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Diversity of centipedes and millipedes (Arthropoda: Myriapoda) in tropical dry forest fragments in Bolívar, Colombia

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ABSTRACT

Introduction: Tropical dry forests are among the most endangered Neotropical ecosystems, characterized by high biodiversity and endemism but increasingly threatened by anthropogenic activities. In Colombia, particularly in the Caribbean region, these forests have been extensively fragmented. Despite their ecological significance, studies on myriapod communities remain scarce. Myriapods play an essential role in soil dynamics and nutrient cycling. However, their diversity and ecological associations in Bolívar's tropical dry forests remain poorly understood.

Objective: To assess the diversity and distribution of centipedes (Chilopoda) and millipedes (Diplopoda) in four tropical dry forest fragments within Bolívar and examine their relationships with environmental variables.

Methods: Fieldwork was conducted in October and November 2020 across four forest fragments in Turbaco, San Jacinto, Magangué, and El Carmen. Specimens were collected using free search, soil monoliths, pitfall traps, and Winkler traps in 50 × 50 m plots. Taxonomic identifications and ecological analyses were performed to assess the diversity and structure of the studied communities. Ecological indices were analyzed, and ANOSIM was used to contrast differences between locations, NMDS was used to visualize patterns of dissimilarity, and Canonical Correspondence Analysis (CCA) was used to evaluate the relationship between species and environmental variables.

Results: A total of 1 106 individuals were recorded, comprising 8 orders, 15 families, and 32 morphospecies. Diplopoda exhibited greater richness and abundance than Chilopoda. Polydesmida and Spirostreptida were the dominant millipede orders, while Geophilomorpha was the most abundant centipede order. Species richness was highest in San Jacinto and Turbaco, while Magangué and El Carmen exhibited lower diversity. The CCA revealed that soil pH, temperature, and humidity influenced species distribution, reinforcing the role of myriapods as bioindicators.

Conclusion: This study provides the first systematic assessment of myriapod diversity in Bolívar's tropical dry forests, emphasizing their ecological significance and the urgent need for conservation efforts.

Key words: Chilopoda; Diplopoda; ecology; environmental variables; Neotropic; sampling methods.

RESUMEN

Diversidad de ciempiés y milpiés (Arthropoda: Myriapoda) en fragmentos de bosque seco tropical en Bolívar, Colombia

Introducción: Los bosques secos tropicales se encuentran entre los ecosistemas neotropicales más amenazados, caracterizados por una gran biodiversidad y endemismo, pero cada vez más amenazados por las actividades antropogénicas. En Colombia, particularmente en la región del Caribe, estos bosques se han fragmentado ampliamente. A pesar de su importancia ecológica, los estudios sobre las comunidades de miriápodos siguen siendo escasos. Los miriápodos desempeñan un papel esencial en la dinámica del suelo y el ciclo de los nutrientes. Sin embargo, su diversidad y sus asociaciones ecológicas en los bosques secos tropicales de Bolívar siguen siendo poco conocidas.
Objetivo: Evaluar la diversidad y distribución de ciempiés (Chilopoda) y milpiés (Diplopoda) en fragmentos de cuatro bosques secos tropicales de Bolívar y examinar su relación con variables ambientales.
Métodos: El trabajo de campo se llevó a cabo en octubre y noviembre de 2020 en cuatro fragmentos de bosques en Turbaco, San Jacinto, Magangué y El Carmen. Las muestras se recolectaron mediante búsqueda libre, monolitos de suelo, trampas de caída y trampas Winkler, en parcelas de 50 × 50 m. Se analizaron índices ecológicos y se utilizó ANOSIM para contrastar diferencias entre localidades, NMDS para visualizar patrones de disimilitud y análisis canónico de correspondencias (CCA) para evaluar la relación entre especies y variables ambientales.
Resultados: Se registraron en total 1 106 individuos, que comprendían 8 órdenes, 15 familias y 32 morfoespecies. Los diplópodos exhibieron mayor riqueza y abundancia que los quilópodos. Polydesmida y Spirostreptida fueron los órdenes de milpiés dominantes, mientras que Geophilomorpha fue el orden de ciempiés más abundante. La riqueza de especies fue mayor en San Jacinto y Turbaco, mientras que Magangué y El Carmen mostraron una menor diversidad. El CCA reveló que el pH, la temperatura y la humedad del suelo influyeron en la distribución de las especies, lo que refuerza el papel de los miriápodos como bioindicadores.
Conclusión: Este estudio proporciona la primera evaluación sistemática de la diversidad de miriápodos en los bosques secos tropicales de Bolívar, enfatizando su importancia ecológica y la urgente necesidad de esfuerzos de conservación.

Palabras clave: Chilopoda; Diplopoda; ecología, variables ambientales, neotrópico; métodos de muestreo

INTRODUCTION

A Tropical Dry Forest are ecosystems distributed between 0 and 1 000 m in altitude, characterized by temperatures ranging from 25 to 38 °C (Murphy & Lugo, 1986) and annual precipitation between 250 and 2 000 mm. These forests experience pronounced seasonal droughts lasting between four and six months (Grainger, 1996; Mayaux et al., 2005; Miles et al., 2006; Pennington, 2006). Due to their unique structural and ecological characteristics, these forests exhibit high levels of alpha diversity and endemism, with species displaying a wide range of adaptive strategies to withstand extreme drought conditions and seasonal climatic fluctuations (Alvarado-Solano & Otero, 2015; Dryflor et al., 2016; Zapata et al., 2023).

