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Jumping spiders (Araneae: Salticidae) as indicators of the conservation status of habitats in Eastern Chaco, Argentina

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Abstract. The spiders of the Salticidae family can be valuable indicators of various environmental conditions because they are distributed over almost all continents and are found in a wide variety of habitats and in all climatic seasons. It was assessed if species of Salticidae function as indicators of the conservation status of habitats and if the use of adult+juvenile or adult-only data yields different results. Spiders were collected in two natural parks and two semi-natural areas located between both parks in an area of Eastern Chaco, Argentina. The samples were taken from three types of habitats: foliage, leaf litter and grassland. The analysis of indicator species was conducted with the indicator value index (IndVal). A high IndVal value for a species in a habitat (e.g., semi-natural grassland) indicates that it is specific (relatively abundant) and faithful (evenly distributed) to that habitat. The species that presented IndVal values >0.45 and >0.70 were classified as detectors and indicators, respectively. Indicator species are highly characteristic of a group (exclusive or nearly exclusive), while detector species prefer a group, but are not exclusive to it. *Philira micans* was found to be a detector for the semi-natural foliage; *Semiopyla viperina*, for the natural leaf litter and *Maeota dorsalis*, for the natural grassland. The use of the adult+juvenile dataset provided more information about the number of IndVal-significant species; the three detector species mentioned were detected exclusively from this dataset. This study demonstrates that Salticidae spiders in the studied area are sensitive to the conservation status of the analyzed habitats as detector species were recorded. Besides, this study demonstrates that the adult+juvenile dataset improves the detection of species sensitive to changes.

[Keywords: indicator value, foliage, grassland, leaf litter, juveniles]

Resumen. Las arañas saltadoras (Araneae: Salticidae) como indicadoras del estado de conservación de los hábitats en el Chaco Oriental. Las arañas de la familia Salticidae pueden ser indicadoras valiosas de diversas condiciones ambientales porque se distribuyen en casi todos los continentes y se encuentran en una gran variedad de hábitats y en todas las estaciones climáticas. Se evaluó si las especies de Salticidae funcionan como indicadores del estado de conservación de los hábitats y si el uso de los datos de adultos+juveniles o solo adultos arroja resultados diferentes. Las arañas fueron recolectadas en dos parques naturales y dos áreas semi-naturales ubicadas entre ambos parques en un área del Chaco Oriental, Argentina. Las muestras se tomaron de tres tipos de hábitats: follaje, hojarasca y pastizal. El análisis de especies indicadoras se realizó con el índice valor indicador (IndVal). Un valor alto de IndVal para una especie en un hábitat (e.g., pastizales semi-naturales) indica que es específica (relativamente abundante) y fiel (distribuida uniformemente) de ese hábitat. Las especies que presentaron valores de IndVal >0.45 y >0.70 fueron clasificadas como detectoras e indicadoras, respectivamente. Las especies indicadoras son muy características de un grupo (exclusivas o casi exclusivas), mientras que las especies detectoras tienen preferencia por un grupo, pero no son exclusivas de él. *Philira micans* resultó detectora para el follaje seminatural; *Semiopyla viperina*, para la hojarasca natural y *Maeota dorsalis*, para los pastizales naturales. El uso de datos de adultos+juveniles proporcionó más información sobre la cantidad de especies IndVal-significativas; las tres especies detectoras mencionadas se detectaron exclusivamente a partir de este conjunto de datos. Este estudio demuestra que las arañas Salticidae en el área de estudio son sensibles al estado de conservación de los hábitats analizados ya que se registraron especies detectoras. Además, este trabajo demuestra que el conjunto de datos de adultos+juveniles mejora la detección de especies sensibles a cambios.

[Palabras clave: valor indicador, follaje, pastizal, hojarasca, juveniles]

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Introduction

The Chaco Phytogeographic Province (Cabrera 1971, 1976) has suffered a remarkable anthropic impact that increased in recent decades. Selective logging of forests and livestock production were conducted for several centuries, while clearcutting has predominated in recent decades to make land available for monocultures (Cabrera 1971; Morello and Rodríguez 2009). Grassland cover has been reduced due to shrub encroachment caused by fire suppression and selective grazing that favor woody species (Grau et al. 2015). Also, grasslands were reduced by conversion to agriculture and implanted pastures (Fernández et al. 2020). Thus, this province requires conservation and restoration efforts to prevent the irreversible loss of its habitats and the isolation of its natural protected areas (Chebez 2005).

Indicator species or bio-indicators are a very useful tool in the field of ecology because they can be applied to assess various conditions of interest quickly and cheaply in ecosystems (Dufrêne and Legendre 1997; McGeoch 1998; McGeoch et al. 2002). The definition of a bioindicator varies according to its classification. Bio-indicators can be classified into biodiversity indicators, environmental indicators and ecological indicators (McGeoch 1998; Pearce and Venier 2006). Biodiversity indicators, also named surrogates of biodiversity, are taxa usually higher than the species level whose biodiversity parameters (e.g., diversities, richness) reflect the biodiversity parameters of higher taxa. For example, the family Salticidae has been suggested as a substitute for the order Araneae by Argañaraz et al. (2018) because in that study, Salticidae was able to predict the richness of the order Araneae by 74%. The environmental indicators (*sensu* Pearce and Venier 2006) are those that indicate changes in the condition of the abiotic environment (e.g., air or water pollution). The ecological indicators indicate functional changes in ecosystems and habitats (e.g., disturbance, fragmentation). Additionally, and unlike the other indicators, the response of the ecological indicators (e.g., change in abundance of indicator species), in itself, is of interest for conservation (McGeoch 1998; Pearce and Venier 2006).

