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Article

Diversity of pollinating butterflies of native plants in the biological corridor of La María campus, Mocache, Ecuador

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Abstract: The conservation of pollinators is essential to maintain ecological stability and the reproduction of native plants, especially in tropical regions where habitat fragmentation compromises key ecological interactions. Among these organisms, butterflies stand out for their functional diversity and adaptability in disturbed environments. This study evaluated the diversity of pollinating butterflies in the biological corridor of the La María campus (Mocache, Ecuador), through systematic transect sampling during the dry season of 2024. Direct observation and capture using an entomological net were employed, recording nine taxa belonging to different families of Lepidoptera. Morphological characterization revealed adaptations for flight and defensive mechanisms such as mimicry, camouflage, and aposematism. The analysis of relative incidence showed that *Heliconius* sp. was the dominant species (25.00 ± 0.87%), followed by *Phoebis philea* and other taxa with lower incidences. The community structure exhibited a specific richness of S = 9, a Shannon index (H′) of 2.08, and a Pielou's evenness (J) of 0.9825, indicating high alpha diversity with an equitable species distribution. Additionally, six plant species were identified as associated with butterfly pollination activity, among them *Lantana camara* and *Silphium asteriscus* being the most incident. The plant community showed intermediate diversity (H′ = 1.57; 1 − D = 0.78). The results reinforce the ecological value of biological corridors as reservoirs of biodiversity and promoters of functional interactions in fragmented tropical ecosystems.

Keywords: pollinating butterflies, native plants, ecological indices, conservation

Resumen: La conservación de los polinizadores es esencial para mantener la estabilidad ecológica y la reproducción de plantas nativas, especialmente en regiones tropicales donde la fragmentación del hábitat compromete interacciones ecológicas clave. Entre estos organismos, las mariposas destacan por su diversidad funcional y adaptabilidad en ambientes perturbados. Este estudio evaluó la diversidad de mariposas polinizadoras en el corredor biológico del campus La María (Mocache, Ecuador), mediante muestreo sistemático por transectos durante la estación seca de 2024. Se emplearon observación directa y captura con red entomológica, registrándose nueve taxones pertenecientes a diferentes familias de Lepidoptera. La caracterización morfológica reveló adaptaciones para el vuelo y mecanismos defensivos como mimetismo, camuflaje y aposematismo. El análisis de incidencia relativa mostró que *Heliconius* sp. fue la especie dominante (25,00 ± 0,87%), seguida de *Phoebis philea* y otros taxones con incidencias menores. La estructura comunitaria presentó una riqueza específica de S = 9, un índice de Shannon (H′) de 2,08 y una equidad de Pielou (J) de 0,9825, lo que indica alta diversidad alfa con una distribución equitativa de especies. Además, se identificaron seis especies vegetales asociadas a la actividad polinizadora de mariposas, entre ellas *Lantana camara* y *Silphium asteriscus* como las de mayor incidencia. La comunidad vegetal mostró una diversidad intermedia (H′ = 1,57; 1 − D = 0,78). Los resultados refuerzan el valor ecológico de los corredores biológicos como reservorios de biodiversidad y promotores de interacciones funcionales en ecosistemas tropicales fragmentados.

Palabras clave: mariposas polinizadoras, plantas nativas, índices ecológicos, conservación

1. INTRODUCTION

Pollinator biodiversity, particularly that of butterflies, is fundamental for maintaining the structure and functionality of ecosystems, especially in tropical regions such as the humid forests of Ecuador (Galetto et al., 2022). Butterflies not only represent a key group of insects in terms of biological diversity, but also play a crucial role in the pollination of numerous plant species, facilitating fertilization and promoting genetic variability within plant populations (Ammir et al., 2024).

This pollination process is essential for the conservation of native plants, which in turn provide habitat and food resources for multiple animal species, including other insects, birds, and mammals (Duque-Trujillo et al., 2023). In the context of the biological corridor of the La María campus, located in the Mocache canton of Ecuador, the interaction between butterfly diversity and native plants has not been sufficiently explored. This area encompasses a variety of ecosystems that host high biodiversity of both flora and fauna, making it an ideal setting to study pollination patterns in the tropics. Understanding the relationship between butterflies and native plants is vital for the development of effective conservation strategies and sustainable management of natural resources (Ancillotto et al., 2024).

