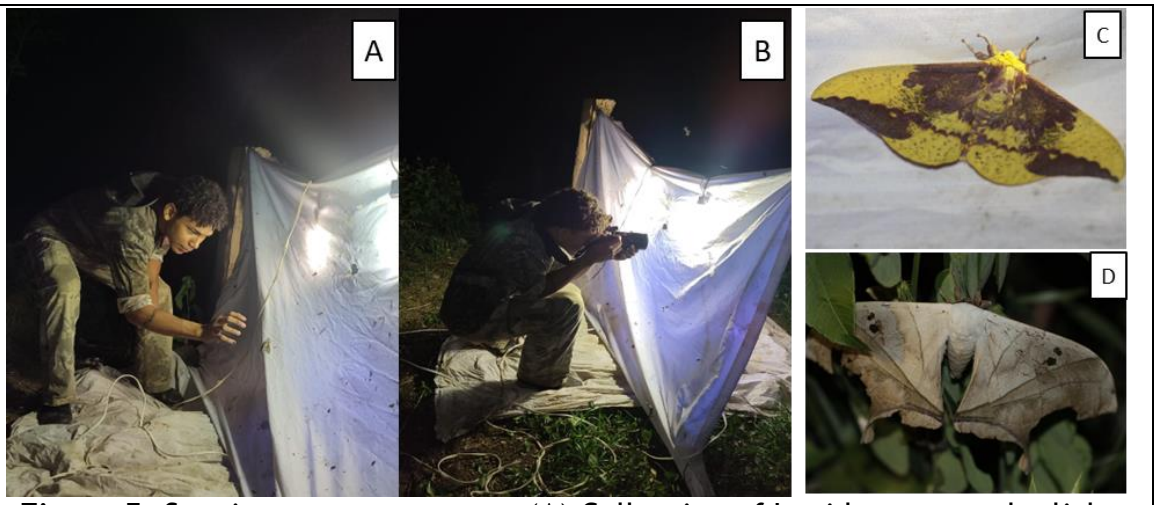

Figure 5. Species capture process: (A) Collection of Lepidoptera at the light trap; (B) Photographic records during trapping; (C) *Eacles imperialis* on the sheet of the light trap; (D) *Dysdaemonia boreas* beneath the light trap.

Identification: Species identification was performed based on references including Maes *et al*. (2001), Chacón & Montero (2007), Tórrez *et al*. (2007), Maes (2007), AGG (2016), and the Online Lepidoptera Catalog (BioNica, 2024). Photographs of the specimens were uploaded to the iNaturalist.org database for dual verification, allowing expert community members to review and correct the scientific names of some species. Photographs were taken with a Canon EOS Rebel T7 camera, a Laowa 100mm lens, and an external flash donated by IdeaWild.org.

RESULTS

A total of 70 individuals and 25 species were captured, demonstrating that ***Manduca lefeburii*** is the most abundant species, with 11 individuals recorded, followed by ***Dysdaemonia boreas*** with 8 individuals. On the other hand, several species, such as ***Caio championi***, ***Cautethia spuria***, and ***Erynnyis crameri***, were represented by only one individual (Figure 7).

