How do assemblages of epigean Araneae and Coleoptera respond to changes in habitat structure caused by sugar cane crops in Northern Argentina?

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ABSTRACT
In Northwest Argentina, nothing is known about the relationship of Araneae and Coleoptera with sugar cane crops. Using pitfall traps in three continuous native forest sites (N) and three native forest windbreaks surrounded by sugar cane crops (W) in the province of Salta, we assessed a) whether the native diversity of epigean Araneae and Coleoptera in the Chaco Serrano forest changes as a result of the fragmentation of the habitat caused by the sugar cane plots, and b) whether the diversity of predatory species increases in native forest windbreaks as a consequence of the contribution of species that come from crops. In the spring of 2006 and the summer of 2007, we collected 599 Araneae and 555 Coleoptera, with community W (S = 132, N = 535) containing much more species but fewer individuals than community N (S = 111, N = 619). We found that the spatial and phenological patterns of the alpha and beta diversities of N were altered in W communities. Thus, habitat fragmentation generated by sugar cane plots led to the local extinction of native Araneae and Coleoptera species. The abundance of generalist Araneae and herbivorous Coleoptera increased in W habitats, but the coprophagous and detritivorous beetles decreased. The diversity of predatory species (Araneae and some Coleoptera) increased in W habitats, although their abundance declined relative to N habitats. Species turnover determined beta diversity between N and W sites; however, between the W sites, nestedness increased and spiders showed a greater loss of species. The spatial heterogeneity between sites, seasons, and habitats had a substantial effect on the composition of the Araneae and Coleoptera assemblages, hence influencing regional diversity. Eight species were habitat indicators, particularly Leprolochus birabeni (Zodariidae), which responds unfavourably to perturbations in the agricultural landscape, and could be deployed as environmental monitors in the Chaco Serrano.

Introduction
The expansion of the agricultural frontier is one of the principal causes of native forest decline [1], resulting in habitat fragmentation, loss, and degradation [2]. In this regard, the South American Chaco is a significant ecoregion that requires conservation efforts, as it is the only remaining dry subtropical forest in the world [1,3], and various productive ventures have replaced its natural ecosystems. The Argentine Chaco has the greatest rates of deforestation in the country [4], and the Serrana sub-region has lost 94% of its forests over the past 30 years [5]. The principal threat to Chaco’s biodiversity is the decrease and fragmentation of its habitats [6]. Due to its vulnerability, the Chaco is one of the most important ecoregions of the country to conserve [7,8]. In order to mitigate the detrimental impacts of agricultural growth in the Argentine Chaco, a number of regulations were enacted in the country thirty years ago regulating the preservation of forest windbreaks [9]. These were created to prevent and alleviate wind erosion in agricultural fields, as well as to preserve and connect the remaining woodland remnants inside the agricultural matrix. However, these restrictions were ineffective, compliance was limited, and the size of forest windbreaks, particularly in Chaco regions, declined over time until they disappeared [9].

In Argentina, the cultivation of sugar cane (Saccharum spp.) has increased in recent years and is expanding in the Chaco Serrano and Yungas forests of Tucumán, Salta, and Jujuy provinces in the country’s Northwest. The aforementioned provinces produce 98% of the nation’s sugar cane, with their cultivated area increasing by almost 24% between 2004 and 2018 [10]. This change in land use has resulted in the fragmentation of continuous forest regions into patches of varying sizes and degrees of isolation. Habitat fragmentation affects the functioning of the ecosystem [11] and has severe effects on biodiversity [12] due to the disruption of population and biotic community organisation [13], the extinction of local species [14], and the increase in genetic isolation [15].

Using guilds [16] is a useful method for determining how biotic communities react to habitat modification.

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Guilds are non-phylogenetic groups of animals that share one or many valuable resources [17]. This approach is interesting because, regardless of taxonomic composition, the majority of the time its members respond similarly to the same environmental changes, and they can also play similar functional roles in the community [16].

The agricultural landscape can affect Araneae and Coleoptera because they respond significantly to habitat structure and are the most sensitive taxa to small-scale spatial changes [18]. This resulted in the proposal of these taxa as bio-indicators for assessing the effects of agriculture on biodiversity [19,20]. Araneae are among the most diverse terrestrial arthropod predators in the world [16], distinguished by their ubiquity and great sensitivity to habitat quality and environmental change [21], and exhibiting taxon-guild responses [22]. On the other hand, Coleoptera are the most diverse group of insects, they are found in all ecosystems [23], and their different feeding patterns represent all trophic roles [24], therefore they can be extremely valuable as tools for environmental monitoring and assessment [25,26].

In northwestern Argentina, the expansion of sugar cane cultivation may have had various consequences on the biodiversity of arthropods, particularly Araneae and Coleoptera. According to studies conducted in other sugar cane producing nations [27,28], this crop supports a rich diversity of Araneae and predatory Coleoptera. However, nothing is known in Argentina about the relationship between these two arthropod taxa and sugar cane crops. There is only one publication that deals with a Curculionidae (Coleoptera) species which is considered a pest of sugar cane [29]. Recent investigations in the Chaco Serrano of Salta province have improved our understanding of spiders [30–33], although information on coleopterans is sparse [30,34]. In this study, we evaluate whether the diversity of epigeal Araneae and Coleoptera in the Chaco Serrano forests changes as a result of the fragmentation of the habitat caused by sugar cane plots, which alter the shelter, feeding, dispersal, and reproduction conditions of these organisms. For this reason, we expect a decrease in species richness, abundance, family composition, and trophic guilds in their communities inhabiting native forest windbreaks within the sugar cane agricultural landscape compared to those inhabiting the continuous native forest. In addition, since agricultural fields and the semi-natural habitats that surround them probably maintain a large diversity of predatory arthropods that move between the two habitats depending on the availability of prey, the phenology of the crop, and the techniques of tillage and field maintenance [35], we predict that the diversity of predatory species will be greater in native forest windbreaks.

Materials and methods

Study area

This study was conducted in the Argentine province of Salta, General Martín Miguel de Güemes and Metán Departments (Figure 1). This area is part of the Chaco Seco ecoregion, the Serrana subregion, between 600 and 1,400 metres above sea level [36]. The climate is semi-arid, with average annual precipitation between 500 and 700 millimetres, except on the eastern slopes, where it reaches 1,500 millimetres in orographic rainfall regions [36]. The mean annual temperature is 23 °C [37], and during winter there is a large daily thermal amplitude. The Chaco Serrano forms a broad ecotone (transition zone) between the Yungas and the Monte ecoregions [38], where the altitude decreases eastward, and the environment is rocky with steep slopes and strong river erosion. On a broader scale, the matrix of the Serrano foothills is a semi-deciduous high open woodland with patches of grassland; yet, as one ascends, one encounters mountain pastures [36]. In the highland forests, hardwood plant species such as Schinopsis haenkeana, Aspidosperma quebracho-blanco, Prosopis alba, and P. nigra, Handroanthus chrysanthus, Ceiba chodatii, and an endemic cardon species, Trichocereus terscheckii, predominate [36,38]. Opuntia quimilo is a major invader in the highland grasslands, gaining the degraded systems (overgrazed grasslands or abandoned crop plots) of the Chaco Serrano with the tar Parkinsonia praecox and many species of acacias (Acacia aorea, A. caven, and A. furcatispina) [36].

