

THOMISIDAE (ARANEAE) ASSEMBLAGES IN DIFFERENT VEGETATION TYPES IN A RAMSAR SITE IN THE NORTHEAST OF ARGENTINA

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ABSTRACT

The RAMSAR Chaco Wetland site is one of the three most diverse biomes in Argentina due to its very heterogeneous environment. Studies on the diversity of spiders on this biome are scarce and there is no study in relation to the diversity of Thomisidae Sundevall, 1833. We analyzed the Thomisidae assemblages in environments with different degrees of structural complexity (gallery forest -GF-, low open forest -LOF-, grassland -Grassl- and palm groves -Palm Grv-) on seven localities of RAMSAR site. The spiders were collected by foliage beating, hand collecting and vacuum sampling (G-vac). 464 individuals were collected, distributed in 34 species/morphospecies. Completeness of sampling was greater than 90% and more than 60% of the expected species were obtained according to the Chao 1 estimator. The highest abundance, richness, and diversity of order 1 and 2 were observed in the GF but these were not significant. The grassl had the lower richness, diversity and equitability. *Tmarus pugnax* (Mello-Leitão, 1929) dominated in the forests, while *T. aff. humphreyi* (Chickering, 1965) dominated in the Grassl, and *Misumenops maculissparsus* (Keyserling, 1891) with *Uraarachne* sp (Keyserling, 1880) in the Palm Grv. The NMDS separated two groups: the forests (GF and LOF) and the Grassl + Palm Grv (stress = 0.28) and the ANOSIM analysis indicated significant differences between groups ($R = 0.38$ $p = 0.02$). Likewise, the Chao-Jaccard index indicated greater similarity between forested environments and the Grassl + Palm Grv. The most richness and abundance of tomisids were obtained in forested environments, possibly due to greater plant complexity in these environments.

Keywords: diversity; conservation; crab spiders; Neotropic.

RESUMEN

Comunidades de Thomisidae (Araneae) en diferentes tipos de vegetación en un Sitio RAMSAR en el noreste de Argentina

El Sitio RAMSAR Humedales Chaco es uno de los tres biomas de mayor diversidad de Argentina, dado que presenta un ambiente muy heterogéneo. Los estudios acerca de la diversidad de arañas en dicho bioma son escasos y en relación a la diversidad de Thomisidae Sundevall, 1833 no se registra ninguno. Se analizaron las comunidades de Thomisidae en ambientes con diferentes grados de complejidad estructural (bosque de galería -SG-, bosque bajo abierto -BA-, pastizales -Pz- y palmerales -Pr-) en siete localidades del sitio RAMSAR. Las arañas fueron recolectadas mediante golpeteo de follaje, captura manual y aspirado (G-vac). Se recolectaron 464 individuos, distribuidos en 34 especies/morfoespecies. La completitud del muestreo superó el 90% y se obtuvo más del 60% de las especies esperadas según el estimador Chao 1. La mayor riqueza, abundancia y diversidad de orden 1 y 2 se observó en la SG, pero no fue estadísticamente significativo. El Pz presentó la menor riqueza, diversidad y equitatividad. *Tmarus pugnax* (Mello-Leitão, 1929) dominó en los bosques, mientras que *T. aff. humphreyi* (Chickering, 1965) dominó en el Pz y *Misumenops maculissparsus* (Keyserling, 1891) con *Uraarachne* sp (Keyserling, 1880) en el Pr. El NMDS separó dos grupos: los bosques (SG y BA) y los Pz + Pr (Stress = 0.28) y el análisis ANOSIM indicó diferencias significativas entre los grupos ($R = 0.38$ $p = 0.02$). Asimismo, el índice de Chao-Jaccard indicó mayor similitud entre los ambientes boscosos y los Pz + Pr. La mayor riqueza y abundancia de tomisidos se obtuvieron en los ambientes boscosos, posiblemente se deba a la mayor complejidad de la vegetación en dichos ambientes.

Palabras clave: diversidad; conservación; arañas cangrejo; neotrópico.

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Introduction

The RAMSAR Convention is the intergovernmental treaty that offers the framework for the conservation and rational use of wetlands and their resources. The term wetland is recent in the world of science and conservation (Canevari *et al.*, 1999). In general, wetlands are intermediate systems between permanently flooded environments and normally dry environments (Finlayson & Moser, 1991). Currently, the RAMSAR List is the most extensive network of the world's protected areas, with 2341 sites of international importance, 23 of these are in Argentina (RAMSAR, 2019).

The RAMSAR Chaco wetlands site encompasses the eastern strip of the province of Chaco (Fig. 1). It is one of the three biomes with the highest biological diversity in Argentina due to its very heterogeneous environment with various units, such as the forest in gallery, lowland flood forest, palm savanna, grasslands, flooded areas with cattle raising and areas with agriculture (Alberto, 2006). In fact, despite being a priority area, cattle raising and agriculture activities are carried out. These activities affect large natural areas such as savannas, grasslands, ravines, marshes and "albardones" (Ginzburg & Adámoli, 2006) and consequently, they affect the flora and fauna diver-