The biological corridor of the La María campus offers a unique opportunity to study local ecological dynamics, particularly the interaction between pollinators and native plants (Parra-Tabla & Arceo-Gómez, 2021). A detailed understanding of butterfly diversity and their role in pollination will not only enhance our comprehension of ecological processes in this ecosystem, but also provide relevant information for the conservation of plant species that rely on these pollinators for reproduction (Patil et al., 2024). Furthermore, this study may yield valuable data on the vulnerability of plant communities in the face of declining pollinator populations a phenomenon threatening global biodiversity due to factors such as climate change, habitat destruction, and pollution (Kantsa et al., 2023).

This study aims to assess the diversity of butterflies present in the biological corridor of the La María campus and to analyze their role in the pollination of native plants in the region. Using entomological and floristic methods, we seek to identify butterfly species that interact with native flora, determine the plant species most dependent on these pollinators, and evaluate pollination effectiveness based on butterfly richness and abundance. The results of this study will not only support biodiversity conservation in the region but will also provide a solid scientific foundation for future research on pollinators in tropical ecosystems.

2. METHODOLOGY

Study Area

The study was conducted in the biological corridor of the La María campus, part of the Universidad Técnica Estatal de Quevedo, located in Mocache canton, Los Ríos province, Ecuador. This area comprises a mosaic of secondary vegetation and agroforestry crops transitioning toward ecologically restored systems. The geographical coordinates of the sampling site are 1°01′30″S, 79°27′15″W, with an average elevation of 35 meters above sea level.

Butterfly Sampling

Systematic sampling was carried out during the dry season of 2024, using 100-meter linear transects within the corridor. Each transect was surveyed three times daily (08:00–10:00, 11:00–13:00, and 15:00–17:00) for three consecutive weeks. Butterflies were recorded both visually and through net capture using a standard 38 cm diameter entomological net, following the protocols of Pollard and Yates (1993). Specimens were handled with entomological forceps and placed in individual collection containers for further analysis.

Morphological Identification

Morphological characterization was performed at the Biology Laboratory of UTEQ. Specimens were anesthetized in a cold chamber (4 °C) and then photographed using a Canon digital camera equipped with a 100 mm macro lens. Wing structures (shape, venation, dorsal and ventral coloration, presence of tails or eyespots), body size, antenna shape, and observed flight patterns were assessed. Taxonomic identification was based on specialized keys for Neotropical Lepidoptera (DeVries, 1987; Lamas, 2004) and compared with reference specimens from the Natural History Museum of the National Institute of Biodiversity (INABIO). Genus and species were determined when possible, and specific traits relevant to mimicry, camouflage, or aposematism were recorded.

Recording and Documentation

Photographs were organized and coded with letters (A–I) for inclusion in representative figures. Each image was standardized with controlled lighting, neutral background, and visible metric scale. Morphological data were tabulated for subsequent descriptive analysis, focusing on functional diversity associated with pollination adaptations in human-impacted tropical ecosystems.

Relative Incidence

In each sampling unit, the number of individuals of each observed species was recorded during the designated time intervals, considering both flying individuals and those perched on vegetation. Data were normalized by calculating the relative incidence percentage for each species using the formula:

$$Relative\ incidence\ (\%) = \left(\frac{ni}{N}\right) X100$$

Where n_i represents the number of individuals of species *i*, and *N* is the total number of individuals recorded across all sampling units. Each estimation was replicated in three independent plots to ensure data representativeness.

Statistical analysis of differences among species was performed using one-way ANOVA, followed by Tukey’s post hoc test for mean comparison ($p < 0.05$), in order to identify statistically significant groupings. All analyses were conducted using R software, employing the agricolae package for the post hoc test application.

Ecological Diversity Analysis

The assessment of butterfly ecological diversity in the biological corridor of the La María campus was based on data obtained from the standardized samplings described previously. For this analysis, only individuals taxonomically identified to the genus or species level were considered, ensuring precision in the calculation of ecological indices. Data were systematized by sampling unit (1 m^2) and processed using commonly accepted alpha diversity metrics in biological community studies.

Species richness (*S*) was estimated as the total number of distinct species recorded during the sampling period, serving as a basic measure of taxonomic composition. Diversity was quantified using the Shannon–Wiener index (*H′*), which incorporates both species richness and the relative abundance of individuals, allowing for the evaluation of community structural complexity. In parallel, Pielou’s evenness index (*J*) was calculated to express how evenly individuals are distributed among the species present, by normalizing the *H′* value in relation to the total number of species.