Spiders are evaluated as potential bio-indicators due to several reasons. First, they are abundant and widely distributed (World Spider Catalog 2022). Second, they are sensitive to abiotic changes such as changes in temperature, precipitation and humidity (Rodríguez-Artigas et al. 2016). Third, they are sensitive to the structure of vegetation and litter (Uetz 1979; Gómez et al. 2016), human disturbances such as fires (Podgaiski et al. 2013) and changes in land use (Prieto-Benítez and Méndez 2011). The Salticidae family is the most diverse among spiders, with more than 6400 described species (World Spider Catalog 2022), and it has a high abundance and richness in spider assemblages (Nadal et al. 2018; Baldissera et al. 2020). The spiders of this family can be indicators of biogeographical areas, habitat, and anthropic disturbance because they have a distribution almost as wide as the order Araneae. So, they are distributed throughout all continents, except Antarctica (Pugh 2014). Besides, they inhabit a wide variety of habitats or microhabitats (Romero 2006; Argañaraz et al. 2017), including natural and anthropized habitats, and can be found in all weather seasons (Nadal et al. 2018).

To evaluate if spiders are good bio-indicators, previous studies have used the indicator value index or IndVal (Dufrêne and Legendre 1997). With this method, spiders, at the species or family level, have been assessed as indicators of different groups. For example, habitat (Ghione et al. 2013; Aisen et al. 2017; Quijano-Cuervo et al. 2019), habitat in a gradient of disturbance (Kaltsas et al. 2014; Argañaraz et al. 2020a; van Rensburg et al. 2020), management (Torma et al. 2019; Argañaraz et al. 2020b; Topa et al. 2021), succession and restoration (Cristofoli et al. 2010; Malumbres-Olarte et al. 2013; Yekwayo et al. 2019), pollution (Horváth et al. 2001; Nahmani et al. 2006), soil quality (Nuria et al. 2011; Rousseau et al. 2013), colonization of agroecosystems (Royauté and Buddle 2012), forest fragmentation and degradation (do Amaral Nogueira and Pinto-da-Rocha 2016), seasons (Campuzano and Padilla-Ramírez 2021) and ecosystem services (Elie et al. 2018). However, the majority of the research mentioned was carried out in non-South American countries. In Argentina, there is an information gap related to this subject as the only studies carried out in this country were those conducted by Aisen et al. (2017), Argañaraz et al. (2020a, 2020b), and Martínez et al. (2022). Besides, such investigations have been conducted using only soil-dwellers spiders, which are also commonly used in other countries. To the best of my knowledge, Quijano-Cuervo et al. (2019) and Yekwayo et al. (2019) were the only ones to evaluate plant-dwellers spiders as bioindicators collecting spiders from the foliage of trees and grasses, respectively.

Among the studies where spiders have been evaluated as possible bio-indicators with IndVal, several have reported species of Salticidae as indicators of different groups. For example, the succession stage of plant communities (Malumbres-Olarte et al. 2013; Yekwayo et al. 2019), different types of natural habitats (Bonte et al. 2002; Bangert and Slobodchikoff 2006; Hore and Uniyal 2008; Aisen et al. 2017), fruticultural habitats (Trivellone et al. 2013), biogeographical areas (Carvalho et al. 2011), unburned sites (Martínez et al. 2022) and unmown grasslands (at the family level) (Cattin et al. 2003). Using other approaches, Alcalde et al. (2021) identified two species of Salticidae associated with logged and unlogged forests, and Leoete et al. (2019) identified four species associated with habitats with different degrees of human intervention.

Spiders, once recognized as bio-indicators, have several potential applications. Ecosystem restoration is one of them. This subject has become an essential tool to address the loss and fragmentation of natural habitats (Wiens and Hobbs 2015; Lindenmayer 2020). However, to be most effective, this requires a thorough linking between ecological theories and well-designed monitoring programs (Lindenmayer 2020). One of the tools that are useful for quickly and cheaply diagnosing the conservation status (i.e., quality in the sense of the degree of fragmentation, selective logging, cattle load, among others) of a site or evaluating the progress of an area undergoing restoration are indicator species monitoring (Dufrêne and Legendre 1997; Cristofoli et al. 2010). Therefore, it is important to evaluate the indicator species not only in disturbed habitats but also in protected or natural habitats as they can serve as control areas (Lindenmayer 2020).

As far as my knowledge, in the Eastern Chaco District, the only studies that have assessed possible indicator species were those of Dufek et al. (2019, 2020) with flies (Diptera) and Calcaterra et al. (2022) with ants (Formicidae). Dufek et al. (2019, 2020) found indicator species of anthropized and natural habitats and Calcaterra found indicator species of Chaco forests. The last authors found that the main indicator was a native species in the Neotropics, but a worldwide invader. They have suggested that the abundance and frequency of that species could be related to the high degradation of the Chaco forest. However, they evaluated forests in general (i.e., they did not distinguish between degraded and non-degraded forests).