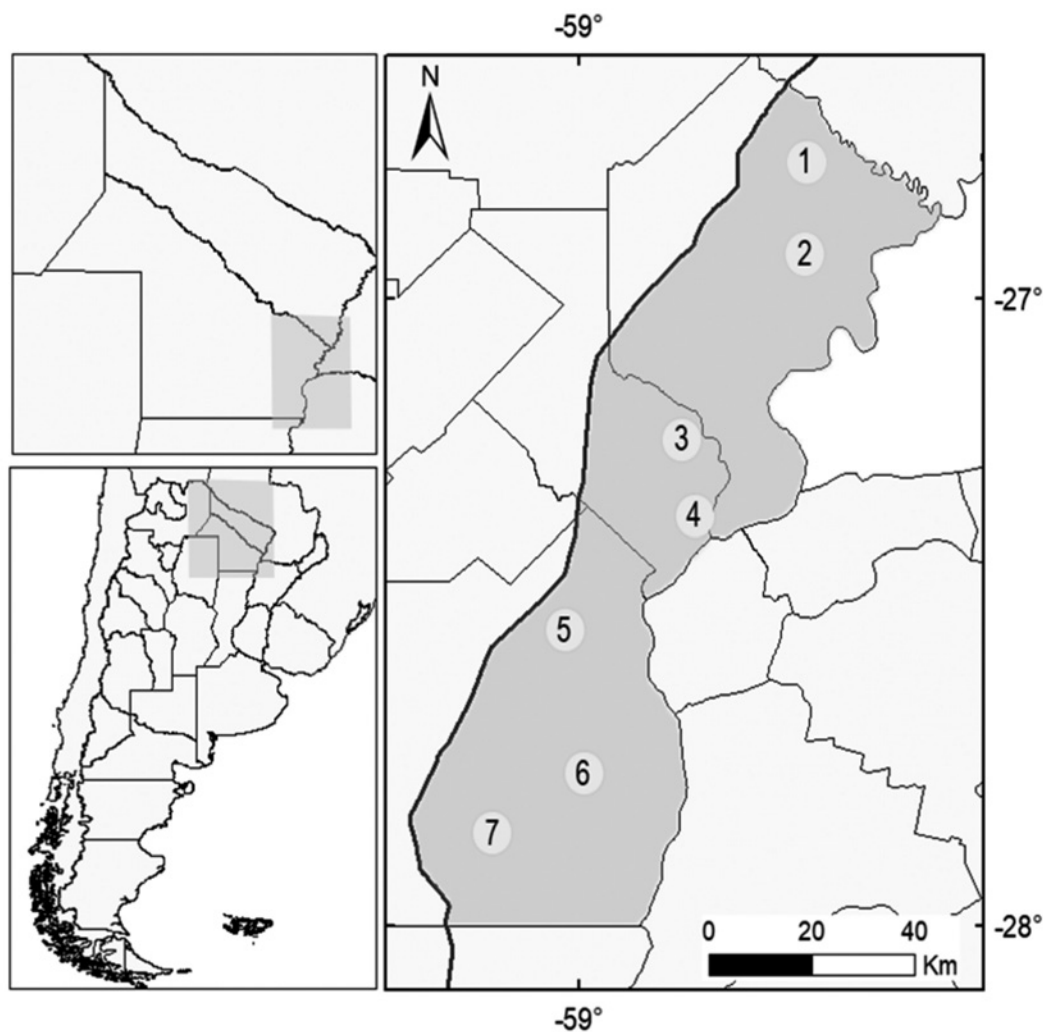


Fig. 1.— Location of the RAMSAR site Chaco wetlands and sampled localities: 1. Estancia San Carlos. 2. General Vedia. 3. Colonia Benítez. 4. Antequeras. 5. Estancia San Francisco. 6. Estancia La Querencia. 7. Estancia María Zaida.

Fig. 1.— Ubicación del Sitio Ramsar Humedales Chaco y de las localidades muestreadas: 1. Estancia San Carlos. 2. General Vedia. 3. Colonia Benítez. 4. Antequeras. 5. Estancia San Francisco. 6. Estancia La Querencia. 7. Estancia María Zaida.

sity of the region. In fact, this is a global problem, the expansion of agriculture in the world has led to the loss and fragmentation of forests, which has resulted in an impoverishment of biodiversity (Barrera *et al.*, 2015).

This problem is further compounded by the Territorial Ordering law of native forests presented by the Executive Branch of the province of Chaco in 2008 (Law: 6409) which awards this site category II allowing modifications to the forests. In this context, studies of spider diversity in native environments or in natural areas become important for conservation actions, as well as in fragmented or remnant forest sites due to human activities such as agriculture, cattle raising and urbanization processes (Tigas *et al.*, 2002). The fragmentation of natural areas leads to a homogenization of the environment; this is associated with a decrease in the number of spider species that can coexist and in the diversity of trophic guilds (Avalos *et al.*, 2009). In addition, as Pinkus-Rendón *et al.* (2006) point out, knowing how the landscape composition of a region affects the distribution and diversity of spiders can be used to characterize this ecosystem.

In this regard, studies on the diversity of spiders in the RAMSAR Chaco wetlands site are still incipient (Escobar *et al.*, 2012; Achitte-Schmutzler *et al.*, 2016), and none of these focused on Thomisidae Sundevall, 1833.

The structure of the vegetation is an important factor that influences the diversity of spiders (Jiménez-Valverde & Lobo, 2006). Additionally, it is postulated that the more diverse or complex the plant organization of an area, the more species of spiders can be found and in greater abundance, due to foliage biomass and prey availability (Hore & Uniyal, 2008). In addition, the habitat structure, mainly due to the complexity of the vegetation, affects the specific interactions of spiders. This influences the presence of species, richness and the composition of communities and reduces the mortality of these communities by providing refuges or influencing interactions with other guilds (Jiménez-Valverde & Lobo, 2007; Malumbres-Olarte *et al.*, 2013). In this way, the variation in vegetation architecture between habitats could lead to different sets of spiders throughout the landscape (Gómez *et al.*, 2016). Thus, forests with greater complexity tend to house greater diversity of spiders as well as many unique species (Simó *et al.*, 2011).

