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Ecological aspects of *Ammotrechella manggi* (Solifugae: Ammotrechidae) in mangrove forest from southern Morrosquillo Gulf, Colombian Caribbean

Aspectos ecológicos de *Ammotrechella manggi* (Solifugae: Ammotrechidae) en bosques de mangle del sur del Golfo de Morrosquillo, Caribe Colombiano

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Abstract

Solifugae are a group of arachnids with strong chelicerae and absence of venom, diverse in the tropics and subtropics, tolerant to levels of humidity, and adapted to coastal ecosystems. The ecological characteristics of *Ammotrechella manggi* Acosta-Berrocal et al. 2017 in mangrove fragments from the southern Morrosquillo Gulf, Colombian Caribbean, were evaluated. The solifuges were collected in four fragments of mangrove forests, between November 2015 and July 2016 in different climatic seasons. A total of 81 individuals were collected, and the occurrence and abundance of solpugids in the evaluated mangrove forest fragments may be influenced by precipitation, height, and bark humidity. *A. manggi* exhibited a preference for fallen trees with or without decomposed areas located in floodable areas at heights between 0.5-2.7 meters and fallen trunks located on sandbars at lower heights of 1.5 m. The mangrove forest fragments offer the conditions and resources for the occurrence of the populations of *A. manggi*, determined by the availability of microhabitats that provide protection, shelter, and nesting sites.

Keywords: Córdoba, Distribution, Ecology, Microhabitat, Selectivity.

Resumen

Los solífugos conforman un grupo de arácnidos caracterizados por sus fuertes quelíceros y ausencia de veneno, diversos en los trópicos y subtrópicos, tolerantes a niveles de humedad, adaptados a ecosistemas costeros. Se evaluaron las características ecológicas de *Ammotrechella manggi* Acosta-Berrocal et al. 2017 en fragmentos de manglar del sur del Golfo de Morrosquillo, Caribe Colombiano. Los solífugos fueron colectados en cuatro fragmentos de bosques de mangle, entre noviembre de 2015 y julio de 2016 en diferentes épocas climáticas. Se recolectó un total de 81 individuos, la ocurrencia y abundancia de solífugos en los fragmentos de bosque de manglar evaluados pueden estar influenciados por la precipitación, la altura y la humedad de la corteza. *A. manggi* mostró preferencia por los árboles caídos con o sin áreas descompuestas en espacios inundables y por troncos caídos ubicados en bancos de arena a alturas inferiores a 1,5 m. Los fragmentos de bosque de manglar ofrecen las condiciones y recursos para la ocurrencia de las poblaciones de *A. manggi*, determinado por la disponibilidad de microhábitats que brindan protección, refugio y sitios de anidación.

Palabras clave: Córdoba, Distribución, Ecología, Microhábitat, Selectividad.

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INTRODUCTION

Solifugae is an order of animals in the class Arachnida known as wind scorpions or sun spiders (Punzo, 1991). Most species of solpugids live in desert and semi-desert areas, being diverse in the tropics and subtropics (Punzo, 1991; Harvey, 2003; Belozerov, 2013; González, 2015). In terms of diversity, it is considered a lesser-order group, with 1187 species, 141 genera, and 12 families (Harvey, 2003; Belozerov, 2013). The family Ammotrechidae is endemic to the Neotropical region, represented by 24 genera and 94 species (Iuri et al., 2014; Botero-Trujillo, 2016; Salleg et al., 2016). In Colombia it is represented by five genera: *Ammotrechella* Roewer, 1934, *Ammotrechulla* Roewer, 1934, *Eutrecha* Maury 1982, *Mummuciona* Roewer, 1934, and *Saronomus* Kraepelin, 1900 (Maury, 1982; Harvey, 2003; Botero-Trujillo, 2016; Salleg et al., 2016).

