Beekeeping

Original

Nest characterization and ecological significance of *Geotrigona* sp. in tropical ecosystems of northern Manabí, Ecuador

Rosa Victoria González Zambrano *, Pedro Francisco Chávez Zambrano **, Carlos Javier Zamora-Macías **

*** Manuel Felix Lopez Higher Polytechnic School of Manabi, Manabí, ESPAM MFL Ecuador. Ecuador.
**Independent researcher.
Correspondence: rgonzales@espam.edu.ec

Received: April, 2026; Accepted: May 2026; Published: May, 2026..

ABSTRACT

Background: Native stingless bees of the genus *Geotrigona* nest exclusively underground, making them particularly vulnerable to habitat degradation in threatened tropical ecosystems. **Aim.** This study aims to characterize nest architecture, internal microclimatic conditions, foraging behavior, and the ecological significance of *Geotrigona* sp. in the tropical ecosystems of northern Manabí province, Ecuador. **Methods:** Eight active nests were studied in five locations. Structural variables, internal temperature and humidity, foraging behavior, and associated flora were evaluated. Descriptive statistics, ANOVA, and Student's t-test were applied. **Results:** Nest depths ranged from 0.60 – 1.20 m and entrance diameters from 1.2 – 2.0 cm. Internal temperature varied significantly among sites (p<0.001), with Rambuche showing the highest mean (33.20±1.30 °C) and Eloy Alfaro the lowest (22.15±1.10 °C). Humidity was homogeneous (80.45–83.00%; p = 0.808). Significant seasonal differences were observed in temperature and relative humidity (p<0.05). Foraging activity exhibited a bimodal pattern that was associated with ambient temperature. Twenty-two associated plant species were identified, *Handroanthus chrysanthus*, *Cordia alliodora*, *Inga edulis* and *Vitex cymosa* standing out. **Conclusions:** *Geotrigona* sp. exhibited specialized nest architecture and the ability to regulate its internal microclimate. Its role as a generalist pollinator and its close association with native flora make *Geotrigona* sp. a key species for conservation in the fragmented landscapes of northern Manabí province.

Keywords: stingless bees; subterranean nesting; conservation; microclimate (*Source*: *AGROVOC*)

INTRODUCTION

Native stingless bees (NSB) comprise a group of approximately 500 species distributed across tropical and subtropical regions, being most abundant in Latin America and playing a fundamental role as pollinators of both natural and cultivated ecosystems (Contreras *et al*., 2020; Ramírez *et al*.,

Citations (APA) González Zambrano, R. V., Chávez Zambrano, P. F., & Zamora-Macías, C. J. (2026). Nest characterization and ecological significance of Geotrigona sp. in tropical ecosystems of northern Manabí, Ecuador *Journal of Animal Prod*, *38*. https://rpa.reduc.edu.cu/index.php/rpa/article/view/e324

ISSN 2224-7920

2025). Within this group, the genus *Geotrigona* (tribe Meliponini) is characterized by a small body size (2.5–5.0 mm), a functionally reduced sting, and wings with simplified venation (Cedeño *et al*., 2025). One of the most distinctive features of this genus is its exclusively subterranean nesting habit, which implies a strong dependence on stable soils and adequate vegetation cover (Rozen *et al*., 2023).

Nests of *Geotrigona* exhibit complex architecture, including tunnels leading to brood and storage chambers that may reach lengths of up to 2m (Gennari, 2019). The construction of these structures involves the use of materials such as wax, resins, soil, and geopropolis (a mixture of resins and soil particles), which provide protection against predators and contribute to the regulation of the internal microclimate (Castillo, 2011; Buckles and Harmon-Threatt, 2019). This close relationship with soil and vegetation makes *Geotrigona* populations highly sensitive to deforestation, soil compaction, and land-use change—factors that affect their foraging behavior, reproductive success, and survival (Martínez *et al*., 2021).

Interactions between *Geotrigona* and plants play a significant role in the pollination of both natural and cultivated ecosystems, as most native plant species depend on this service for fruit and seed production (Zariman *et al.*, 2022). These bees are generalist pollinators (*polylectic*), which allows them to exploit a wide diversity of floral resources year-round, including nectar, pollen, and resins (Collantes *et al*., 2023; Ramírez-Montero *et al.*, 2025). However, in Ecuador, despite constitutional guarantees for the protection of nature, the lack of effective local policies hinders their conservation, while intensive agriculture and deforestation continue to degrade their habitats (Córdova *et al*., 2025).