In Colombia, the original extent of Tropical Dry Forest was estimated to be approximately 80000 km² (Etter, 1993). Later assessments by Instituto de Hidrología, Meteorología y Estudios Ambientales et al., (2007) estimated a current coverage of 76 581 km², primarily distributed across six major regions: The Caribbean, the inter-Andean valleys of the Cauca and Magdalena rivers, the North Andean region (Santander and Norte de Santander), the Patía Valley, and the Llanos (Arauca and Vichada). This represents roughly 7 % of the national territory (Díaz, 2006). However, these forests have been extensively fragmented by anthropogenic pressures, with 97 % of their original coverage impacted by activities such as livestock farming, mining, deforestation, and monoculture agriculture, accelerating the rate of habitat degradation (Álvarez Hincapié et al., 2021; García-Herrera et al., 2019; Miles et al., 2006).

Among Colombia's remaining Tropical Dry Forests, the Caribbean region contains the largest remnants, covering 1 355 km² (Rodríguez et al., 2012). However, most of these forests exist as highly fragmented and heavily altered patches (Díaz, 2006). The Department of Bolívar is a key area for forest conservation, comprising 4.1 % of the national territory and ranking third in Tropical Dry Forest coverage, following Atlántico (5.7 %) and Cesar (4.9 %) (Pizano et al., 2014). Given the ecological significance of these relictual forests, it is essential to investigate arthropod diversity to better understand ecosystem dynamics and inform future conservation and restoration strategies (Bello et al., 2014; Ramírez, 2018).

Among arthropods, Myriapods (subphylum Myriapoda) are particularly relevant as soil ecosystem engineers. This group comprises four classes: Chilopoda (centipedes), Diplopoda (millipedes), Symphyla, and Pauropoda (Edgecombe, 2011; Shelley, 2002). Myriapods contribute significantly to soil health by increasing porosity and water retention, promoting nutrient cycling, and accelerating decomposition processes (Bueno-Villegas, 2012). Due to their close association with microhabitat conditions, myriapods are often used as bioindicators for evaluating soil quality, environmental change, and ecosystem integrity (Adis et al., 1996; Druce et al., 2004). Additionally, centipedes serve as biological control agents, preying on soil mesofauna, macroinvertebrates, and occasionally small vertebrates (Lewis, 1981; Molinari et al., 2005). They also represent an important food source for birds, mammals, reptiles, insects, and arachnids (Cantú-Salazar et al., 2005; Cupul-Magaña, 2014).

Despite their ecological importance, myriapod diversity in Colombian Tropical Dry Forests remains poorly studied. Most research has focused on the Andean region, where four orders, seven families, twelve genera, and forty species of Chilopoda (Chagas-Jr et al., 2014; Prado-Sepúlveda et al., 2016), and seven orders, 20 families, 76 genera, and approximately 215 species of Diplopoda have been documented (Castillo-Ávila et al., 2015; Martínez-Torres & Flórez, 2015). In the Caribbean region, early contributions were made by Carl (1914) and Chamberlin (1921), who described several myriapod species in Magdalena and Atlántico. However, in Bolívar, myriapod records remain scarce, with only a few inventories presented at scientific meetings. These inventories report four orders, six families, and nine morphospecies of Chilopoda, along with seven orders, eleven families, and over 20 morphospecies of Diplopoda (Carrillo-Pallares et al., 2019; Sociedad Colombiana de Entomología [SOCOLEN], 2016).

Given these knowledge gaps, this study aimed to assess the diversity of centipedes and millipedes in various Tropical Dry Forest fragments within the Department of Bolívar. Additionally, we investigate how species from Chilopoda and Diplopoda correlate with environmental variables, including ambient humidity, ambient temperature, soil temperature, and soil pH. Our findings contribute to the taxonomic and ecological understanding of myriapods in Bolívar and Colombia, providing baseline data for biodiversity conservation and management.

MATERIALS AND METHODS

Study Area: The Department of Bolívar is located in Northern Colombia, within the Caribbean plain region (Fig. 1). It covers 25 978 km^2, with altitudes ranging from sea level to 2 700 m above sea level (MASL). Bolívar is positioned between 07º00’03”-10º48’37” N & 73º45’15”-75º42’18” W, sharing borders with the Caribbean Sea and the Department of Atlántico to the North, the Magdalena River to the East, the departments of Santander and Antioquia to the South, and the departments of Antioquia, Córdoba, Sucre, and the Caribbean Sea to the West. The department accounts for approximately 20 % of the Caribbean region’s total area and 2.3 % of Colombia’s national territory (Galvis, 2009). The region experiences an average temperature ranging from 19 to 30 °C, with annual precipitation between 911 and 1 157 mm. Bolívar comprises 45 municipalities and 348 townships, with a mosaic of land uses, including Tropical Dry Forest fragments at different successional stages, shrublands, gallery