Some representatives of the family Ammotrechidae are tolerant to increase relative levels of humidity, characteristic of coastal ecosystems, wetlands, and mangroves, these differ from other sun spiders that are present in arid regions, adapted to little rainfall, extreme temperatures, and scarce vegetation, typical of xerophilous ecosystems with large areas (Punzo, 1991; Belozerov, 2013). However, due to their low population abundance, solpugids are difficult to collect and little attended by arachnologists, so aspects such as biology, behavior, and ecology remain relatively poorly studied and focused only on the ecosystems where they are more abundant (Valdivia et al., 2008; Catenazzi et al., 2009; Iuri et al., 2014). The solpugids of the genus *Ammotrechella* can commonly be found in arid and semi-arid habitats, taking refuge in burrows built with the assistance of their chelicerae and pedipalps, or while climbing bushes to look for prey (Muma, 1966; Gore & Cushing, 1980). In América, the records of these arachnids are found in coastal and sub xerophytic areas (Armas and Alegre, 2001; Rocha and Cancello, 2002; Catenazzi et al., 2009; Teruel & Questel, 2011).

In Colombia, taxonomy studies have been carried out, restricting themselves to xerophilous areas of the country, ignoring the ecological aspects of solpugids under natural conditions (Maury, 1982; Harvey, 2003; Chapman, 2009; Zhang, 2013; Perafán et al., 2013; Llorente & Monrrone, 2002; Villarreal-Blanco et al., 2017). In mangrove forests of the Colombian Caribbean region, the first report of the genus *Ammotrechella* associated with the bark of *Rhizophora mangle* L. 1753 trees were made by Salleg et al. (2016), and later these specimens were described as *Ammotrechella manggi* (Acosta-Berrocal et al., 2017).

Mangroves are characterized by being one of the most productive ecosystems, despite the poverty of their soil, harboring a large faunal richness, providing galleries for food, nesting, and shelter, contributing to the establishment of numerous populations of animals of economic importance, due to this, they are suffering fragmentation processes due to anthropic interventions and modification of environmental factors, causing alterations in these ecosystems (Avalos et al., 2007; Cortés & Rangel, 2011; INVEMAR, 2012). The mangrove forests from the southern Morrosquillo Gulf are the third largest and one of the best-preserved in the entire Caribbean region (CVS-INVEMAR, 2010). Therefore, it was considered of great importance to initiate studies that contribute to generating knowledge about the solpugids fauna in these coastal marine environments. For this reason, different ecological parameters were evaluated, such as the structure, in terms of the variation of its relative abundance, selection and preference of microhabitat, and distribution of *A. manggi* in fragments of mangrove forest in this area of the Colombian Caribbean.

MATERIALS AND METHODS

Study area. The study was conducted in four fragments of mangrove forests from southern Morrosquillo Gulf (9°24'34.29"N, 75'20.95"W), in the San Antero region, Colombian Caribbean (Figure 1). The climate is rainforest or tropical, marked by a mean annual temperature of 28°C (Cortés & Rangel, 2011). The precipitation regime is adjusted to a unimodal-bi-seasonal pattern, presenting a dry season (December to March) and a rainy season (April to November) with a decrease in rainfall in July (CVS-INVEMAR, 2010).

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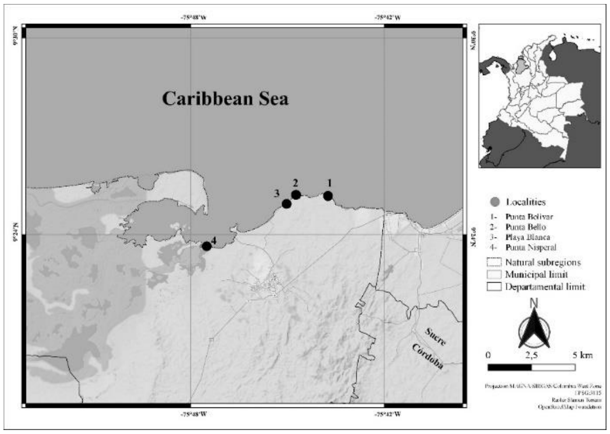

Figure 1. Location of collection sites in the Department of Córdoba, Colombian Caribbean. Map credits: © OpenStreetMap contributors, base map, and data from OpenStreetMap and the OpenStreetMap Foundation.