In northern Manabí province, tropical ecosystems are heterogeneous, comprising tropical dry forest, semi-humid forest, and traditional agroecosystems, which create a landscape mosaic that may favor nesting and foraging activity of *Geotrigona* (Zúñiga *et al.*, 2022; Padilla *et al*., 2023). However, these ecosystems have been classified as highly threatened by agricultural expansion, livestock farming, and habitat fragmentation (Ministry of the Environment of Ecuador, 2013), which has reduced native pollinator populations and undermined ecological stability (Manzanarez-Villasana *et al*., 2025).

Understanding the ecological requirements of *Geotrigona*, including the characteristics of their nesting sites, the microclimatic conditions that sustain their colonies, and the floral resources they exploit, is essential for generating baseline information to design effective conservation strategies (Cevallos *et al*., 2025). Accordingly, the present study aims to characterize the nest architecture, internal microclimatic conditions, foraging behavior, and ecological importance of *Geotrigona* sp. in the tropical ecosystems of northern Manabí, Ecuador.

MATERIALS AND METHODS

Study Area

The study was conducted in tropical ecosystems in northern Manabí province, Ecuador, specifically at five localities: Rambuche (2 nests) in Jama canton; the parishes of Boyacá (1 nest) and Eloy Alfaro (3 nests) in Chone canton; El Zapallo (1 nest) in Flavio Alfaro canton; and El Cabuyal (1 nest) in San Vicente canton. These localities correspond to coastal and subcoastal areas, characterized by a mosaic of tropical dry forest, semi-humid tropical forest, and remnants of evergreen forest, interspersed with agricultural and livestock areas. The climate is megathermal tropical, with mean annual temperatures between 24 and 26 °C and precipitation ranging from 500 to 1,500 mm per year, featuring a pronounced rainy season (December–May) and a drier season (June–November).

Nest selection and structural characterization

Through directed (non-probabilistic) sampling, eight active subterranean nests of *Geotrigona* sp. were selected and georeferenced for identification. For structural characterization, direct measurements were taken of nest depth, entrance diameter, distance from the entrance to the main chamber, access-tunnel architecture, soil type, and the presence of brood cells, honey/pollen pots, and the involucrum. Excavations were carried out using hand tools, proceeding carefully so as not to damage the nest structure.

Microclimatic conditions monitoring

The internal microclimate of each nest was recorded using a digital thermohygrometer (Extech, model 445702; accuracy ±0.5 °C for temperature and ±2.5 % for relative humidity). Measurements were taken at three times of day (morning: 06:00–08:00; noon: 12:00–14:00; afternoon: 16:00–18:00) during the study period, with five repetitions per time period at each nest.

Foraging behavior assessment

Foraging behavior was assessed by direct observations in four blocks (06:00–08:00, 10:00–12:00, 14:00–16:00 and 18:00–19:00) over three consecutive days per nest. The activity of worker entries and exits was counted in 30-minute intervals, recording the average flow per minute. For the correlation analyses between foraging activity and environmental variables, daily means per nest were used to avoid pseudoreplication.

Assessment of associated flora

To assess floral resource availability, 50-m linear transects were established in four cardinal directions (north, south, east, west) centered on the nest entrance. Plant species present were identified and classified by growth form (trees, shrubs, herbs, lianas) and by their potential as sources of nectar, pollen, or resins for *Geotrigona,* based on direct observations of visits.

Data analysis

Data were analyzed using SPSS version 25.0. Descriptive analyses were performed for all quantitative variables. To evaluate significant differences in microclimatic variables between sites, a one-way ANOVA with Tukey post hoc test was applied after verifying normality (Shapiro–Wilk) and homogeneity of variances (Levene). An independent-sample Student's t-test was used to compare climatic periods. A significance level of $\alpha = 0.05$ was used.

Although the sample size was small (eight nests) and statistical power was limited (error degrees of freedom (gl_error = 3), results are presented and discussed as an exploratory, descriptive analysis. This number is comparable to that reported in other studies of cryptic, low-density species (Cane & Neff, 2011), and the significant differences found ($p < 0.05$) suggest consistent biological patterns that justify further research with larger samples. The findings provide a valuable empirical basis for understanding the subterranean nesting ecology of *Geotrigona* sp.