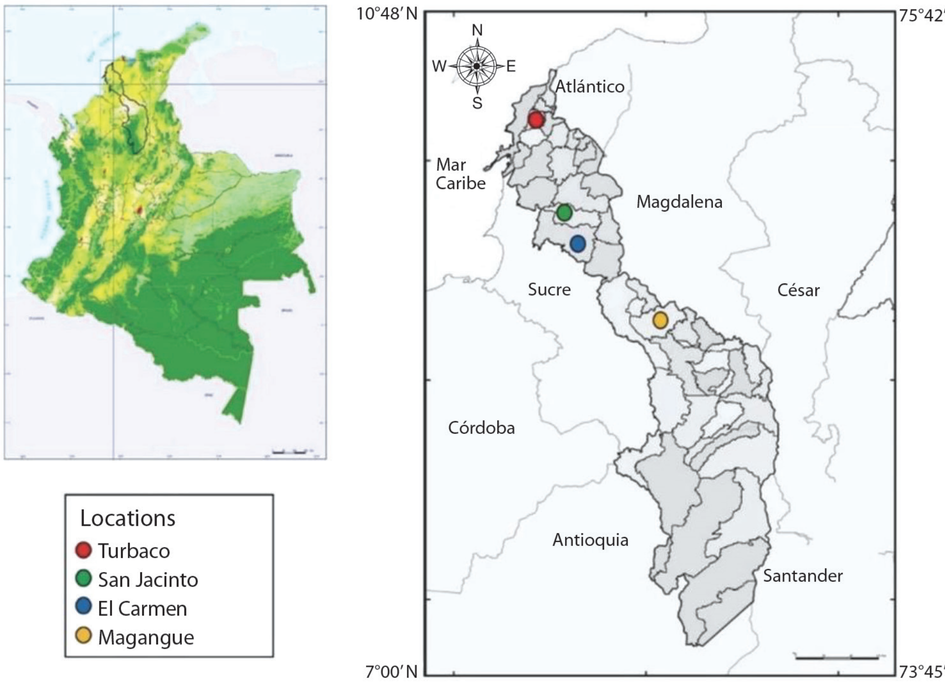


Fig. 1. Sampling locations in the department of Bolívar, Colombia.

forests, and deforested areas due to livestock and agricultural expansion (Pizano et al., 2014).

Field Sampling: Was conducted between October and November 2020 at four sites: Turbaco, San Jacinto, Magangué, and El Carmen (Table 1). Each location contained remnants of these forests at varying degrees of conservation (Fig. 2). The sampling design followed the COBRA (Conservation-Oriented Rapid Biodiversity Assessment) protocol (Cardoso et al., 2009; Malumbres-Olarte et al., 2017), incorporating modifications by Morales (2019) and Galvis (2019).

At each site, a 50 × 50 m plot was established, where myriapod specimens were

Table 1
General characteristics of the conserved patches of tropical dry forest sampled for myriapods in the Bolívar department, Colombia.

Locality, Municipality	Coordinates	Elevation (MASL)	Description
Cañaveral, Turbaco	10°22’07.1” N-75°21’30.1” W	104	It is located near a water source and remains minimally disturbed by anthropogenic activities.
Brasilar, San Jacinto	9°54’33.1” N-75°11’06.1” W	435	It is surrounded by mountainous areas and located near a water source.
Henequén, Magangué	9°12’29.9” N-74°53’45.9” W	56	In the vicinity of the flood zone, surrounding areas are disturbed by anthropogenic activities such as livestock farming, access roads, monocultures, and semi-urban areas.
Tolemaida, El Carmen	9°38’07.4” N-75°07’29.3” W	253	Surrounding areas, affected by anthropogenic activities such as armed conflict, monocultures, and livestock, are in a state of succession within mountainous areas. There are no nearby water sources.

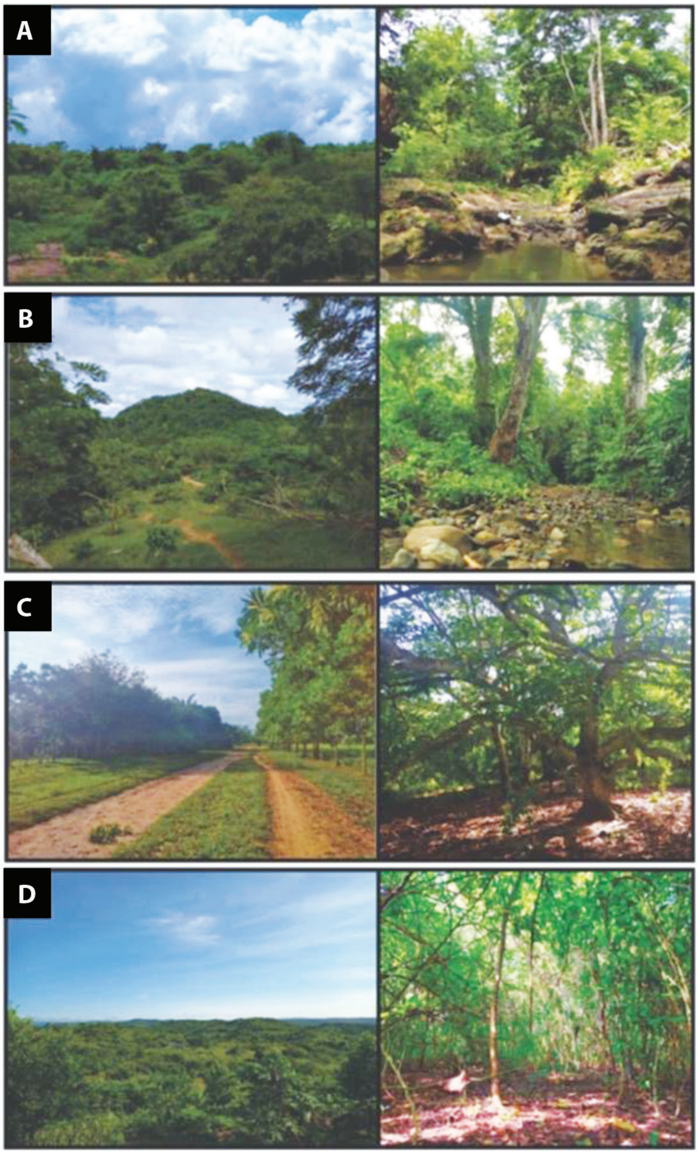


Fig. 2. Locations where myriapods were captured in the department of Bolívar, Colombia. a. Turbaco. b. San Jacinto. c. Magangué. d. El Carmen.

collected using the following techniques: Free Search: Four researchers conducted active manual searches for one hour during both daytime and nighttime shifts. Searches focused on decaying logs, tree trunks, leaf litter, and other microhabitats known to harbor myriapods. Soil Monolith Extraction: A metal sampling frame (25 cm × 25 cm × 10 cm) was used to extract ten soil monoliths per sampling day. These were randomly selected within the plot. The extracted soil was spread on a white cloth and examined under artificial light to locate specimens. Winkler Traps: Twelve 1 m^2 leaf litter samples were randomly collected within each plot. The samples were processed using Winkler extractors, placed in Winkler bags, and left at room temperature for three days before analysis. Pitfall Traps: A total of 48 pitfall traps (disposable 10 cm diameter plastic cups) were placed in groups of four, evenly distributed along the perimeter of each quadrant. Traps were covered with disposable plates positioned 5 cm above ground level to prevent rainwater ingress. The traps were filled with propylene glycol and remained in place for 15 days before specimen retrieval.

