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Article

Diversidad de arañas en ecosistemas forestales como indicadoras de altitud y disturbio

Diversity of spiders in forest ecosystems as elevation and disturbance indicators

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Resumen:

Las arañas son organismos depredadores que por ser pequeños y fáciles de detectar resultan ideales para la realización de estudios de variación ambiental y disturbio. Se estudiaron 45 comunidades de arañas en dos grandes montañas del noreste de México: el cerro El Potosí, en el sur de Nuevo León; y Peña Nevada, en el sur de Tamaulipas. Se determinó el tipo de vegetación, la actividad humana, la ganadería, y la degradación de suelo. Se definió un índice de disturbio. La hipótesis planteada se refiere a la presencia de una menor diversidad de arañas en los sitios con más disturbio. Se obtuvieron 541 individuos, agrupados en 23 familias; de ellas, las más abundantes fueron: Lycosidae, Anyphaenidae y Gnaphosidae. La distribución de las especies se asoció con la presencia de hojarasca. No se detectó relación entre la diversidad de arañas y la altitud o el disturbio. *Pardosa* sp. fue la más abundante en sitios conservados. Las familias Lycosidae, Thomisidae y Pholcidae fueron las mejor representadas en zonas con mayor intervención humana. Este estudio en dos zonas forestales importantes del noreste de México servirá de pauta para investigaciones posteriores de biodiversidad en ecosistemas forestales y la influencia de la variación ambiental y el disturbio.

Palabras clave: Arácnidos, biodiversidad, ecosistemas de montaña, gradiente ecológico, Lycosidae, *Pardosa* sp.

Abstract:

Spiders are ideal predators for studies of environmental variation and disturbance due to their small size and ease of collection. In two major mountains of northeastern Mexico: *Cerro El Potosí* (in Southern Nuevo León) and *Peña Nevada* (in Southern *Tamaulipas*), 45 spider communities were studied. Human activity, vegetation type, disturbance, livestock, and land degradation were measured. As a hypothesis, it was anticipated finding low spider diversity in highly degraded sites. 541 individuals from 23 families were found. The most abundant families were Lycosidae, Anyphaenidae and Gnaphosidae. Spider species distribution was highly associated with presence of leaf-litter. Spider diversity was unrelated to elevation or disturbance. *Pardosa* sp. was the most abundant and dominant at well-preserved sites. Lycosidae, Thomisidae and Pholcidae were more abundant in areas with greater human intervention. This study in two important forest zones in northeastern Mexico will be a guide for future research on biodiversity on forest ecosystems and influence of environmental variation and disturbance.

Key words: Spiders, biodiversity, mountain ecosystems, ecological gradient, Lycosidae, *Pardosa* sp.

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Introduction

The edaphic macrofauna consists of invertebrates larger than 2 mm in diameter (Cabrera, 2012). Of these, spiders are a group of ecologically important predators (Eggs and Sanders, 2013); they are located in the highest part of the food chain of invertebrates (Uma and Weiss, 2012); they influence the density and activity of detritivorous and fungivorous fauna, and they also indirectly affect the decomposition processes (Willett, 2001; Ávalos *et al*., 2007).

Spiders are a regular component of any ecosystem where they live (Deza and Andía, 2009). Despite being considered among the most numerous entomophages, little is known about their role as predators, their diversity and abundance in temperate forests (Ruíz and Coronado, 2002; Ávalos *et al.,* 2007, Gómez-Rodríguez and Salazar, 2015). Because their diversity and density respond to changes in ecosystems, they have been considered as indicators of habitat quality (Willett, 2001; Ávalos *et al.,* 2007). Among the features that justify them as such, the following can be pointed out: the advantage of their ecological diversification, their continuous presence throughout the year, and the possibility of their being manipulated and identified, as well as the short period that elapses between their generations (Willett, 2001).

Spiders have been little investigated in Mexico; however, there are very good studies in natural environments such as tropical forests (Rivera-Quiroz *et al.,* 2016), coniferous forest and eucalyptus plantations (Corcuera *et al.,* 2016), cloud forest (Campuzano *et al*., 2016) and in urban conditions (Desales-Lara *et al*., 2013; Rodríguez-Rodríguez *et al.,* 2015). The objective of this study is to identify and establish variations in spider communities, depending on the disturbance in two forest ecosystems of northeastern Mexico. In addition, it is hypothesized that its diversity is lower in the sites with more disturbance.