The spiders of the families Araneidae Clerck, 1757 and Thomisidae have species with broad environmental tolerance but with a great dependence on the physical structure of the environment (Jiménez-Valverde & Lobo, 2007). Indeed, several species of Thomisidae preferably inhabit foliage and they are commonly abundant in natural areas (Podgaiski *et al.*, 2007; Ricetti & Bonaldo, 2008; Rubio *et al.*, 2008). Furthermore, these spiders build refuges of silk threads where they move, oviposit, reproduce

and remain for long periods of inactivity (Foelix, 1982) which could imply some dependence on the substratum where they live. Tomisids are wandering spiders, that do not build webs to trap prey, and live almost exclusively on branches, leaves or flowers in which they hide thanks to their mimetic colors (Mello-Leitão, 1929). They are popularly called “crab spiders” because they walk sideways like the crabs, this similarity is accentuated by the stalking posture that they adopt when waiting for their preys (Grismado, 2007). For these characters, the family is placed within the trophic guild of ambush hunters (Cardoso *et al.*, 2011).

Currently there are more than two thousand species of tomisids distributed worldwide and only 40 of them were reported for Argentina (WSC, 2019). However, spider diversity studies in Argentina report low tomisids richness (Avalos *et al.*, 2007, 2009, 2013; Rubio *et al.*, 2008; Achitte-Schmutzler *et al.*, 2016; Nadal *et al.*, 2018). This could be due the fact that these works focus on spiders in general and not on a particular family or that actually these are not very diverse in a certain area. As Grismado *et al.* (2014) point out, only Araneidae and Salticidae Blackwall, 1841 are well studied, while Thomisidae, the seventh spider family in terms of species richness is poorly researched. In this study we characterized and compared the assemblages of tomisids, in terms of structure, richness and abundance, in the gallery forest environments, low open forest, grassland and palm grove of the RAMSAR Chaco wetlands site. Besides, we evaluated the change of species between these environments with different degrees of structural complexity.

Material and Methods

STUDY AREA

Sampling was carried out at the RAMSAR Chaco wetlands site in Argentina, it covers the eastern strip of the Chaco Province, including San Fernando, Primero de Mayo and Bermejo Departments. The study area is delimited in the North by the Bermejo River, in the South by the 28° parallel, in the East by the courses of the Paraná and Paraguay rivers and in the West by the National Route No. 11. Biogeographically the area is included in the Neotropical Region, sub region of Chaco, which corresponds to the Center and North of Argentina, South of Bolivia, West of Paraguay and Southeast of Brazil (Morrone, 2001).

Seven locations of the RAMSAR site (Fig. 1) were selected with the following environmental units: Gallery forest (GF), Low open forest (LOF), Grassland (Grassl) and Palm groves (Palm Grv) (Table 1). Characterization of environmental units follows Alberto (2006) and Ginzburg & Adámoli (2006):

Table 1.— Environmental units and coordinates of sampled localities of the RAMSAR Chaco wetlands site.

Tabla 1.— Unidades ambientales de las localidades muestreadas del Sitio RAMSAR Humedales Chaco.

Environments	Localities	Latitude	Longitude
Gallery forest	Estancia San Carlos (SC)	26°57'46.80"S	58°38'12.50"W
	Antequeras (AN)	27°25'40.85"S	58°01'58.19"W
	General Vedia (GV)	26°56'02.60"S	58°38'50.53"W
	RN Colonia Benítez (CB)	27°19'04.00"S	58°57'00.00"W
Low open forest	Estancia San Francisco (SF)	27°30'29.87"S	59°04'50.91"W
	Estancia La Querencia (LQ)	27°42'34.52"S	59°13'08.14"W
	Estancia María Zaida (MZ)	27°44'46.20"S	59°13'33.20"W
Grassland	Estancia San Carlos (SC)	26°58'40.60"S	58°39'03.00"W
	General Vedia (GV)	26°55'50.25"S	58°38'52.06"W
	Estancia La Querencia (LQ)	27°42'37.99"S	59°13'23.25"W
Palm groves	Antequeras (AN)	27°26'31.25"S	58°53'12.86"W
	Estancia San Francisco (SF)	27°30'42.93"S	59°04'47.60"W
	Estancia María Zaida (MZ)	27°44'52.90"S	59°13'41.00"W

Gallery forest: strips of riparian forests that are located in the “albardones” on both sides of the river; it is formed by trees, shrubs, vines, herbs and epiphytes. Two arboreal strata are observed, a higher one (specimens > 12 m tall) with predominance of Lapacho (*Tabebuia* sp A. I. Gomes ex DC), Ivirá-pitá (*Peltophorum dubium* (Spreng.) Taub.), Palo piedra (*Diplokeleba floribunda* N. E. Br.), Palo lanza (*Phyllostylon rhamnoides* (J. Poiss.) Taub.), Espina corona (*Gleditsia amorphoides* (Griseb.) Taub.), Guayacán (*Caesalpinia paraguariensis* (D. Parodi) Burkart, 1952), Timbó Colorado and Oreja de negro (*Enterolobium contortisiliquum* (Vell.) Morong.); and a lower one (between 8 and 12m tall) composed of low trees and shrubs such as the Pindó palm trees (*Syagrus romanzoffiana* (Cham.) Glassman) and Mbocayá (*Acrocomia tota* (Jacq.) Lodd. ex Mart.) with strong spines in their stipe, the Tembeterí (*Fagara* spp L.), Aguay (*Chrysophyllum gonocarpum* (Mart & Eichler ex Miq) Engl.), Ñangapirí (*Eugenia uniflora* L.), Guabiyú (*E. pungens* O. Berg), Jazmín del monte (*Randia spinosa* (Thunb.) Poir.), Azucena del monte o Jazmín del Paraguay (*Brunfelsia australis* Benth), and Congorosa (*Maytenus ilicifolia* Mart. ex Reissek).