To complement the analysis, the Simpson index (*1 − D*) was used to measure the probability that two randomly selected individuals belong to different species. This index is particularly useful for detecting ecological dominance within the evaluated community. Additionally, maximum relative abundance was calculated, defined as the percentage represented by the most frequent species in relation to the total number of individuals recorded, serving as an indicator of localized dominance while accounting for overall system equity.

All calculations were performed using PAST software version 4.03 and the R statistical environment version 4.3.1, specifically with the support of the vegan package. The resulting values enabled the interpretation of the ecological structure of the lepidopteran community and its degree of resilience within a human-impacted tropical ecosystem.

3. RESULTS

3.1. Morphological Characterization

The morphological characterization of butterflies observed in the biological corridor of the La María campus at Universidad Técnica Estatal de Quevedo documented a representative diversity of species associated with pollination processes in disturbed tropical ecosystems. In total, nine taxa were recorded, corresponding to various genera and families of Lepidoptera, with detailed wing structures and color patterns illustrated in Figure 1.

The specimen identified as *Papilio cresphontes* (Figure 1A), belonging to the family Papilionidae, is distinguished by its considerable wingspan, black coloration with creamy yellow spots, and prominent tails on the hindwings—features associated with defensive and mimetic adaptations. *Agraulis vanillae* (Figure 1B), a member of the Nymphalidae family, exhibits bright orange wings with scattered black spots, a morphology typical of fast-flying butterflies commonly found in open environments.

Specifically, *Dryas iulia* (Figure 1C) shows elongated wings with a uniform orange tone and no contrasting markings, a feature related to camouflage strategies in dry vegetation habitats. In contrast, *Anartia jatrophae luteipicta* (Figure 1D) displays eye-like patterns on both wings with light and dark brown tones that create an illusion of depth, serving as a deterrent mechanism against predators.

Moreover, *Urbanus proteus* (Figure 1E), from the Hesperiidae family, exhibits a compact morphology with triangular forewings in a greenish-brown color and an elongated abdomen—traits that promote an erratic and rapid flight. Specimen F was classified within the genus *Lasaia* (Riodinidae) and features iridescent metallic blue coloration on the dorsal wings with dark margins, a trait common in territorial species.

Likewise, *Phoebis philea* (Figure 1G), belonging to the Pieridae family, was easily recognized by its uniformly yellow, elliptically shaped wings, and lack of visible dorsal markings, enhancing its mimicry of senescent leaves. The genus *Heliconius* (Figure 1H) was represented by a specimen with black wings and transverse white bands—an aposematic pattern linked to chemical defense and Müllerian mimicry in Neotropical environments.

Finally, the butterfly classified within the genus *Danaus* (Figure 1I) exhibited bright orange coloration with black venation and white marginal spots, forming a classic Batesian mimicry pattern that imitates toxic species such as *Danaus plexippus*.