Materials and Methods

The investigation was carried out in the *Cerro El Potosí,* in *Galeana* municipality, *Nuevo León* state and in the *Sierra Peña Nevada*, which includes *Zaragoza* municipality, in *Nuevo León* and *Miquihuana* municipality, in *Tamaulipas* state in northeastern Mexico. The two places are promontories that are part of the *Gran Sierra Plegada*, within the *Sierra Madre Oriental* province; they are characterized by having temperate ecosystems and reaching the highest altitudinal range in the region (Cantú *et al.,* 2013).

Sierra de Peña Nevada is located in the *Sierra Madre Oriental* and is part of the priority land region (RTP) No. 86, *San Antonio-Peña Neva*da (Arriaga *et al.*, 2000). It has a height of 3 500 masl and an area of 60 500 hectares. Its extreme coordinates are 23°33'18'' to 23°52'28'' N and 99°38'55'' to 99°56'45'' W.

Cerro El Potosí has an area of 989.38 hectares; is located 15 km west of *Galeana, Nuevo León*, between 24°50'35'' and 24°53'16'' N and 100°13'9'' and 100°15'12'' W It has a maximum height of 3 700 masl.

Samplings were carried out throughout the year, in such a way that an attempt was made to incorporate the greatest seasonal variation. As far as possible, the field work dates were stratified, so that the two sampling sites and the altitudes were homogeneously distributed in the seasons of the year, to avoid biases when sampling. Other studies have determined that the density, but not the diversity and activity of the spiders varies according to the time of collection (Campuzano *et al.,* 2016, Rivera-Quiroz *et al*., 2016).

Sampling was carried out between 2013 and 2015. The sites were visited only once and were selected based on an altitudinal distribution that included 10 levels, with an increase of 150 m, started at 2 100 m and finished at 3 450 m; in each one, two collections were conducted in geographically registered sites, by means of a satellite geolocator (Garmin eTrex 10). A transect of 100 m was established in each site, in which five alternating points were placed, marked with flags. The capture was direct, when the spiders were found visually and were taken from the ground above and under the litter, this action was executed around noon, to decrease variables in the activity of the same, with a sampling effort of 75 minutes per site; that is, 15 minutes per meter.

The specimens were captured with the help of entomological tweezers and with a brush moistened in alcohol, they were placed in a pet bottle, labeled and kept fixed in ethyl alcohol at 70 % (v / v). Individuals were initially identified as morphospecies, and subsequently as a family, genus or species, using taxonomic keys (Levi, 1991; Ubick *et al.,* 2005), databases (Gómez-Rodríguez *et al.,* 2014; World Spider Catalog, 2018) and with the help of specialists. The specimens were deposited in the invertebrate collection of the *Laboratorio de Ecología* of the *Instituto Tecnológico of Ciudad Victoria, Tamaulipas.*

The number of sites sampled was limited by access to the locations and each point corresponds to a replication by altitude or disturbance condition. These were quantified independently of the spider sampling; for this, a quadrant of 50 m^2 was established where the sources of disturbance were counted, according to the method of Martorell and Peters (2005). This allowed us to obtain a disturbance index based on the analysis of 13 parameters, in three categories: 1) human activities, 2) cattle breeding and 3) state of soil degradation. The compaction of soil was not considered, because it consumed a lot of time, nor severely modified surfaces, as it was not the case in the study areas.

The index of each site was determined with the formula proposed by Martorell and Peters (2005) that considers values from 0 (without disturbance) to 100 (highly disturbed). A logarithmic base 10 scale was used and the 45 sites sampled were categorized into: High Disturbance: (1.4 -1.8), Medium (1- 1.4) and Low (0.6 - 1).

A matrix was constructed from the perturbation variables, in which each of the sites obtained a disturbance index. After the designation of the disturbance indexes, the highest value variables were extracted (component 1), which together with the litter, altitude and disturbance were considered as dependent variables in the Principal Component Analysis.

The Shannon diversity index was calculated for each sampling point; Spearman correlation analyzes were also made between the altitude and the disturbance index; the diversity of spiders (Shannon index) and disturbance, as well as between the diversity of spiders and altitude. To determine differences in diversity in relation to the perturbation gradient, a one-way analysis of variance was used. An analysis of Kruskal-Wallis was used as well, whose dependent variable was the disturbance index and the altitude as the independent one (2 000-2 400 low, 2 500-2 900 average and 3 000-3 500 high).