Low open forest: formed by smaller trees and shrubs, generally with a predominance of legumes of the genus *Prosopis* L. and *Acacia* Mill. such as carob trees (*Prosopis alba* Griseb and *P. nigra* J. F. Arnold), Ñandubay or Espinillos (*P. algarrobilla* Spreng.), Aromitos o churquis (*Acacia caven* (Molina) Molina), Tuscas o aromito (*A. aroma* Gillies ex Hook. & Arn.), Uña de gato, Ñapindás negros or Garabatos (*A. praecox* Griseb.), accompanied by specimens of Talas (*Celtis* sp L.), Molles (*Schinus* sp L.), Chañares (*Geoffroea decorticans* (Gill, ex Hook, et Arn.) Burkart), Membrillos de monte (*Capparis teewdiana* (Eichler) H.H. Iltis & X. Cornejo), Granaditas or Quebrachillos

(*Acanthosyris spinescens* (Mart. & Eichler) Griseb.), Palo cruz or Tororatay (*Tabebuia nodosa* (Griseb.) Griseb.), Niño rupá (*Aloysia gratissima* (Gill. et Hook.) Tronc.), with dense understory of thistles (*Bromelia serra* Griseb. and *Aechmea distichantha* Lem.), Doradilla colorada (*Cheilanthes tweediana* Hook.), and prickly-pear cactus (Cactaceae). Near the Paraguay-Paraná fluvial axis, these underbrushes, xerophilous, may appear accompanied by Caranday palm trees (*Copernicia alba* Morong) in their transition to the gramineous savannas.

Palm groves: the woody component, towards the Paraguay-Paraná fluvial axis, consists mainly of Caranday palm groves (*C. alba*) on alkali soils, specimens of low trees and shrubs, isolated or forming wooded islets, such as carob trees (*Prosopis* sp), Chañares (*G. decorticans*), Talas or *Celtis ehrenbergiana* Gillies ex Planch, molles (*Schinus* sp) and granaditas or quebrachillos (*A. spinescens*), among others.

Grassland: the savannas make up a landscape dominated by medium and tall grasses, prevailing gramineans (*Elionurus* sp Humb. & Bonpl. ex Willd, *Andropogon* sp L., *Spartina* sp Scherb., *Paspalum* sp L., *Aristida* sp L., etc.) accompanied by other herbaceous and suffruticose plants. Several species of compound (Asteraceae), leguminous (Leguminosae), euphorbiaceous (Euphorbiaceae), malvaceous (Malvaceae) and rubiaceous (Rubiaceae) families are common in this place.

SAMPLING

The samples were taken during the summer months (November to March) during the years 2013-2016, with a repetition in each locality and by environment. Three transects were delimited in all sites (200 m long to 2 m wide), with five points separated

from each other by 50 m. The spiders were collected by a combination of sampling methods suitable for each phytophysiognomy, to optimize efficacy and minimize effort (Jiménez-Valverde & Lobo, 2005). In woods and forests: foliage beating and direct observation; in grasslands and palm groves: G-vac (vacuum sampling) and direct observation. In this way, two techniques and 30 samples per environment were applied in each environment, totalizing 840 samples.

Foliage beating: consisting of 15 blows on the bushy vegetation and in the lower portion of the arboreal strata, the material was collected on a 2.50 m² white canvas.

Direct day capture: tomisids were captured with tweezers during ten minutes of observation for each transect sampling point.

G-vac (vacuum sampling) capture: using a G-vac garden vacuum (Mod. 220 V-AR) on the vegetation. The vacuum has a 1.10 m long and 12 cm diameter (flow 710 m³/h) tube. The sample of vegetation suction was carried out in a 4 m² area for 1 minute.

The specimens obtained were placed in bottles with 70% alcohol and deposited in the CARTROUNNE collection of the Arthropod Biology laboratory, Universidad Nacional del Nordeste (UNNE), Corrientes Argentina.

STATISTICAL ANALYSIS

For the analysis, only adult individuals were taken into account. The non-parametric Chao 1 estimator was used to estimate the proportion of species in the sampling with respect to those expected, based on the quantification of the collected species rarity (Toti *et al.*, 2000).

The sample coverage for each environment was estimated as a measure of the completeness of the sampling (Hsieh *et al.*, 2014). The coverage of the sample indicates the proportion (with respect to the total number of individuals in an assembly) that belongs to the species represented in the sample (Pineda & Moreno, 2015). In addition, it allows direct comparisons of diversity to be made when the environments to be compared register coverage levels close to 1 (Chao & Jost, 2012).