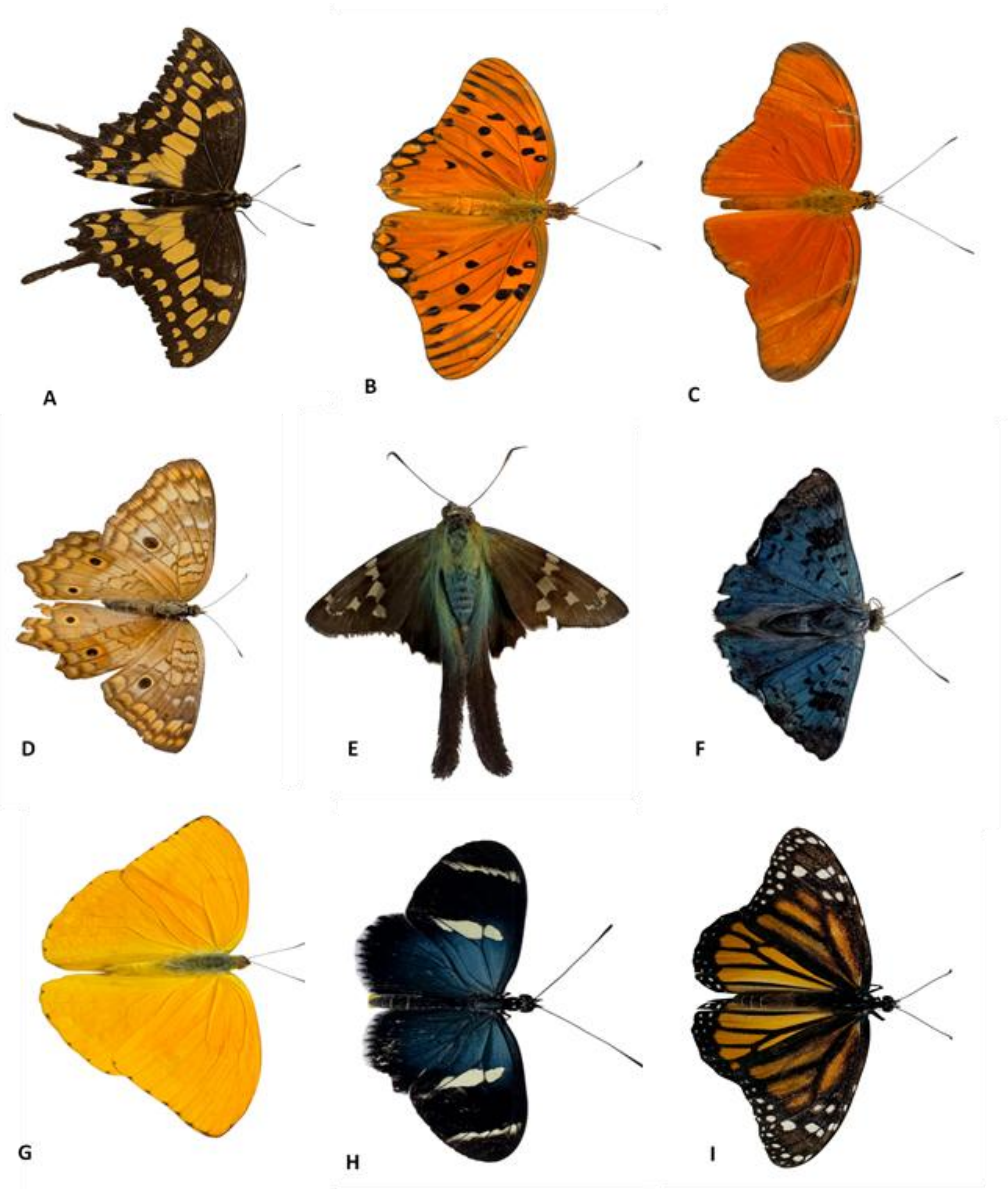

Figure 1. Morphological characterization of butterflies associated with the pollination of native plants in the La María Biological Corridor, Mocache, Ecuador. The images show the butterflies observed during the study, identified by letters from A to I. The photographs were taken under controlled conditions to illustrate the complete morphology of each species and their relevance in the pollination process.

3.2. Relative Incidence

The analysis of butterfly relative incidence per square meter in the biological corridor of the La María campus revealed significant differences ($p < 0.05$) among the observed species (Figure 2). The species with the highest incidence was *Heliconius* sp., with an average value of 25.00 ± 0.87%, statistically surpassing all other analyzed species, thus establishing itself as the dominant taxon within the sampling system. *P. philea* showed the second highest incidence, with a value of 16.67 ± 0.65%, also significantly different from the remaining species.

In particular, *Dryas iulia*, *A. jatrophae*, and *D. plexippus* exhibited intermediate incidence values, ranging between 11.80% and 12.50%. These species were statistically grouped within the same range, suggesting a relatively uniform distribution among these taxa.

In contrast, *U. proteus* showed a lower incidence (8.33 ± 0.34%), differing from the intermediate group. Finally, *P. cresphontes*, *A. vanillae*, and *Lasaia* recorded the lowest incidence values, all below 5%, with no significant differences among them, indicating marginal presence within the study area. These results reflect a lepidopteran community structure where few species exhibit high relative abundance, while the majority are less frequently distributed.