Description of the mangrove forest fragments. 1) Punta Bolívar; forest dominated by *R. mangle*, located by the sea, occupying the basin or depression behind the littoral sandbar, with a maximum height of 12 m and a maximum DBH (diameter at breast height) of 35 cm, with a mangrove swamp area, directly influenced by the contribution of water from a nearby stream (CVS-INVEMAR, 2010). 2) Punta Bello; forest with a more complex plant structure, consisting of *R. mangle*, *Laguncularia racemosa* (L.) C.F. Gaertn, and lower abundance of *Conocarpus erectus* L., maximum height of 7 m, in addition to some shrubs and creepers plants, with a large swamp area, influenced by water from rain and runoff from water bodies close to the area (CVS-INVEMAR, 2010). 3) Playa Blanca; forest located by the sea, and basin at the back of the sandbar, characterized by presenting a more complex and heterogeneous plant structure, dominated by *Avicennia germinans* L., but with the presence of *R. mangle*, *L. racemosa*, and *C. erectus*, lower DBH and maximum canopy height of 8 m (CVS-INVEMAR, 2010). 4) Punta Nisperal; forest with some remnants of *R. mangle* on the coastline and a regeneration area of *L. racemosa*. This area has suffered from a fragmentation process, due to strong anthropogenic intervention, causing degradation and deterioration of the quality of habitat for fauna and the hydrobiological resources, due to the processes of hyper salinization and sedimentation, which have caused the reduction of vegetal cover in extensive areas of this fragment (CVS-INVEMAR, 2010).

Field phase. Solifugae were collected between November 2015 and July 2016, covering the different climatic periods (one dry, one rainy, and transitional seasons). Four fragments of mangrove forests were evaluated, separated by an average of 2.3 km (to ensure independence), the fragment of Punta Nisperal the most distant, located approximately 5.72 km from the fragment of Playa Blanca. The selection of each of the sites was made, considering the state of conservation, the forest plant structure, microhabitats, and the presence of Solifugae. The sites were geographically positioned using a Garmin GPS (± 15 m) (Table 1).

Table 1. Location of mangrove forest fragments on the coastline of San Antero, Córdoba (Colombia).

Ubication			
Nº	**Latitude N**	**Longitude W**	**Localities**
1	9°25'14.5"	75°43'52.0"	Punta Bolívar
2	9°25'13.0"	75°44'44.1"	Punta Bello
3	9°24'50.5"	75°45'10.8"	Playa Blanca
4	9°23'38.2"	75°47'30.5"	Playa Nisperal

Solifugae sampling. The methodologies proposed by Muma (1974, 1979, 1980), Rocha and Carvalho (2006), and Valdivia et al. (2011) were adapted and applied. The specimens were sampled using a random preferential model and collected using manual collection (07:00-16:00 hrs.), from ground level to three meters in height, for an effective time of 60 min/collector, covering an approximate area of 1122 m^2 for study sectors. The specimens were stored in plastic jars, preserved in 70% alcohol, and labeled with information that contained the sample code, sector, date, and time.

Spatial distribution, microhabitat preference, and food source. Four types of microhabitats were defined: trees without decayed areas (6-8 m tall with 3-4 m canopy cover), trees with decayed areas (4-8 m tall with 3-4 m canopy cover), fallen trunks (remains of live or dead trees in contact with the ground), fallen tree (with

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heights less than 2 m, with different degrees of decomposition) distributed along the coastline, sandbars, and flooded areas. Subsequently, in the microhabitats where the presence of the individuals was recorded, an area of 25 x 25 cm was taken to capture the associated fauna, and 100 gr of decomposed wood, was used to process and find the percentage of humidity of the microhabitats. Vegetation cover was estimated using a DSM43A crown densiometer. Additionally, data such as the height at which specimens were found, the abundance and type of associated fauna, the zonation it occupies within the mangrove were recorded, as well as the plant species where they were found.

Meteorological and microhabitat variables. The temperature and precipitation variables were provided by the Institute of Hydrobiology, Meteorology, and Environmental Studies (IDEAM). To determine the percentage of bark moisture, the samples were initially weighed using an XT 220A precision analytical balance to determine the total weight. Subsequently, the tree bark was taken to a drying process in an oven at a temperature of 115°C for 24 hours. Finally, the bark was weighed, and to obtain the percentage of humidity, the following formula was used: % Humidity = Wet Weight-Dry Weight / Wet Weight * 100 (Bastienne et al., 2001).

