Diurnal butterfly diversity in a human-modified landscape of the subtropical montane forest of NW Argentina

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Running title: Butterfly diversity on a modified forest landscape

Abstract.

The change and intensification in land-use is currently among the main causes of species declines and local extinctions around the world, therefore, forecasting changes in species diversity concerning habitat conditions may be crucial for conservation strategies. We explored the diurnal lepidopteran diversity in a modified landscape of subtropical montane forests of Jujuy, NW Argentina. We considered that degradation of the natural forest habitat would likely impact on resources crucial for butterflies, consequently altering both species richness and composition within these forests. We assessed and compared alpha diversity through Hill diversity profiles and beta diversity through the beta-diversity partitioning method. Additionally, we employed a multivariate permutational analysis of variance, and rank-abundance curves of butterfly species at different habitat types. Our results suggest that land-use changes diminish the number of forest-dependent species and increase species more tolerant to modified habitats and open areas. While alpha diversity did not decrease as land use changed, beta diversity showed significant changes in the butterfly species composition with a worrying reduction of forest-related species in altered habitats. Species composition became increasingly dominated by open area butterfly species resulting in biota homogenization, with possible consequences for ecosystem functioning and services of these forests. Further research on the mechanisms underlying the effects of human-induced habitat changes on forest butterfly diversity could help clarify which mitigation efforts are most likely to be successful for the conservation of butterflies of the subtropical montane forests.
Keywords. Lepidoptera, butterflies, species richness, land use-change, abundance, Van Someren Rydon trap, sweep net, diurnal, Nymphalidae, Jujuy.

Introduction

The transformation of large areas of native forests into mosaics of human-modified habitats with different land uses is among the main drivers of biodiversity loss and currently represents an important threat to species extinctions globally (Newbold *et al.* 2015; Picanco *et al.* 2017). Therefore, forecasting changes in species diversity concerning habitat deterioration may be crucial for conservation strategies. Several studies have found that human-made disturbances on natural landscapes such as habitat loss and fragmentation are among the most critical causes of species loss and declines of butterfly communities (Steffan-Dewenter & Tscharntke 2000; Uehara-Prado *et al*. 2007; Vasconcelos *et al*. 2019). Consequently, critical ecosystem processes may be affected, altering the ecosystem

functioning and also the provision of goods and services for humans (Klein *et al.* 2007; Steffan-Dewenter & Westphal 2008; Potts *et al.* 2010). To these conditions, species communities react differently, being able to persist or become extinct when the habitats are smaller or very isolated (Barlow *et al*. 2009; Thomas 2016; Vasconcelos *et al*. 2019).

Among insect groups, butterflies have been pointed out as good biological models to detect responses to land-use changes by several authors (Barlow *et al*. 2007ab; Lazzeri *et al*. 2011; Sagwe *et al*. 2015) mainly because they react sensitively and quickly to changes in habitat conditions (Thomas *et al*. 2004; Thomas 2005; Bonebrake *et al*. 2010). In this way, changes in ambient temperature, microclimate, humidity, and lighting (Checa *et al*. 2014), as well as the composition and structure of vegetation can drive variation in species diversity (Barlow *et al*. 2007b; Uehara-Prado & Freitas 2007). Unlike most other insect groups, its systematics and taxonomy are relatively well documented (Thomas 2005; Lucci Freitas *et al*. 2014).

Several studies measuring the impacts of land-use changes have shown distinct effects on species richness and composition such as local extinctions or lower persistence of certain threatened or rare species and increases in the number of more non-threatened or widespread species (Barlow *et al*. 2007ab; Bubová *et al.*, 2015; Thomas, 2016; Vasconcelos *et al*. 2019). These responses have also been found not only at the level of the family taxa but also within the same subfamily of butterflies (Veddeler *et al*. 2005).