For the collection of epigeal Araneae and Coleoptera, six sampling sites were chosen (Figure 1), three of which correspond to a continuous native forest (N) and the other three to native forest windbreaks (W) in the middle of a sugar cane agricultural matrix. The distance between plots N and W was 50 kilometres. To maintain the independence of the samples in each habitat, the sampling locations were more than 500 metres apart [39]. Thus, 3 km separated the N sites while the W sites were separated by around 2.5 km. We selected the native forest areas as part of a continuous 1,150-ha serrano forest area in a good condition of conservation and without human intervention for over 50 years; we consider them to be natural ecosystems of the Chaco Serrano in the Juramento River Valley in the Metán Department (N1: 25° 07’ 31.44”S 65° 02’ 16.92”W, 755 m a.s.l.; N2: 25° 07’ 22.85”S 65° 03’ 44.44”W, 813 m a.s.l. and N3: 25° 07’ 25.25”S 65° 05’ 52.8”W, 829 m a.s.l.). The vegetation is dominated by Schinopsis haenkeana, Trichocereus terscheckii, Aspidosperma quebracho-blanco, Ziziphus mistol, Acacia sp., and Capparis sp. Native forest windbreaks comprise a 10 km long and 30–40 m wide continuous windbreak of native serrano forest that is flanked by sugar cane crops in the El Algarrobal neighbourhood of the Gral. Martín Miguel de Güemes Department (W1:...
24° 40' 13.54"S 65° 1' 43.74"W, 719 m.a.s.l.; W2: 24° 39' 45.48"S 65° 0' 40.90"W, 690 m.a.s.l. and W3: 24° 39' 17.94"S 64° 59' 35.94"W, 666 m.a.s.l.). Acacia visco, Tipuana tipu, Enterolobium contortisiliquum, Opuntia quimilo, Prosopis ruscifolia, and Ruprechtia trailer were the prevailing plant species.

**Sampling**

Sampling was performed in the spring and summer of 2006 and 2007, respectively. At each sampling site, a rectangular area of 4,500 m² (150 x 30 metres) was delineated; at its center and along a 100 m linear transect (random start), 10 pitfall traps were positioned 10 metres apart to assure sample independence [40,41]. These traps were 12.5 cm in diameter, transparent plastic containers containing saline solution (sodium chloride (kg): water (lt) in a 1:8 ratio) and detergent drops as a preservative. Per sampling season, each trap was active for seven days. This interval of time permits the achievement of higher capture rates [40] and would not have unintended consequences due to higher disturbance levels at the study site [42]. We accessed the sampling period’s temperature and precipitation values from the Windows 10 application meteored.com.ar [43].

**Identification of spiders and beetles**

We utilised the dichotomous keys published by Grismado et al. [44] and Bentancourt et al. [45] for the identification of Araneae and Coleoptera families. Following Cardoso et al. [16] for spiders, Susilo et al. [19] and Norfolk et al. [46] for coleopterans, families were matched with guilds. In the case of the Coleoptera families Tenebrionidae and Scarabaeidae, whose species belong to multiple guilds due to their diverse feeding patterns, we analysed each species prior to assigning them to guilds. The morphospecies of Carabidae and Coccinellidae (Coleoptera) were assigned to guilds based on the dietary preferences of the majority of species within each family. We considered the original descriptions and dichotomous keys of Mello-Leitao [47], Marvaldi and Lanteri [48],

![Figure 1. Map of the sampling area located in northwestern Argentina showing the location of the sites considered. Abbreviations N = continuous native forests and W = native forest windbreaks.](image-url)
Aguirre-Tapiero [49], Aballay et al. [50], Bíly [51], the World Spider Catalog version 22.5 [52], and Lanteri and del Río [53] to identify habitat indicator species. Specimens were recognised at the genus or specific taxonomic level, and when this was not possible, they were classified into morphospecies based on distinguishable structural and morphological characteristics [54]. A morphospecies is a recognised entity equivalent to a species, but not formally designated as such. They can be used to classify and describe diversity without compromising precision, keeping in mind that species richness is the most commonly used measure of diversity [55]. Therefore, the term “species” will be used throughout this work to refer to both morphospecies and specimens recognised at a particular level.

Data analysis

Alpha diversity and inventory

Due to the fact that the data did not conform to normality (Bartlett test of goodness of fit and homogeneity of variances), non-parametric statistical tests were conducted.

The quality of the inventories for each habitat (N and W) was determined by the sample coverage, whose values range from 0 to 1 and are reported as a percentage. This determines the proportion of the total number of individuals in the community that belongs to the sampled species [56]. We calculated the completeness of the inventories obtained for each taxon as the relationship between the observed species richness and the species richness estimated by ACE, whose value was obtained using the SPADE programme [57]. We evaluated the completeness values of the inventories according to Chao et al. [58] and Cardoso’s [59] criteria, which provide three categories: “reasonable” (50–70 percent completeness), “complete” (70–80 percent completeness), and “exhaustive” (80 percent or more). Species richness was compared between habitats (N and W) by extrapolating the rarefaction of Hill numbers for q = 0 (species richness), q = 1 (Shannon exponential), and q = 2 (Simpson’s inverse) (see calculation formulas in Jost [60]). This technique assures that samples are comparable regardless of sample size, allowing for robust statistical inferences of species richness patterns in communities [56]. The calculations were performed using the programme iNEXT [61] and were based on individuals with the same degree of sample coverage, confidence intervals of 95 percent, and 100 permutations.

Families, guilds and community structure

A bootstrapping method [62] calculated by the PAST 3.08 programme [63] was used to determine if there were statistically significant differences in the values of species abundance and species richness between habitats (N and W) and between seasons (spring and summer). We compared the richness and abundance of predatory species per habitat for both orders of arthropods using the same methodology. We used graphs of the relative abundances and species richness to compare the guilds between habitats (N versus W). According to the type of food consumed, epigeal coleopterans were categorised into seven guilds: fungivores (feed on mushrooms) (F), xylophages (feed on wood) (X), necrophagous (feed on dead animals) (N), detritivorous (feed on decaying organic materials) (D), herbivores (feed on plants) (H), predators (feed on living animals) (P), and coprophagous (feed on faeces) (C). Following Cardoso et al. [16], epigeal spiders were classified into seven guilds according to the used hunting strategies: Ambush hunters (AH), Ground hunters (GH), Other hunters (OH), Orb web weavers (OWW), Specialists (S), Sheet web weavers (ShWW) and Space web weavers (SpWW). We analysed and compared the structure of Araneae and Coleoptera family assemblages in each habitat type using rank-abundance curves (N and W) [64], wherein the position denotes the decreasing abundance order of the families.

Beta diversity

To assess the degree of association/similarity of the assemblages of families and their relationship with the habitats selected a priori and with the phenological seasons, a Principal Component Analysis (PCA) was conducted using PC-Ord v.7.0 [65] on a variance/covariance matrix.

Beta diversity is a crucial term for quantifying biodiversity and comprehending the functioning of ecosystems [66]. Changes in species composition between communities (beta diversity) can represent two underlying phenomena: turnover (βSIM) and nestedness (βSNE), which are caused by distinct mechanisms (replacement of species and species loss, respectively) [67]. Due to fragmented habitats frequently generate nestedness patterns in beta diversity [68], the effect of sugar cane plots on species composition was evaluated by comparing beta diversity between habitats, sampling sites, and seasons for both taxonomic groups collectively and individually, to reveal underlying patterns. Beta diversity was measured using the Sorensen dissimilarity index (βSORE), and its value was partitioned applying the Baselga additive approach [67] by the Betapart package in R [69]. The partition distinguishes what proportion of beta diversity is due to species turnover (βSIM) and what proportion is attributable to the nestedness of assemblages (βSNE).

Importance of beta diversity on a regional scale

To analyse how the alpha and beta diversities of epigeal Araneae and Coleoptera are distributed across the
Serrano forest landscape of the dry Chaco, a multiplicative partition of regional species richness (gamma diversity) was carried out using the PARTITION 3.0 programme [70]. In this analysis, we took into account four hierarchical levels: $y = a_1$ (within the sample = microhabitat) $x b_1$ (between samples) $x b_2$ (between sites) $x b_3$ (between seasons) $x b_4$ (between habitats = native and disturbed). The observed $\alpha$ and $\beta$ values were compared to the values predicted by a random sample distribution [71]. If $p = 1$ or a close approximation of this number, the species are distributed randomly at the considered level, and the samples are therefore independent. If $p$ is closer to zero, the distribution of species at that level is not random.