Juvenile spiders generally represent the largest percentage of individuals in the samples (Nadal et al. 2018). They often are not considered in indicator spider assessments and other ecological studies because they are difficult to identify (Ghione et al. 2013; Malumbres-Olarte et al. 2013; Martínez et al. 2022). However, certain antecedents show that what it is won in accuracy is probably far less relevant than what is lost in information by excluding them (Jiménez-Valverde and Lobo 2006; Domènech et al. 2022).

The aims of this study were 1) to evaluate whether species of the Salticidae family are potential indicators and/or detectors of the conservation status of three types of habitats (grassland, forest foliage, and forest leaf litter) for two conditions (natural habitats and semi-natural habitats) in an area of the Eastern Chaco District of Chaco Phytogeographic Province, Argentina; and 2) to assess whether the use of data of adult+juvenile yield better outcomes resulting from the IndVal analysis to those reported by the adults only. Therefore, two hypotheses were proposed: A) the species of Salticidae spiders are not distributed homogeneously under the different conservation statuses of the habitats, showing a different degree of affinity with them, and B) the inclusion of juveniles improves the resulting affinity of species for habitats of different conservation status rather than the use of only adult specimens. Regarding the first hypothesis, it is expected to find indicator or detector species of the conservation status of the habitats sampled. In relation to the second hypothesis, it is expected to find higher values of IndVal with the adult+juvenil dataset than with the adult dataset only due to its greater abundance and frequency in the samples.

Materials and Methods

Study area

The study area is located in Chaco province, Argentina. Phytogeographically, this area is within the Eastern Chaco District of Chaco Phytogeographic Province (Cabrera 1971), also known as Gran Chaco (Morrone 2014). Four sites were selected, two protected natural areas and two unprotected semi-natural areas located between the protected ones (Figure 1): 1) Chaco National Park (26°50′ S - 59°48′ W), extending over the Presidencia de la Plaza and Sargento Cabral departments; 2) Pampa del Indio Provincial Park (26°16′ S - 59°58′ W), located in the Libertador General San Martín department; 3) intermediate site I (26°34′ S - 59°46′ W), located in Sargento Cabral department, and 4) intermediate site II (26°27′ S - 59°59′ W), located in the Veinticinco de Mayo department.

The main plant communities of the Eastern Chaco District consist of forests of *Schinopsis balansae* and *Aspidosperma quebracho-blanco*, and forests of *Schinopsis* spp. and *Bulnesia* sp. (Cabrera 1976). But, historically, these forests suffered selective logging and clearcutting (Cabrera 1971; Morello and Rodríguez 2009). The other communities are characterized by forests of other species, palm groves, grasslands, savannahs and aquatic plant communities (Cabrera 1976). The intermediate sites are located within an area where rural people have livestock (Barreto et al. 2019).

The climate of the Eastern Chaco District is humid and temperate, with hot summer and no dry season (Peel et al. 2007). The mean annual temperature is 21 °C (Morello et al. 2012). The mean annual rainfall is 1300 mm (Cabrera 1971; Cabrera 1976; Morello et al. 2012).

Sampling design

Samples were taken during daytime hours when Salticidae spiders are active. The samplings were systematic over three types of habitats: forest foliage, forest leaf litter, and grassland. Forest leaf litter and foliage can be considered microhabitats, but they were termed habitats for simplicity. Three collection techniques were used, a different one in each habitat. The first method was leaf litter sieving, through which leaf litter was taken from an area of 1x1 m. Then, it was passed through a 1 cm mesh opening sieve on a white cloth to catch the spiders. The second method was the foliage beating, which consisted of approximately 15 beats on the shrubby vegetation and the lower portion of the tree stratum (up to 2.5 m high). The material was obtained from a 2x2 m white canvas placed on the ground under the trees and bushes that were beaten. The third method was grassland vacuuming, through which grassland was sucked into the vacuum in an area of 2x2 m for a time of 1 min. For this technique, a G-Vac garden vacuum cleaner (Mod. 220 V-AR) was used. The material collected was scattered on a white canvas to catch the spiders. In the three types of sampling, once the spiders were detected on the canvas, they were captured with entomological forceps and placed in bottles with 70% ethyl alcohol.

The samples were taken along transects. In forests and grasslands, three 200-m transects were drawn, separated by no less than 2 km. In the grassland transects a sample (i.e., the minimum sample unit) was taken every 50 m. In the forest transects, two samples were taken every 50 m, one for leaf litter and one for foliage. That is, for each technique, 5 samples were taken per transect.

The samplings were seasonal: from March 6 to 9, 2017 (summer), from August 7 to 10, 2017 (winter), from December 4 to 7, 2017 (spring), and from May 28 to 31, 2018 (autumn). The total sampling consisted of 720 samples (4 dates x 4 sites x 3 transects x 5 samples per transect x 3 techniques).