To assess habitat conditions, we recorded four environmental variables at each sampling site: Relative humidity (%) and ambient temperature (°C) were measured using a UNI-T UT333 digital meter. Soil temperature (°C) was recorded every three hours using a digital soil thermometer. Soil pH was measured with a portable pH meter.

Laboratory Processing and Taxonomic Identification: Collected specimens were fixed and preserved in 70 % ethanol, labeled, and transported to the University of Cartagena laboratories. Taxonomic identification was performed to the lowest possible level, based on morphological traits. Identification followed standard taxonomic keys, including those by Hoffman et al. (2002), Cupul-Magaña (2012), Chagas-Jr et al. (2014), and Prado-Sepúlveda et al. (2016). Additionally, expert taxonomists provided verification.

For species confirmation, collected specimens were compared with reference collections housed at the Institute of Natural Sciences (ICN), National University of Colombia. The studied specimens are currently stored at the University of Cartagena research laboratories and the ICN collections.

For ecological analyses, individuals were categorized into morphospecies, ensuring that each morphospecies included at least one adult individual. Sex differentiation was not considered in abundance estimates.

Data Analysis: To evaluate sampling effectiveness, we generated species accumulation curves using non-parametric estimators (Chao1 and ACE) based on abundance data. These models incorporated: Singletons (species represented by a single individual) and Doubletons (species represented by two individuals). Species accumulation curves were constructed using R Studio and EstimateS v. 9.1 software (Colwell et al., 2012; Colwell, 2013).

To compare alpha diversity among sites, we calculated Hill numbers at three diversity orders (Moreno et al., 2011): Species richness ($q = 0$): Number of observed species. Shannon diversity ($q = 1$): The exponent of the Shannon-Wiener index, weighting species by their relative abundance. Simpson diversity ($q = 2$): The inverse of the Simpson index, emphasizing dominant species. Confidence intervals were computed for each diversity order using Spade software and R Studio (Chao et al., 2016).

To assess differences among sites, we performed an Analysis of Similarities (ANOSIM) with 9 999 permutations and a significance threshold of $p < 0.05$. The null hypothesis (H_0) stated that there were no differences among sites.

Additionally, we conducted a classification and ordination analysis using the Chao-Jaccard index to visualize grouping patterns among study sites. This was implemented in PAST v. 3.01 and R Studio (Chao et al., 2016; Hammer et al., 2001).

To identify morphospecies responsible for site dissimilarities, we performed a non-metric multidimensional scaling (NMDS) analysis using species abundance data.

Finally, to explore the potential influence of environmental variables (ambient humidity, ambient temperature, soil temperature, and soil pH) on morphospecies abundance, we conducted a Canonical Correspondence Analysis (CCA). Morphotypes with fewer than 10 individuals were excluded from this analysis to minimize bias.

RESULTS

A total of 1 106 myriapod individuals were collected during the study, comprising 326 individuals of Chilopoda and 780 individuals of Diplopoda. The centipedes were distributed across three orders, six families, and 11 morphospecies, while the millipedes represented five orders, nine families, and 21 morphospecies, indicating greater richness and abundance within the Diplopoda (Table 2).

Among the Chilopoda, the order Geophilomorpha exhibited the highest abundance, with 162 individuals, representing 14.6 % of the total collected specimens. This was followed closely by Scolopendromorpha, which had 158 individuals (14.3 %). In contrast, Lithobiomorpha was the least represented, with only

Table 2
Taxonomic composition and abundances of centipedes and millipedes in the evaluated localities' Tropical Dry Forest fragments, using different collection techniques.

Class	Order	Family	Morpho-species	Abundance				Techniques	Total
				Tur	SaJ	Mag	Car		
Chilopoda	Geophilomorpha	Geophilidae	Geo1	8	17	8	8	Free Search Soil Monolith Pitfall Traps Winkler Traps	41
		Oryidae	Ory1	0	5	0	0	Soil Monolith Pitfall Traps Winkler Traps	5
			Ory2	17	54	10	30	Free Search Winkler Traps	111
		Schendylidae	Sch1	0	5	0	0	Free Search Soil Monolith Winkler Traps	5
	Lithobiomorpha	Henicopidae	Hen1	1	0	5	0	Free Search	6
	Scolopendromorpha	Scolopendridae	Sco1	0	1	1	0	Free Search Soil Monolith	2
			Sco2	0	0	0	9	Free Search	9
			Sco3	6	1	7	16	Free Search Soil Monolith Winkler Traps	30
			Sco4	5	2	0	5	Free Search	12
		Scolopocryptopidae	Scp1	15	60	4	25	Free Search Soil Monolith Winkler Traps	104
			Scp2	1	0	0	0	Free Search	1
Diplopoda	Polydesmida	Chelodesmidae	Che1	22	116	0	8	Free Search Winkler Traps	146
			Che2	3	0	0	0	Free Search Soil Monolith	3
			Che3	23	4	26	2	Free Search Soil Monolith Pitfall Traps	55
			Che4	3	2	6	0	Free Search Winkler Traps	11
		Cyrtodesmidae	Cyr1	0	5	0	0	Soil Monolith Winkler Traps	5
			Cyr2	0	2	0	0	Winkler Traps	2
		Fuhrmannodesmidae	Fhu1	105	18	0	0	Soil Monolith	123
			Fhu2	39	25	0	0	Free Search Soil Monolith Pitfall Traps Winkler Traps	64