The composition of the species with respect to environmental factors; that is, the variables that make up the main components of greater importance (with values of 0.654 to 0.775), was analyzed by means of a canonical correspondence (ACC) of two matrixes, one with abundance data by species (species matrix) and another with the environmental factors (ecological-environmental matrix), both with classification of the 45 sites sampled. The elements of the latter were the presence of feces of bovines and horses; number of plants in the quadrant with parts or branches extracted for fuel; surface of the trails within the quadrant (surface of the intersection); percentage of the area of the quadrant used for some type of activity (foraging, logging and agriculture), stoniness, altitude and litter.

A one-way ANOVA was applied; when the data did not meet the theoretical assumptions, nonparametric tests were used; all analyzes were done with the IBM SPSS Statistics ver. 22 program, except for the canonical correspondence analysis (Canoco for Windows 4.5 Software) that was used.

Results and Discussion

541 spiders were obtained which belong to 71 morphospecies, 42 genera and 23 families; from them, the most abundant were Lycosidae (56 %), Agelenidae (10 %) and Anyphaenidae (9 %) (Table 1). It is probable that the number of morphospecies overestimates that of taxonomic species, due to the risk of incorrectly identifying juvenile individuals. The total of morphospecies is comparable with that cited for Mexico in other studies; thus, 91 taxa were recorded in a remnant fragment of tropical

forest (Rivera-Quiróz, 2016), 63 in the urban area of *Chilpancingo* (Rodríguez-Rodríguez *et al*., 2015) and 41 taxa in *Toluca* (Desales-Lara , 2013).

Table 1. Spiders in *Cerro El Potosí* and *Sierra Peña Nevada* in *Nuevo León* and *Tamaulipas,* as well as characteristics of the zones.

State	Ecosystem	Altitude elevation	Site state	Family	Species
Nuevo León	Pine forest	2800-3400	Preserved	Agelenidae	*Melpomene* sp.
				Thomisidae	s/i
				Lycosidae	*Pardosa* sp.
				Salticidae	*Mexigonus* sp.
Tamaulipas	Pine forest Pine forest	2100-3300	Preserved	Lycosidae	*Pardosa* sp.
				Lycosidae	*Rabidosa rabida*
				Lycosidae	*Hogna* sp.
				Caponiidae	*Orthonops lapanus*
				Agelenidae	*Melpomene coahuilana*
				Anyphaenidae	*Clubiona* sp.
Nuevo León	Pine forest	2850-3850	Disturbed	Agelenidae	s/i
				Anyphaenidae	*Anyphaena* sp.
				Corinnidae	*Castianeira* sp.
				Dictynidae	s/i
				Gnaphosidae	*Zelotes* sp.
				Gnaphosidae	s/i
				Hahniidae	s/i
				Linyphiidae	s/i
				Lycosidae	*Melocosa* sp.
				Lycosidae	*Pardosa* sp.
				Salticidae	*Hasarius* sp.
				Salticidae	s/i
				Theridiidae	s/i
				Thomisidae	s/i

Tamaulipas	Pine forest	2850-3300	Disturbed	Agelenidae	s/i
				Agelenidae	*Melpomene* sp.
				Filistatidae	*Kukulcania hibernalis*
				Linyphiidae	*Agyneta* sp.
				Linyphiidae	s/i
				Linyphiidae	*Frontinella* sp.
				Lycosidae	*Pardosa* sp.
				Lycosidae	s/i
				Phrurolithidae	*Piabuna* sp.
				Salticidae	s/i
				Tetragnathidae	*Chrysometa* sp.
				Theridiidae	s/i
Nuevo León	Conifer forest	3000-3150	Preserved	Agelenidae	s/i
				Gnaphosidae	*Zelotes* sp.
				Lycosidae	s/i
				Lycosidae	*Pardosa* sp.
Tamaulipas	Conifer forest	3150-3450	Preserved	Agelenidae	s/i
				Anyphaenidae	*Anyphaena* sp.
				Anyphaenidae	s/i
				Gnaphosidae	s/i
				Linyphiidae	*Agyneta* sp.
				Lycosidae	*Pardosa* sp.
				Lycosidae	s/i
				Tetragnathidae	s/i
				Tetragnathidae	*Chrysometa* sp.
				Thomisidae	s/i
Nuevo León	Oak forest	2500-2550	Disturbed	Agelenidae	s/i
				Anyphaenidae	*Anyphaena* sp.
				Eutichuridae	*Strotarchus* sp.
				Gnaphosidae	*Zelotes* sp.
				Linyphiidae	s/i