Laboratory work

Adult and juvenile spiders were identified using the information provided by their genitalia or their habitus, respectively. The information provided by the habitus are the shape of the prosoma and opisthosoma, characteristics of the hairs and spines, eye position, shape and size of spinners, and coloration of the entire body, among others. Adult specimens were identified to genus or species level using the World Spider Catalog (2022) and the Metzner Catalog of Salticidae Spiders (2022). Juvenile specimens were identified to genus or species level based on the habitus of adults with which they were compared, and considering a set of supporting evidence or information, as follows: 1) geographical distribution of the potential species, 2) occurrence of both juvenile and adult individuals in the sample, and 3) comparison with specimens from the CARTROUNNE collection (Facultad de Ciencias Exactas y Naturales y Agrimensura, Universidad Nacional del Nordeste, Corrientes, Argentina) previously collected in the Eastern Chaco District.

The level of confidence that the juvenile spiders are correctly identified in this research is very high because the author is a specialist

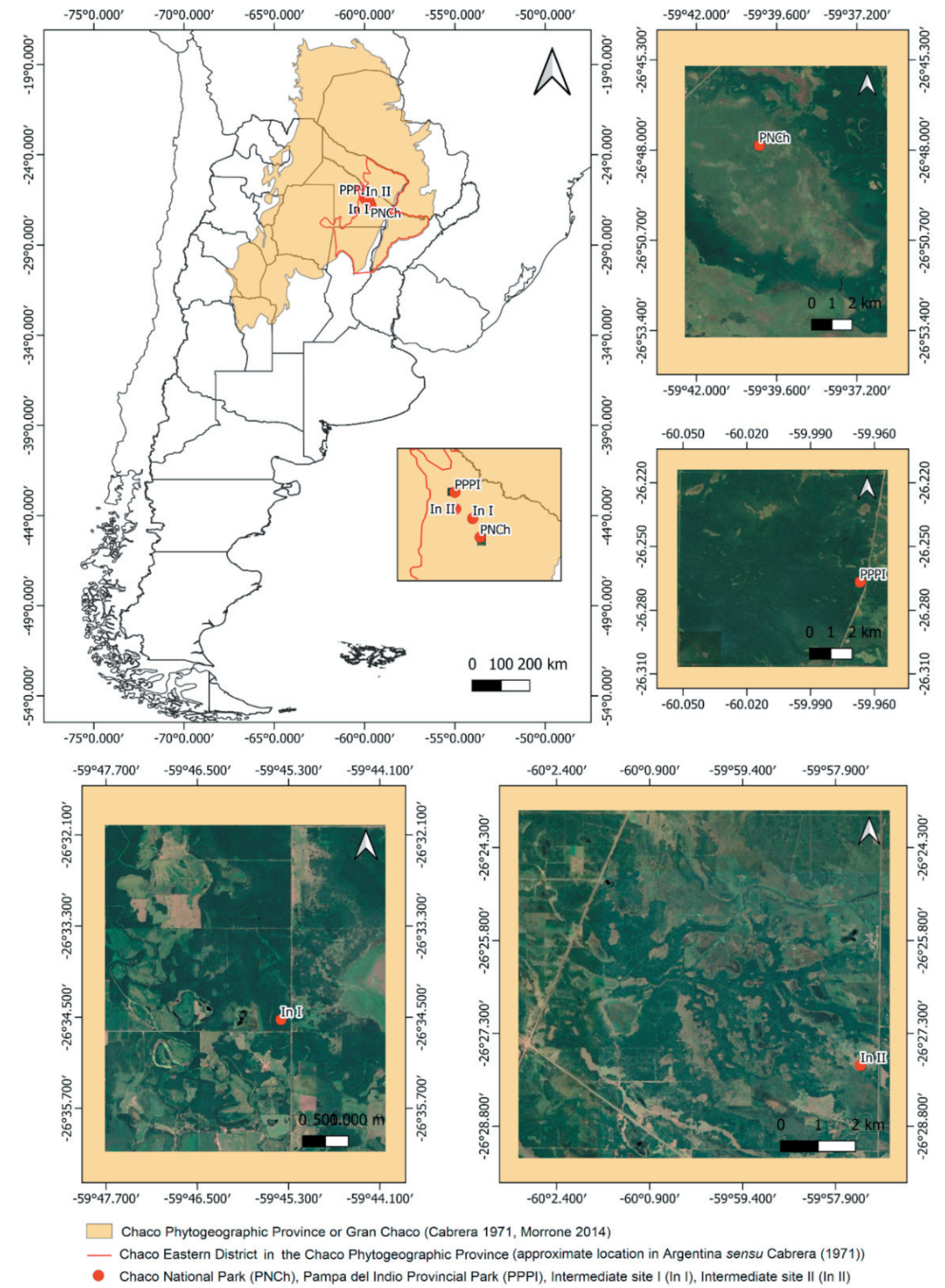

Figure 1. Location of the study area within the Chaco Phytogeographic Province. This map was made with QGIS version 3.16.7 (QGIS Development Team 2021) and the satellite images were downloaded from SAS.Planet (SAS.Planet Development Team 2019).