The Southern Andean Yungas ecoregion in Argentina, defined as an outstanding biodiverse region, is considered a critical area for biodiversity conservation because of the levels of species richness and endemism that are among the highest in the country, but also increasing land-use changes that threaten several species (Brown *et al.*, 2006). This ecoregion covers only 2% of the country's land and is the second most diverse ecoregion (Pacheco & Brown 2006; Nanni *et al*. 2020) that extends as a narrow strip of montane forest in the NW region of the country, corresponding to the southernmost extension of Neotropical cloud forests (Kapelle & Brown, 2001) that stands out for its high heterogeneity of environments with important extensions of subtropical montane forests, small plots with subsistence agriculture, logging sectors, large areas with commercial crops, and areas with different degrees of urbanization (Malizia *et al.*, 2012). In such human-intervened landscapes, it will be particularly relevant to investigate the response of local biodiversity to human pressures and, thus, to estimate biodiversity changes at local scales to determine conservation priorities

(Reynolds *et al.*, 2011). However, the lack of information on how several groups of species respond to such heterogeneity and land-use changes in these montane forests makes a great challenge to the reversion of species declines or disappearances and the preservation and restoration of suitable habitats to maintain the species diversity (Izquierdo & Grau, 2009). Successful long-term conservation plans will require an understanding of the relationships between land-use intensification and species composition to identify variables driving species diversity in the region.

In this study, we describe diurnal lepidopteran diversity in a portion of the subtropical montane forests of Jujuy, NW Argentina where human intervention has transformed the entire area into a mosaic formed by habitat patches of different land-uses, such as remnants of native forest, *Eucalyptus* plantations, and secondary grasslands. We expect that butterfly assemblage of the area should be particularly sensitive to human-induced changes showing the highest richness and densities at patches of native forests. Meanwhile, the species assemblage will show a reduction in diversity at more altered patches.

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Material and methods

Study area

The study was conducted at Finca “Las Capillas”, (24° 05 34’’ S; 65° 09 32’’ W, 1160 m asl), located in the province of Jujuy, NW Argentina (Fig. 1). The average annual temperature varies between 18 and 20 °C (Bianchi *et al*. 2005). This area is composed of a mixed-use landscape of secondary forests and plantations of exotic *Eucalyptus* sp. (Entrocassi 2015).

We selected habitat patches defined by three dominant land-uses types: (1) Secondary native forest (FO) area, covering approximately 0.08 km^2. This has undergone wood extraction through selective logging and has low-intensity livestock grazing. This was considered as a relatively preserved natural forest with minimal land-use change (2) *Eucalyptus* plantation (EU) area, covering approximately 0.065 km^2, with a low-intensity livestock grazing, and (3) Secondary grassland (GR) area, located at a mixed-use flat area

covering approximately 0.10 km^2, this habitat type was originated following the clearance and burning of the primary forest. Poaceas dominate it and have moderate livestock grazing (Fig. 1).

Data collection

Butterfly surveys were carried out between September and May 2016-2018, in coincidence with the period of higher adult butterfly activity in the region and favourable weather conditions. To ensure a comprehensive assessment of diversity, we employed a combination of hand nets and bait trap survey techniques, as both methods are considered complementary (Sparrow *et al.* 1994; Checa *et al.* 2019). In each habitat patch, we placed twenty 50 mts-long transects. We set two Van Someren Rydon bait traps (VSR) (DeVries 1987, 1988; Villareal *et al.* 2004) located at 10 and 40 meters from the start of each transect, accounting for a total of 40 traps per habitat type. The VSRs, manufactured according to the specifications of DeVries (1987, 1988), were slightly modified (i.e. replacing the metal plate of the base with a plastic container). The bait traps consisting of decaying fruit (banana, apple, peach, mango, pear, based on seasonal availability in the local market) were suspended 1.5-2.0 m above the ground. The traps were operational for three consecutive days (72 hours) and visited every 24 hours. Additionally, we conducted entomological net sampling (Villareal *et al.* 2004) along the transects on the second day after activating the VSR traps. Two researchers sampled flying butterflies using a sweep net for 15 minutes along a standard line transect of 2 m wide (Pollard & Yates 1993), between 11:00 am and 4:00 pm, in coincidence with the peak of butterfly activity (Villareal *et al.* 2004).