**Indicator species of each habitat**

To determine whether a species has significant preferences for a particular habitat type, an analysis of the indicator value (IndVal) was conducted. The indicator value is computed as the product of the degree of specificity (exclusive to a particular habitat) and the degree of fidelity (frequency of occurrence within the same habitat) [72]. We determined the statistical significance of the indicator value obtained for each species using the Monte Carlo test with 9999 permutations using PC-Ord v.7.04 programme [65]. Species with indicator value greater than 70% were considered “indicator species” following McGeoch et al. [73].

**Results**

**Alpha diversity and inventory**

In the Chaco Serrano forests of Salta province, a total of 1,154 adult individuals (599 Araneae and 555 Coleoptera) belonging to 89 species of spiders (Annex Table A1) and 111 species of coleopterans (Annex Table A2) were recorded. Coverage of the sample reached 91% for habitats N and 88% for habitats W. There were no statistically significant differences in their values; hence, the environments are equivalent. The completeness of the Araneae inventory achieved 76% (ACE = 117 species), whereas the inventory of Coleoptera reached 55% (ACE = 203 species). Interpolation-extrapolation analysis based on individuals at the same coverage level found that habitats W supported a more diverse community (Figure 2).

**Families, guilds and community structure**

Significantly more ($p = 0.05$) epigeal Araneae were observed in habitats N (N = 347) than in W (N = 252). The number of Araneae families varied between collection sites, with greater diversity in the W habitats (Table 1). Both the species richness and abundance of Araneae in habitats N differed significantly between spring and summer ($p = 0.05$), with summer being the most species-rich and abundant season. In habitats W, there were only significant differences in Araneae abundances between seasons ($p = 0.05$), with summer having the highest number of individuals.

The abundance of epigeal Coleoptera was substantially greater in W ($p = 0.05$), with a larger number of families (Table 1). We observed in N habitats a similar pattern reported in Araneae, where abundance and species richness were considerably greater in the summer ($p = 0.05$). In W habitats, the only significant difference in the abundance of Coleoptera was observed during the spring. During the sampling period, the average spring temperature was 20 °C, while precipitation peaked at 169 mm from October to December. In contrast, the average summer temperature was 21 °C, with 556 mm of precipitation falling between December and March.

![Figure 2](image-url) Species richness analysis by interpolation and extrapolation of continuous native forest (N) and native forest windbreak (W) assemblages by sugar cane plots in the province of Salta. Bars indicate 95% confidence intervals. Abbreviations $S_{\text{obs}}$ = observed species richness, $S_{\text{exp}}$ = estimated species richness, LCL and UCL = the bootstrap lower and upper confidence limits for the diversity of order q (with a default value of 0.95) and C. hat = the estimated sample coverage.
Table 1. Abundance and richness of the families and guilds of Araneae and Coleoptera recorded in the Chaco Serrano.

| Guild                  | Family                        | Continuous native forests (N) | Native forest windbreaks (W) |
|------------------------|-------------------------------|-------------------------------|-----------------------------|
|                        | Abundance | Species richness | Abundance | Species richness |
| Ambush hunters         | Thomisidae | 6 | 4 | 12 | 5 |
| Ground hunters         | Corinnidae | 11 | 2 | 14 | 4 |
|                        | Gnaphosidae | 11 | 2 | 8 | 4 |
|                        | Lycosidae | 66 | 9 | 80 | 8 |
|                        | Prodidomidae | 8 | 2 | 4 | 2 |
|                        | Trachelidae | 0 | 0 | 3 | 2 |
| Orb web weavers        | Araneidae | 6 | 3 | 0 | 0 |
|                        | Tetragnathidae | 0 | 0 | 3 | 1 |
|                        | Theridiosomatidae | 0 | 0 | 27 | 1 |
| Other hunters          | Anyphaenidae | 2 | 1 | 7 | 2 |
|                        | Clubionidae | 9 | 3 | 0 | 0 |
|                        | Ctenidae | 0 | 0 | 1 | 1 |
|                        | Miturgidae | 1 | 1 | 9 | 2 |
|                        | Oxyopidae | 1 | 1 | 0 | 0 |
|                        | Philodromidae | 3 | 2 | 6 | 4 |
|                        | Salticidae | 30 | 6 | 17 | 9 |
| Sheet web weavers      | Amphivenata | 1 | 1 | 3 | 1 |
|                        | Hahniidae | 0 | 0 | 4 | 1 |
|                        | Linyphiidae | 3 | 2 | 30 | 6 |
|                        | Pisauridae | 5 | 2 | 7 | 1 |
| Space web weavers      | Dictyidae | 4 | 2 | 3 | 1 |
|                        | Micropholcommatidae | 11 | 3 | 6 | 2 |
|                        | Pholcidae | 1 | 1 | 0 | 0 |
|                        | Theridiidae | 1 | 1 | 3 | 1 |
| Specialists            | Mimetidae | 0 | 0 | 1 | 1 |
|                        | Zodariidae | 167 | 2 | 4 | 3 |
| Total 7                | 26 | 347 | 50 | 252 | 62 |
| COLEOPTERA             |                      |                              |                             |
| Coprophagous           | Geotrupidae | 29 | 4 | 7 | 4 |
|                        | Hybosoridae | 1 | 1 | 0 | 0 |
| Detritivorous          | Glareidae | 5 | 1 | 0 | 0 |
| Fungivore              | Corylophidae | 1 | 1 | 0 | 0 |
| Herbivore              | Chrysomelidae | 57 | 10 | 20 | 15 |
|                        | Curculionidae | 16 | 6 | 22 | 9 |
|                        | Elateridae | 2 | 2 | 6 | 2 |
|                        | Mordellidae | 0 | 0 | 3 | 1 |
|                        | Nitidulidae | 22 | 1 | 59 | 1 |
|                        | Scarabaeidae | 3 | 2 | 0 | 0 |
| Herivore and Coprophagous | Tenebrielongoidea | 36 | 6 | 7 | 5 |
| Herbivore, Necrophagous and detritivorous |                       |                              |                             |
| Necrophagous           | Dermestidae | 0 | 0 | 38 | 2 |
|                        | Trogidae | 0 | 0 | 1 | 1 |
| Predator               | Carabidae | 25 | 9 | 18 | 6 |
|                        | Cicindelidae | 0 | 0 | 8 | 2 |
|                        | Cleridae | 2 | 1 | 1 | 1 |
|                        | Coccinellidae | 4 | 4 | 9 | 4 |
|                        | Histeridae | 23 | 1 | 4 | 1 |
|                        | Meloidae | 0 | 0 | 3 | 2 |
|                        | Melyridae | 0 | 0 | 1 | 1 |
|                        | Pielaphidae | 0 | 0 | 1 | 1 |
|                        | Staphylinidae | 15 | 9 | 17 | 7 |
| Xylophagous            | Anobiidae | 0 | 0 | 5 | 2 |
|                        | Bostrychidae | 0 | 0 | 2 | 2 |
|                        | Buprestidae | 30 | 2 | 51 | 1 |
|                        | Lycidae | 1 | 1 | 0 | 0 |
| Total 7                | 24 | 272 | 61 | 283 | 70 |

All seven guilds of epigean Araneae were found in both habitats (Table 1). In native forest windbreaks, the abundance of specialist spiders (S) decreased significantly, but the communities of ambush hunters (AH), orb-web weavers (OWW), and sheet web weavers (ShWW) increased significantly (Figure 3a). The species diversity of spider guilds of ground hunters (GH), other hunters (OH), space web weavers (SpWW), and specialists (S) increased in the same habitats (Figure 3a).