Laboratory phase. The identification process was carried out in the Zoology (LZUC) and Entomology laboratories of the University of Córdoba (LEUC), Montería, Colombia. To confirm the solpugids collected belong to the family Ammotrechidae, and to *A. manggi*, the descriptions made by Muma (1951), Roewer (1934), and Acosta-Berrocal et al. (2017) were used. After the study, the collected specimens were deposited in the Zoological Laboratory of the University of Córdoba (LZUC), Montería, Colombia.

Statistical analysis. The total number of individuals (N) and the relative abundance per month in each mangrove forest fragment and microhabitat were estimated. For the statistical validation of each variable, the ANOVA F-Fisher (for normal distributions), and Kruskal-Wallis (for nonnormal distributions) tests were applied, and a multiple range test of Tukey-HSD was used to assess the differences between sectors. To evaluate possible multicollinearity between the meteorological and microhabitat variables, a diagnosis was made using the Variance Inflation Factor (VIF).

To evaluate the effect of meteorological and microhabitat variables, such as temperature (ºC), precipitation (mm), humidity percentage (%) and vegetation cover (m) on the relative abundance of *A. manggi* in each mangrove forest fragment evaluated, generalized linear models (GLM) with Poisson distribution and negative binomial error (abundance, residual deviance/residual df > 2) were used. The Akaike Information Criterion (AIC) was used to select the model that best explained the changes in the relative abundance of *A. manggi* (Venables y Ripley, 2002; Zuur et al., 2010). The normality of the residuals was assessed from normal q–q plots, and the presence of outliers was tested using Cook's distance (Cook's distance <1). The significance of each variable was calculated using the Monte Carlo test, with 999 permutations (Legendre & Legendre, 2012). All analyzes were performed with the R software v.4.1.0 (R Core Team, 2020).

To establish the spatial distribution pattern of *A manggi*, the Morisita dispersion index (Id) was used, which uses the relative position of each individual that forms the population (Id = 0, the population sample has a random scattering pattern; if Id < 0, a uniform pattern is displayed; if Id > 0, the pattern is aggregate), and allows obtaining different metrics such as Uniformity Index (MU), Aggregation Index (MC), and the Morisita Standardized Index (IP) (Amaral et al., 2015). Finally, to infer the microhabitat preference by *A. manggi* in each microhabitat, the measure of selectivity was calculated using Manly's selectivity measure, which allows estimating the selection proportions, that is, the same availability for all individuals, but the use is measured independently, likewise, it calculates the use and availability of each individual with a unique use and availability for each individual's movements and habitat use. All analyzes were performed using adehabitatHR package in R software v.4.1.0 (R Core Team, 2020).

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RESULTS

A total of 81 individuals were collected, of which 37 were nymphs, representing 45.6%, with a mean of 4.6 ± 2.8 ind./month, 17 sub-adults, representing 20.9%, with a mean of 2.1 ± 1.9 ind./month, and 27 adults, representing 33.3%, with a mean of 3.4 ± 2.0 ind./month. The highest abundance values of *A. manggi* were registered in the mangrove forest fragment of Punta Nisperal with 27 individuals corresponding to 33.3% and with a mean of 6.75 ± 1.2 ind./month, followed by the mangrove forest fragment of Punta Bolivar with 22 individuals that correspond to 27.16 % and with a mean of 5.5 ± 3.1 ind./month, the fragment of Playa Blanca with 18 individuals that corresponds to 22.2 % with an average of 6.2 ± 4.07 ind./month, and the Punta Bello mangrove forest fragment registered the lowest abundance values with 14 individuals, which corresponds to 17 % and with an average of 3.5 ± 2.5 ind./month (Table 2).

Table 2. The abundance of *A. manggi* in each fragment of mangrove forest by climatic season.

Localities	Zoning	Rainy season	Transition season	Dry season	Total
Punta Bolívar	Coastline	0	0	0	0
	Sandbar	4 ± 0.5	0	3 ± 0.35	7
	Flood zones	8 ± 1.3	7 ± 0.8	0	15
Punta Bello	Coastline	0	0	0	0
	Sandbar	3 ± 0.72	4 ± 0.5	4 ± 0.5	11
	Flood zones	3 ± 0.72	0	0	3
Playa Blanca	Coastline	0	0	0	0
	Sandbar	6 ± 0.65	5 ± 0.25	7 ± 1.8	18
	Flood zones	0	0	0	0
Punta Nisperal	Coastline	0	0	1	1
	Sandbar	0	0	0	0
	Flood zones	19 ± 1.35	4±1	3 ± 0.35	26
Total		**43**	**20**	**18**	**81**