Class	Order	Family	Morpho-species	Abundance				Techniques	Total
				Tur	SaJ	Mag	Car		
			Fhu3	0	0	3	0	Free Search Pitfall Traps	3
			Fhu4	0	53	0	0	Free Search Soil Monolith Winkler Traps	53
		Pyrgodesmidae	Pyr1	8	0	0	0	Free Search	8
	Polyxenida	Lophoproctidae	Pol1	5	7	3	5	Free Search Soil Monolith Winkler Traps	20
			Pol2	0	9	0	0	Free Search Soil Monolith	9
	Siphonophorida	Siphonophoridae	Sip1	6	6	0	0	Free Search Soil Monolith	12
			Sip2	0	1	0	0	Free Search	1
			Sip3	0	0	4	0	Free Search Soil Monolith Winkler Traps	4
	Spirobolida	Rhinocricidae	Rhi1	3	0	0	74	Free Search Soil Monolith Pitfall Traps Winkler Traps	77
	Spirostreptida	Pseudonannolenidae	Pse1	1	1	95	12	Free Search Soil Monolith Winkler Traps	109
			Pse2	0	0	61	0	Free Search Soil Monolith	61
		Spirostreptidae	Spt2	7	0	0	0	Free Search	7
			Spt3	3	3	1	0	Free Search Soil Monolith	7
				281	397	234	194	-	1 106

* Turbaco (Tur), San Jacinto (SaJ), Magangué (Mag), and El Carmen (Car).

six specimens, accounting for less than 1 % of the total abundance. Within the Chilopoda families, Oryidae was the most abundant, comprising 10.5 % of the total individuals, while Schendylidae was the least abundant, contributing less than 1 %.

For Diplopoda, the order Polydesmida was the most dominant, with 473 individuals, representing 42.7 % of the total collected specimens. The second most abundant order was Spirostreptida, with 184 individuals (16.5 %), while Siphonophorida exhibited the lowest abundance, with only 17 individuals (2 %). Regarding family-level composition, Fuhrmannodesmidae was the most abundant, comprising 21.9 % of the total individuals, followed by Chelodesmidae (19.4 %). The families Pyrgodesmidae and Cyrtodesmidae were the least represented, each accounting for less than 1 % of the total Diplopoda individuals.

The species accumulation curves (Fig. 3) indicated a sampling efficiency of 97 %, as estimated by ACE and Chao1 non-parametric estimators. The proportion of Singletons and Doubletons (species with only one or two individuals recorded) accounted for approximately 10 % of the total sample, confirming the adequacy and representativeness of the sampling effort. The negative trend in the Singletons curve suggested a decline in newly

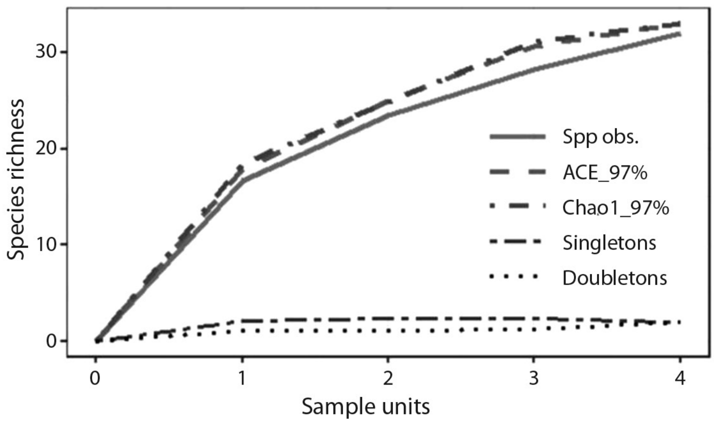
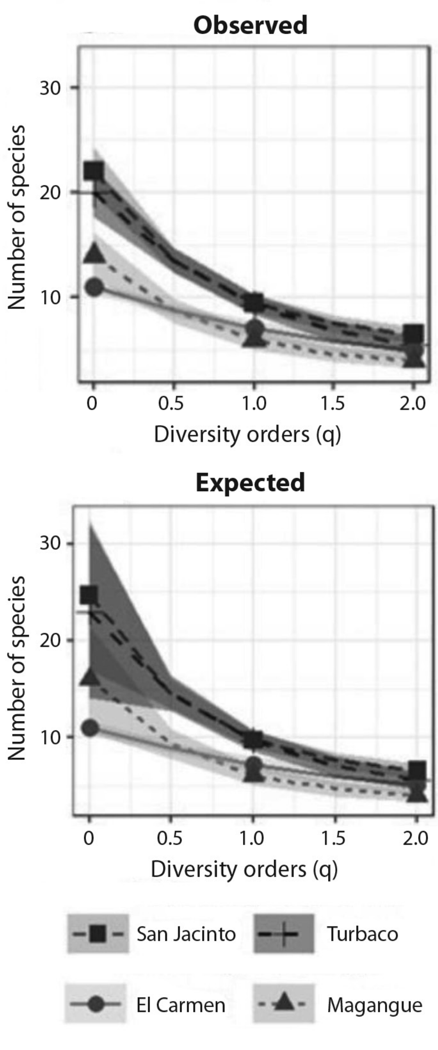


Fig. 3. Accumulation curves of myriapod species richness from Tropical Dry Forest fragments from the department of Bolívar, Colombia.



(q0), indicating potential underrepresentation of rare species in the dataset.

The ANOSIM analysis detected significant differences among the study sites (R = 0.8208, p = 0.0001), suggesting that each locality harbors distinct myriapod assemblages. The classification (Fig. 5A) and NMDS ordination analyses (Fig. 5B) further identified three distinct clusters. The first group comprised samples from San Jacinto and Turbaco, which exhibited the highest similarity in species composition, likely due to minimal anthropogenic disturbance in these areas. The second group corresponded to El Carmen, which exhibited moderate dissimilarity from the previous group. The third and most distinct cluster was formed by Magangué, which showed the greatest divergence from the other study sites, suggesting that its myriapod assemblage was the most dissimilar.