We recorded six guilds of Coleoptera in native forest windbreaks (W) and seven in the N habitats (Table 1). Compared to the N habitats, the native forest windbreaks exhibited a considerable abundance of xylophages (X) and necrophagous (N) coleopterans and a marked decrease in the number of coprophagous (C) and detritivores (D) species (Figure 3b). In addition, the species richness of herbivores (H), xylophagous (X), and necrophagous (N) increased in the W habitats.
Fungivores (F) have only been documented in N habitats.

The abundance of predatory species (spiders and some coleopterans) was substantially greater in N (NN = 416, NW = 310, p = 0.05) compared to W. The number of predatory species was higher in native forest windbreaks (S = 86) than in continuous native forest habitats (S = 75), although the difference was not statistically significant (p = 0.2).

In terms of the composition of families and the distribution of their abundances, the epigal Araneae communities of the two environments (N and W) were distinct (Figure 4a). In the native communities, three families accounted for 75.7% of the total abundance. The Zodariidae family dominated (N = 167) with 48.13 %, followed by the Lycosidae family (N = 66) with 19 % and the Salticidae family (N = 8) with 8.64 %. This usual pattern of N habitats in the dry Chaco Serrano was distinct from W habitats, where Lycosidae constituted 32%, followed by Linyphiidae (12%), and Theridiosomatidae (11%) (Figure 4a).
The composition and dominance of families in the epigeal communities of the studied Coleoptera differed between habitats, as shown in Figure 4b. Chrysomelidae represented 21% of the total abundance in the N habitats, followed by Tenebrionidae (13%), Buprestidae (11%), and Geotrupidae (11%). In contrast, Nitidulidae dominated W habitats with 21% of the total abundance, followed by Buprestidae with 18% and Dermentidae with 13%; the latter family was only found in native forest windbreaks.

**Beta diversity**

The PCA for Araneae displayed a pattern of the ordering of the sites impacted mostly by the differences between the N and W habitats (Figure 5a), with the first two axes ($p = 0.05$) explaining 42% of the total variation (27% and 15%, respectively). The first axis organised all native communities along a short gradient involving the seasons (spring to summer). Both Araneidae and Zodariidae were abundant throughout both seasons. Other families were particularly numerous during the summer.

Figure 4. Range / abundance curves of families Araneae (a) and Coleoptera (b) collected in continuous native forest (N) and native forest windbreak (W) habitats in northwestern Argentina.
(Salticidae, Micropholcommatidae, Pholcidae and Clubionidae). The second axis could better explain the divergence of communities within the W habitats, where the effect of seasonality was notably evident. On these sites, the abundance varied dramatically from season to season. Thus, Miturgidae, Anyphaenidae, Pisauridae,

Figure 5. Ordination obtained by PCA of the assemblages of families and guilds of Araneae (a) and Coleoptera (b) in relation to the habitats selected a priori (N and W) and with the phenological seasons (Spring= Spr and Summer= Sum).
Thomisidae, and Mimetidae prevailed in the spring, and in the summer, typical weaver spiders dominated the W communities, including Theridiosomathidae, Tetragnathidae, and Hahniidae, as well as Linyphiidae, Amphinectidae, and Trachelidae; the latter families were present only in the W habitats.

For the Coleoptera, the PCA produced a distinct ordering pattern, which is mostly driven by the seasonality of the Chaco, with the first two axes (p = 0.05) explaining 46% of the total variation (30% and 16%, respectively) (Figure 5b). On the first axis, the N and W communities were organised with similar assemblages during the spring; the most abundant families were Hybosoridae, Glaresidae, and Buprestidae, which are characteristic of N habitats. Dermentidae, together with Melyridae, were typical of W habitats. On the second axis, two distinct groups were distinguished: the summer N communities, represented by Lycidae, Corylophidae, and Scarabaeidae; but also Cleridae, Histeridae, Chrysomelidae, Geotrupidae, Tenebrionidae, and Carabidae. The summer W communities were negatively associated with the second axis, with Meloidae, Pselaphidae, Cicindelidae, and Anobiidae, typical of this habitat, as well as Nitidulidae, Elateridae, and Curculionidae, composing the assemblages.

All comparisons showed moderate to high beta diversity levels ($β_{SOR}$ values between 0.5 and 0.9) (Table 2). The spatial pattern identified in the partition of beta diversity ($β_{SOR}$), in its two components (species turnover and nestedness), was the same regardless of whether Araneae or Coleoptera were considered separately or together. Species turnover ($β_{SIM}$) was the primary factor determining variations between N and W habitats (Table 2). When partitioning the beta diversity within each habitat, we found that the turnover of species influenced the pattern of these arthropods in the Chaco Serrano’s pristine environments, whereas nestedness was higher in the assemblages of W habitats ($β_{SNE}$). When comparing the beta diversity patterns of Araneae and Coleoptera separately, Araneae showed a higher species loss ($β_{SNE}$).

When analyzed independently, Araneae and Coleoptera exhibited the same pattern; however, in N habitats, the loss of Araneae species was approximately double (40.7%) that of Coleoptera species.

**Importance of beta diversity on a regional scale**

For both Araneae and Coleoptera, the multiplicative partition of gamma diversity into its two components (alpha and beta) followed the same pattern. Thus, at the sample level, the alpha and beta diversities did not differ significantly from what would be predicted by chance (p = 1); hence, the samples are independent. In contrast, the beta diversity between sites within the same habitat, between seasons, and between habitats was much higher than predicted by chance. Consequently, the spatial heterogeneity present at these three levels of analysis influenced the composition of the Araneae and Coleoptera assemblages. At the regional level, alpha diversity contributed just 26% to Araneae and 23% to Coleoptera, whereas beta diversity contributed more to gamma diversity at each hierarchical level analysed. Thus, for Araneae, beta diversity between samples contributed 33%, between sites 17%, and 12% for both seasons and habitats; for Coleoptera, the respective values were 35%, 18%, 12%, and 12%.

| Comparisons               | Araneae+Coleoptera | Araneae | Coleoptera |
|---------------------------|--------------------|---------|------------|
|                           | $β_{SIM}$ | $β_{SNE}$ | $β_{SOR}$ | $β_{SIM}$ | $β_{SNE}$ | $β_{SOR}$ | $β_{SIM}$ | $β_{SNE}$ | $β_{SOR}$ |
| Continuous native forests (N) | 96.5%     | 3.5%     | 0.65      | 85.4%     | 14.6%     | 0.58      | 97.2%     | 2.8%      | 0.71      |
| Native forest windbreaks (W) | 94.1%     | 5.9%     | 0.81      | 89.6%     | 10.4%     | 0.76      | 94.7%     | 5.3%      | 0.85      |
| N vs W                    | 94.8%     | 5.2%     | 0.65      | 91.6%     | 8.4%      | 0.59      | 96.8%     | 3.2%      | 0.69      |
| N1 vs N2                  | 93.7%     | 6.3%     | 0.59      | 82.9%     | 17.1%     | 0.48      | 99.0%     | 1.0%      | 0.70      |
| N2 vs N3                  | 95.0%     | 5.0%     | 0.61      | 80.4%     | 19.6%     | 0.59      | 95.5%     | 4.5%      | 0.62      |
| N1 vs N3                  | 99.3%     | 0.7%     | 0.59      | 89.6%     | 10.4%     | 0.48      | 95.6%     | 4.4%      | 0.68      |
| W1 vs W2                  | 81.0%     | 19.0%    | 0.69      | 67.0%     | 33.0%     | 0.65      | 91.0%     | 9.0%      | 0.73      |
| W2 vs W3                  | 99.5%     | 0.5%     | 0.81      | 96.0%     | 4.0%      | 0.75      | 97.4%     | 2.6%      | 0.88      |
| W1 vs W3                  | 93.7%     | 6.3%     | 0.88      | 94.0%     | 6.0%      | 0.86      | 93.5%     | 6.5%      | 0.89      |
| Between seasons N         | 69.3%     | 30.7%    | 0.67      | 59.3%     | 40.7%     | 0.56      | 78.1%     | 21.9%     | 0.77      |
| Between seasons W         | 95.9%     | 4.1%     | 0.72      | 98.5%     | 1.5%      | 0.75      | 92.9%     | 7.1%      | 0.71      |
**Indicator species for each habitat**

Eight species of Coleoptera and one species of Araneae were identified as having a strong relationship with one of the two environments evaluated and so having the potential to be utilized as indicators. In Araneae communities of N habitats, *Leprolochus birabeni* Mello-Leitao, 1942 (Zodariidae) (89%, \( p = 0.003 \)) recorded abundance peaks in the spring, whereas the Coleoptera *Eusipilus* (Hesperosaprinus) strobeli Steinheil, 1880 (Histeridae) (74.7%, \( p = 0.01 \)) during the summer.