				Salticidae	*Mexigonus* sp.
				Tetragnathidae	*Leucauge* sp.
				Theridiidae	*Theridion* sp.
				Theridiidae	s/i
Tamaulipas	Oak forest	2700-3000	Preserved	Agelenidae	s/i
				Anyphaenidae	*Anyphaena* sp.
				Dipluridae	s/i
				Linyphiidae	s/i
				Lycosidae	s/i
				Salticidae	s/i
Nuevo León	Pine-oak forest	2100-3000	Disturbed	Agelenidae	*Agelenopsis* sp.
				Gnaphosidae	s/i
				Linyphiidae	s/i
				Lycosidae	s/i
				Lycosidae	*Pardosa* sp.
				Pholcidae	s/i
				Salticidae	s/i
				Theridiidae	s/i
Tamaulipas	Pine-oak forest	2500-2550	Preserved	Agelenidae	s/i
				Araneidae	s/i
				Linyphiidae	*Frontinella* sp.
				Lycosidae	*Pardosa* sp.
				Lycosidae	s/i
Nuevo León	Scrubland	2100-2700	Disturbed	Lycosidae	Pardosa sp.
				Oxyopidae	s/i
				Diguetidae	*Diguetia* sp.
				Agelenidae	s/i
Nuevo León	Scrubland	2100-2700	Preserved	Lycosidae	s/i
				Corinnidae	*Castianeira* sp.
				Agelenidae	s/i
Tamaulipas	Scrubland	2500-2700	Preserved	Agelenidae	*Melpomene* sp.

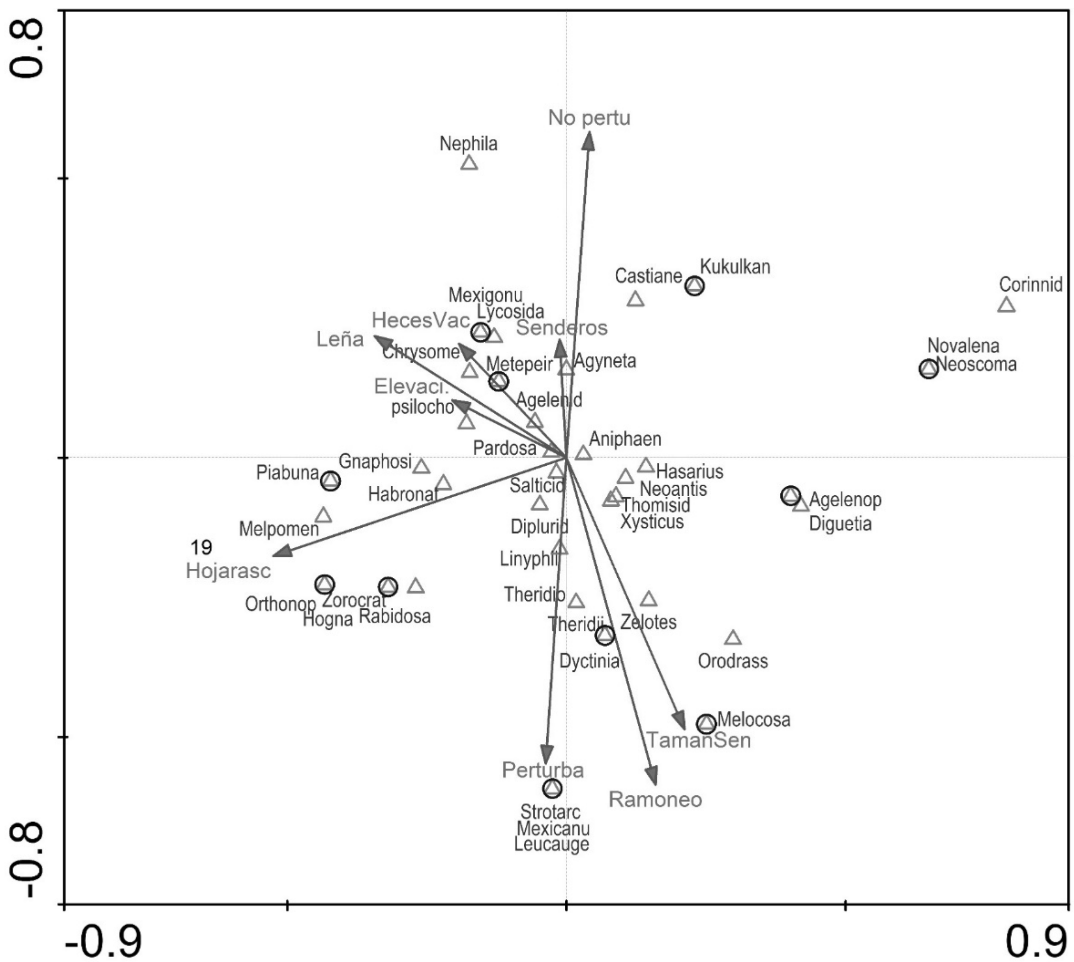
				Anyphaenidae	*Anyphaena* sp.
				Araneidae	*Metepeira* sp.
				Araneidae	s/i
				Gnaphosidae	s/i
				Lycosidae	*Pardosa* sp.
				Salticidae	*Habronattus* sp.
				Salticidae	s/i
				Theridiidae	s/i
				Zoropsidae	*Zorocrates unicolor*
Tamaulipas	Desert Rosetophyllous scrub	2100-2250	Preserved	Agelenidae	*Novalena* sp.
				Anyphaenidae	s/i
				Araneidae	*Neoscona* sp.
				Araneidae	s/i
				Linyphiidae	*Frontinella* sp.
				Lycosidae	s/i
Tamaulipas	Desert Rosetophyllous scrub	3000-3300	Disturbed	Agelenidae	s/i
				Lycosidae	*Pardosa* sp.
				Linyphiidae	s/i
				Lycosidae	s/i