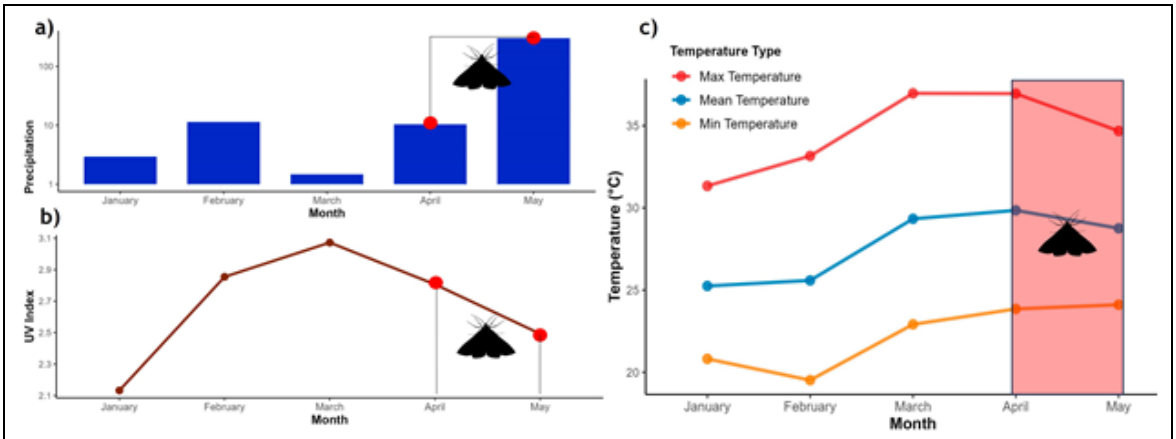

Figure 6. Monthly variation of climatic variables in the study region. (a) Precipitation (blue bars). (b) UV Index (brown line). (c) Maximum, mean, and minimum temperatures (red, blue, and orange lines, respectively). (Species were collected in April and May).

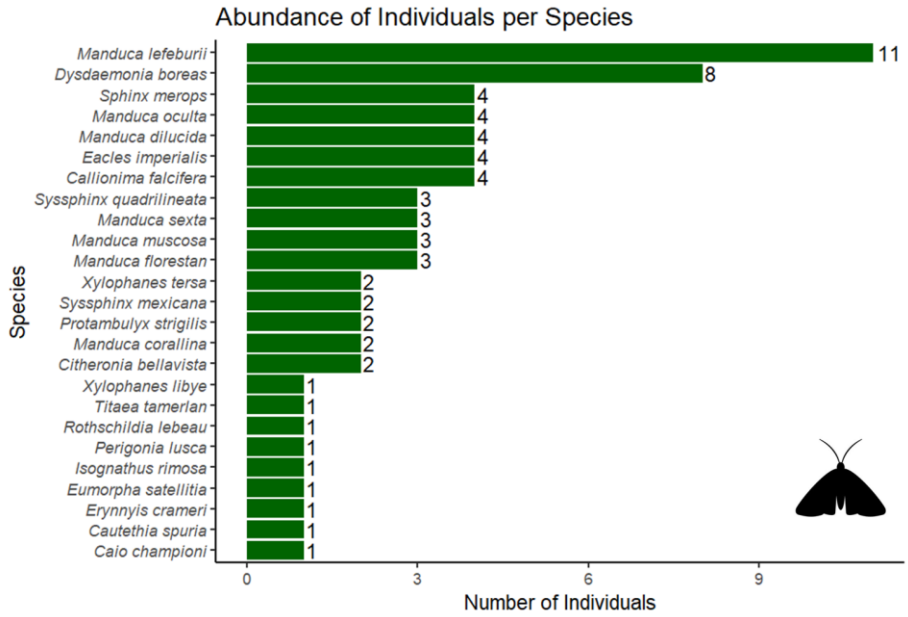

Figure 7. Species captured in the study area indicating the number of individuals captured.

The land use classification (Figure 4) indicates that the expansion of crops, primarily maize and sorghum, is significant in the area and may continue to spread, leading to a reduction in premontane forest cover. Future studies should focus on analyzing forest fragmentation and its ecological impacts. Additionally, this area holds great potential for ecotourism, had not been unsampled in terms of its entomological fauna, a photographic catalog was created to document the species captured during the study (Figure,9,10,11,12 & 13).