In the W habitats, six species of coleopterans performed as indicators: *Helius tuberculosis* Perty, 1832 (Curculionidae) (100%, \( p = 0.01 \)); *Systena* sp. 2 (Chrysomelidae) (100%, \( p = 0.01 \); *Conoderus* sp. (Elateridae) (100%, \( p = 0.01 \); *Paederinae* sp. (Staphylinidae) (86.5%, \( p = 0.02 \); *Systena* sp. 1 (Chrysomelidae) (74.9%, \( p = 0.03 \); and *Pantomorus setulosus* Hustache, 1923 (Curculionidae) (73.9%, \( p = 0.03 \). *Tetragnoschema undatum* Steinheil, 1874 (Buprestidae), was abundant in all habitats during spring (97.1%, \( p = 0.0006 \), however, it was most abundant at W1.

**Discussion**

**Alpha diversity and inventory**

This is the first study to explore how epigean Araneae and Coleoptera in the Chaco Serrano forest respond to changes in habitat structure caused by sugar cane crops. The Araneae and Coleoptera species richness observed here is greater than in Chaco Serrano of Córdoba province (Argentina) [74] and other ecoregions of Salta province such as Monte de Sierras y Bolsones and Puna [33,75]. Also, the species richness outnumbers the Araneae richness of families recorded by Rubio [31] and Cruz et al. [33] for Salta’s Chaco Serrano forests. Obtaining thorough animal inventories is typically challenging [76], especially when working with hyper-diverse groups [77] such as Araneae and Coleoptera. However, according to Chao et al. [58], the inventories obtained for both groups were adequate. According to Cardoso [59], the inventory for Araneae is “complete,” while the inventory for Coleoptera is “reasonable.” This allows us to believe that the collecting data protocol is efficient, allowing us to make meaningful judgments regarding alpha diversity in each community.

**Families, guilds and community structure**

The fragmentation of habitat has a significant impact on biodiversity, species composition, and ecosystem function [78,79]. These arguments are supported by our findings. When compared to continuous native forest habitats (N), native forest windbreaks (W) demonstrate changes in alpha and beta diversity patterns, as well as in the abundance and composition of Araneae and Coleoptera families and guilds. Epigean coleopteran abundance and species richness rise in W habitats, as does epigean Araneae species richness; but the abundance of the latter is greatly reduced. In N communities, both the abundance and species richness of the two taxonomic groups increase throughout the summer, whereas in W, only the abundance of spiders and coleopterans altered significantly across seasons: Araneae rose in the summer, while Coleoptera did so in the spring.

The reproductive season and the emergence of offspring coincide with the summer peak of the abundance of Araneae in the Chaco Serrano. These phases are related to the rapid growth of vegetation during the wet season. As a result, the spiders manage to occupy the new micro-habitats as refuge sites or to seek prey [80], which is also related to the phenology and dynamics of arthropods in crops and surrounding habitats. In the case of Coleoptera, the increase in species richness and abundance found during the summer in continuous native forests coincides with months of more copious rain and elevated monthly average temperature, both of which influence their diversity [81]. Crop irrigation, particularly during dry seasons (such as spring 2006), may have favoured the humid conditions of the native forest windbreaks. The last point could explain the increase in Coleoptera abundance in W during the spring.

Both collection sites’ Araneae guilds exhibit changes in abundance, richness, and composition. Thus, 90% of Araneae in N habitats belong to the specialist guild (48%), ground hunters (28%), and other hunters (14%). The increased concentration of the specialist spider guild is linked to *Leprolochus birabeni* (Zodariidae) which is an indicator spider of the Chaco environment with high abundance values [32,33]. Specimens of this species have also been identified in two other dry Argentine ecoregions, the Espinal [82] and the Monte [83], but no study corroborates that it also works as an indicator taxon in these ecoregions. In this study, which coincided with that of Torres et al. [32], agricultural disturbance reduced the abundance of this species and resulted in its extinction in native forest windbreaks. This species’ extremely specialised food could explain this effect, which has been linked to the extinction of the species in anthropically modified landscapes [84]. *Leprolochus birabeni* only preys on ants [85], a rich resource in the Chaco’s natural forests, but less so in forest remnants surrounded by monocultures [86]. Potentially, the local extinction of *L. birabeni* in native forest windbreaks could be attributed to its susceptibility to crop-applied pesticides [32].

Our findings suggest that ground hunter spiders (43%) exceed orb weavers and ambush hunter spiders in native forest windbreaks. Authors such as Buddle
et al. [87], Gurdebeke et al. [88], and Magura et al. [89] have reported that generalist spider species invade degraded forest patches from the surrounding matrix. The great majority of hunting spiders are generalists [90], and their species are pioneers, invading and dominating highly damaged agricultural landscapes [89,91]. This would explain the increased species diversity and abundance of the ground hunter and ambush hunter spiders in the Chaco Serrano native forest windbreaks in an agricultural matrix with sugar cane crops. Web-building spiders, on the other hand, are often habitat specialists [92,93] and represent a sizable portion of the crop spider community [94]. Sugar cane, corn, sorghum, and cotton have a higher proportion of orb-weavers and ambush hunters [27]. This would also add credibility to the finding of a rise in the abundance and diversity of weaver spiders in W habitats.

Our observations for Coleoptera reveal that six of the seven guilds are shared between N and W environments, albeit with differences in abundance, richness, and assemblage composition. Herbivores and predators are the most diverse and abundant guilds in both environments; nevertheless, the first guild increased its abundance and species richness in W habitats. In the aforementioned environment, the coprophagous and detritivores Coleoptera guilds fall significantly, whilst the necrophagous and xylophages guilds increase. The fungivores guild, represented by a single Corylophidae species, is only found in the N habitats. The guild species richness changed between N and W, indicating an increase in herbivores, xylophages, and necrophagous in W.

One possible explanation for these observations is that sugar cane plots alter the trophic structure of native Coleoptera communities. Monocultures restrict food supply for multiple species while allowing over-exploitation by a few herbivore species [19]. Predatory insects dominate the entomofauna linked with sugar cane in other nations, according to Atencio et al. [95] and Castro Herrera et al. [28]. Although predatory beetles were more diverse and abundant in N (S = 25, N = 69) in our study, they were also well represented in W (S = 24, N = 58).

The detrimental consequences of agriculture and its tillage techniques have resulted in a significant drop in the abundance and species richness of coprophagous and detritivore Coleoptera species in native forest windbreaks. These actions damage micro-niches and available feeding places [19]. Geotrupidae and Scarabaeidae are among the families most affected by this because they are epigeal build nests by digging tunnels in the soil under the faeces or in its proximity [96,97], and are sensitive to environmental changes caused by habitat fragmentation [98,99]. This conclusion is critical to note since these associations could perform valuable ecological functions to balance agroecosystems [98] due to the transformation of organic matter into mineral elements that promote soil fertility [98,100]. Gardner et al. [101] and Molina et al. [102] underlined the importance of detritivore insects as macro-decomposers in arid and semi-arid environments, where other decomposing agents have restricted action because of unfavourable climatic conditions.