RESULTS AND DISCUSSION

Architectural characterization of nests

The characterization of the eight subterranean nests of *Geotrigona* sp. revealed a relatively homogeneous structure across the different localities. Depths ranged from 0.60 to 1.20 m, while entrance diameters varied from 1.2 to 2.0 cm (Table 1). The distances from the entrance to the main chamber ranged from 1.0 to 1.6 m, with an outlier of 5 m in the nest located in Barrio Santo Domingo; this may be explained by the typical architecture of leafcutter ants (genera *Atta* and *Acromyrmex*), which build extensive, complex underground systems where tunnels of 5 m or more are the rule rather than the exception.

Table 1. Structural variables of the nests of *Geotrigona* sp.

Site / locality	Entrance–chamber distance (m)	Depth (m)	Entrance hole diameter (cm)	Soil type
El Zapallo	1.35	1.16	1.2	Clay loam
Barrio Santo Domingo	5.00	1.20	1.5	Clay loam
Balzar 3 – Nest 1	1.50	1.00	1.5	Clay
Balzar 3 – Nest 2	1.60	0.80	2.0	Clay
Balzar 3 – Nest 3	1.00	0.60	2.0	Clay
El Cabuyal	1.00	0.65	2.0	Sandy loam
Rambuche – Nest 1	1.40	1.20	2.0	Sandy
Rambuche – Nest 2	1.40	0.85	2.0	Sandy
± DE average	1.78 ± 1.38	0.93 ± 0.23	1.78 ± 0.32	—

The depth and entrance-diameter values recorded in this study are comparable to those reported by Elizarde and Castillo (2011) for *Geotrigona* in tropical ecosystems of Central America, who documented depths between 0.50 and 1.30 m and entrance diameters of 1.0 to 2.5 cm. The variability in the distance from the entrance to the main chamber observed in this study (1.0–5.0 m) matches that reported by Gennari (2019), who notes that this distance can vary depending on terrain topography, soil compaction, and the presence of roots or rocks that the bees must negotiate during tunnel construction. The outlier value of 5 m recorded in Barrio Santo Domingo, although exceptional, has been previously documented by Arnold (2018) in nests of Geotrigona located in highly compacted soils.

The predominance of clayey and clay-loam soils at most sites agrees with the findings reported by Martínez *et al.* (2021), who highlight that species of the genus Geotrigona prefer soils with high clay content due to their greater cohesion and stability, which facilitates the construction of tunnels and chambers that maintain their structural integrity over time. In contrast, the Rambuche nests located in sandy soils exhibited a simpler architecture, with less-branched tunnels, suggesting an adaptation to the lower cohesion of this soil type, as observed by Padilla *et al.* (2023) in similar studies on the Ecuadorian coast.

Internal microclimatic conditions

The analysis of temperature in the subterranean nests revealed significant differences among the five study sites (one-way ANOVA: F = 376.26; p<0.001). Rambuche showed the highest mean temperatures (33.20 ± 1.30 °C), while Eloy Alfaro recorded the lowest (22.15 ± 1.10 °C). Internal relative humidity, by contrast, did not show significant differences among sites (F = 0.400; p = 0.808) (Table 2).

Table 2. Internal microclimatic variables by study site

Site / Canton	Minimum temperature (^{0}C)	Maximum temperature (^{0}C)	Mean temperature (°C ± SD)	Relative humidity (% ± SD)
Eloy Alfaro / Chone	21.00	23.30	22.15 ± 1.10 a	82.50 ± 2.30 a
El Zapallo / Flavio Alfaro	29.50	32.80	31.15 ± 1.00 b	81.20 ± 2.10 a
Boyacá / Chone	30.50	33.80	32.15 ± 1.20 c	80.45 ± 2.50 a
El Cabuyal / San Vicente	30.50	33.80	32.15 ± 1.10 c	81.80 ± 2.20 a
Rambuche / Jama	31.65	34.75	33.20 ± 1.30 d	83.00 ± 2.40 a
F statistic	298.34	428.92	376.26	0.400
p-value	<0.001	<0.001	<0.001	0.808

Different scripts in the same column indicate significant differences according to Tukey's post hoc test (p<0.05).

The internal temperature values recorded in this study fall within the optimal range of 30–35 °C reported by Vázquez *et al*. (2011) for brood development and the maintenance of foraging activity in meliponines. The ability of *Geotrigona* to maintain stable internal temperatures, even at sites with contrasting external conditions such as Rambuche (coastal area with high temperatures) and Eloy Alfaro (inland area with more moderate temperatures), demonstrates efficient thermoregulation mediated by behaviors such as worker clustering and wing fanning to generate heat or cool the brood area, as documented by Calderón *et al.* (2021).