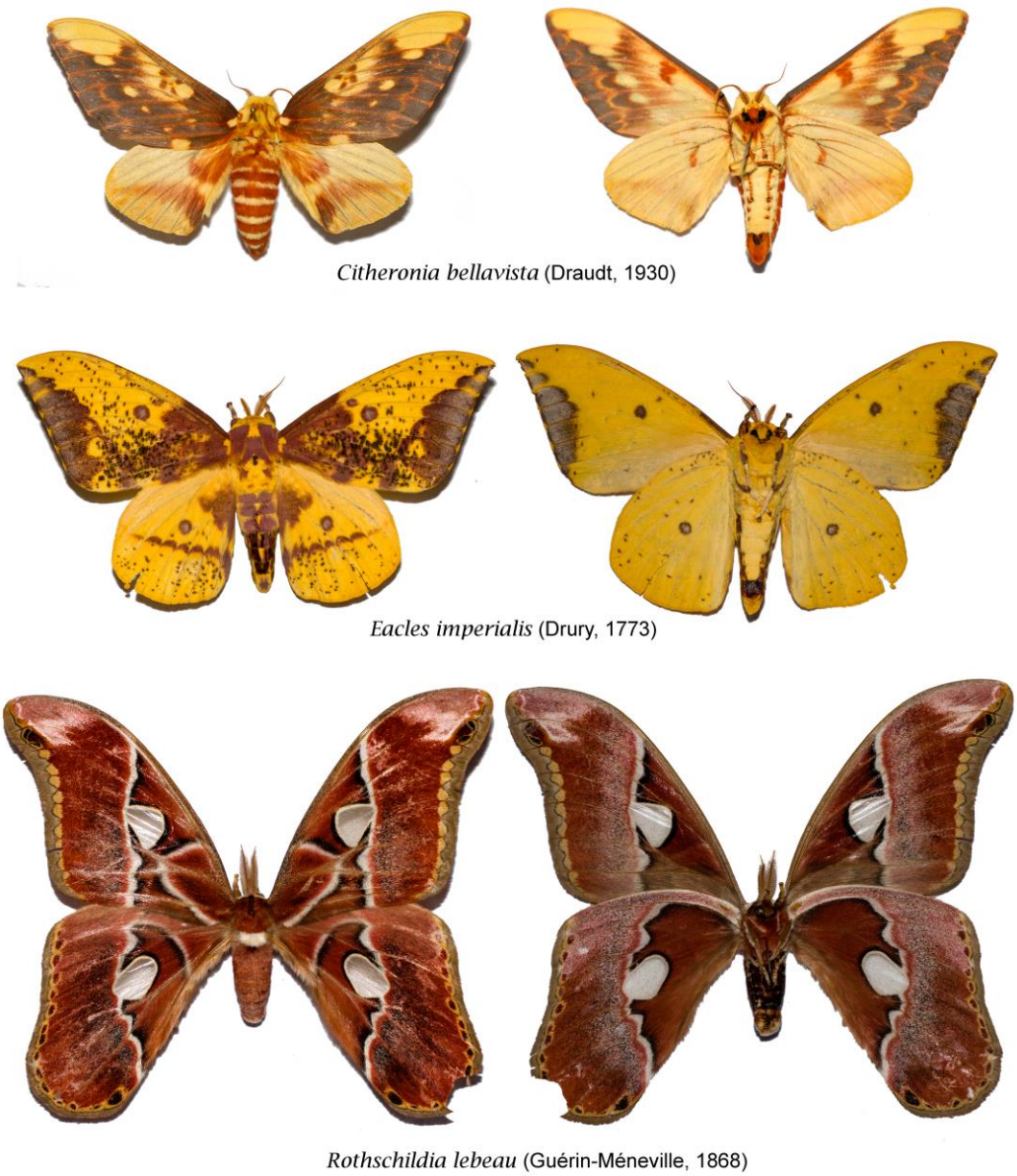

Figure 8. Photographic catalog, Moths of Quizaltepe hill, Boaco.

Titaea tamerlan nobilis (Schaus, 1912)

Caio championi (Druce, 1886)

Dysdaemonia boreas (Cramer, 1775)

Figure 9. Photographic catalog, Moths of Quizaltepe hill, Boaco.