The Morisita dispersion index classified *A. manggi* as a species of aggregate distribution (Id = 6.3; MU = 1.77; MC = 1.136; IP = 1.03), the highest number of individuals was found in the rainy season (N = 43), with a mean of 14.3 ± 4.7 ind./month, followed by waters in transition (N = 20), with a mean of 6.6 ± 2.2 ind./month and the dry season (N = 18) with an average of 5.9 ± 1.7 ind./month. In this sense, *A. manggi* was distributed towards the sandbar and flooded zones in the fragment of Punta Bolívar, being more abundant in the transition and rainy season. In the fragments of Punta Bello and Playa Blanca, this arachnid appeared more frequently in the sandbar, while in Punta Nisperal it appeared more frequently in the flooded zones and to a lesser extent the coastline (Figure 2).

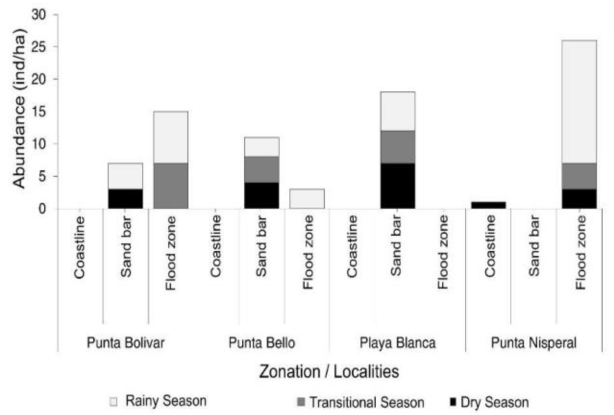

Figure 2. The relative abundance of *A. manggi* according to the zoning in mangrove fragments during the climatic seasons in each fragment of mangrove forests.

Parameters of the meteorological and microhabitat variables: The DBH presented significant differences for the four evaluated mangrove forest fragments (KW= 8.578; p<0.035), the mangrove fragment of Playa Blanca presented greater variation with a mean of 30.2 cm, followed by Punta Nisperal with a mean of 28.5 cm, and Punta Bello presented less variation with a mean of 23.1 cm. The height at which the solifuges were collected presented significant differences (KW = 11.107; p <0.011); the mangrove fragment of Playa Blanca recorded the highest height values for the occurrence of *A. manggi* with a mean of 5.2 cm, followed by Punta Bello with a mean of 3.1 cm, however, Punta Bolívar had the lowest records with a mean of 1.8 cm. On the other hand, canopy opening (KW= 5.235; p>0.1554), bark humidity (KW= 1.253; p> 0.7402), temperature (KW= 1.867; p> 0.604) and precipitation (KW= 1.679; p > 0.641) did not present significant differences. The degree of collinearity of the meteorological and microhabitat variables in the four mangrove forest fragments was low (VIF≤ 1.78),

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indicating that there are no problems related to the multicollinearity of the data (Table 3). In this sense, the analysis of the generalized linear model revealed that canopy opening, precipitation, height, and bark humidity significantly affected the abundance of *A. manggi* in the mangrove fragments studied.

Table 3. Generalized linear models to test the effect of meteorological and microhabitat variables on the occurrence of *A. manggi* in mangrove forest fragments, San Antero, Córdoba, Colombian Caribbean. (*) Statistically significant variables.

Metrics	GLM Summary		
	Estimate	|Z| Value	P
Bark humidity	0.68	2.25	< 0.024*
DBH	0.01	1.08	0.279
Height	0.56	2.88	< 0.003**
O. Canopy	0.73	3.68	< 0.0002***
Precipitation	0.79	5.73	< 0.0001***
Temperature	4.39	3.660	0.230

Microhabitat preference and offer food: Manly's selectivity measure indicated the use of the six types of microhabitats by *A. manggi* (Khi2L = 0.306; $p < 0.009$); this arachnid prefers fallen trees to a greater extent in flooded areas, on the sandbar, and in marine areas. Although they were also collected from live trees on the sandbar, however, it uses less frequently (Figure 3A). Based on the Manly selectivity measure, both in the fragment of Punta Bolívar and in Punta Nisperal the individuals preferred ranges between 0.5-2.7 m in height, where the nymphs were located at a lower height (0.7-1.5 m), subadults between 0.5-2.5 m, and adults between 0.5-2.7 m, while their eggs are laid at higher altitudes (1.5-2.5 m) (Table 4).