Significant differences in temperature among sites (p<0.001) reflect the influence of local geographic factors such as altitude, surrounding vegetation cover, and nest depth. Cane and Neff (2011) reported similar patterns in tropical ecosystems, highlighting that spatial heterogeneity is a key factor in the distribution of thermal resources and that tree cover acts as a buffer against extreme temperatures.

The homogeneity of relative humidity among sites (80.45–83.00%; p = 0.808) matches the observations of Vicente-Serrano *et al*. (2018), who explained that relative humidity in tropical regions responds mainly to large-scale atmospheric circulation patterns, which would explain the absence of significant differences among geographically close localities with similar maritime influence. Taylor *et al*. (2025) added that the constant influx of moist air masses into the coastal areas of northern Manabí tends to homogenize this parameter, overriding local variations.

Seasonal analysis revealed significant differences between the rainy season and the less rainy season for all evaluated microclimatic variables (t-test: $p<0.05$) (Table 3).

Table 3. Comparison of microclimatic variables between climatic seasons

Variable	Rainy season (n=50)	Dry season (n=50)	Difference	t	gl	p-value
Minimum temperature (^{0}C)	29.56 ± 4.18	27.70 ± 3.73	1.86	2.350	98	0.021
Maximum temperature (^{0}C)	32.58 ± 4.50	30.80 ± 4.11	1.78	2.066	98	0.041
Mean temperature (°C)	31.07 ± 4.33	29.25 ± 3.91	1.82	2.206	98	0.030
Relative humidity (%)	83.68 ± 6.03	79.52 ± 7.78	4.16	2.989	98	0.004

The observed seasonal pattern, with higher temperatures and humidity during the rainy season, is consistent with the climatic dynamics of tropical regions described by Taylor *et al*. Taylor *et al.* (2025) noted that the rainy season generally coincides with higher temperatures due to increased cloud cover that raises longwave radiation at night and higher humidity that buffers nighttime cooling. They further explain that, in tropical ecosystems, higher temperatures during the rainy season are associated with a reduced incidence of cold air masses from the south, which are more frequent during the dry season.

The humidity differences of 4.16% between periods ($p = 0.004$) are comparable to those reported by Ruiz-Ochoa *et al*. Ruiz-Ochoa *et al*. (2023) in studies conducted in the Ecuadorian humid tropics, attributing them to the annual precipitation cycle and its effect on water availability in the soil–plant–atmosphere system. Lema *et al*. (2024) noted that these seasonal differences have direct implications for colony activity, since temperatures below 22 °C reduce foraging activity, while values above 35 °C can trigger thermoregulatory behaviors that decrease foraging efficiency.

Forage behavior

Foraging showed a bimodal pattern at all sites, with peaks in the morning hours (06:00–10:00) and, to a lesser extent, in the afternoon (14:00–16:00). In Rambuche, with higher temperatures, activity was concentrated in the early hours (45 ± 8 workers/min between 06:00–08:00), whereas in Eloy Alfaro, with lower temperatures, activity peaked between 10:00–12:00 (38 ± 6 workers/min). The correlation analysis showed a moderate negative relationship between ambient temperature and foraging during the central hours of the day ($r = -0.52$; $p<0.01$), and a weak positive correlation with relative humidity ($r = 0.31$; $p<0.05$).

The bimodal foraging pattern observed matches that reported by Padilla *et al.* The bimodal foraging pattern observed matches that reported by Padilla *et al.* (2023) for meliponines in coastal ecosystems of Ecuador, who documented that bees adjust their foraging schedules to avoid the hottest hours, thereby maximizing energy efficiency. The negative correlation between ambient temperature and foraging activity during the central hours of the day has been widely documented by Vázquez *et al.* (2011), who reported that temperatures above 32 °C induce thermoregulatory behaviors that reduce the colonies' external activity.

The positive correlation between relative humidity and foraging activity ($r = 0.31$; $p<0.05$) suggests that higher humidity conditions favor foraging activity, possibly due to greater nectar availability in flowers and more favorable conditions for bee flight, as documented by Collantes *et al*. (2023) in studies of meliponine ecophysiology.

Nest-associated flora

The vegetation analysis along the established transects revealed high floristic diversity, with 22 species identified as potential resources for *Geotrigona* sp. Table 4. The most frequent species, and those exhibiting the highest foraging activity, included native timber trees such as guayacan (*Handroanthus chrysanthus*), laurel costeño (*Cordia alliodora*) and ceibo (*Ceiba trischistandra*); fruit trees such as guabo (*Inga edulis*) and pechiche (*Vitex cymosa*); and shrubs such as muyuyo (*Cordia lutea*) and palo santo (*Bursera graveolens*).