We performed a Kruskal–Wallis nonparametric test in order to detect significant differences of the tomisids abundance between the sampled environments, considering the significance of $p < 0.05$. The richness between the tomisids assemblages of each environment were compared using the rarefaction and extrapolation curves based on samples of equal completeness, measured by the sample coverage (Chao & Jost, 2012). The coverage-based rarefaction allows to express in a less biased way the magnitude of the differences in richness between the communities. Be-

sides, the proportion of richness does not suffer reductions (even for small samples) and avoids the biases given by the distribution of abundances by standardizing all the samples at the same level of coverage (López-Mejía *et al.*, 2017). The analysis was carried out with 100 randomizations and extrapolating twice the number of individuals in the community with the lowest sample coverage (Chao & Jost, 2012). Furthermore, effective numbers of species were incorporated (Jost, 2006): $q = 0$ (expressing species richness), $q = 1$ (exponential of Shannon's diversity) and $q = 2$ (inverse of Simpson's dominance index). The advantage of expressing the diversity of a community in numbers of effective species is that it allows comparing the magnitude of the difference in the diversity of two or more communities (Moreno *et al.*, 2011). These calculations were done with iNEXT programme (Hsieh *et al.*, 2014).

A non-metric multidimensional scaling (NMDS) analysis was performed based on the Bray-Curtis distance measurement, in order to observe patterns of species grouping in the different sampled environments. Bray-Curtis was calculated on square-root transformed data to reduce the effect of dominant species. The NMDS is associated with a measure of the goodness of the two-dimensional representation called stress. As a general rule, the values of this measure below 0.2 are considered to correspond to an optimal representation (Kruskal, 1964). Then, One-way Analysis of similarity (ANOSIM) was carried out to test the degree and significance ($p < 0.05$) of differences between Thomisidae assemblages in the NMDS plot. ANOSIM output is a statistical test, where R equal to 1 indicates differences between assemblages and R equal to 0 indicates no differences (Clarke, 1993). These analysis were done with the PAST program version 1.12 (Hammer *et al.*, 2003).

Beta diversity between environments was analyzed using the Chao-Jaccard index, which takes into account the unseen shared species and is more appropriate for the evaluation of similarity between samples of different sizes with numerous rare species (Chao *et al.*, 2005). For this, we used the program EstimateS version 9.1.0 (Colwell, 2013).

Results

We collected 288 adult individuals from the total of specimens collected ($n = 464$), distributed in 34 species / morphospecies of Thomisidae spiders. In this work, *Titidius albifrons* (Mello-Leitão, 1929) and *Epicadus camelinus* (Pickard-Cambridge, 1869) are registered for the first time for Argentina (WSC, 2019).

The species exclusive of gallery forest (GF) were: *Epicadus trituberculatus* (Taczanowski, 1872), *E. camelinus*, *Tmarus* sp 6, *T.* sp 9, *T.* sp 11, *T.* sp 13, *T.* sp 16, *T.* sp 18, *Synaemops pugilator* Mello-Leitão, 1941,

Runcinioides aff. sp Mello-Leitão, 1929; the species exclusive of open forest (LOF) were: *Thomisus* aff. sp (Walckenaer, 1805), *Tmarus* sp 7 and *T.* sp 14; and the species exclusive of palmar groves (PalmGrv) were: *Tmarus* sp 17, *Misumenoides* sp (Pickard-Cambridge, 1900) and *M.* sp2. Grassland (Grassl) did not have any exclusive species.

The dominant species of both forested environments was *Tmarus pugnax* (Mello-Leitão, 1929); the dominant species of Grassland was *T.* aff. *humphreyi* (Chickering, 1965) and dominant species of the Palm groves were *Misumenops maculisparsus* (Keyserling, 1891) and *Uraarachne* sp (Keyserling, 1880) with equal abundance. In general, in the GF, Grassl and Palm Grv the most abundant species correspond to different genera, while in the LOF the *Tmarus* species dominate (see Appendix).

In general, the completeness of the sampling in the environments exceeded 90% and more than 60% of the expected species were obtained according to the Chao 1 estimator (Table 2, data in brackets). The greatest richness and abundance was obtained in the gallery forest followed by the low open forest (Table 2). However Kruskal–Wallis test results showed that there was no significant difference between the GF-LOF ($H = 1.85$, $p > 0.05$) and Grassl-Palm Grv ($H = 0.33$, $p > 0.05$). The only significant difference was between the forested and non-forested environments ($p < 0.05$).

The rarefaction/extrapolation curves for the three effective numbers of species showed that the specific richness in GF is significantly higher compared to the other environments. However, with extrapolation, the differences with LOF are not significant. On the other hand, the richness of tomisids in the Grassl and Palm Grv were significantly different of both forests (Fig. 2). The GF was also the most diverse ($q = 1$) and equitable ($q = 2$) compared to the other environments, but without statistical significance. On the contrary, grassl had the lower richness, diversity and (in part) equitativity compared with other environments, and this was significant (Fig. 2).

The ordination analysis NMDS showed an evident separation between forests (GF and LOF) and Grassl + Palm Grv, with a stress of 0.28 (Fig. 3); and the ANOSIM indicated significant differences between groups ($R = 0.38$, $p = 0.02$).

Likewise, the Chao-Jaccard index indicated a clear separation between the composition of tomisids with greater similarity between forest environments ($J-C = 0.85$) and between the Grassl and Palm Grv ($J-C = 0.70$) (Table 3).

Table 3.— Chao-Jaccard similarity index among the Thomisidae assemblages of the sampled environments.

Tabla 3.— Índice de similitud Chao-Jaccard entre las comunidades de Thomisidae de los ambientes muestreados.