Analysis of environmental factors revealed that Turbaco and Magangué recorded the highest air temperatures, reaching 28.1 and 27.4 °C, respectively, while San Jacinto and El Carmen exhibited lower temperature values of 25.6 and

Fig. 4. Diversity profiles (Diversity orders q0 for species richness, q1 for common species, q2 for dominant species) observed and expected for myriapods from Tropical Dry Forest. fragments in the department of Bolívar. Confidence intervals are presented as the projections of each curve on the graph.

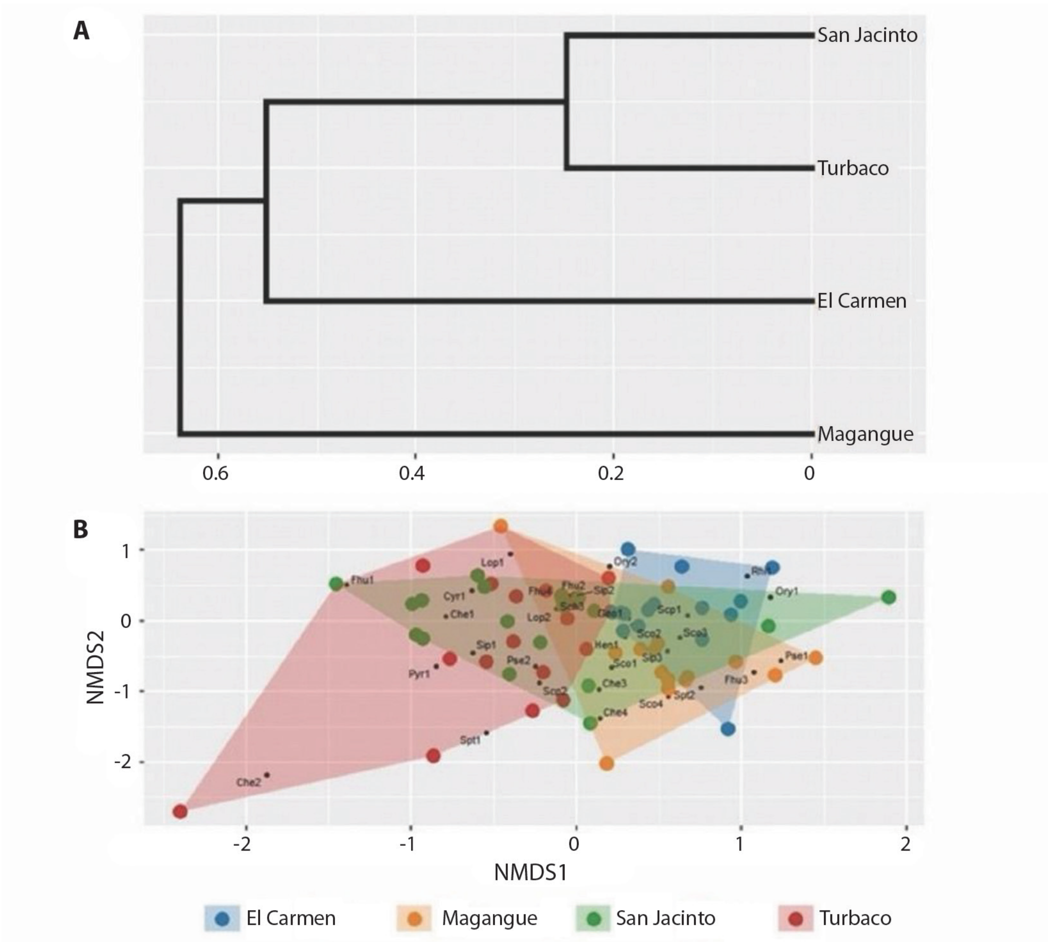


Fig. 5. Classification **A.** and ordination **B.** of samples of myriapod assemblages carried out in fragments of Tropical Dry Forests in the department of Bolívar. Note the formation of three groups: Group 1 (San Jacinto and Turbaco), El Carmen, and Magangué.

26.0 °C. Similarly, soil temperature followed the same trend, with Turbaco and Magangué reaching 27.9 and 27.6 °C, and San Jacinto and El Carmen showing lower values. In terms of relative humidity, Turbaco exhibited the highest percentage, at 93.6 %, followed by El Carmen at 92.8 %, San Jacinto at 90.3 %, and Magangué at 88.0 % (Fig. 6A). Soil pH varied across sites, with Turbaco and Magangué displaying acidic soils with pH values of 6.9 and 6.6, respectively, whereas El Carmen had a neutral pH of 7.0, and San Jacinto exhibited the highest pH value of 7.1 (Fig. 6B).

The Canonical Correspondence Analysis (CCA) (Fig. 7) identified a strong association between species distribution and environmental variables. The first CCA axis explained 64.2 % of the total variance, indicating a strong environmental influence on myriapod composition across sites. The species Pse1, Spt2, Che3, and Che4 were positively associated with high air and soil temperatures, particularly in Magangué, which had the highest recorded temperatures. This pattern suggests that these species exhibit a preference for warm environments. In contrast, environmental humidity