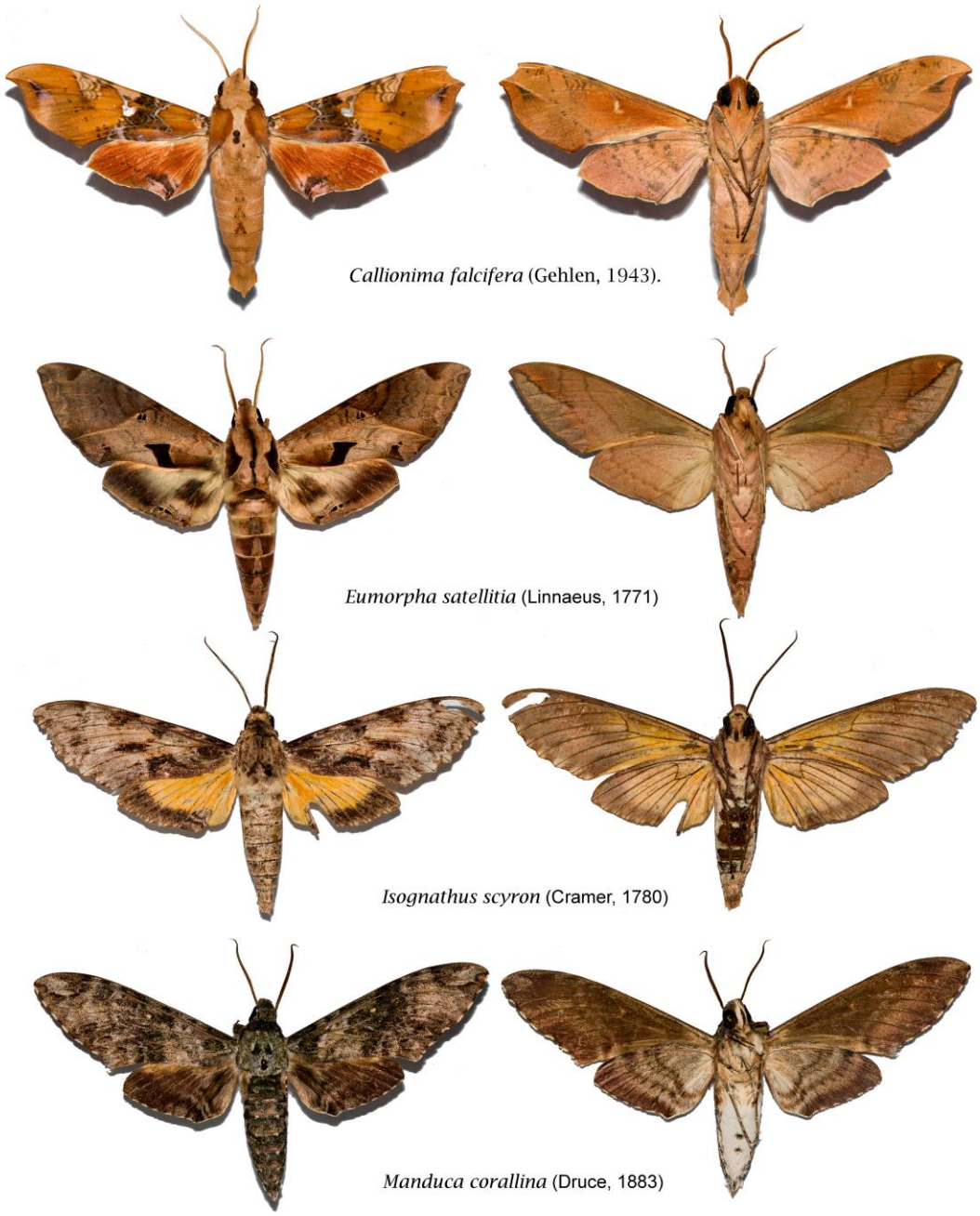

Figure 10. Photographic catalog, Moths of Quizaltepe hill, Boaco.