Figura 1. Ubicación del área de estudio dentro de la Provincia Fitogeográfica del Chaco. Este mapa se realizó con QGIS versión 3.16.7 (QGIS Development Team 2021) y las imágenes satelitales se descargaron de SAS.Planet (SAS.Planet Development Team 2019).

in the Salticidae family and has been studying these spiders in the Eastern Chaco District for seven years. Besides, the identifications were made meticulously. Some specimens that could not be identified were excluded from the analyses; these were 1) juveniles at a very early stage of development and juveniles of two species of *Gastromicans* spp. that had a very similar habitus, and 2) adult males of *Gastromicans* that even though they had different colored hairs, they could not be differentiated with accuracy because their palps (male genitalia) and their chelicerae (a characteristic that sometimes assists in the identification of adults) were very similar. Unidentified specimens were listed as 'not determinable' and '*Gastromicans* spp.', and represented 8% of the total.

To identify specimens, stereoscopic microscopes (Olympus SZ51, Olympus SZ40, Leica ES2 and Leica EZ4) were used at the Biología de los Artrópodos Laboratory of the Facultad de Ciencias Exactas y Naturales y Agrimensura (FACENA), Universidad Nacional del Nordeste (UNNE), Corrientes, Argentina. The identified material was deposited in the CARTROUNNE collection and the IBSI-Ara collection (Instituto de Biología Subtropical, Misiones, Argentina).

Data analyses

For the first aim of this research, the potential indicator or detector species of the conservation status of the habitats were analyzed using the IndVal index (Dufrêne and Legendre 1997; De Cáceres and Legendre 2009). This index combines information on the specificity (a measure of exclusivity) and fidelity (a measure of occurrence frequency) of a species by a group (e.g., how specific and faithful a species is to a crop without herbicide application compared to a crop with herbicide application) (Dufrêne and Legendre 1997; McGeoch et al. 2002; Cáceres and Legendre 2009). This analysis was performed with the adult+juvenile and adult datasets separately. IndVal Index was calculated with the R program version 4.0.2 together with the indicspecies and stats packages (De Cáceres and Legendre 2009; R Core Team 2020). This index was calculated with a significance level of 0.05 and 999 permutations. To carry out this analysis, the data from the intermediate sites were grouped under the category of 'semi-natural habitats' and the Chaco National and Provincial Pampa del Indio parks under the category of 'natural habitats'. In the analyses, six groups were compared: natural foliage, semi-natural foliage, natural grassland, semi-natural grassland, natural leaf litter and semi-natural leaf litter. Then the species resulting from the IndVal Index were classified with a significant P-value ($P<0.05$) following the criterion used by Tonelli et al. (2017): those species that yielded an IndVal>0.70 were considered indicator species and those that yielded an IndVal>0.45 and <0.70 were considered detector species. Indicator species are highly characteristic of a particular ecological status or group and may rapidly decline under other ecological conditions to the extent that they could disappear (Dufrêne and Legendre 1997; McGeoch et al. 2002; Tonelli et al. 2017). Detector species have a different degree of preference for different ecological conditions or groups, and relative changes in their abundance among these conditions may be indicative of the direction in which the change is occurring (McGeoch et al. 2002; Tonelli et al. 2017). The species that in this study showed an IndVal>0 and <0.45 and a $P<0.05$ were named IndVal-significant species. These species, despite being significant for IndVal, are not useful as indicators or detectors.

The IndVal Index was calculated with the following formula:

$$IndVal_{ij} = \sqrt{A_{ij}} \times \sqrt{B_{ij}} \qquad \text{Equation 1}$$

where IndVal: indicator value of the species i in the group (habitat in this study) of sites j (samples in this study); A_{ij}: calculation of specificity, that is, the average abundance of species i in the sites of group j, compared to all groups in the study; B_{ij}: fidelity calculation, that is, the relative frequency of occurrence of species i in the sites of group j. A_{ij} is maximum (1 or 100%) when species i is only present in group j. B_{ij} is maximum when species i is present in all sites of group j. The IndVal Index is maximum when individuals of species i are observed at all sites of a single site group.

For the second aim of this research, a nonparametric Kruskal-Wallis test was used to compare IndVal values and their components (given that the IndVal distribution statistically differed from normal distribution as shown by a Shapiro-Wilk test). These analyses were performed in R.

There are other valid analyses that can be conducted to evaluate associations of species to certain groups, such as canonical correspondence analysis, two-way indicator species analysis and redundancy analysis (Moreno et al. 2007; Alcalde et al. 2021). However, these approaches serve to recognize groups of species rather than species individually. IndVal provides numerical values of association for each species; these values vary from 0 to 1 and are easy to interpret. Thus, for the purpose of searching for indicator or detector species, IndVal is superior to those indices. Leote et al. (2019) proposed the use of market basket analysis, a method mathematically similar to IndVal, but designed to handle large amounts of data. However, this method was not chosen herein because its efficacy has not been widely demonstrated yet.

Results

A total of 1697 spiders of Salticidae were collected, 27% of them were adults. A total of 69 species were identified, 59 of which were found in the adult stage (Supplementary Material-Table S1). The species richness for each habitat and site was higher when the adults+juvenil dataset was considered when compared to the adult dataset. The leaf litter was the habitat where the lowest richness was recorded (Table 1).