Unidentified (s / i). The nomenclature follows the World Spider Catalog (2018).

Three components explained 62.40 % of the variance of the correlation of sources of disturbance. Component 1 corresponded to 32.67 % which refers to the presence and frequency of feces of cattle and horses, number of plants in the quadrant with parts or branches extracted for fuel, number of paths in the quadrant used by people, surface of the trails within the quadrant (surface of the intersection) and percentage of the area of the quadrant for foraging, logging, agriculture, and so on. Component 2 explained 10.71 % of the variables.

A negative correlation was obtained for the proximity to nuclei of human activities (number of activities that are located up to 200 m), evidence of signs of fire, percentage of soil erosion and exposed soil. Component 3 explained 9.65% of the total variables, is associated with the proximity of human settlements in kilometers.

The analysis of canonical correspondence between groups showed an impact of the disturbance in the assemblages of spiders present in the areas sampled under some degree of disturbance. The most important factor regarding axis 1 corresponded to the leaf litter variable; in axis 2 the relevant independent variables were perturbation and non-perturbation (Figure 1). The diversity index did not differ with the disturbance index in the ANOVA ($p < 0.05$).



Axis 1 (19.9 %); Axis 2 (34.6 %); (Hecesvac = Frequency of stools found at the site; Trails = Small trails used by animals; Firewood = Frequency of plants used for the extraction of fuel (wood, firewood); Hojarasc = Level of litter per sampling site; Elevation = Altitude elevation; Ramoneo = Number of plants browsed; Tamasen = Diameter of the intersection between the paths and paths within the quadrant; NoPerturb = Sites with disturbance index under 0.6-1.2; Disturbance = Sites with high disturbance index 1.2-1.8).

Figure 1. Canonical correspondence analysis that indicates the dynamics of spider groups with respect to environmental and disturbance factors.

The leaf litter was determinant in the distribution and assembly of the spiders, since almost half of them were associated with the presence of this factor. *Hogna* sp., *Orthonops lapanus*, *Melpomene* sp. and *Rabidosa rabida* were associated to that variable in pine forests. *Novalena* sp., *Neoscona* sp. and some species of the Corinnidae family are located in the opposite direction of the leaf litter vector, because they are distributed in areas of desert scrub devoid of litter and with a low level of disturbance. *Kukulcania hibernalis* and *Castianeira* sp., were recorded in areas devoid of litter and in the least disturbed. The first is located, mainly, under rocks and trunks. The influence of leaf litter and the structure of the understory are determining factors in the density of hunting spiders in Mexican coniferous forests (Corcuera *et al*., 2016).

Axis 2 defines the disturbance as a determining factor in the assembly of the spiders. *Leucauge* sp., *Mexigonus* sp. and *Strotarchus* sp. were present in sites with a high degree of disturbance and never in undisturbed sites. This condition is also related to the browsing and size of paths variables; together they include the families Salticidae, Dipluridae and Linyphiidae.

For the non-disturbance variable, the relationship with *Mexigonus* sp., *Agyneta* sp. and some species of Agelenidae and Lycosidaeis well defined; which in turn have a close association with the trails variable, most likely because they were present in virtually all areas.