Table 4. Plant species associated with *Geotrigona* sp. nests in northern Manabí

Category	Species (common name)	Scientific name	Resource type	Visiting frequency
Native timber trees	Guayacan	*Handroanthus chrysanthus*	Nectar, pollen	High
	Cedro colorado	*Cedrela odorata*	Nectar	Medium
	Ceibo	*Ceiba trischistandra*	Nectar, pollen	High
	Algarroba	*Prosopis juliflora*	Nectar, pollen	Medium
	Laurel costeño	*Cordia alliodora*	Nectar, pollen	High
	Amarillo	*Centrolobium ochroxylum*	Nectar	Low
	Cojojo	*Anacardium excelsum*	Nectar	Medium
	Moral fino	*Maclura tinctoria*	Nectar	Low
Fruit trees	Guabo	*Inga edulis*	Nectar, pollen	High
	Pechiche	*Vitex cymosa*	Nectar	High
	Guanabana	*Annona muricata*	Nectar	Low
	Caimito	*Chrysophyllum cainito*	Nectar, pollen	Medium
	Guava	*Psidium spp.*	Nectar, pollen	Medium
	Moral fino	*Maclura tinctoria*	Nectar	Low
	Mango*	*Mangifera indica*	Nectar, pollen	Medium
	Banana*	*Musa spp.*	Nectar	Low
Native shrubs	Muyuyo	*Cordia lutea*	Nectar, pollen	High
	Palo santo	*Bursera graveolens*	Resins	High
	Barbasco	*Lonchocarpus spp.*	Nectar	Low
	Escobillo	*Chromolaena odorata*	Nectar, pollen	Medium
	Chabelillo	*Hibiscus tiliaceus*	Nectar, pollen	Medium
	Achiotillo	*Bixa orellana*	Nectar	Low
	Bejuco loco	*Mucuna spp.* / *Ipomoea spp.*	Nectar	Medium

The diversity of plant species associated with *Geotrigona* sp. nests confirms its status as a generalist (*polylectic*) pollinator, as documented by Collantes *et al.* (2023) for the genus in tropical dry forest ecosystems (Zelaya and López, 2025). The presence of species such as guayacan, laurel costeño, and pechiche as preferred sources of nectar and pollen is consistent with the findings of Vázquez *et al.* (2021), in studies conducted on the Ecuadorian coast, reported that these species exhibit abundant, accessible flowering, making them key resources for meliponine bees.

The importance of large canopy trees such as ceibo and cojojo as providers of microhabitats, shade, and shelter, in addition to floral resources, has been noted by Erazo *et al.* (2023), who document that these trees play a complementary role by promoting the persistence of *Geotrigona* colonies within the landscape. The presence of palo santo (*Bursera graveolens*) as a resin source is particularly relevant, since resins are essential for nest construction and maintenance as well as for colony defense (Elizarde and Castillo, 2011).

Introduced species, such as mango and banana, exhibited moderate to low visitation frequencies, suggesting that, while they serve as complementary resources, they are not primary sources for these native bees. This finding aligns with Padilla *et al*. (2023), who observed that native meliponine species in Manabí exhibited a strong preference for native flora, underscoring the importance of conserving original vegetation within productive landscapes.

Ecological relevance of *Geotrigona* in northern Manabí

The ecological relevance of *Geotrigona* sp. in the tropical ecosystems of northern Manabí was evaluated based on three main axes: availability of floral resources and vegetation cover; taking into account the particular characteristics of the cantons studied (Table 5).

Table 5 Ecological relevance of *Geotrigona* sp. by canton in northern Manabí

Ecological component	San Vicente	Chone	Flavio Alfaro	Regional ecological contribution
Ecological location	Pacific coastal zone	Intermediate valley and lower basin	Interior zone of hills and foothills	Coast–cordillera transition that increases environmental diversity
Prevailing ecosystems	Tropical dry forest	Dry forest, humid forest, and riparian forests	Tropical humid and premontane forest	Representativeness of strategic and threatened ecosystems
Vegetation cover	Xerophytic vegetation and remnants of dry forest	Mixed natural–productive vegetation cover	Greater natural cover and forest remnants	Biodiversity conservation and carbon sequestration.
Hydrological importance	Low–medium, coastal runoff areas	High, middle and lower Chone River basin	High — water recharge areas and headwaters	Flow regulation and water supply
Ecological corridors	Coastal connectivity	Ecological linkage zone	Source area for connectivity	Species movement and ecosystem resilience
Environmental vulnerability	High (deforestation and urbanization)	Medium–high (flooding and agricultural use)	Medium (agricultural expansion)	Priority for environmental management and planning