From both the adult+juvenile dataset and the adult dataset, the IndVal Index yielded five groups out of the six tested (natural foliage, semi-natural foliage, natural litter, natural grassland, semi-natural grassland). The adult+juvenile dataset yielded 39 IndVal-significant species, 15 of which were from natural habitats (four from foliage, two from leaf litter, and nine from grassland) and 24 were from semi-natural habitats (12 from foliage and 12 from grasslands). The adult dataset resulted in 24 IndVal-significant species, eight of which were from natural habitats (one from foliage, two from leaf litter, and five from grassland) and 14 were from semi-natural habitats (eight from foliage and six from grassland). None of the IndVal-significant species were identified as indicator species, but three were identified as detector species: *Philira micans* from the semi-natural foliage, *Maeota dorsalis* from the natural grassland and *Semiopyla viperina* from the natural leaf litter (Table 2, Figure 2).

The adult+juvenile dataset provided more information on the number of IndVal-significant species and the IndVal values, that were higher. Twenty IndVal-significant species were shared by both datasets and this number was greater than the number of exclusive species in each dataset. Nineteen IndVal-significant species were exclusively detected from the adult+juvenile dataset, while only two IndVal-significant species were exclusively detected from the adult dataset. These results were consistent with those expected in relation to the spiders would be correctly identified. Among the 20 species detected from both datasets, those obtained from the adult+juvenile dataset had significantly higher IndVal values than those obtained from the adult dataset (Kruskal-Wallis test, chi-squared=6.6086, df=1, P-value=0.01015). These results were consistent with those expected in relation to higher IndVal values that would produce adult+juveniles when compared to adults only. The high values of IndVal when adult+juvenile was considered were mainly explained by the fidelity component since this component index had significant higher values in the adult+juvenil dataset than in the adult dataset (Kruskal-Wallis

Table 1. Species richness in three habitats in Chaco National Park (PNCh), Pampa del Indio Provincial Park (PPPI), intermediate site I (In I) and intermediate site II (In II) in Chaco, Argentina.

Tabla 1. Riqueza de especies en tres hábitats del Parque Nacional Chaco (PNCh), el Parque Provincial Pampa del Indio (PPPI), el sitio intermedio I (In I) y el sitio intermedio II (In II) en Chaco, Argentina.

Area		Stage/habitat	Foliage	Leaf litter	Grassland
Natural	PNCh	Ad+J	16	5	28
		Ad	11	2	20
	PPPI	Ad+J	24	8	19
		Ad	13	3	17
Semi-natural	In I	Ad+J	20	9	23
		Ad	13	5	15
	In II	Ad+J	27	8	19
		Ad	18	6	16

Ad: adults, J: juveniles

Table 2. IndVal-significant species of the family Salticidae in natural and semi-natural habitats in an area encompassing Chaco National Park, Pampa del Indio Provincial Park and two intermediate sites between both parks, Chaco, Argentina.

Tabla 2. Especies de la familia Salticidae IndVal-significativas en hábitats naturales y seminaturales en un área que comprende el Parque Nacional Chaco, el Parque Provincial Pampa del Indio y dos sitios intermedios entre ambos parques, Chaco, Argentina.