Piabuna sp. and certain taxa of the Gnaphosidae family were correlated with leaf litter and altitude. *Chrysometa* sp. was associated with the altitude and the areas where there was wood extraction, they were only observed in pine forests. *Pardosa* sp. was located in the center of the disturbance and leaf litter vectors mainly in forested areas (Figure 1).

Table 2 presents the information of the sampling sites, the number of spider morphospecies and the Shannon diversity index. No correlation was detected between altitude and disturbance index (Rho = 0.18, P = 0.10), nor between diversity and disturbance (Rho = 0.92, P = 0.39). Neither between diversity and altitude (Table 2) (Rho = 0.18, P = 0.23). The sampling sites along the mountains did not show a relationship between disturbance index and diversity (Rho = 0.002, P = 0.98).

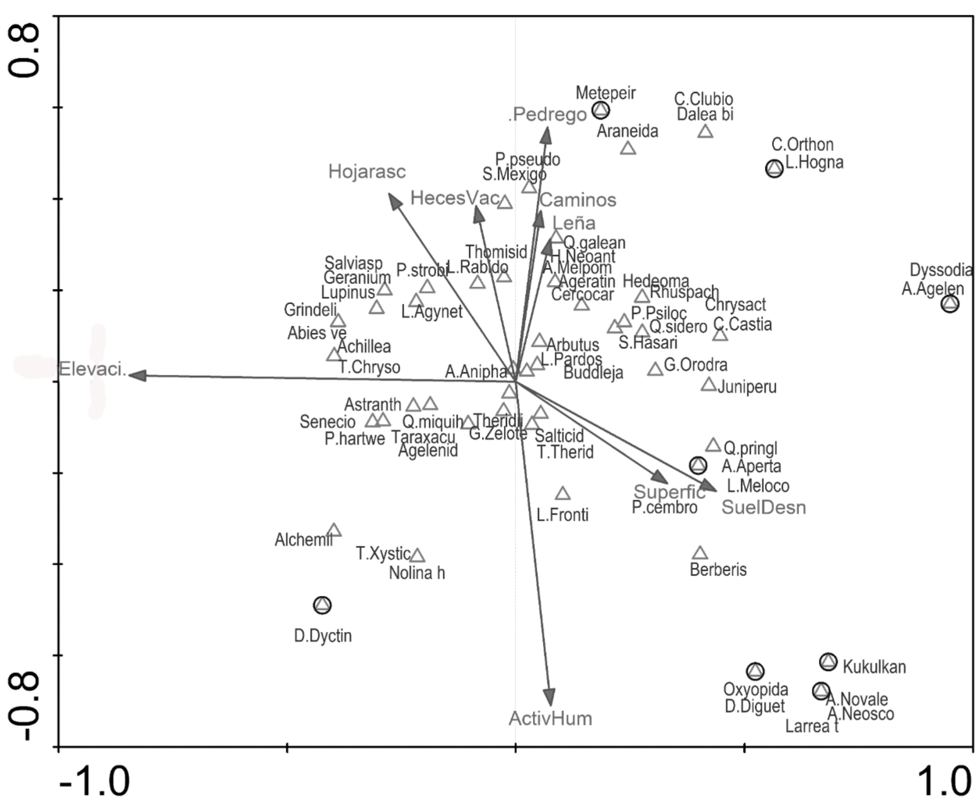
Table 2. Characteristics of the sampling points and number of morphospecies in the *Cerro El Potosí* (EP) and *Sierra Peña Nevada* (PN) in *Nuevo León* and *Tamaulipas.*

Area	Type of vegetation	Sampling dates	Disturbance index	State of the site	Altitude masl	Morphospecies	Diversity (*Shannon*)
PN	Pine forest	12/04/13	1.467	Disturbed	2 850	12	0.59
PN	Scrubland	09/06/13	1.485	Disturbed	2 565	10	1.38
PN	Oak forest	19/06/13	1.024	Undisturbed	2 686	17	1.26
PN	Pine forest	20/08/13	0.694	Undisturbed	2860	20	1.30
PN	Scrubland	25/10/13	1.371	Disturbed	2 715	11	1.47
EP	Pine forest	20/02/14	1.314	Disturbed	3 275	22	1.08
EP	Pine forest	22/02/14	1.228	Disturbed	2 864	9	1.13
EP	Oak forest	12/04/14	1.338	Disturbed	2 562	27	1.46
EP	Pine-oak forest	12/04/14	1.710	Disturbed	3 012	6	0.90
PN	Coniferous forest	01/08/14	1.195	Undisturbed	3 140	15	1.14
PN	Pine forest	31/07/14	1.424	Disturbed	3 135	6	0.67
PN	Desert Rosetophyllous scrub	31/07/14	1.379	Disturbed	2 254	14	1.07
EP	Coniferous forest	09/08/14	0.882	Undisturbed	3 015	15	0.33
EP	Coniferous forest	10/08/14	1.023	Undisturbed	3 000	16	0.54