	GF	LOF	Grassl	Palm-Grv
GF	1	-	-	-
LOF	0.85	1	-	-
Grassl	0.04	0.06	1	-
Palm-Grv	0.06	0.05	0.70	1

Discussion

This is the first study of the diversity of Thomisidae in the northeast of Argentina and it reveals a high specific richness, since the number of species/morpho-species reported represents almost 70% of the species registered for Argentina (49 spp.) according to the Catálogo de Arañas de Argentina (CAA, 2019).

In most of the articles about spider diversity in natural environments and crops in the northeast of Argentina, the richness of Thomisidae is generally represented by a dozen or less species, although with a remarkable abundance (Avalos *et al.* 2007, 2009, 2013; Rubio *et al.*, 2008; Achitte-Schmutzler *et al.*, 2016; Nadal *et al.*, 2018). Although the same capture techniques were used in these works and most of the

Table 2.— Values of alpha diversity, Chao-1 estimator, brackets indicate the percentages of species collected with respect to those expected; and sample coverage of tomisids for sampled environments: gallery forest (GF), low open forest (LOF), grassland (Grassl) and palm groves (Palm Grv).

Tabla 2.— Valores de diversidad alfa, estimador Chao-1, en paréntesis se indican los porcentajes de las especies recolectadas respecto a las esperadas; y la cobertura de muestra de tomisidos para los ambientes muestreados: selva en galería (SG), bosque abierto (BA), pastizal (Pz) y palmar (Pr).

	GF	LOF	Grassl	Palm Grv
N	123	106	27	32
S	26	19	5	8
Cm IC(95%)	0.90(0.96 ± 0.85)	0.92(0.96 ± 0.87)	1.00(1.02 ± 0.97)	0.97(1.03 ± 0.92)
Chao-1 IC(95%)	37(48.5 ± 23.88) (70.3%)	31(40.5 ± 17.86) (61.3%)	5(6 ± 5) (100%)	8(11 ± 8) (100%)

N: abundance, S: specific richness, Cm: sample coverage.

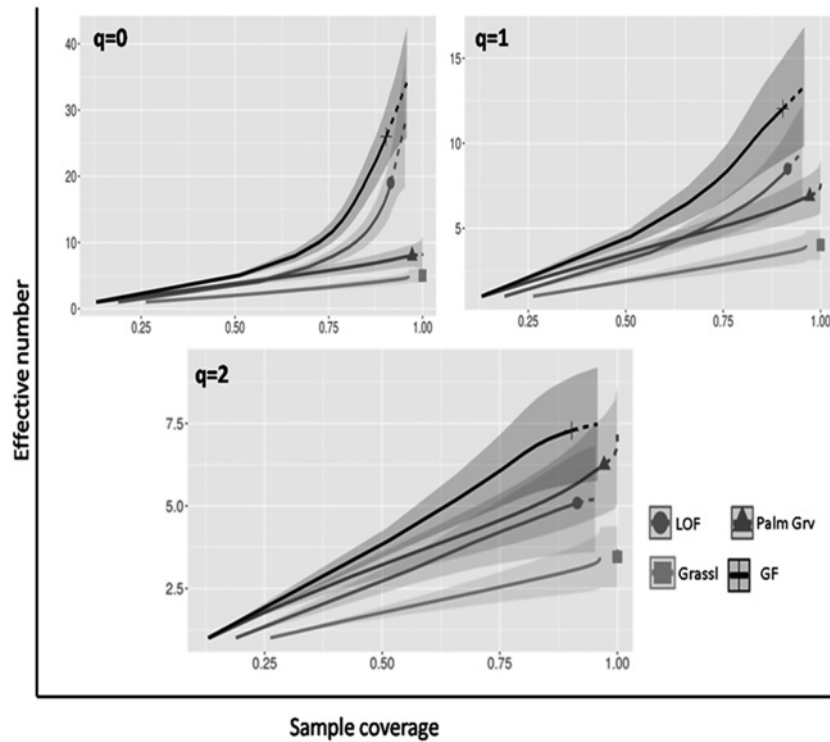


Fig. 2.— Rarefaction/extrapolation curves based on the coverages of the samples with 95% confidence intervals for the recollected Thomisidae data in the gallery forest (GF), low open forest (LOF), grassland (Grassl) and palm groves (Palm Grv) of RAMSAR site, separated by diversity order $q = 0$ (species richness), $q = 1$ (Shannon diversity) and $q = 2$ (Simpson diversity).

Fig. 2.— Curvas de rarefacción/extrapolación basadas en la cobertura de las muestras con sus intervalos de confianza al 95% para los datos de Thomisidae recolectados en la selva en galería (SG), el bosque bajo abierto (BA), el pastizal (Pz) y el palmar (Pr) del sitio RAMSAR, separado por orden de diversidad: a) $q = 0$ (riqueza de especies), b) $q = 1$ (diversidad de Shannon) y c) $q = 2$ (diversidad de Simpson).