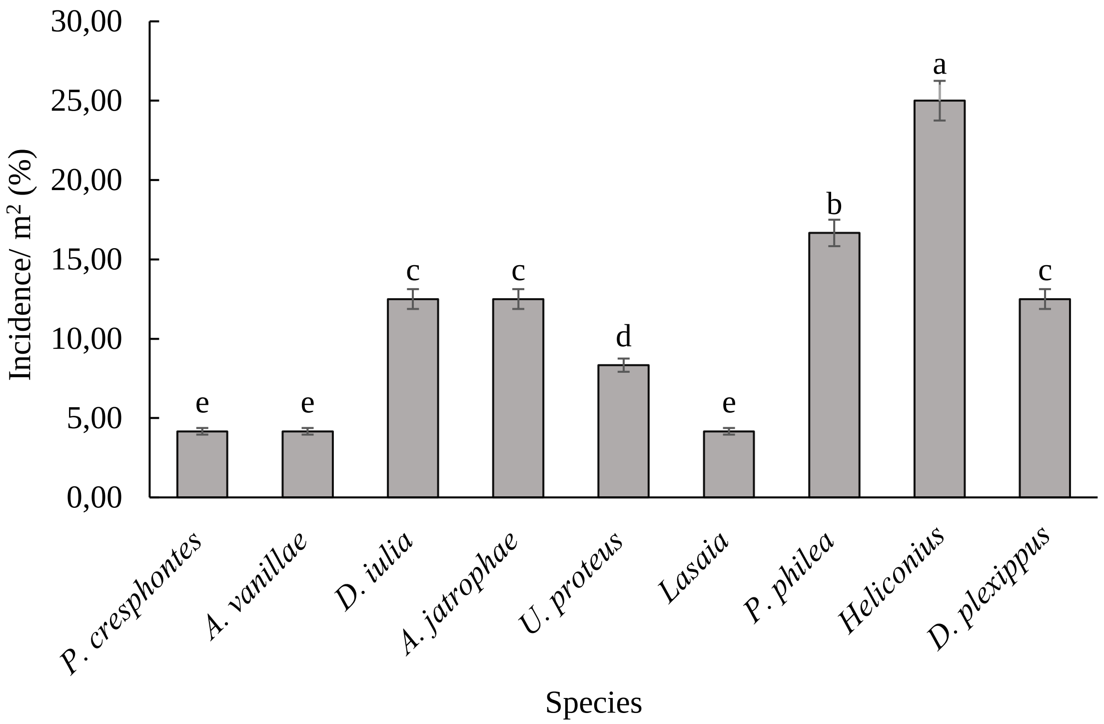

Figure 2. Relative incidence (%) of butterfly species per square meter (m²) recorded in the biological corridor of the La María campus, Universidad Técnica Estatal de Quevedo. Bars represent the mean ± standard error (n = 3). Different letters above the bars indicate significant differences among species according to Tukey's test ($p < 0.05$).

3.3. Lepidopteran Ecological Diversity

The diversity indices calculated for the butterfly community in the biological corridor of the La María campus revealed high heterogeneity and evenness in species distribution (Table 1). Species richness (*S*) was 9, indicating a community with relatively broad composition for a human-impacted environment.

The Shannon index (*H′* = 2.08) indicated moderately high alpha diversity, reflecting not only the number of species present but also a relatively even distribution of individual abundance. This result was supported by Pielou's evenness index (*J* = 0.9825), which shows that species are equitably represented in the community, with no strong dominance by a single taxon.

The Simpson index (*1 − D* = 0.8722) also confirmed this pattern, indicating a high probability that two randomly selected individuals belong to different species. Additionally, the maximum relative abundance was 24%, corresponding to the *Heliconius* species, which was the most frequently observed in the surveys, though it did not exert absolute ecological dominance.

Table 1. Ecological diversity indices for the butterfly community recorded. Shown are maximum relative abundance (%), species richness (*S*), Shannon diversity index (*H′*), Pielou's evenness index (*J*), and Simpson diversity index (*1 − D*), calculated based on counts per square meter (m²).

Index	Value
Maximum relative abundance (%)	24
Specific wealth (S)	9
Shannon Index (H′)	2,08
Pielou's fairness index (J)	0,9825
Simpson's Index (1 − D)	0,8722

3.4. Morphological Identification of Plant Species

During the sampling in the biological corridor of the La María campus, six plant species were identified whose foliar and floral morphology suggests a high level of interaction with native and visiting butterflies in the ecosystem. Figure 4 displays the vegetative (leaves) and reproductive (flowers) structures of these species, captured under controlled conditions to highlight their diagnostic features.

Species (A) *Musa velutina* was characterized by large leaves with an entire blade and prominent parallel venation, along with a terminal inflorescence bearing pink bracts and fleshy fruits. (B) *Silphium asteriscus* exhibited an alternate arrangement of simple lanceolate leaves and a bright yellow capitulum-type flower, typical of the Asteraceae family. (C) *Alpinia purpurata* had oblong leaves arranged alternately and a terminal inflorescence composed of overlapping pink bracts emerging from a robust scape. Meanwhile, (D) *Heliconia latispatha* displayed elliptical leaves with entire margins and an erect inflorescence with alternate orange-reddish bracts, enhancing visual attraction for pollinators. (E) *Heliconia psittacorum* showed similar foliage morphology but with more slender inflorescences and partially exposed flowers, suggesting a distinct pollen transfer strategy within the same genus. Lastly, (F) *Lantana camara* exhibited opposite leaves with serrated margins and a compound inflorescence of small flowers grouped into spherical clusters, colored in shades of orange and red, highly attractive to nectar-feeding lepidopterans (Figure 3).