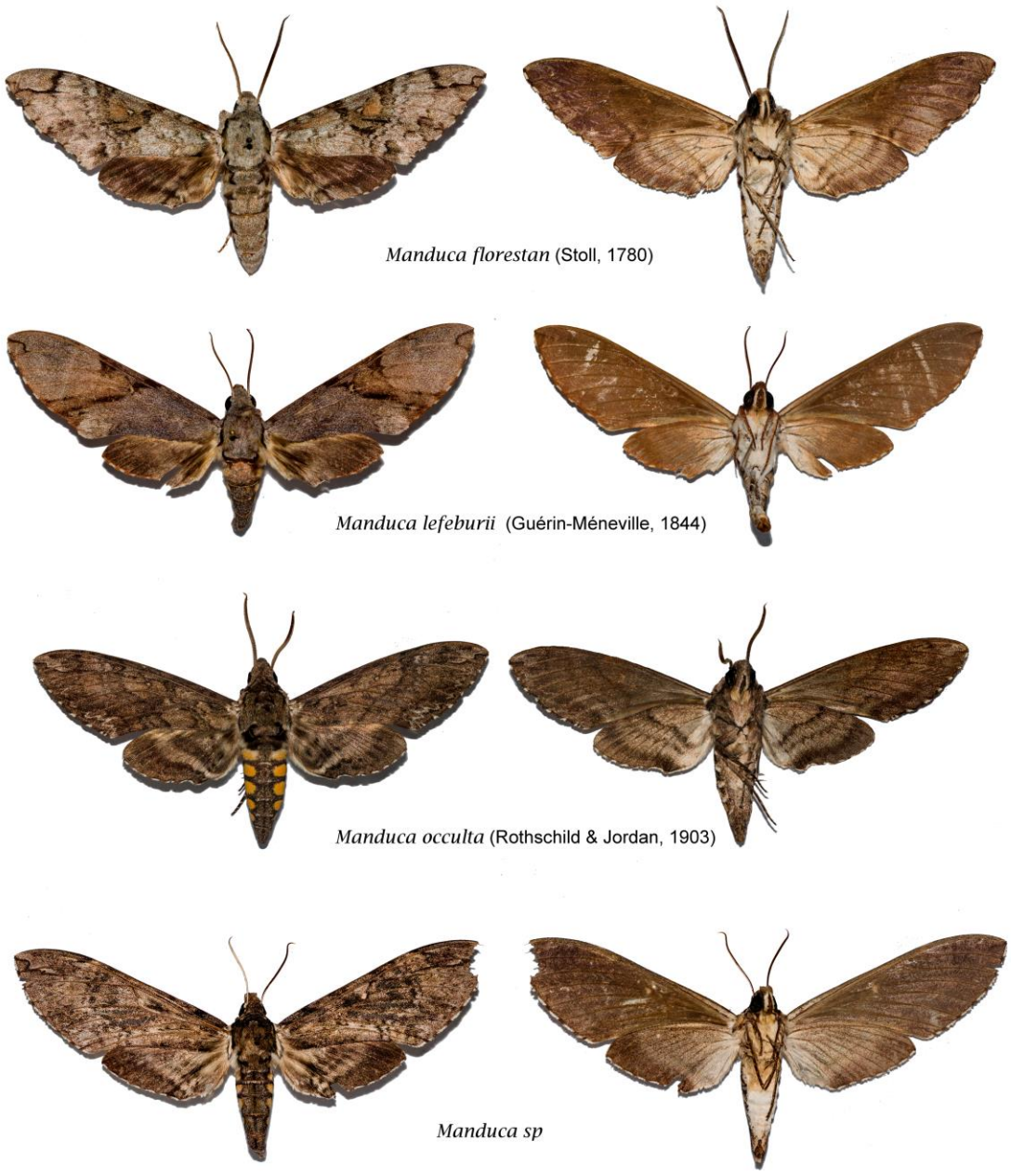

Figure 11. Photographic catalog, Moths of Quizaltepe hill, Boaco.