The ecological importance of *Geotrigona* sp. varies according to the particular characteristics of each canton, but in all cases its role as a key pollinator for maintaining biodiversity and ecosystem services is evident. In San Vicente, characterized by tropical dry forest and xerophytic vegetation, *Geotrigona* sp. contributes to the pollination of species adapted to arid conditions, promoting the reproduction of native flora and maintaining the structure of fragile ecosystems, as documented by Gaona *et al.* (2019) for pollinators in arid areas.

In Chone, where dry, humid, and riparian forests predominate with mixed natural-productive vegetation cover, *Geotrigona* plays a strategic role in biological connectivity. The diversity of floral resources enables continuous foraging, increasing cross-pollination and the reproduction of native and productive species, which enhances water provision, soil fertility, and ecosystem resilience (Padilla *et al.*, 2023).

In Flavio Alfaro, with tropical humid and premontane forests and the largest natural cover in the area, *Geotrigona* acts as an agent of biological conservation, promoting the reproduction of sensitive species of great ecological importance. The activity of these bees supports water regulation and soil conservation, essential functions for regional sustainability (MAATE, 2021) The ability of *Geotrigona* to adapt to different environmental conditions, such as temperature variations and resource availability, ensures the persistence of ecosystem services even in fragmented landscapes or those affected by human activities (Hernández-García, 2024; Cevallos *et al.*, 2025).

CONCLUSIONS

The nests of *Geotrigona* sp. in the five localities studied in northern Manabí exhibit a relatively homogeneous structure (depth 0.60–1.20 m; entrance diameter 1.2–2.0 cm) with significant differences in internal temperature between sites (22.15–33.20 °C), suggesting a thermoregulation capacity that operates within variable ranges depending on local conditions.

Geotrigona sp. showed a bimodal foraging pattern adapted to local thermal conditions, and was observed visiting 22 plant species, with native trees such as *Handroanthus chrysanthus*, *Cordia alliodora*, *Inga edulis*, and *Vitex cymosa* standing out as the most frequently visited floral resources. This is consistent with generalist pollinator behavior.

The species is a functional component essential to the resilience of the tropical ecosystems of northern Manabí, with particular relevance in cantons of high environmental vulnerability (San Vicente and Chone), where its conservation is a priority for maintaining ecosystem services and local biodiversity.

RECOMMENDATIONS

These results should be interpreted as a preliminary, descriptive characterization, and the need to increase the number of nests and localities studied, as well as to implement continuous and experimental measurements, is emphasized to underpin conservation strategies for *Geotrigona* sp. in fragmented landscapes of northern Manabí.

REFERENCES

Arnold, N., Ayala, R., Mérida, J., Sagot, P., Aldasoro, M., & Vandame, R. (2018). Registros nuevos de abejas sin aguijón (Apidae: Meliponini) para los estados de Chiapas y Oaxaca, México. *Revista mexicana de biodiversidad*, *89*(3), 651-665. https://doi.org/10.22201/ib.20078706e.2018.3.2429

Buckles, B. J., & Harmon-Threatt, A. N. (2019). Bee diversity in tallgrass prairies affected by management and its effects on above-and below-ground resources. *Journal of Applied Ecology*, *56*(11), 2443-2453. https://besjournals.onlinelibrary.wiley.com/doi/abs/10.1111/1365-2664.13479

Calderón Fallas, R. Á., Sánchez Chávez, L. A., & Aguilar Monge, I. (2021). XII Congreso Mesoamericano de Abejas Nativas: Desafíos y oportunidades para la conservación de las abejas nativas, 20 y 21 de noviembre. https://agris.fao.org/search/en/providers/122384/records/67485b767625988a371b0457

Cane, J. H., & Neff, J. L. (2011). Predicted fates of ground-nesting bees in soil heated by wildfire: thermal tolerances of life stages and a survey of nesting depths. *Biological conservation*, *144*(11), 2631-2636. https://doi.org/10.1016/j.biocon.2011.07.019

Castro, A., & Espinosa, C. I. (2016). Dinámica estacional de invertebrados en un matorral seco tropical a lo largo de un gradiente altitudinal. *Ecosistemas*, *25*(2), 35-45. https://www.redalyc.org/pdf/540/54046745010.pdf