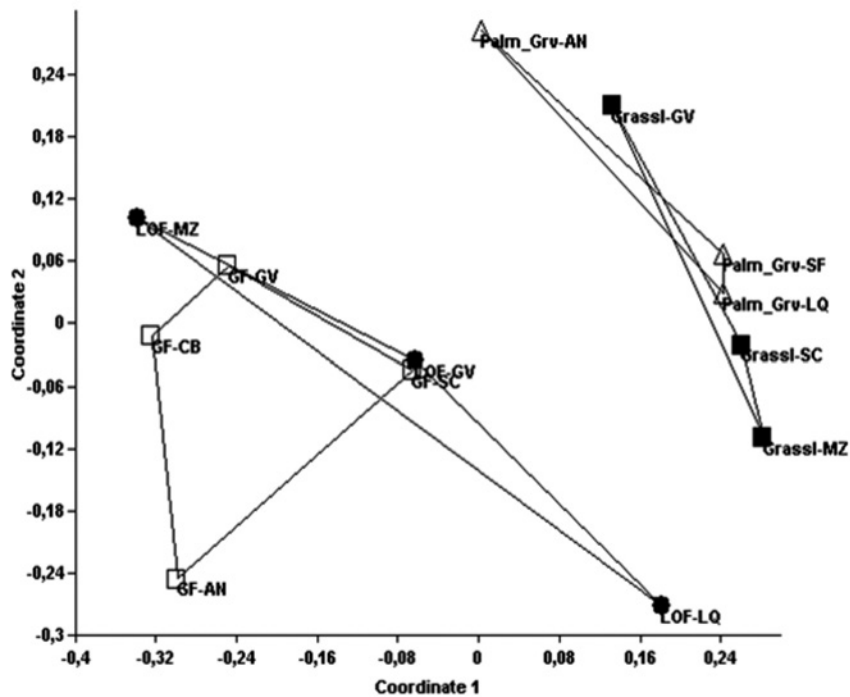


Fig. 3.— Non-metric multidimensional scaling (NMDS) analysis based on the Bray-Curtis distance measurement of tomisids assemblages of sampled environmental units of the RAMSAR site Chaco wetlands.

Fig. 3.— Análisis de escalamiento multidimensional no métrico (NMDS) basado en la medida de distancia de Bray-Curtis de las comunidades de tomisidos de las unidades ambientales muestreadas del sitio RAMSAR Humedales Chaco.

samples were seasonal, the tomisids were poorly represented compared to this research.

It should be noted that only seven species of the total collected in this work are mentioned in the CAA (2019), although several *Misumenops* and *Tmarus* have not been identified at a specific level. *Tmarus* is represented by numerous species globally distributed (WSC, 2019); they are cryptic foliage spiders and are found in certain tree species, many of them are Mirtáceas or trees with dry branches (personal observation). Therefore, foliage beating was the most effective technique to collect them, as reported by Jiménez-Valverde & Lobo (2006). Only two species were found in non-forested environments: *T. aff. humphreyi*, which was dominant in grassland, and *Tmarus* sp17 found only in the palm grove. *T. aff. humphreyi* was also reported in grasslands of the Espinal Region by Nadal *et al.*, (2018), although predominantly in cold seasons of the year.

Tmarus pugnax, which was dominant in both forests, was also dominant in the forests of a reserve in the Espinal region (Nadal *et al.*, 2018). Likewise, species of *Tmarus* were dominant in forests of Chaco Húmedo (Avalos *et al.*, 2007; Achitte-Schmutzler *et al.*, 2016) and in the Pampeana region (Grismado *et al.*, 2011). However, comparisons at a specific level are impossible since in most spider diversity studies tomisids are reported as morphospecies (Avalos *et al.*, 2007, 2009; Schwerdt *et al.*, 2014; Rubio, 2015). The lack of reviews at the family and genus level is associated with taxonomic problems (Grismado, 2007), and makes it difficult to compare tomisid species assemblages in different regions. This problem extends to several countries in South America (Bizuet-Flores *et al.*, 2015; Castanheira *et al.*, 2016).

The species of *Misumenops* that dominated in the palm grove and in the grassland seem to prefer these types of environments since their abundance decreased in the forests. This was also verified in other studies in which they were also not very abundant or were absent in forested areas (Grismado, 2007; Bonaldo & Dias, 2010; Ibarra-Núñez *et al.*, 2011). In contrast, they were abundant in open environments and/or with herbaceous strata, as in grasslands (Nadal *et al.*, 2018; Schwerdt *et al.*, 2014), in various crops (Armendano & González, 2010; Almada *et al.*, 2012) and in urbanized areas (Argarañaz & Gleiser, 2017). Moreover, Rubio (2015) also reported a greater abundance of *Misumenops* species in the Yungas in transition, an area characterized by a simpler and less diverse plant structure (Brown *et al.*, 2002).

The richness and diversity of tomisids in forested environments were notorious, as well as the presence of numerous rare species in such environments when compared with grasslands and palm groves. Halffter & Moreno (2005) affirm that the variation in the alpha diversity of the communities is related to local factors and to the interactions between the populations. Nevertheless, the structural complexity of the habitat

is also an important factor that influences spider diversity (Avalos *et al.*, 2009), probably because complex habitats increase the availability of niches (Jiménez-Valverde *et al.*, 2010). So, according to the results of this work, forested environments seem to have favorable ecological conditions for tomisid assemblages.

The specific richness of a site is influenced not only by high environmental heterogeneity, but also by other elements such as the presence of rare species, tourist species, demographic phenomena and the area occupied by the study community (Halffter & Moreno, 2005). In this work, the high proportion of tomisids that appear to be missing in both forests could partly be explained by the numerous species that were represented by few individuals, which are generally difficult to collect in environments of greater structural complexity (Almada & Sarquis, 2017).

However, the high proportion of rare species can also be attributed to edge effects, to species that are collected outside their mating season, to species that are difficult to collect with the methods used or due to biases in the procedures during collection (Cardoso *et al.*, 2008; Rubio *et al.*, 2008). Rare species are very important in terms of conservation (Elphick, 1997) because they are more prone to extinction due to the loss and/or fragmentation of their habitat by mismanagement and various other human activities (Isik, 2010; Mouillot *et al.*, 2013). In this regard, in this work several species of *Tmarus* were found only once in the entire sampling, possible because they are more sensitive to change in the environment.