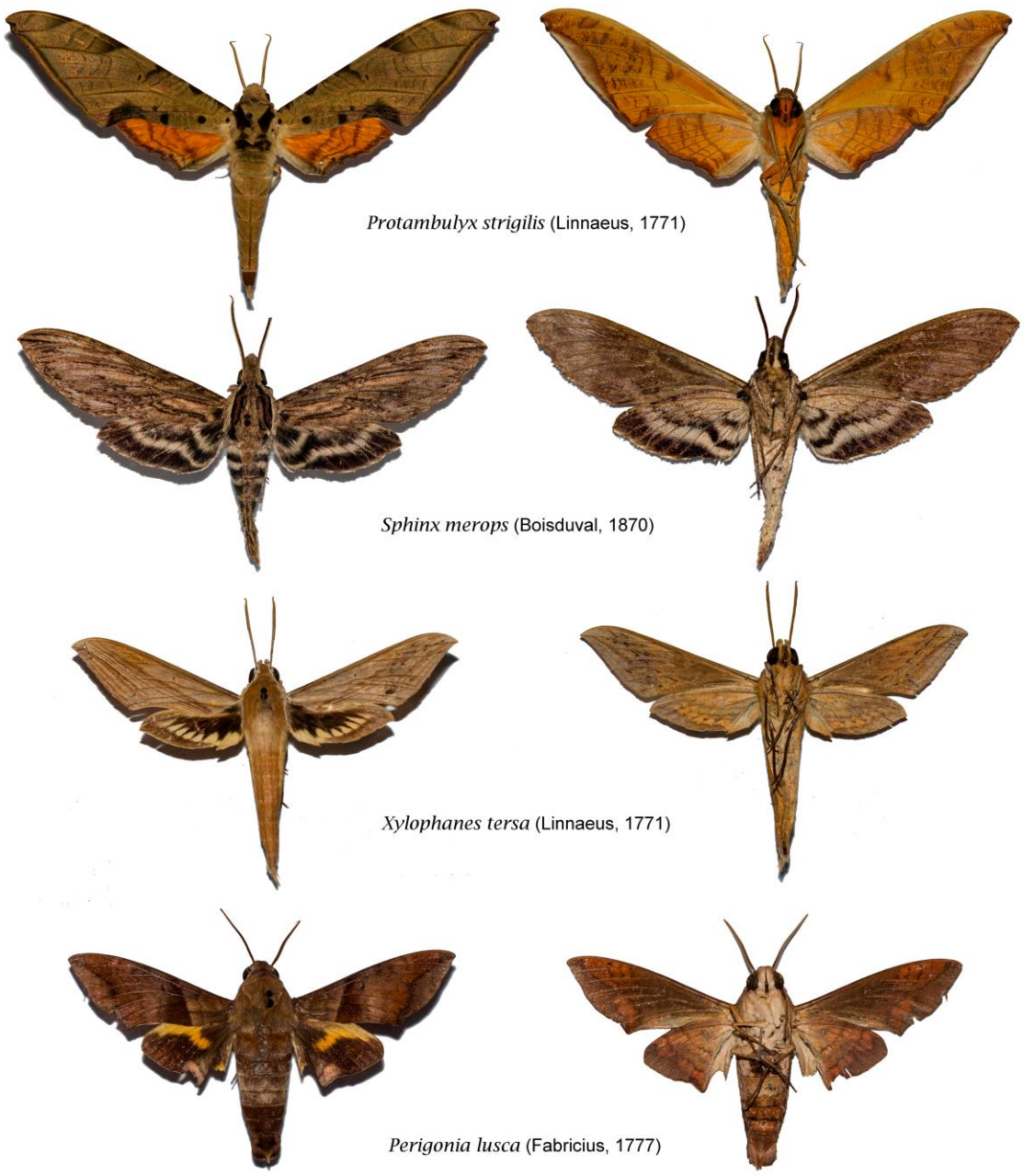

Figure 11. Photographic catalog, Moths of Quizaltepe hill, Boaco.

Temperature were extracted, providing a record of the temporal climatic parameters of the area, as meteorological station data for the country is not available. As shown in Figure 6, the collection points were established at the beginning of the rainy season. The average monthly rainfall is 120 mm for the study area, with temperature ranges from 27 to 30°C. During these months, due to cloud accumulation, solar radiation is lower.

DISCUSSION

The genera *Callionima*, *Eumorpha*, *Manduca*, and *Protambulyx* are predominantly found in lowland areas, as noted by Sublett *et al.*, 2019. However, captures made on Cerro Quizaltepe during the dry season not only include lowland species but also mountain and humid area species, as detailed in Table 1. This indicates that the area retains a diversity of plant species that support a rich biodiversity, positioning the site as a transition zone. Conducted during the dry season, and considering that the conditions of the area (Quizaltepe) favor many species to take refuge or distribute themselves in the region. It is expected that a greater number of individuals and species will be recorded during the rainy season, when climatic conditions are more favorable for insect activity (Lara-Pérez *et al.*, 2017).

Table 1. Characterization of some individuals captured, based on the area.

Species	Individuals	Area	Cited
Caio championi	1	LowLand	Sublett *et al.*, 2019
Callionima falcifera	4	Tropicopolitan	Ignatov *et al.*, 2011
Erynnyis crameri	1	Hills/Mountain	
Eumorpha satellitia	1	Hills/Mountain	
Isognathus rimosa	1	Tropicopolitan	
Manduca corallina	2	LowLand	Sublett *et al.*, 2019
Manduca dilucida	4	LowLand	
Manduca florestan	3	LowLand	
Manduca lefeburii	11	LowLand	
Manduca muscosa	3	LowLand	
Manduca oculta	4	LowLand	
Manduca sexta	3	LowLand	Ignatov *et al.*, 2011
Perigonia lusca	1	Hills/Mountain	
Protambulyx strigilis	2	LowLand	
Xylophanes libye	1	LowLand	
Xylophanes tersa	2	Tropicopolitan	

Conservation efforts in this area have allowed it to function as a refuge for many species during the dry season, and species richness and abundance are likely to increase during the rainy season. Future research could confirm the presence of endemic species from humid forests within this study area. The observed ranges of climatic variables provide a baseline, as fluctuations in species richness and abundance may result from factors such as land use changes, climate change (e.g., temperature increases), or disturbances like burning (Kocsis & Hufnagel, 2011), all of which could influence species composition in both the dry and rainy seasons.