Table 4. Manly's selectivity measure Wi (used/available) showing habitat preferences and avoidances: Wi < 1 (avoided habitat), Wi > 1 (preferred habitat).

Microhabitat	Wi	SE	Used	Bonferroni level
Sandbar Decaying tree	0.990	0.311	0.111	P < 0.0083
Sandbar Living tree	1.210	0.590	0.049	P < 0.0083
Sandbar Fallen tree	0.994	0.175	0.284	P < 0.0083
Floodplain Decaying tree	0.973	0.107	0.506	P < 0.0083
Flood zone Fallen tree	1.210	0.685	0.037	P < 0.0083
Marine zone Decaying tree	1.210	1.202	0.012	P < 0.0083

A preference of *A. manggi* for trees over four meters tall was observed in areas flooded with a greater frequency of termite mounds. However, the fragments of Punta Bello and Playa Blanca presented lower percentages of vegetation cover (10.2-43.6%) compared to the other sectors, where *A. manggi* preferred lower heights. In Punta Bello, the nymphs and adults were found between 1-2.5 m high, while the subadults were collected between 0.2-1.5 m, for Playa Blanca this last instar was recorded at a very low height (< 0.5 m) and, unlike the other sampling sites, the eggs were placed close to the ground (Figure 3B).

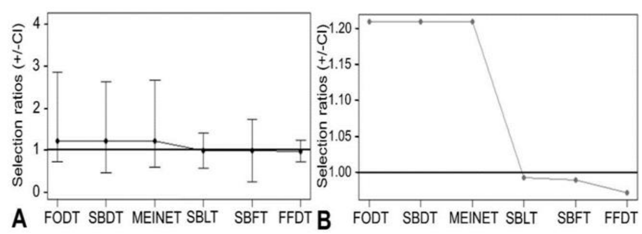

Figure 3. Selection ratios for *A manggi* using Manly's measure of selectivity. A, all microhabitats. B, use, and availability. Sandbar decaying tree: SBDT, Sandbar living tree: SBLT, Sandbar fallen tree: SBFT, Floodplain decaying tree: FFDT, Flood zone fallen tree: FODT, Marine zone decaying tree: MEINET.

The temporal dynamics of *A. manggi* are closely related to the termites *Kalotermes* Hagen, 1853, which during the rainy season the worker caste increases and the soldier caste decreases, while in transition and a dry season the worker caste decreases and the soldier increases; the presence of *A. manggi* is proportional to the abundance of worker termites and inversely to the presence of soldier termites (Figure 4A). Also, during the dry season, this arachnid shared microhabitats with ants of the genus *Crematogaster* Lund 1831, in contrast to microhabitats colonized by large arachnids such as Sparassidae and ants of the genus *Cephalotes* Latreille, 1802 where this solifuge was not recorded (Figure 4B). The laying of eggs and development of the nymphs of *A. manggi* coincide with the periods and in places where there is a greater number of worker termites, fewer soldiers, and an absence of predators in the microhabitat.

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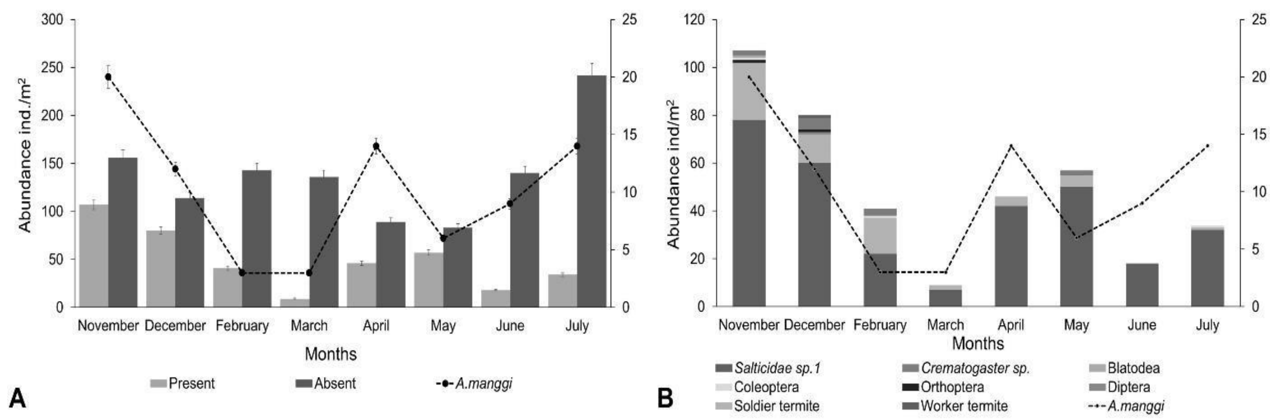