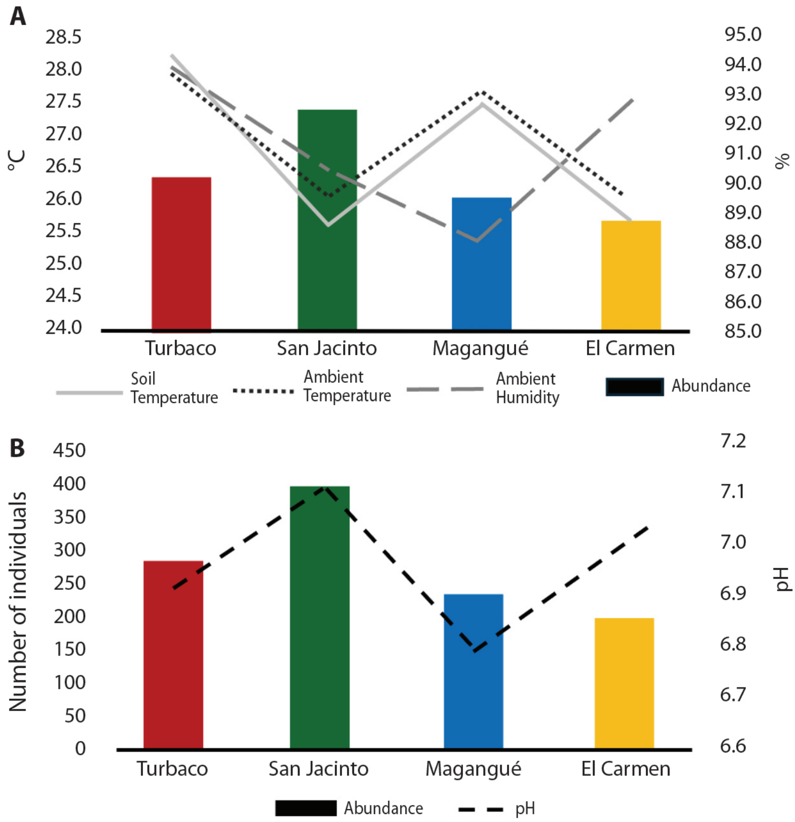


Fig. 6. Variation of environmental parameters concerning the abundance of each location. **A.** Ambient humidity, ambient temperature, and soil temperature, vs abundances. **B.** pH vs abundance.

was positively correlated with El Carmen, reinforcing the presence of species associated with more humid conditions.

Additionally, morphospecies Ory2, Geo1, and Scp1 exhibited a strong association with soil pH variations, with their abundance increasing in response to changes in pH across the four evaluated localities. These findings highlight the significant role of environmental variables in shaping the composition and distribution of myriapod communities within the Tropical Dry Forest fragments of Bolívar.

DISCUSSION

Class Chilopoda: In this study, we identified three of the four Chilopoda orders previously documented in Colombia within the department of Bolívar. Geophilomorpha emerged as the most predominant order, encompassing all three families reported for the country (Foddai et al., 2000; Prado-Sepúlveda et al., 2016). At the family level, 60 % of those documented for Colombia were represented (Chagas-Jr et al., 2014), with Scolopendridae (Scolopendromorpha) being the most diverse. This contrasts with previous studies, such as those conducted by Castillo (2017) and Prado-Sepúlveda et al. (2016), where Scolopocryptopidae exhibited the highest richness.

Previous research identified the genera *Newportia* Gervais, 1 847, and *Scolopocryptops* Newport, 1 844, along with the species *Scolopocryptops ferrugineus* Linnaeus, 1 767,

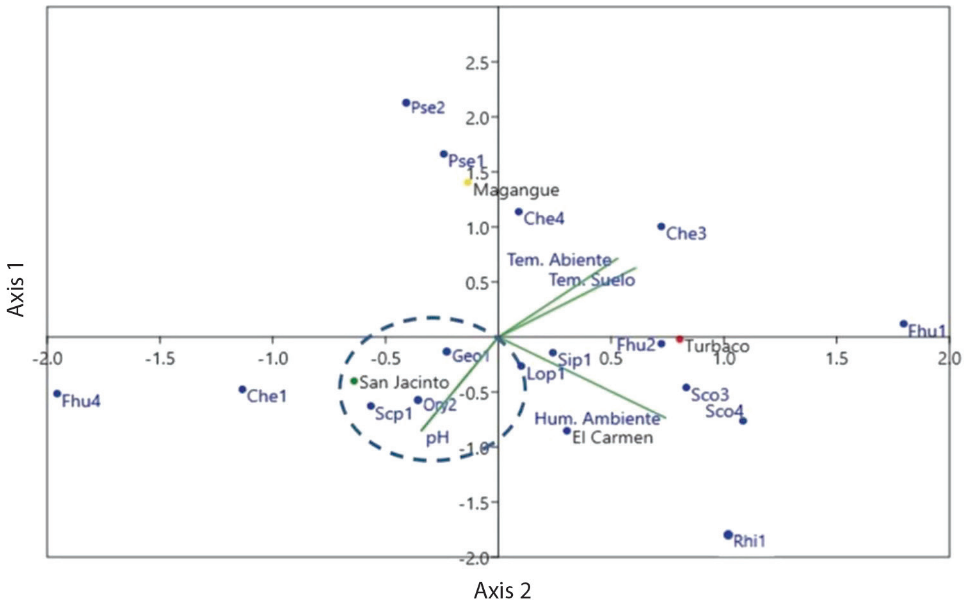


Fig. 7. Canonical correspondence analysis (ACC) between the environmental variables (ambient humidity, ambient temperature, soil pH, and soil temperature) and the abundances of the morphospecies of the evaluated localities.

Rhisyda Wood, 1 862, *Rhisyda celeris* (Humbert & Saussure, 1869), *Scolopendra arthrorhabdoides* Ribaut, 1 912, and *Scolopendra gigantea* Linnaeus, 1 758 in Bolívar. Additionally, the genus *Cormocephalus* Newport, 1 844 (order Scolopendromorpha) and *Notiphilides* Latzel, 1 880 (order Geophilomorpha) have been recorded for the Colombian Caribbean region (Chagas-Jr et al., 2014).