Conserving semi-natural environments around crops promotes pest natural enemies (predators and parasitoids) and increases biocontrol services in crops worldwide [35]. Semi-natural vegetation, which provides alternative resources for natural enemies of pests (such as food, hibernation/wintering places, and shelter), might influence biocontrol within crops [103]. In particular, woody vegetation in optimal conditions (no grazing, middle stratum and undergrowth, and good ground cover) supports a wide range of natural enemies that go to crops in search of prey and then return to semi-natural habitats when crop conditions deteriorate [35]. This could explain the observed increase in the richness of predatory species (Araneae and certain Coleoptera) in the Chaco Serrano’s native forest windbreaks.

Araneae from the families Zodariidae, Lycosidae, and Salticidae dominate the Chaco Serrano’s continuous native forest environments. Spider abundance changes in native forest windbreaks, with an increase in the number of Lycosidae, Linyphiidae, and Theridiosomatidae. Zodariidae is often dominant in the Chaco Serrano, Monte, and Espinal environments [32,33,82,83], with high specificity to the Chaco Serrano habitats in Salta province [32,33]. Salticidae is extremely dependent on habitat type [31] and the structural complexity of its plants [104]. Lycosidae, on the other hand, are numerous in both the studied habitats and the Chaco Humedo forests [105]. Because they are a generalist spider family, they have increased in number in anthropized habitats [106]. These species are active hunters on the ground, and in disturbed habitats, they can swiftly exploit unoccupied niches in search of food [107].

Agrobiont spiders like Lycosidae and Linyphiidae are abundant in the Chaco Serrano’s native forest windbreaks. The last family is one of the best adapted to disturbed ecosystems [108,109]. These spiders are abundant in crops during the summer [110]. Sugar cane harvests in Louisiana (USA) [111], India [112,113], Pakistan [114], and South Africa [115] have a great abundance of both families. This would imply that the rise in the abundance of both spider families in the W habitats could be due to a contribution from the araneofauna of the neighbouring sugar cane plots.

We captured two Coleoptera families that are not considered ground-active, such as Chrysomelidae and Buprestidae, in both environments (N and W). This somewhat correlates with the findings of Flores et al. [83], who studied epigeal arthropods in the Monte dry.
forest by capturing seven species of Buprestidae using the same sampling technique. Only two Buprestidae species were found in our study, *Tetragonoschema undatum* and *Buprestis* sp. 1, being the first more abundant in both environments. This buprestid species is related to the genus *Trichocerus* and *Opuntia* (Cactaceae) [116,117], both of which are part of the usual vegetation of the collection sites.

Chrysomelidae and Tenebrionidae dominated the structure of the Chaco Serrano’s natural forest; in W habitats, these families are replaced by Nitidulidae and Buprestidae (Figure 4b). Grez [118] found results comparable to ours in Chile because Chrysomelidae predominated in continuous forest habitats against remnant fragments in an agricultural matrix. This family has also been reported as one of the most diverse, although not particularly abundant, in Panama’s sugar cane crops [28]. Tenebrionidae are found in dry and semi-arid habitats [119], as well as in the forests of Argentina’s western Chaco [105]. They are important in the fragmentation of plant and animal resources [120,121], nutrient cycling, and trophic networks as components of other eating species’ diets [119]. Tenebrionidae species collected are herbivorous [120], necrophagous [121], and detritivorous [119]. Tenebrionidae family accounts for 65% of detritivorous species in N habitats but disappears in W habitats. *Trichoton rotundatum* (Curtis, 1845) (Tenebrionidae) and *Psectrascelis urusina* (Burmeister, 1875) (Tenebrionidae) dominate the Chaco Serrano’s native forest, but show local extinction in W habitats, reducing family abundance by 80%. The significant abundance of the buprestid *Tetragonoschema undatum* in W habitats could be attributed to the increased availability of food, because this species has been observed feeding on pollen from various *Opuntia* species in the humid Chaco [117]. *Opuntia quimilo* is typical of agriculturally degraded environments in the Chaco Serrano [36].

**Beta diversity**

The beta diversity values in all comparisons are moderate or high (β_{SOR} values between 0.5 and 0.9), and species turnover is the main component (Table 2). However, the nestedness component of beta diversity increases in W habitats, particularly between W1 and W2, for both Araneae and Coleoptera. Species turnover indicates environmental sorting or dispersal processes [122], whereas nestedness across sites occurs because of changes in species richness [67] and represents an orderly loss of Araneae and Coleoptera species in W sites. This species loss happens due to a higher number of local extinctions of species in W habitats due to reduced production, historical reasons, and harsh environmental conditions [67]. Because landscapes are mosaics of patches of varying sizes and degrees of isolation, habitat fragmentation causes ordered species’ extinction events [68,123]. That could have happened to *Leptolopus birabeni* (Zodariidae), *Trichoton rotundatum* (Tenebrionidae), *Psectrascelis urusina* (Tenebrionidae), and other species that went extinct locally in W habitats.

**Indicator species of each habitat**

It is vital to remember that *L. birabeni* (Zodariidae) is a specialist spider, whereas *E. (Hesperosapidus) strobeli* (Histeridae) is a predator beetle that prefers the Chaco Serrano’s continuous natural forest habitats. Rather, *P. setulosus* (Curculionidae), *H. tuberculosus* (Curculionidae), *Systena* sp. 1, *Systena* sp. 2 (Chrysomelidae), *Paederinae* sp. (Staphylinidae), *Conoderus* sp. (Elateridae), and *T. undatum* (Buprestidae) are associated with native forest windbreak habitats.

Torres et al. [32] and Cruz et al. [33] previously documented a strong association between *L. birabeni* (Zodariidae) and the natural habitats of the Chaco Serrano and advocated this species as a viable future environmental monitor for this ecoregion. This claim is based on the negative species behaviour to anthropic disturbances, such as the cattle ranch documented by Torres et al. [32] and, in this case, the agricultural landscape.

**Importance of beta diversity on a regional scale**

Finally, our findings support the notion advanced by Gobbi and Fontaneto [124] and Magura et al. [89] that species richness alone is insufficient to determine the effect of human impact on biodiversity. To acquire a more realistic view of the situation, it is essential to consider the responses of different functional groups [90] in the analysis. In the instance of the windbreaks of the Chaco Serrano native forest surrounded by a sugar cane agricultural matrix, the increase in Araneae and Coleoptera diversity is related to the incorporation of agrobiotic species, resulting in local extinctions of native and typical species of that ecoregion. The pattern of increased nestedness in their communities could have resulted from the agricultural frontier’s expansion over the original woodlands. As species similarity increases across space, this will result in progressive and future biotic homogenisation [125] in these habitats. As a result of colonisation by generalist agrobiotic species, biotic homogenisation increases the loss of native species [126,127], contributing to changes in habitat quality and the distribution of species abundance [128].

**Acknowledgments**

We would like to thank Victor Torres, Mariana Chani-Posse, Anaia Lanteri, Gerardo Arriagada, and Federico Agrain for their assistance in identifying the species that were habitat indicators. HBM and AXG-R are grateful for the financial
support of the CIN (Argentina’s National Inter-University Council), as this work was completed as part of a “Scholarship Stimulus to Scientific Vocations.” We also thank CONICET (Argentina) for its ongoing assistance.

Disclosure statement
No potential conflict of interest was reported by the author(s).