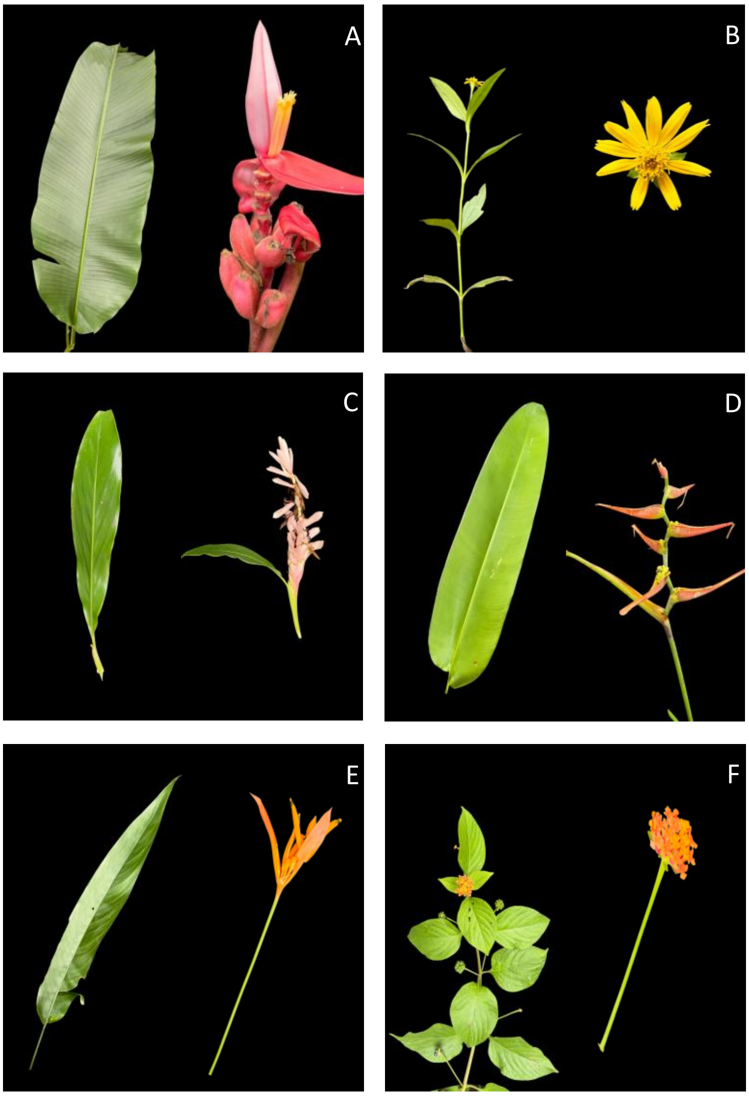

Figure 3. Morphological identification of plant species associated with the presence of butterflies in the biological corridor of the La María campus, Universidad Técnica Estatal de Quevedo. The images show leaf and flower characteristics of the plant species observed during field sampling: (A) *Musa velutina*, (B) *Silphium asteriscus*, (C) *Alpinia purpurata*, (D) *Heliconia latispatha*, (E) *Heliconia psittacorum*, (F) *Lantana camara*.

3.5. Incidence of Native Plant Species

The incidence of native plant species presents in the biological corridor of the La María campus showed significant differences among species ($p < 0.05$), with values varying widely depending on the type of plant evaluated (Figure 4). *L. camara* exhibited the highest incidence, with an average of 33.33% per square meter, being statistically different from all other species. It was followed by *Silphium asteriscus*, with an incidence of 23.81%, indicating a high level of representation in the study area.

On the other hand, *H. latispatha* and *M. velutina* showed similar incidences, approximately 14.29%, suggesting a moderate distribution within the evaluated ecosystem. In contrast, *H. psittacorum* presented a significantly lower incidence, while *A. purpurata* had the lowest recorded value, close to 4.76%.