Class Diplopoda: Five of the seven Diplopoda orders registered for Colombia were found in the department of Bolívar, with Polydesmida and Spirostreptida being the most representative. This pattern aligns with findings from studies in Colombia and the Neotropics, which highlight the dominance of these orders in various ecosystems, such as the Otún River basin (Ruiz-Cobo et al., 2010), the Andean humid forest of Icononzo, and the Eastern Hills of Bogotá (Castillo-Ávila et al., 2015; Prado & Herrera, 2013), as well as the high tropical rainforest of Los Tuxtlas in Mexico (Bueno & Rojas, 1999).

At the family level, 69.2 % of the Diplopoda families documented in Colombia were represented (Castillo-Ávila et al., 2015; Martínez-Torres & Flórez, 2015; Ruiz-Cobo et al., 2010). Additionally, the number of recorded families has increased compared to prior inventories conducted in Bolívar and presented at scientific conferences (SOCOLEN, 2016; Carrillo-Pallares et al., 2019). The new records also expand upon previously unregistered families in ICN databases and the Universidad de Cartagena collections (consulted in December 2020). However, despite their presence in neighboring areas, Aphelidesmidae and Paradoxosomatidae were absent from this study.

Furthermore, For Paradoxosomatidae, Hoffman (1999), Pérez-Asso & Pérez-Gelabert (2001), Shelley & Lehtinen (1998), and Suriel (2012) suggested that species such as *Oxidus gracilis* (Koch, 1847) and *Orthomorpha coarctata* (De Saussure, 1860) were likely introduced via the greenhouse plant trade from Asia. The absence of these species in Bolívar may indicate environmental or ecological barriers limiting their establishment in the studied fragments.

Myriapod Diversity in Tropical Dry Forest Fragments: The species accumulation curve suggests that the sampling effort successfully captured a robust representation of myriapods, supporting the reliability of the dataset for characterizing Tropical Dry Forest assemblages in Bolívar. The decreasing trend in Singleton and Doubleton curves, which eventually intersect, suggests that the probability of discovering additional rare species is low. However, further sampling in new localities containing forest fragments would be valuable in assessing whether diversity patterns remain consistent.

The ANOSIM analysis revealed significant differences among localities, a result further supported by classification and ordination analyses (Fig. 5). The similarity observed between San Jacinto and Turbaco can be attributed to their low levels of anthropogenic disturbance and the presence of well-preserved Tropical Dry Forest remnants. The shared biotic and abiotic conditions in these locations, including proximity to water sources (Aguilera, 2014; Menco, 2013), may facilitate species coexistence and interactions, leading to higher local diversity (González-Montaña et al., 2017; Wardle, 2006). Conversely, El Carmen and Magangué exhibited greater dissimilarity, likely due to intensive habitat modification. These areas have been heavily affected by armed conflict, extensive livestock farming, monocultures, and semi-urban expansion (Aguilera, 2014; Daniels-Puello, 2016). Such disturbances can degrade forest structure, disrupt ecological interactions, and lead to biodiversity loss (Rendón-Carmona et al., 2009). Despite these transformations, some morphospecies were shared across multiple sites, suggesting that certain myriapods possess ecological plasticity, allowing them to adapt to fragmented forest environments.

The CCA analysis showed that the morphospecies Ory1 and Geo1 (order Geophilomorpha) were associated with soil pH variations in San Jacinto. Their abundance increased in soils with higher pH values, likely reflecting their preference for microhabitats within surface soil layers, where they construct galleries. Since soil chemistry can directly influence species distribution, this result aligns with previous studies on macroinvertebrate communities, where chilopod densities were linked to soil pH, nitrogen, and carbon content (Díaz et al., 2014). Given these relationships, further investigations into soil properties would enhance our understanding of myriapods as bioindicators of soil health (Rendón et al., 2011; Ruiz-Cobo et al., 2010).

Interestingly, the morphospecies Fhu1 (order Polydesmida) and Rhy1 (order Spirobolida) did not show significant variations in abundance across environmental gradients. However, numerous individuals of these species were observed engaging in courtship and copulation behaviors during the study. Similar patterns have been reported in the Andean humid forest of Icononzo, Tolima, where Spirostreptidae morphospecies displayed comparable reproductive behaviors (Castillo, 2017).

Conservation Implications: Tropical Dry Forests are recognized for their high arthropod richness and serve as valuable ecological models for assessing biotic and abiotic interactions (Janzen, 1980; Janzen, 1988). In Colombia, previous biodiversity assessments have focused primarily on insect communities, such as ants (Formicidae) (Chacón et al., 2012; Simanca-Fontalvo et al., 2013), dung beetles (Scarabaeinae) (Rangel-Acosta et al., 2016), and certain spider groups (Escorcia et al., 2012). This study represents the first systematic evaluation of myriapods in these forest fragments in Bolívar, contributing new taxonomic and ecological insights for this arthropod group.

The rapid loss of Tropical Dry Forest vegetation has direct consequences for myriapod communities, as many species depend on stable microhabitats for survival. The observed diversity variations across forest fragments underscore the importance of conserving remaining forest patches, which harbor unique species assemblages. If these remnants were lost, a significant portion of the region's myriapod diversity would disappear, further diminishing ecosystem integrity.

Despite ongoing anthropogenic pressures, the Tropical Dry Forest remnants of Bolívar continue to support high arthropod diversity, including myriapods. The results of this study indicate that species richness and abundance remain high, likely due to microhabitat heterogeneity across different successional stages. This underscores the ecological significance of these forests and highlights their priority status for conservation efforts. Given the limited research on Neotropical myriapods, further assessments are necessary to expand taxonomic knowledge and refine conservation strategies for these ecosystems.

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Ethical statement: The authors declare that they all agree with this publication and made significant contributions; that there is no conflict of interest of any kind; and that we followed all pertinent ethical and legal procedures and requirements. All financial sources are fully and clearly stated in the acknowledgments section. A signed document has been filed in the journal archives.

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