Funding
This work was supported by the CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas); CIN (Consejo Interuniversitario Nacional)

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Table A1. Araneae: Supplementary material.

| Family          | Species/morphospecies                      | Continuous native forests (N) | Native forest windbreaks (W) |
|-----------------|--------------------------------------------|------------------------------|------------------------------|
| **Amphinectidae** | *Metaltella simoni* Keyserling, 1877       | 1                            | 3                            |
| **Anyphaenidae** | *Anyphaenidae sp. 1*                       | 0                            | 5                            |
|                 | *Anyphaenidae sp. 2*                       | 2                            | 0                            |
|                 | *Arachosia* sp.                            | 0                            | 2                            |
| **Araneidae**   | *Alpida sp. 1*                             | 1                            | 0                            |
|                 | *Alpida sp. 2*                             | 4                            | 0                            |
|                 | *Araneus* sp.                              | 1                            | 0                            |
| **Clubionidae** | *Clubionidae sp. 1*                        | 1                            | 0                            |
|                 | *Clubionidae sp. 2*                        | 3                            | 0                            |
|                 | *Clubionidae sp. 3*                        | 5                            | 0                            |
| **Corinnidae**  | *Castianeira* sp.                          | 6                            | 10                           |
|                 | *Corinniidae sp. 1*                        | 0                            | 1                            |
|                 | *Corinniidae sp. 2*                        | 0                            | 2                            |
| **Falconina gracilis** Keyserling, 1981 | 5                            | 1                            |
| **Ctenidae**    | *Ctenidae* sp.                            | 0                            | 1                            |
| **Dictynidae**  | *Dictyna* sp.                              | 2                            | 0                            |
| **Goeldia zyngierae** Almeida-Silva, Brescovit & Dias, 2009 | 2                            | 3                            |
| **Gnaphosidae** | *Apopyllus silvestrii* Simon, 1905         | 0                            | 1                            |
|                 | *Camillina* sp.                            | 5                            | 4                            |
|                 | *Gnaphosidae sp. 1*                        | 0                            | 2                            |
|                 | *Gnaphosidae sp. 2*                        | 6                            | 0                            |
| **Hahniidae**   | *Hahniidae sp. 1*                         | 0                            | 4                            |
| **Linyphiidae** | *Linyphiidae sp. 1*                       | 0                            | 1                            |
|                 | *Linyphiidae sp. 2*                       | 0                            | 1                            |
|                 | *Linyphiidae sp. 3*                       | 0                            | 1                            |
|                 | *Linyphiidae sp. 4*                       | 2                            | 0                            |
|                 | *Linyphiidae sp. 5*                       | 0                            | 3                            |
|                 | *Linyphiidae sp. 6*                       | 0                            | 11                           |
|                 | *Linyphiidae sp. 7*                       | 0                            | 13                           |
| **Lycosidae**   | *Lycosa* sp. 1                             | 3                            | 27                           |
|                 | *Lycosa* sp. 2                             | 12                           | 0                            |
|                 | *Lycosa* sp. 3                             | 3                            | 0                            |
|                 | *Lycosidae sp. 1*                         | 1                            | 3                            |
|                 | *Lycosidae sp. 2*                         | 4                            | 0                            |
|                 | *Lycosidae sp. 3*                         | 1                            | 5                            |
|                 | *Lycosidae sp. 4*                         | 0                            | 20                           |
|                 | *Lycosidae sp. 5*                         | 3                            | 3                            |
|                 | *Lycosidae sp. 6*                         | 0                            | 7                            |
|                 | *Lycosidae sp. 7*                         | 2                            | 0                            |
|                 | *Lycosidae sp. 8*                         | 37                           | 14                           |
| **Lycosidae**   | *Pardosa* sp.                              | 0                            | 1                            |
| **Micropholcommatidae** | *Euryopis* sp.         | 8                            | 1                            |
|                 | *Micropholcommatidae sp. 1*                | 2                            | 5                            |
|                 | *Micropholcommatidae sp. 2*               | 1                            | 0                            |
| **Mimetidae**   | *Mimetidae sp. 1*                         | 0                            | 1                            |
| **Miturgidae**  | *Teminus agalenoïdes* Badcock, 1932         | 1                            | 5                            |
| **Oxyopidae**   | *Oxyopidae sp. 1*                         | 0                            | 4                            |
| **Philodromidae** | *Paracleocnemis* sp.               | 0                            | 1                            |
|                 | *Philodromidae sp. 1*                     | 1                            | 1                            |
|                 | *Philodromidae sp. 2*                     | 0                            | 3                            |
| **Pholcidae**   | *Guaranita goloboffi* Huber, 2000          | 1                            | 0                            |
| **Pisauridae**  | *Pisauridae sp. 1*                        | 3                            | 0                            |
| **Prodidomidae** | *Eilica* sp. nov.                      | 6                            | 2                            |
| **Salticidae**  | *Aillutticus pinquidor* Galliano, 1987      | 23                           | 7                            |
|                 | *Aillutticus pilosus* Galliano, 1987       | 0                            | 1                            |
|                 | *Aillutticus texanus* Galliano, 1987       | 0                            | 1                            |
|                 | *Salticidae sp. 1*                        | 0                            | 1                            |
|                 | *Salticidae sp. 2*                        | 1                            | 0                            |
|                 | *Salticidae sp. 3*                        | 1                            | 0                            |
|                 | *Salticidae sp. 4*                        | 0                            | 1                            |
|                 | *Salticidae sp. 5*                        | 0                            | 1                            |
|                 | *Salticidae sp. 6*                        | 0                            | 1                            |
|                 | *Salticidae sp. 7*                        | 0                            | 2                            |
|                 | *Salticidae sp. 8*                        | 2                            | 0                            |
|                 | *Salticidae sp. 9*                        | 0                            | 2                            |
|                 | *Salticidae sp. 10*                       | 2                            | 1                            |
| **Tetragnathidae** | *Tetragnatha* sp.           | 0                            | 3                            |
| **Theridiidae** | *Theridion sp. 1*                        | 0                            | 3                            |
| **Theridiosomathidae** | *Theridiosoma* sp.    | 0                            | 27                           |
### Table A1. (Continued).

| Family       | Species/morphospecies | Continuous native forests (N) | Native forest windbreaks (W) |
|--------------|------------------------|------------------------------|------------------------------|
| Thomisidae   |                        |                              |                              |
|              | *Misumenops* sp.       | 3                            | 0                            |
|              | Thomisidae sp. 1       | 1                            | 0                            |
|              | Thomisidae sp. 2       | 0                            | 1                            |
|              | Thomisidae sp. 3       | 0                            | 1                            |
|              | Thomisidae sp. 4       | 1                            | 1                            |
|              | Thomisidae sp. 5       | 0                            | 4                            |
|              | Thomisidae sp. 6       | 0                            | 5                            |
|              | *Tranus* sp.           | 1                            | 0                            |
| Trachelidae  | *Menioila cetiformis* Strand, 1908 | 0                          | 2                            |
| Zodariidae   |                        |                              |                              |
|              | *Cybaeodamus ornatus* Mello-Leitão, 1938 | 0                      | 2                            |
|              | *Leprolochus birubeni* Mello-Leitão, 1942 | 163                     | 1                            |
| Zodariidae sp. 1 |                      | 4                            | 1                            |
| **TOTAL**    |                        | 347                          | 252                          |