Cedeño, J., Luna, Y., & Murillo, V. (2025). Abejas sin aguijón (Apidae: Meliponinae) y sus sustratos de nidificación en dos sitios con intervención antrópica en la comunidad de Gandona, provincia Colón. *Centros: Revista Científica Universitaria*, *14*(1), 9-25. https://revistas.up.ac.pa/index.php/centros/article/view/6595

Cevallos, N. V. M., Zambrano, M. B., & Zambrano, R. V. G. (2025). Plan de manejo ambiental participativo para la conservación de hábitats naturales de abejas Geotrigona, parroquia Eloy Alfaro-Chone. *Revista Científica y Tecnológica UPSE*, *12*(2), 15-28. https://www.revistas.upse.edu.ec/index.php/rctu/article/view/926

Collantes, R. D., Ruth Del Cid, A., Santos-Murgas, A., & Atencio, R. (2023). Importancia de los insectos polinizadores en la sostenibilidad de los agroecosistemas productivos. *Revista Semilla del Este*, *3*(2), 8-26. https://revistas.up.ac.pa/index.php/semilla_este/article/view/3755

Contreras Cortés, L. E. U., Vázquez García, A., Aldasoro Maya, E. M., & Mérida Rivas, J. (2020). Conocimiento de las abejas nativas sin aguijón y cambio generacional entre los mayas lacandones de Nahá, Chiapas. *Estudios de cultura maya*, *56*, 205-225. https://doi.org/10.19130/iifl.ecm.2020.56.2.0008

Córdova Muguerza, A. N., Vélez Zambrano, G. B., & González Zambrano, R. V. (2025). Estudio del comportamiento de las abejas Geotrigona para su conservación en la parroquia Eloy Alfaro, Chone. *Revista Científica Y Tecnológica UPSE*, *12*(2), 48-69. https://doi.org/10.26423/nzt5k085

Elizarde V., R., & Castillo-Carrillo, P. S. (2011). Identificación, morfología y comportamiento de la “abeja de tierra” Geotrigona fumipennis Camargo & Moure, 1996 (Hymenoptera: Apidae), en Tumbes, Perú. *Revista Peruana De Entolomogía*, *46*(1 & 2), 31–37. https://www.revperuentomol.com.pe/index.php/rev-peru-entomol/article/view/227

Erazo, A. G. C., Tapia, M. F. B., Rivera, S. A. G., & Moposita, D. A. M. (2023). La meliponicultura: una alternativa de conservación y aprovechamiento sostenible de abejas nativas en la Amazonía ecuatoriana. *Tesla Revista Científica*, *3*(1), e157-e157. https://tesla.puertomaderoeditorial.com.ar/index.php/tesla/article/view/157

Gaona, F. P., Guerrero, A., Gusmán, E., & Espinosa, C. I. (2019). Pollen resources used by two species of stingless bees (Meliponini) in a tropical dry forest of southern Ecuador. *Journal of Insect Science*, *19*(6), 22. https://doi.org/10.1093/jisesa/iez125

García, E. (2004). *Modificaciones al sistema de clasificación climática de Köppen*. Universidad Nacional Autónoma de México. https://librosoa.unam.mx/handle/123456789/1372

Gennari, G. P. (2019). Manejo racional de las abejas nativas sin aguijón (ANSA). https://www.sidalc.net/search/Record/oai:localhost:20.500.12123-4670/Description

Jackson, L. S., Birch, C. E., Chagnaud, G., Marsham, J. H., & Taylor, C. M. (2025). Daily rainfall variability controls humid heatwaves in the global tropics and subtropics. *Nature Communications*, *16*(1), 3461. https://doi.org/10.1038/s41467-025-58694-6

Lema, J. D. Z., Lema, L. D. C. Z., Zambrano, S. B. R., & Hidalgo, E. F. M. (2024). Predicción de series temporales de humedad relativa mediante bootstrap y modelos de regresión funcional no paramétrica. *Polo del Conocimiento*, *9*(10), 133-146. https://revistas.uteq.edu.ec/index.php/cyt/article/view/580

Macri, I. N. (2023). *La abeja Apis mellifera como bioindicador del impacto ambiental: estudio sobre su fisiología, comportamiento y sociabilidad en un agroecosistema* (Doctoral dissertation, Universidad de Buenos Aires). https://bibliotecadigital.exactas.uba.ar/download/tesis/tesis_n7365_Macri.pdf