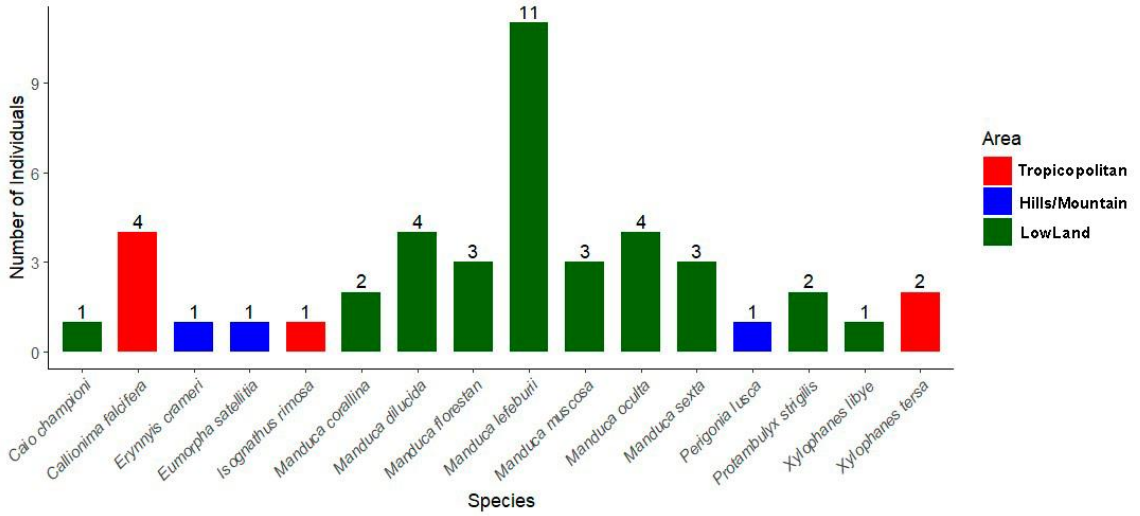

Figure 12. Distribution of species found in the study by area (Tropicopolitan, Lowland, Hill/Mountain), based on the studies by Ignatov *et al.*, 2011, and Sublett *et al.*, 2019.

Transitional plant communities may provide food sources for both montane and lowland hawkmoths. Beck & Chey (2008) found positive correlations between moth and plant species richness. Suggesting that during the dry season, more humid areas on the hill (Quizaltepe) could harbor species absent from drier zones. Mountains, with their environmental gradients such as temperature and habitat in small areas, facilitate biodiversity studies with high reproducibility and enable pattern comparisons across various habitats and latitudes (Beck and Kitching, 2009; Malhi *et al.*, 2010).

Boggs & Murphy (1997) emphasized the critical influence of weather conditions, particularly temperature and precipitation, on the availability of food resources, which in turn affects species distribution. They pointed out that habitat type significantly determines species presence, while both precipitation and elevation are key factors in shaping community composition.

Due to the altitudinal and microclimatic gradient of Cerro Quizaltepe, ranging from 300 to 750 meters above sea level, a greater diversity of species and individual counts may be observed across different seasons.

Additionally, the area's microclimate is further enriched by the presence of four springs, enhancing local biodiversity. This zone serves as a transitional area between dry and humid forests. The preliminary findings, documenting 25 species during the dry season, likely represent just a fraction of the actual moth community structure in the study area.

CONCLUSION

During the investigation, the presence of 25 moth species was recorded, representing only a fraction of the estimated total due to sampling during the dry season. It is suggested that a greater diversity of species could be observed during the rainy season. Additionally, land-use classification maps were generated, providing a foundation for future research. It is essential to consider the influence of altitudinal gradients, as Quizaltepe Hill, with its forest strata and fragments, possesses high ecological value, serving as a refuge for species adapted to both dry and humid climates. These results highlight the need for further studies to better understand the dynamics of moth communities across seasons and to confirm the area's potential for species conservation.

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