Figure 4. Effect of the presence of *A. manggi*: A, on the associated macrofauna in each microhabitat. B, the variation of macrofauna associated with microhabitats and relative abundance of *A. manggi* during climatic seasons.

DISCUSSION

Our study produced the first ecological data on the ecology of solpugids in mangrove forests from Colombia, contributing to the fragmented information on the ecology of sun-spiders in the country, and that has ignored the ecological aspects of these arachnids under natural conditions (Maury, 1982; Harvey, 2003; Chapman, 2009; Zhang, 2013; Perafán et al., 2013; Villarreal-Blanco et al., 2017). In this sense, *A. manggi* exhibits an aggregate distribution, sharing the microhabitat and its resources by making use of cavities, cracks or burrows. Studies in other solpugids have shown that most of the species, although they share microhabitats during early stages of life, some species such as *Eremobates palpisetulosus* Fichter, 1941, register an aggregate distribution in first stage nymphs maintaining proximity to each other, although after the ecdysis cannibalism can be recorded (Punzo, 1994). Similarly, some environmental parameters such as the distribution of habitat resources, the type of vegetation and the availability of food allow the aggregation of certain species, so that if the density of prey is unusually high and the characteristics of the microhabitat are favorable, they can form fortuitous aggregations (Colebourn, 1974; Buskirk, 1981; Burgess & Uetz, 1982; LeBorgne & Pasquet, 1987).

The precipitation, height, and bark humidity influenced the abundance of *A. manggi* in the fragments of mangrove forest evaluated. However, it is known that certain environmental factors are related to population aspects of solpugids depending on geographic location where these are found, so some species can tolerate seasonal temperatures in xerophilic conditions or exhibit greater tolerance to high temperatures and more humid climatic conditions (Punzo, 1991).

A. manggi is the smallest species registered within the genus *Ammotrechella* and its body size allows it to use microhabitats such as burrows, cracks, or depressions in the bark and decomposing vegetation, which are characterized by low temperatures and higher humidity, allowing the establishment of populations even in the driest ecosystems (Buxton 1923; Cloudsley-Thompson, 1975; Hadley, 1990); in addition, these factors influence the duration of embryonic development and hatching success, which can vary considerably between species depending on temperature and humidity, with ranges of 30ºC and 70% respectively being optimal (Muma, 1966; Cloudsley-Thompson, 1977; Punzo, 1994). Similarly, local rainfall patterns intervene in the construction and permanence of individuals in burrows and their microhabitats, so that if rainfall increases and remains for a long time, solpugids choose to build burrows and

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stay in them until the humidity decreases to considerable values (Punzo, 1991).

A. manggi has preferences towards the fragments of Punta Bolívar and Punta Nisperal, being less disturbed, better developed, and in a better state of conservation, showing similarities in terms of the availability of microhabitats and plant structure; areas with more closed canopies favor the humidity conditions of the substrate and the occurrence of termite mounds, therefore, are the ones that provide the greatest number of habitats and help the establishment of populations. Punta Bello and Playa Blanca were the fragments with the least abundance, probably associated with the conditions of these fragments, which present intervened environments and in which the vegetation responds to succession processes associated with economic and tourist activities, therefore, the adverse conditions create environmental stress, resulting in a lower supply of microhabitats, which has repercussions on the permanence of populations. These results indicate that the species exhibiting a certain degree of tolerance to disturbed environments, as long as it finds sites with the availability of food and refuge (McCormick & Polis, 1990).