Manzanarez-Villasana, G., Briseño-Sánchez, M. I., Lobo, J., & Quesada, M. (2025). Large trees in tropical dry Forest facilitate the presence of stingless bee nests (Apidae: Meliponini): The case of Ficus crocata. *Sociobiology*, *72*(3), e11423-e11423. https://periodicos.uefs.br/index.php/sociobiology/article/view/11423

Ministerio del Ambiente del Ecuador (MAE). (2013). *Sistema de Clasificación de Ecosistemas del Ecuador Continental*. Quito: MAE. https://archive.org/details/ecosistemas-del-ecuador-2013

Padilla Arroyo, R. E., Rivera Barre, Y. L., & González Zambrano, R. V. (2023). Caracterización de la abeja sin aguijón (Geotrigona leucogastra) en el sitio rambuche del cantón Jama. https://agris.fao.org/search/en/providers/124692/records/669e7a5400eb85b7d72b8aee

Ramírez-Montero, M., Chaves, L. S., & González, E. H. (2025). Preferencias florales de la abeja nativa sin aguijón Melipona beecheii. *Notas Apícolas*, *18*(34). https://www.researchgate.net/profile/AuroraXolalpa/publication/400179423_Caracterizacion_del_microbioma_de_mieles_mexicanas_de_abejas_nativas_con_secuenciacion_masiva/links/697ad0e4ca66ef6ab98e2b29/Caracterizacion-delmicrobiomademielesmexicanas-de-abejas-nativas-con-secuenciacion-masiva.pdf#page=34

Rozen Jr, J. G., Danforth, B. N., Smith, C. S., Decker, B. L., Dorian, N. N., Dority, D., ... & Urban-Mead, K. R. (2019). Early nesting biology of the bee Caupolicana yarrowi (Cresson)(Colletidae: Diphaglossinae) and its cleptoparasite Triepeolus grandis (Friese)(Apidae: Nomadinae). *American Museum Novitates*, *2019*(3931), 1-20. https://bioone.org/journals/americanmuseumnovitates/volume2019/issue3931/3931.1/Early-Nesting-Biology-of-the-Bee-CaupolicanayarrowiCressonColletidae/10.1206/3931.1.full

Ruiz-Ochoa, M. A., Torres-Corredor, J. S., Vargas-Corredor, Y. A., & Orduz-Amaya, L. P. (2023). Variabilidad climática (precipitación, temperatura y humedad relativa) para la gestión hídrica del departamento del Casanare, Colombia. *Información tecnológica*, *34*(5), 47-60. https://doi.org/10.4067/S0718-07642023000500047

Vázquez, M., Almeida, H., Navarro, J. M., Yanes, N., Febles, H., & Marrero, A. (2011). Tecnología de crianza de Abejas de la Tierra (Melipona beechii Bennett, 1831). *Empresa Cultivos Varios Horquita*.

Vicente-Serrano, S. M., Nieto, R., Gimeno, L., Azorin-Molina, C., Drumond, A., El Kenawy, A., & Peña-Gallardo, M. (2018). Recent changes of relative humidity: regional connections with land and ocean processes. *Earth System Dynamics*, *9*(2), 915-937. https://doi.org/10.5194/esd-9-915-2018

Zariman, NA., Omar, NA., & Huda, AN. (2022). Atrayentes vegetales y recompensas para polinizadores: su importancia para una polinización exitosa de los cultivos. *Int. J. Life Sci. Biotechnol.*, *5*(2), 270-293. https://dergipark.org.tr/en/pub/ijlsb/article/1069254

Zelaya, F. R. R., & López, J. R. L. (2025). Servicios ecosistémicos de las abejas en sistemas agroecológicos: impacto en productividad frutal y resiliencia socioambiental. *Revista Agropolka*, *1*(1). https://revista.unflep.edu.ni/index.php/Agropolka/article/view/12

Zúñiga, K. A., Llerena, F. D., Freire, G. G., & Mora, J. M. (2022). Entomofauna de árboles nativos, medicinales o bioplaguicidas en fincas agrícolas de Mariscal Sucre, Guayas-Ecuador. *Ciencia y Tecnología*, *15*(2), 53-61. https://revistas.uteq.edu.ec/index.php/cyt/article/view/580

AUTHOR CONTRIBUTION STATEMENT

Research conception and design: RVGA, PFCHZ; data analysis and interpretation: PFCHZ; manuscript writing: RVGZ.

CONFLICT OF INTEREST STATEMENT

The authors state there are no conflicts of interest whatsoever.