Adults + juveniles					Adults				
Natural foliage group (4 spp.)					Natural foliage group (1 sp.)				
Species	IndVal	P	A	B	Species	IndVal	P	A	B
Maeota dichrura	0.419	0.001	0.81	0.22	-				
Wedoquella macrothecata	0.316	0.001	1.00	0.10	-				
Cotinusa vittata	0.242	0.001	1.00	0.06	*Cotinusa vittata*	0.224	0.001	1.00	0.05
Frigga quintensis	0.149	0.031	0.67	0.03	-				
Semi-natural foliage group (12 spp.)					Semi-natural foliage group (8 spp.)				
Species	IndVal	P	A	B	Species	IndVal	P	A	B
Philira micans	0.582	0.001	0.78	0.43	*Philira micans*	0.382	0.001	0.79	0.18
Scopocira histrio	0.385	0.001	0.66	0.22	*Scopocira histrio*	0.295	0.001	0.87	0.10
Gypogyna forceps	0.357	0.001	0.85	0.15	*Gypogyna forceps*	0.245	0.001	0.90	0.07
Chira spinosa	0.339	0.001	0.60	0.19	-				
Titanattus parvus	0.305	0.001	0.93	0.10	*Titanattus parvus*	0.258	0.001	1.00	0.07
Colonus germaini	0.280	0.001	0.47	0.17	-				
Chira gouneillei	0.272	0.001	0.68	0.11	*Chira gouneillei*	0.163	0.022	0.80	0.03
Arachnomura querandi	0.265	0.001	0.60	0.12	*Arachnomura querandi*	0.236	0.001	0.67	0.08
"*Coryphasia*" sp. n.	0.254	0.001	0.86	0.07	-				
Cyllodania zoobotanica	0.207	0.002	0.86	0.05	*Cyllodania zoobotanica*	0.158	0.031	1.00	0.02
Bryantella smaragda	0.204	0.003	0.62	0.07	-				
Gastromicans sp. n. 1	0.154	0.032	0.71	0.03	*Gastromicans* sp. n. 1	0.154	0.032	0.71	0.03
Natural leaf litter group (2 spp.)					Natural leaf litter group (2 spp.)				
Species	IndVal	P	A	B	Species	IndVal	P	A	B
Semiopyla viperina	0.467	0.001	0.58	0.37	*Semiopyla viperina*	0.216	0.001	0.80	0.06
Hisukattus transversalis	0.173	0.014	0.71	0.04	*Hisukattus transversalis*	0.149	0.047	0.67	0.03
Natural grassland group (9 spp.)					Natural grassland group (5 spp.)				
Species	IndVal	P	A	B	Species	IndVal	P	A	B
Maeota dorsalis	0.495	0.001	0.54	0.45	*Maeota dorsalis*	0.405	0.001	0.70	0.23
Akela ruricola	0.312	0.001	0.61	0.16	*Akela ruricola*	0.214	0.002	0.55	0.08
Pachomius sp. n.	0.242	0.001	1.00	0.06	-				
Aphirape gamas	0.240	0.001	0.87	0.07	-				
Pseudofluda palachiyaxa	0.230	0.001	0.49	0.11	-				
Zygoballus sp. n.	0.194	0.009	0.50	0.07	-				
Cotinusa cf. *melanura*	0.173	0.012	0.71	0.04	*Cotinusa* cf. *melanura*	0.158	0.027	1.00	0.02
Coryphasia bulbosa	0.163	0.017	0.80	0.03	-				
Tullgrenella guayapae	0.158	0.021	1.00	0.02	-				
-					"*Euophrys*" *melanoleuca*	0.307	0.001	0.49	0.19
-					*Tartamura adfectuosa*	0.203	0.001	0.55	0.07
Semi-natural grassland group (12 spp.)					Semi-natural grassland group (6 spp.)				
Species	IndVal	P	A	B	Species	IndVal	p	A	B
Pseudofluda capandegui	0.378	0.001	0.50	0.28	*Pseudofluda capandegui*	0.325	0.001	0.57	0.18
Wedoquella rubrogastra	0.366	0.001	0.80	0.17	-				
"*Euophrys*" *melanoleuca*	0.325	0.001	0.53	0.20	-				
"*Dendryphantes*" aff. *mordax*	0.317	0.001	0.57	0.17	"*Dendryphantes*" aff. *mordax*	0.185	0.010	0.59	0.06
Pachomius areteguazu	0.306	0.001	0.93	0.10	*Pachomius areteguazu*	0.204	0.001	1.00	0.04
Aillutticus aff. *rotundus*	0.265	0.001	0.84	0.08	*Aillutticus* aff. *rotundus*	0.158	0.031	1.00	0.02
Neonella sp. n. 1	0.258	0.001	0.72	0.09	*Neonella* sp. n. 1	0.234	0.001	0.73	0.07
Tartamura adfectuosa	0.236	0.001	0.52	0.11	-				
Neonella sp. n. 2	0.235	0.001	0.74	0.07	*Neonella* sp. n. 2	0.229	0.001	0.79	0.07
Tapsatella abocastanea	0.207	0.003	0.64	0.07	-				
Jollas sp.	0.179	0.015	0.48	0.07	-				
Aphirape riparia	0.169	0.022	0.57	0.05	-				

Ad: adults, J: juveniles, A: specificity, B: fidelity

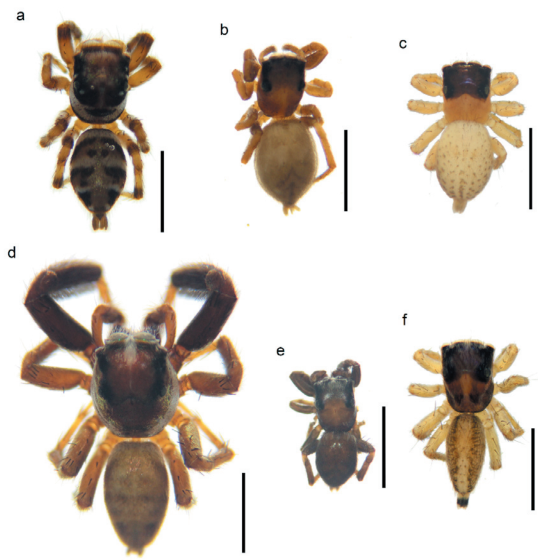

Figure 2. Detector species of the family Salticidae of the state of conservation of habitats in the Eastern Chaco, Argentina. a-d) *Philira micans*, semi-natural foliage detector. b-e) *Semiopyla viperina*, natural leaf litter detector. c-f) *Maeota dorsalis*, natural grassland detector. a-c) Females. d-f) Males. Scales: 2mm

Figura 2. Especies detectoras de la familia Salticidae del estado de conservación de hábitats en el Chaco Oriental. a-d) *Philira micans*, detectora de follaje semi-natural. b-e) *Semiopyla viperina*, detectora de hojarasca natural. c-f) *Maeota dorsalis*, detectora de pastizal natural. a-c) Hembras. d-f) Machos. Escalas: 2mm

test, chi-squared=6.4971, P=0.01081). The specificity component did not show significant differences in both datasets (Kruskal-Wallis test, chi-squared=2.5642, P=0.1093) (Table 2, Supplementary Material-Table S2).

Discussion

This study demonstrated that Salticidae family is a valuable detector species of semi-natural/natural habitats of the Chaco province. In addition, it is confirmed that the inclusion of juveniles improves the detection of species with high values of IndVal. Three species were identified for the first time as detectors of the conservation status in forest foliage, forest leaf litter and grassland: *Philira micans*, *Maeota dorsalis* and *Semiopyla viperina*. These species were exclusively identified with the adult+juvenile dataset.