Some species of solpugids seem to prefer habitats characterized by compact substrates associated in some way with the construction of burrows or tunnels, however, *A. manggi* did not discriminate between types of substrates in the bark but coincides with most of the species when found in open spaces with sandy substrate commonly without vegetation (Hewitt, 1912; Lawrence, 1972). It should be noted that in the Punta Bello and Playa Blanca fragments, the escape behavior of *A. manggi* when captured, was to fall from any height to the ground where they later buried themselves. In Punta Nisperal and Punta Bolívar, solpugids were found at high altitudes, preferring developed, tall trees with a large canopy, close to the area of influence of the termite mounds in flooded areas of the mangrove, however, in Punta Bello and Playa Blanca the vegetation cover decreased compared to the other fragments, so that individuals make use of the available resources found closer to the ground, since the resources are distributed in greater amount towards sandbars and trees without decomposed areas; this behavior suggests that the species has terrestrial and arboreal habits taking advantage of the soil resource as a possible microhabitat (Punzo, 1991).

It is known that the solpugids are predatory, voracious, and cursory arachnids that can travel long distances in search of prey or limit their feeding activities to relatively small areas near their burrows, thus depending on the density of their prey (Bolwig, 1952; Muma, 1966; Lawrence, 1972; Cloudsley-Thompson, 1977; Polis & McCormick, 1986; Punzo, 1994); therefore, *A. manggi* is considered here a termitophage specialist, since it limits its diet to the worker caste of termites of the genus *Kalotermes*.

According to the studies of Punzo (1991), where the selection of prey is mainly influenced by the size and degree of sclerotization, which was observed in individuals of *Ammotrechella stimpsoni* Putnam, 1883; which fed on termites *Reticulitermes flavipes* (Kollar, 1837) found inside decomposing logs (Muma, 1966); considering that the climatic seasons affect the distribution of the macrofauna associated with the microhabitats and in turn the establishment of the species in an area where seasonality and life cycles are related, in the case of Isoptera (worker caste) represented as the most important prey, it is known that they need a certain degree of humidity to live, for this reason, they are more abundant in places close to water courses or where the groundwater is not deep (Gaju-Ricart et al., 2015).

The variation in its structure and density can be explained by the periodicity of the rains, in the same way, the ants *Crematogaster* and *Cephalotes* also represented an important part by acting as possible competitors within the microhabitat. Similarly, arachnids also influence the population of *A. manggi* mainly as controllers and predators, since some species can be considered insectivorous, with the expectation that they will compete for prey.

Trees with or without decayed areas and fallen trunks were the most widely used microhabitats since they

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offer sites for foraging, shelter, and displacement. *A. manggi* was found foraging on trees without cavities, smooth surfaces, in galleries under bark and fallen trunks with different degrees of decomposition near termite mounds, except for its presence in dead trees devoid of resources. The structural complexity in mangrove ecosystems offers greater coverage, diversity of flora, and the contribution of wood and litter, consequently it provides a greater number of sites for colonization and feeding of the different species, *A. manggi* is dependent on termites of the worker caste and changes in the local termite structure may depend on factors such as temperature, humidity and solar radiation along latitudinal and altitudinal gradients, which may influence their development and foraging activity of the worker caste (Jones, 2000; Cabrera-Dávila & Hernández-Marrero, 2015), although the variables do not directly affect solpugids, they can determine the conditions of more sensitive organisms such as termites and consequently favor populations of *A. manggi*.

CONCLUSIONS

Finally, it can be said that the fragments of mangrove forest from San Antero, offer the necessary conditions for the establishment of *A. manggi* populations in all their stages of development. Microhabitat selection is determined by the structure and density of termites of the genus *Kalotermes* found distributed in trees with and without decomposed areas or fallen trunks located in the sandbar, which mostly had termite mounds and substrates with galleries or cavities in the bark suitable for refuge, hunting and nesting of solifugae in all their stages of life. Furthermore, considering their aggressive behavior towards other individuals, *A. manggi* takes advantage of the conformation of microhabitats to disperse, but contact is physically limited by tunnels or burrows, however, taking into account the favorable ecosystem and the great supply of food, it is possible that fortuitous aggregations are formed even in groups as territorial and aggressive as solpugids are.

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