EP	Oak forest	10/08/14	1.035	Undisturbed	2 710	14	0.78
PN	Pine forest	29/11/14	1.204	Disturbed	3 012	11	0.82
PN	Pine forest	29/11/14	1.069	Undisturbed	2 842	12	0.37
PN	Pine forest	30/11/14	1.396	Disturbed	2 100	13	1.18
PN	Pine forest	30/11/14	1.455	Disturbed	2 720	14	0.69
EP	Pine-oak forest	24/02/15	1.482	Disturbed	2 125	10	0.90
EP	Pine forest	25/02/15	1.544	Disturbed	3 425	4	0.52
EP	Pine forest	25/02/15	1.412	Disturbed	3 305	7	0.65
EP	Oak forest	13/05/15	1.187	Undisturbed	2 405	10	0.73
EP	Oak forest	13/05/15	0.882	Undisturbed	2 256	10	0.74
EP	Scrubland	13/05/15	0.943	Undisturbed	2 109	8	0.60
PN	Pine forest	16/05/15	1.397	Disturbed	3 290	13	0.60
PN	Pine forest	17/05/15	0.661	Undisturbed	3 277	9	0.48
EP	Pine forest	14/06/15	0.945	Undisturbed	3 434	12	0.63
EP	Pine forest	14/06/15	1.169	Undisturbed	3 426	7	0.62
PN	Pine forest	30/08/15	1.430	Disturbed	2 978	11	0.51
PN	Pine-oak forest	30/08/15	1.064	Undisturbed	2 550	19	0.86
EP	Scrubland	20/10/15	1.483	Disturbed	2 266	14	0.59
EP	Pine forest	21/10/15	1.009	Undisturbed	3 324	7	0.38
EP	Pine forest	21/10/15	1.321	Undisturbed	3 138	9	0.60
EP	Coniferous forest	22/10/15	1.009	Undisturbed	3 174	9	0.53
EP	Pine forest	29/10/15	0.699	Undisturbed	2 875	12	0.62
EP	Scrubland	29/10/15	1.584	Disturbed	2 716	12	0.34
PN	Pine forest	01/11/15	1.577	Disturbed	2 232	18	0.57
PN	Coniferous forest	01/11/15	0.874	Undisturbed	3 425	12	0.70
PN	Pine forest	02/11/15	1.538	Disturbed	2 085	9	0.55
PN	Pine forest	08/11/15	1.234	Disturbed	2 385	11	0.60
PN	Desert Rosetophyllous scrub	08/11/15	1.531	Disturbed	3 330	9	0.52
PN	Pine forest	08/11/15	1.480	Disturbed	2 425	11	0.50
EP	Pine forest	11/11/15	1.299	Disturbed	2 393	9	0.56
EP	Pine forest	11/11/15	0.804	Undisturbed	2 542	15	0.35

In axis 1 of the canonical analysis of correspondence it was observed that the altitude explains almost by itself the graph, its magnitude reflects the high correlation that exists between altitude and vegetation. For example, *Abies vejarii* Martínez, *Lupinus* sp. and *Geranium crenatifolium* H. E. Moore tend to be in the higher areas along with *Chrysometa* sp., a spider that was only recorded in coniferous forests. *Dyssodia pinnata* (Cav.) B. L. Rob. is a herb found in more desertic and in lower areas; Agelenidae is a family of spiders that was mainly recorded in pine forests with scrubland elements (Figure 2).

Kukulcania hibernalis, Diguetia sp., *Novalena* sp. and *Neoscona* sp. are associated with *Larrea tridentata* (Sessé & Moc. ex DC.) Covill from the desert rosetophyllous scrub. *Hasarius* sp. and *Castianeira* sp. were found under logs, trunks, stones and small herbs which coincide with the following plants: *Hedeoma palmeri* Hemsl*., Rhus pachyrachis* Hemsl*., Chrysactinia* sp. and *Cercocarpus* sp., from scrubland and oak forest. *Pardosa* sp. was located at the center of vectors, mainly in the pine forests.