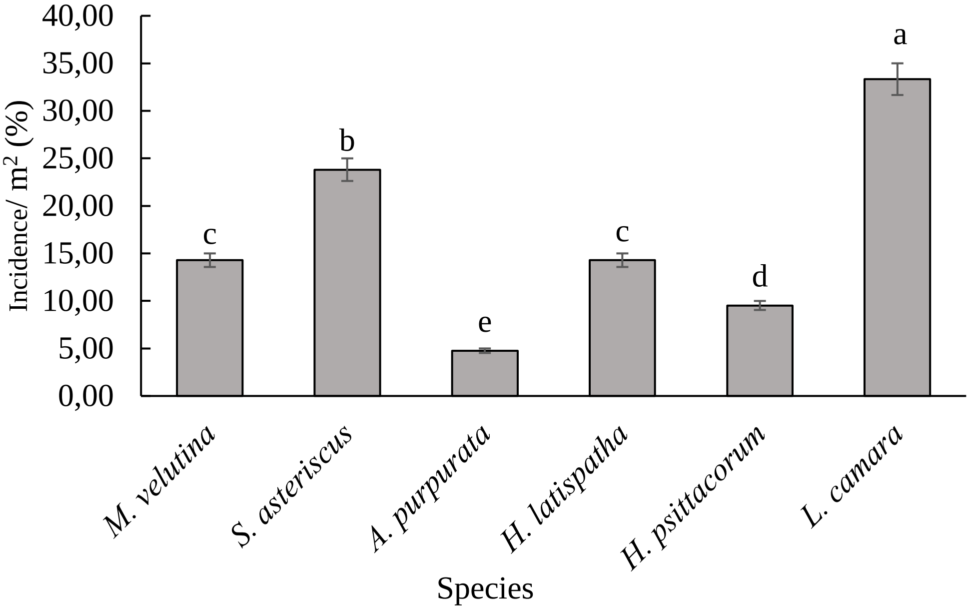

Figure 4. Incidence (%) of native plant species per square meter in the biological corridor of the La María campus. Different letters above the bars indicate statistically significant differences between means according to Tukey's test ($p < 0.05$). Values represent the mean ± standard deviation.

3.6. Diversity Indices for Plant Species

The diversity indices obtained in this study reveal a moderately diverse ecological structure within the analyzed plant community (Table 2). Species richness (*S*) was 6, indicating the presence of six distinct species in the evaluated area. The Shannon diversity index (*H′*) reached a value of 1.57, reflecting intermediate diversity by accounting for both species abundance and evenness.

Pielou's evenness index (*J*) was 0.874, suggesting a fairly uniform distribution of individuals among the present species. Likewise, the Simpson index ($1 - D$) showed a value of 0.78, confirming low dominance by any single species and thus a relatively balanced community. The maximum relative abundance recorded was 33.33%, indicating that a single species accounted for one-third of all individuals, without fully dominating the community.

Table 2. Ecological diversity indices obtained for the plant community in the biological corridor. Included are values for species richness (*S*), Shannon index *H′*), Pielou's evenness index (*J*), Simpson index ($1 - D$), and maximum relative abundance (%).

Index	**Value**
Maximum relative abundance (%)	33,33

Specific wealth (S)	6
Shannon Index (H′)	1,57
Pielou's fairness index (J)	0,874
Simpson's Index (1 − D)	0,78

4. DISCUSSION

This study revealed intermediate butterfly diversity within the transects evaluated at the La María campus. According to Halali et al. (2021), the high presence and diversity of butterflies in tropical zones can be attributed to various ecological, evolutionary, and biogeographic factors converging in these ecosystems. Studies such as De Brito and De Souza (2020) highlight the importance of understanding ecological interactions and perceptions of biodiversity, which aligns with our findings on the role of butterflies as key pollinators in tropical ecosystems. Their work emphasizes how human perceptions and ecological studies can synergize to inform conservation strategies, particularly in fragmented landscapes like the biological corridor examined here. Furthermore, Hulshof et al. (2024) note that tropical regions especially those between the central tropics harbor the highest levels of biodiversity globally and serve as ideal habitats for butterfly development due to climatic stability, high primary productivity, and structurally complex vegetation landscapes.

From an ecological standpoint, von Schmalensee et al. (2023) highlight that consistently warm temperatures and high humidity throughout the year in tropical regions support rapid life cycles, multivoltine reproduction, and constant activity in butterfly populations unlike temperate regions where entomological activity is seasonally restricted. Additionally, López-Vázquez et al. (2024) demonstrated that the vegetative heterogeneity of tropical ecosystems provides a broad array of ecological niches, allowing for the coexistence of multiple species with diverse trophic requirements, both at the larval level (host plant specificity) and in adulthood (floral and nectar sources).