In this study, the gallery forest presented the most richness of tomisids with species collected only in this environment, such as several of the genus *Tmarus* and *Epicadus*. This type of environment showed greater spider diversity in the studies conducted by Simó *et al.* (2011) and those carried out with other groups of organisms by Sanchez *et al.* (2004). These authors emphasize the importance of these types of environments for biodiversity conservation by providing food and refuge to the species.

According to Pearce *et al.* (2004), the composition of spiders tends to change as long as a plant succession exists which provides microhabitats and availability of specific prey, thus certain species are distributed in particular areas of vegetation (Jiménez, 1996). In this regard, exclusive species were found in each environmental unit except in the grassland. It is interesting to note that in the open forests the species that are at the top with the highest range of abundance are those of the genus *Tmarus*. This genus was also representative in several forests in the northeast of Argentina (Bar *et al.*, 2008; Rubio *et al.*, 2008; Rubio, 2015).

The lower diversity in the grassl compared with other environments suggests that environments with less complexity are only favorable for a few species which significantly increase their abundance in detriment of others. Moreover, most of this grassland is used for

cattle raising and this could be affecting the diversity of Thomisidae; according to Almada (2014), cattle raising could have negative effects on spider fauna.

Probably, the presence of shrubs and low trees in the palm grove has some influence on the composition of the tomisids assemblage. In this sense, Weeks & Holtzer (2000) reported significant differences between the grassland and the mixed grassland (with bushes), which presented the greatest abundance of Thomisidae. Additionally, the abundance of tomisids reported in the understory of low tropical forests, in edge habitats and in more open areas (Halaj *et al.*, 2000; Álvares *et al.*, 2004; Sørensen, 2004), suggests that shrubs along with other low-bearing plant species, such as those present in sampled palm groves, are conducive to the establishment of several species of tomisids. Although palm trees were not sampled in this study, in another study conducted in Brazil tomisids were reported to be rare on them (Battirola *et al.*, 2004).

Taking into account that the composition of spiders is strongly influenced by the type of habitat (Weeks & Holtzer, 2000; Jiménez-Valverde & Lobo, 2007) and that habitat heterogeneity could involve strong differences in the composition of spider assemblages (Cabra-García *et al.*, 2010), this work shows how tomisids assemblages differ according to the different environmental units. The results show that the change in plant structure and composition in each environment reflect a change in the structure and diversity of the Thomisidae, with unique species and others that vary in terms of abundance in each environment. Furthermore, forested and non-forested environments showed low similarity and in consequence a high species turnover.

Considering that the western strip of the Province of Chaco was declared of interest for conservation and that the increase in the degradation of natural habitats has strengthened the need to know and evaluate biodiversity patterns, this work becomes important in assessing the tomisids assemblages in this site.

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Appendix.— List of Thomisidae species (adult individuals) in different environments of RAMSAR Chaco wetlands site, Argentina.

Apéndice.— Lista de especies de Thomisidae (individuos adultos) en diferentes ambientes del sitio RAMSAR Humedales Chaco, Argentina.

Species/morfospecies	Gallery forest	Low open forest	Grassland	Palm groves	TOTAL
<i>Bucranium taurifrons</i>	11	2	0	0	13
<i>Titidius albifrons</i>	1	1	0	0	2
<i>Epicadus trituberculatus</i>	17	0	0	0	17
<i>Epicadus camelinus</i>	2	0	0	0	2
<i>Thomisus</i> aff sp.	0	1	0	0	1
<i>Tmarus pugnax</i>	36	41	0	0	77
<i>Tmarus</i> aff <i>humphreyi</i>	3	1	12	5	21
<i>Tmarus</i> sp.1	2	1	0	0	3
<i>Tmarus</i> sp.2	2	0	0	2	4
<i>Tmarus</i> sp.3	1	1	0	0	2
<i>Tmarus</i> sp.4	2	2	0	0	4
<i>Tmarus</i> sp.5	1	7	0	0	8
<i>Tmarus</i> sp.6	2	0	0	0	2
<i>Tmarus</i> sp.7	0	3	0	0	3
<i>Tmarus</i> sp.8	1	9	0	0	10
<i>Tmarus</i> sp.9	1	0	0	0	1
<i>Tmarus</i> sp.10	14	15	0	0	29
<i>Tmarus</i> sp.11	1	0	0	0	1
<i>Tmarus</i> sp.12	10	11	0	0	21
<i>Tmarus</i> sp.13	3	0	0	0	3
<i>Tmarus</i> sp.14	0	1	0	0	1
<i>Tmarus</i> sp.15	1	4	0	0	5
<i>Tmarus</i> sp.16	4	0	0	0	4
<i>Tmarus</i> sp.17	0	0	0	2	2
<i>Tmarus</i> sp.18	1	0	0	0	1
<i>Tmarus</i> sp.19	3	1	0	0	4
<i>Synaemops pugilator</i>	1	0	0	0	1
<i>Misumenoides</i> sp.	0	0	0	4	4
<i>Misumenops maculisparsus</i>	1	1	5	7	14
<i>Misumenops pallidus</i>	1	3	4	4	12
<i>Misumenops</i> sp.1	0	1	1	0	2
<i>Misumenops</i> sp.2	0	0	0	1	1
<i>Runcinioides</i> aff sp.	1	0	0	0	1
<i>Uraarachne</i> sp.	0	0	5	7	12
TOTAL	123	106	27	32	288