Axis 1 (50.6 %); Axis 2 (41.8 %); Hecesvac = Frequency of stool found at the site; Firewood = Frequency of plants used for fuel extraction (wood, firewood); Hojarasc = Level of litter per sampling site; Elevation = Altitude elevation; SuelDesn = Percentage of bare soil found in the area; Pedrego = Percentage of stoniness in the area).

Figure 2. Graph of canonical analysis of correspondence that indicates the dynamics of spider groups and vegetation with respect to environmental variables.

The number of families identified in the study areas corresponds to 30 % of the known families in the area according to Ruíz and Coronado (2002), who document 72 families and 135 species for the states of *Nuevo León* and *Tamaulipas*. In the present investigation, a high morphospecies richness was obtained (tables 1 and 2), considering that the size of the sampled area is less than 1 % of the total area of both states. However, it is possible that the lack of identification at the species level implies an overestimation. Unidentified genera were rare and with low diversity, possibly taxa not registered for the region, although they could be juvenile organisms.

The variable that best explained the presence of spiders was leaf litter, which coincides with Podgaiski and Rodrigues (2017), who indicate that their existence and complexity are of great importance for the diversity of said invetebrate group. The disturbance to a lesser degree did not influence the presence of spiders. The above is consistent with that recorded for other environments (Bonte *et al.,* 2004; Langlands *et al.,* 2011). Noteworthy in particular is that of Michoacán, where the species composition differs with the disturbance, but not the diversity index (Maldonado-Carrizales and Ponce-Saavedra, 2017).

The diversity of spiders and leaf litter are linked to plant cover, since this relationship reflects a greater number and diversity of niches (Ávalos *et al*., 2007). The distribution of the spiders on the litter shows the dependence to a permanent cover in the ground, which provides refuge, availability of prey, aeration and the regulation of the ambient temperature, reason why said areas are more propitious for the development of the spiders (Ávalos *et al*., 2007).

Disturbed ecosystems, due to their characteristics, can lead to higher productivity and favor a high abundance of spiders, although their diversity does not necessarily increase (Nyffeler y Benz, 1988; Maelfait *et al*., 2004; Ávalos *et al*., 2007; Arana *et al*., 2014). This coincides with what was observed in the present work, in which some groups of spiders were more frequent in the disturbed areas. *Pardosa* sp. was located in all the altitudinal gradient and of disturbance, perhaps as a result of its dynamics to colonize practically all the territories (Nyffeler y Benz, 1988; Major *et al*. 2006; Arana *et al.*, 2014). The family Lycosidae and the *Pardosa* genus, in particular, are the most common predators in modified ecosystems or with some degree of disturbance, which responds to their generalist condition in the use of resources. This allows them to have a greater tolerance to unfavorable conditions (Major *et al*., 2006; Cabrera, 2012).

Ávalos *et al.* (2007) indicate that Lycosidae and Linyphiidae do not together exceed 45 % of individuals in undisturbed areas, but reach up to 85 % in deteriorated areas. For this reason, *Pardosa* sp. as an indicator of disturbed areas; a statement shared by Urones and Majadas (2002), who point to this group as a pioneer in burned forests and during the first stages of succession. However, for the *Cerro El Potosí* they were also observed in areas with a low disturbance index, where they inhabit independently and dominantly, perhaps displacing other species.

Opposite to what was expected, no relationship was found between altitude and diversity of spiders, which coincides with Gobbi *et al*. (2006) who neither registered it with richness, nor with density in an altitudinal gradient.

Contrary to the hypothesis, no greater diversity of spiders was detected in the sites with less disturbance. Leaf litter was a factor that was associated with the distribution of the invertebrate group under study. Likewise, a high number of families of spiders was obtained, if it is considered that the sampled area is less than 1 % of the territory of *Nuevo León* and *Tamaulipas*.

Conclusions

The influence of the altitudinal gradient is not decisive in the distribution of the spiders, since there is no relationship among altitude, diversity and species richness.

Leaf litter influenced the distribution and assembly of spiders.

Pardosa sp. was recorded along the altitudinal gradient and was abundant in disturbed areas.

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Conflict of interests

The authors declare no conflict of interests.

Contribution by author

Indira Reta-Heredia: field work, data analysis and writing of the manuscript; Enrique Jurado, Marisela Pando-Moreno, Humberto González-Rodríguez, Arturo Mora-Olivo and Eduardo Estrada-Castillón: data analysis, and writing and correction of the manusript.

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