### Table A2. Coleoptera: Supplementary material.

| Family       | Species/morphospecies | Continuous native forests (N) | Native forest windbreaks (W) |
|--------------|------------------------|------------------------------|------------------------------|
| Anobiidae    | *Anobiidae* sp. 1      | 0                            | 1                            |
|              | *Anobiidae* sp. 2      | 0                            | 4                            |
| Bostrichidae | *Bostrichidae* sp. 1   | 0                            | 1                            |
|              | *Bostrichidae* sp. 2   | 0                            | 1                            |
| Buprestidae  | *Buprestidae* sp. 1    | 1                            | 0                            |
|              | *Tetragonoschema undatum* Steinh, 1874 | 29                      | 51                           |
| Carabidae    | *Carabidae* sp. 1      | 1                            | 0                            |
|              | *Carabidae* sp. 2      | 0                            | 1                            |
|              | *Carabidae* sp. 3      | 13                           | 0                            |
|              | *Carabidae* sp. 4      | 2                            | 0                            |
|              | *Carabidae* sp. 5      | 1                            | 0                            |
|              | *Carabidae* sp. 6      | 1                            | 0                            |
|              | *Carabidae* sp. 7      | 2                            | 0                            |
|              | *Carabidae* sp. 8      | 1                            | 1                            |
|              | *Carabidae* sp. 9      | 1                            | 0                            |
|              | *Carabidae* sp. 10     | 3                            | 11                           |
|              | *Carabidae* sp. 11     | 0                            | 2                            |
|              | *Carabidae* sp. 12     | 0                            | 1                            |
|              | *Carabidae* sp. 13     | 0                            | 2                            |
| Chrysomelidae| *Chrysomelidae* sp. 1  | 0                            | 1                            |
|              | *Chrysomelidae* sp. 2  | 0                            | 1                            |
|              | *Chrysomelidae* sp. 3  | 1                            | 0                            |
|              | *Chrysomelidae* sp. 4  | 1                            | 0                            |
|              | *Chrysomelidae* sp. 5  | 1                            | 0                            |
|              | *Chrysomelidae* sp. 6  | 17                           | 1                            |
|              | *Chrysomelidae* sp. 7  | 1                            | 0                            |
|              | *Chrysomelidae* sp. 8  | 29                           | 0                            |
|              | *Chrysomelidae* sp. 9  | 4                            | 1                            |
|              | *Chrysomelidae* sp. 11 | 1                            | 1                            |
|              | *Chrysomelidae* sp. 12 | 1                            | 1                            |
|              | *Chrysomelidae* sp. 13 | 1                            | 1                            |
|              | *Chrysomelidae* sp. 14 | 0                            | 1                            |
|              | *Chrysomelidae* sp. 15 | 0                            | 1                            |
|              | *Chrysomelidae* sp. 17 | 0                            | 1                            |
|              | *Chrysomelidae* sp. 18 | 0                            | 1                            |
|              | *Chrysomelidae* sp. 19 | 0                            | 1                            |
|              | *Chrysomelidae* sp. 20 | 0                            | 1                            |
|              | *Systena* sp. 1        | 1                            | 5                            |
|              | *Systena* sp. 2        | 0                            | 2                            |
| Cicindelidae | *Cicindelidae* sp. 1   | 0                            | 6                            |
|              | *Cicindelidae* sp. 2   | 0                            | 2                            |
| Cleridae     | *Cleridae* sp. 1       | 2                            | 1                            |
| Coccinellida | *Coccinellidae* sp. 1  | 1                            | 0                            |
|              | *Coccinellidae* sp. 2  | 1                            | 0                            |
|              | *Coccinellidae* sp. 3  | 0                            | 2                            |
|              | *Coccinellidae* sp. 4  | 0                            | 1                            |
|              | *Coccinellidae* sp. 5  | 1                            | 0                            |
|              | *Coccinellidae* sp. 6  | 1                            | 0                            |
|              | *Coccinellidae* sp. 7  | 0                            | 4                            |
|              | *Coccinellidae* sp. 8  | 0                            | 2                            |
| Corylophydae | *Corylophydae* sp. 1   | 1                            | 0                            |

(Continued)
| Family            | Species/morphospecies | Continuous native forests (N) | Native forest windbreaks (W) |
|-------------------|------------------------|------------------------------|------------------------------|
| Curculionidae     | Curculionidae sp. 1    | 1                            | 0                            |
|                   | Curculionidae sp. 2    | 0                            | 1                            |
|                   | Curculionidae sp. 3    | 1                            | 0                            |
|                   | Curculionidae sp. 4    | 1                            | 1                            |
|                   | Curculionidae sp. 5    | 6                            | 0                            |
|                   | Curculionidae sp. 6    | 0                            | 4                            |
|                   | Curculionidae sp. 7    | 1                            | 0                            |
|                   | Curculionidae sp. 8    | 0                            | 2                            |
|                   | Curculionidae sp. 9    | 0                            | 1                            |
|                   | Curculionidae sp. 10   | 0                            | 1                            |
|                   | Heilus tuberculatus     | 0                            | 3                            |
|                   | Pantomorus setulosus    | 6                            | 8                            |
| Dermestidae       | Demestidae sp. 1       | 0                            | 37                           |
|                   | Demestidae sp. 2       | 0                            | 1                            |
| Elateridae        | Conoderus sp.          | 0                            | 5                            |
|                   | Elateridae sp. 1       | 0                            | 1                            |
|                   | Elateridae sp. 2       | 1                            | 0                            |
|                   | Elateridae sp. 3       | 1                            | 0                            |
| Geotrididae       | Geotrididae sp. 1      | 4                            | 1                            |
|                   | Geotrididae sp. 2      | 16                           | 1                            |
|                   | Geotrididae sp. 3      | 7                            | 4                            |
|                   | Geotrididae sp. 4      | 2                            | 0                            |
|                   | Geotrididae sp. 5      | 0                            | 1                            |
| Glaresidae        | Glaresidae sp. 1       | 5                            | 0                            |
| Histeridae        | *Eusipilus* (Hesperosaprinus) strobeli Steinheil, 1869 | 23                           | 4                            |
| Hybosoridae       | Hybosoridae sp. 1      | 1                            | 0                            |
| Lycidae           | Lycidae sp. 1          | 1                            | 0                            |
| Meloidae          | Meloidae sp. 1         | 0                            | 1                            |
|                   | Meloidae sp. 2         | 0                            | 2                            |
| Melyridae         | Astylus sp.            | 0                            | 1                            |
| Mordellidae       | Mordellidae sp. 1      | 0                            | 3                            |
| Nitidulidae       | Nitidulidae sp. 1      | 22                           | 59                           |
| Pselaphidae       | Pselaphidae sp. 1      | 0                            | 1                            |
| Scarabaeidae      | *Canthon* sp.          | 2                            | 0                            |
| Staphylinidae     | Paederinae sp.         | 1                            | 0                            |
|                   | Staphylinidae sp. 1    | 1                            | 0                            |
|                   | Staphylinidae sp. 2    | 1                            | 0                            |
|                   | Staphylinidae sp. 3    | 3                            | 0                            |
|                   | Staphylinidae sp. 4    | 1                            | 0                            |
|                   | Staphylinidae sp. 5    | 0                            | 1                            |
|                   | Staphylinidae sp. 6    | 1                            | 0                            |
|                   | Staphylinidae sp. 7    | 2                            | 0                            |
|                   | Staphylinidae sp. 8    | 1                            | 2                            |
|                   | Staphylinidae sp. 9    | 2                            | 0                            |
|                   | Staphylinidae sp. 10   | 3                            | 3                            |
|                   | Staphylinidae sp. 11   | 0                            | 1                            |
|                   | Staphylinidae sp. 12   | 0                            | 2                            |
|                   | Staphylinidae sp. 13   | 0                            | 1                            |
| Tenebrionidae     | *Entomoderes draco* Waterhouse, 1844 | 3                            | 2                            |
|                   | *Gondwanocrypticus platensis* Fairmaire, 1883 | 1                            | 0                            |
|                   | *Gondwanocrypticus* sp. | 1                            | 1                            |
|                   | *Poecyl cripticus formicophilus* Gebien, 1928 | 0                            | 2                            |
|                   | *Psectrascelis unis* Burmeister, 1875 | 7                            | 0                            |
|                   | *Salax lacordairei* Guérin-Ménéville, 1834 | 0                            | 1                            |
|                   | *Trichoton occidentale* Berg, 1883 | 2                            | 0                            |
|                   | *Trichoton rotundatum* Curtis, 1845 | 22                           | 0                            |
|                   | *Vanious profana* Kalter, 1956 | 0                            | 1                            |
| Trogidae          | Trogidae sp. 1         | 0                            | 1                            |
| **TOTAL** | **272** | **283** |