Other authors, such as Sinha et al. (2023), emphasize that butterflies have developed complex co-adaptive relationships with tropical angiosperms, evidenced by specialized mouthpart structures (proboscises), mimicry patterns, and preferences for flowers with specific colors, shapes, and chemical compositions. These interactions have promoted speciation and ecological differentiation in various lepidopteran families, including Nymphalidae, Pieridae, and Papilionidae (Deoramnauth et al., 2025). Tropical environments also exhibit ecological succession and habitat fragmentation dynamics which, although potentially harmful to sensitive species, create expansion opportunities for many generalist butterflies in secondary habitats and biological corridors (Bussan & Schultz, 2023).

Ecuador's coastal region is characterized by a warm-humid climate, with average annual temperatures above 24 °C and seasonal rainfall that supports continuous flowering of numerous plant species. These conditions favor a constant availability of trophic resources, both for larval stages (host plants) and adults (nectar sources), thereby supporting stable and diverse lepidopteran populations throughout the year (Endara et al., 2022).

The mosaic of secondary vegetation, agroforestry crops, and forest remnants in disturbed areas such as the La María campus provides a range of microhabitats and gradients in light, moisture, and plant structure. This results in a broad array of ecological niches for different butterfly species (Bruschini et al., 2024). Such conditions promote the coexistence of taxa with distinct ecological strategies from generalist species like *A. vanillae* and *P. philea* to specialists like *Heliconius* sp., which maintain specific associations with *Passiflora* species and exhibit chemical defenses linked to Müllerian mimicry (Mattila et al., 2021).

Likewise, the presence of species such as *P. cresphontes* and *Danaus* sp. reflects broad dispersal patterns and tolerance for fragmented landscapes, consistent with reports from other tropical ecosystems with intermediate disturbance levels (Condamine et al., 2023). The morphological traits observed such as aposematic patterns, prominent wing tails, or cryptic coloration represent evolutionary adaptations that enhance survival under varying predation pressures and interspecific competition (Mutamiswa et al., 2023).

Research on butterflies in tropical environments faces inherent limitations due to the high ecological complexity and seasonality of these ecosystems. Climatic fluctuations, including changes in precipitation and temperature, can drastically influence flight activity, reproduction, and floral resource availability thereby affecting the detectability and representativeness of sampled species (Sunde et al., 2024). Moreover, many tropical species exhibit cryptic behavior or are difficult to identify taxonomically, especially when mimicry is present or when clear morphological keys for immature stages are lacking (Tan et al., 2021). These challenges complicate exhaustive assessments of diversity and plant-pollinator interactions, potentially compromising long-term ecological interpretations unless complemented by molecular methods or phenological studies (Núñez et al., 2022).

Several authors, including Chowdhury et al. (2023), stress that investigating butterfly diversity and ecological function in tropical ecosystems is essential due to their key role as bioindicators and pollination agents in highly diverse yet vulnerable environments. As butterflies rely on host plants and floral resources throughout their life cycles, they reflect shifts in ecosystem structure and health (Kotze et al., 2022). Their study facilitates understanding of ecological connectivity, plant community resilience, and functional stability in fragmented or anthropogenic landscapes. Furthermore, documenting pollinator–plant interactions in tropical settings supports more targeted conservation strategies, enabling sustainable management of biological corridors and ecosystem restoration efforts focused on critical services such as pollination (Oliveira et al., 2024).

5. CONCLUSION

The biological corridor of the La María campus hosts a diverse and evenly distributed lepidopteran community, with *Heliconius* sp. emerging as the dominant species without disrupting the balanced structure of the assemblage.

The documented butterfly–plant interactions underscore the role of biological corridors as key areas for the conservation of pollination processes in fragmented tropical ecosystems.

The study has certain limitations, primarily related to the temporal scope of sampling, which was restricted to the dry season. This limitation may have affected the detection of seasonal or migratory species, potentially leading to an underestimation of the full Lepidopteran diversity in the area.

Future studies should consider year-round monitoring to capture the seasonal dynamics of butterfly populations and their interactions with native plants. Additionally, longitudinal data collected over multiple years could help identify trends related to climate variability and habitat alteration.

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Data Availability Statement: The data are available upon reasonable request from the corresponding author: acedenom@uteq.edu.ec

Conflict of Interest: The authors declare no conflict of interest.

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