No species of Salticidae were identified as indicators, whereas Malumbres-Olarte et al. (2013) identified one, Carvalho et al. (2011), three, and Martínez et al. (2022), one. Although no indicator species were found, detector species should not be underestimated, as they can provide information on the direction of ecological change, which indicator species cannot (Mcgeoch et al. 2002). Indicator species tend to abruptly disappear from sites where they do not have an affinity. In a dissimilar way, detector species have different degrees of specificity and fidelity across different groups being compared. Thus, they can be even more useful than indicator species to notice gradual changes (Mcgeoch et al. 2002).

Species that are indicators or detectors of disturbed habitats are usually generalist species that replace specialists (Calcaterra et al. 2022). That could explain why *Philira micans* was a detector, as this species is generalist in terms of its distribution and, consequently, in the range of climatic tolerance. This species is distributed in Argentina, Brazil, Paraguay and Uruguay (Laborda et al. 2020; World Spider Catalog 2022). The known distributions of the species that were indicators of natural habitats are smaller than that of *P. micans*; though, it could be due to a lack of records (World Spider Catalog 2022).

The number of species of the Salticidae family recorded as detectors herein agrees with the number of detector species identified in other studies. Malumbres-Olarte et al. (2013) and Aisen et al. (2017) identified one detector species, Carvalho et al. (2011) found two and Yekwayo et al. (2019), four. However, none of the studies developed by the aforementioned authors are comparable to this study because they compared different things and with different techniques. Carvalho et al. (2011) used pitfall traps that were active for 15 days and compared significantly different biogeographical areas located at different latitudes in Portugal. Malumbres-Olarte et al. (2013) used the technique of digging grass squares and compared recently-burned areas with never-burned areas in New Zealand. Yekwayo et al. (2019) compared burned areas three months, one year and seven years after burning in Africa. The last authors used three sampling techniques (pitfall trapping that was active for seven days, active searching and vacuuming), but they pooled them, and they also pooled 16 pitfall samples into one. Aisen et al. (2017) compared different habitats instead of the conservation status of habitats, like herein, and used pitfall traps active for seven days. These last authors pooled 9 pitfall samples into one, similar to Yekwayo et al. (2019). Analyzing whether or not the authors pooled the samples and the time the traps were active is not a minor detail because pooling the samples or large samples increases the value of the fidelity component of IndVal and, therefore, that of IndVal (personal observation). Furthermore, and most importantly, the species that are indicators or detectors in those cases may be more dispersed in the field, so the real usefulness of those species as indicators or detectors decreases. This can be inferred by interpreting the fidelity component formula and relating it to logical probabilities (Dufrêne and Legendre 1997; De Cáceres and Legendre 2009).

In relation to the above, the low fidelity values of the IndVal index obtained with the sampling techniques used in this study, in general, and in the adult dataset, in particular, can be attributed to the small size of the samples and/or to the scattered distribution of spiders in the field. Both factors decrease the probability that the species will appear in the samples. Thus, the smaller the samples or the more dispersed the individuals of a species, the fewer samples they are likely to appear in. In several studies with spiders, when epigean spiders were sampled by pitfall, detector and indicator species were obtained with high values (Gurdebeke et al. 2003; Carvalho et al. 2011; Ghione et al. 2013; Argañaraz et al. 2020b; Martínez et al. 2022). Probably, those findings are partially related to the long time (two weeks) the pitfall traps were active in those studies, as this increased the probability of a species falling in a larger number of samples. Thus, high fidelity added to high specificity could have resulted in high IndVal values in those studies. In contrast to the fidelity component, the specificity component does not seem to be explained by the sample size. Their high values recorded of this component compared to those of the fidelity agree with what was obtained by Aisen et al. (2017), but it differs from what was found by Argañaraz et al. (2020a, 2020b).

This study showed different results with the inclusion of juveniles, a novel approach as no previous studies had evaluated their effect on the analyses of indicator species. However, improved results by including juveniles in other types of analysis have been found. On the one hand, Jiménez-Valverde and Lobo (2006) found that the inclusion of juveniles decreased the proportion of singletons and increased the asymptotic trend in accumulation curves. On the other hand, Domènech et al. (2022) found that the inclusion of juveniles increased the richness and decreased the difference in species composition between communities. Both studies recommended the inclusion of juveniles in ecological studies, especially when short-term sampling protocols or limited areas are considered. Herein, the main advantage of using the adult+juvenile dataset was that it yielded detector species that were not detected in the adult dataset. Thus, the use of juveniles is also recommended, but not mandatory. Each researcher can decide whether or not to include the juveniles according to the difficulty they find in identifying them. It is necessary to mention that unless juveniles are genetically identified as in Domènech et al. (2022), it will not be possible to identify all of them, especially those that were newly hatched.

In sum, it has been demonstrated that: A) spiders of Salticidae in the studied area are sensitive to the conservation status of the analyzed habitats as detector species were recorded, and B) the inclusion of juveniles provides more information than the analysis of only adults. The detector species could be useful for future applications of monitoring programs in the Eastern Chaco when restoration projects are implemented or to monitor its conservation status.

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