Trapped butterflies were carefully placed in paper envelopes. Subsequently, specimens were kept in a humid chamber for 24 to 48 hours for later assembly (Villareal *et al*. 2004). All collected material was examined and identified at the species levels following Canals (2000, 2003), Lamas (2004), Volkmann & Núñez-Bustos (2010) and Klimaitis *et al.* (2018ab). In addition, we reviewed the database of butterflies of America (Warren *et al.* 2023). We followed the taxonomy proposed by Mielke (2008) for the Hesperiidae family, and Lamas (2004) for the remaining Papilionoidea. Approximately three hundred specimens were prepared and deposited at the "Entomological Collection of the Instituto de Biología de la Altura Dra. Liliana Estela Neder (CEINBIAL)", Universidad Nacional de Jujuy, Jujuy, Argentina.

Statistical analyses

To evaluate the adequacy of sampling effort at each habitat patch, we employed

measures of sample coverage following Chao & Jost (2012). Coverage represents the percentage of individuals in an assemblage that belong to a species represented in the sample; it ranges from 0 to 100% (Chao & Jost 2012). As this value is a measure of inventory completeness, when coverage is close to 100%, the sample is near complete and diversity values (^{q}D) can be compared directly (Chao & Jost 2012). We constructed diversity profiles based on Hill numbers (^{q}D) to assess the changes in cumulative species diversity among the three habitat patches. We considered *q*-values from 0 to 2 at increments of 0.25 and computed the 95% confidence intervals. Significant differences in species diversity between two assemblages were inferred when the confidence intervals of the diversity profile curves did not overlap.

We compared species composition among the three habitat patches with the beta-diversity partitioning method following Baselga (2010). This method partitions the total beta diversity into its components of nestedness and species turnover. Nestedness refers to the overlap of species occurrence among habitat patches, indicating that species composition of a given assemblage is a subset of the species composition of a larger assemblage (Ulrich & Gotelli 2007). Conversely, species turnover refers to the replacement of species in one habitat patch by different ones in another habitat, leading to less frequent or even segregated species occurrence, with many species never co-occurring (Ulrich & Gotelli 2007). To further examine the assemblage structure between habitat patches, we applied a multivariate permutational analysis of variance on Bray-Curtis distances (PERMANOVA; Anderson 2001). Lastly, we assessed changes in community structure with rank-abundance curves based on the log-transformed relative abundances of butterfly species in each habitat patch. These curves visually compare species richness, relative abundance, dominance, and the sequence of each species without losing their identity (Feinsinger 2004). We statistically tested for differences in rank-abundance distribution between habitat patches using Kolmogorov–Smirnov two-sample tests under the null hypothesis that two samples can be generated from the same distribution.

All statistical analyses were conducted using R 3.6.1 (R Development Core Team, 2019). The database, R script, and packages are available as supplementary material (Supplemental information, Tables S1 and S2).

Results

The combined diurnal butterfly collection comprised 3914 individuals, representing

an overall diversity of 78 species distributed in six families (Table 1), including Hesperiidae (with two subfamilies: Eudaminae and Pyrginae), Nymphalidae (with nine subfamilies: Apaturinae, Biblidinae, Charaxinae, Danainae, Heliconiinae, Libytheinae, Limenitidinae, Satyrinae, and Nymphalinae), Pieridae (with two subfamilies: Coliadinae and Dismorphiinae), and Lycaenidae, Riodinidae, and Papilionidae, with only one subfamily each (Theclinae, Riodininae, and Papilioninae, respectively).

Sample coverage estimates exceeded (90%) for each habitat patch. Diversity profiles based on Hill numbers (CI: 95%) showed that the GR exhibited the highest diversity with 74 species, followed by the EU with 41 species, and FO with 18 species (Table 1, Fig. 2).

Butterfly species composition differed significantly among the three habitat patches (PERMANOVA, F= 30.69, P <0.001). The FO habitat presented a significant dissimilarity in species composition with both, GR and EU habitats, slightly above 60% (PERMANOVA F= 59.82, P <0.001; F= 30.44, P= 0.001, respectively). Observed differences between FO and GR were given mainly by a nestedness process, indicating that the species composition of forest assemblage is a subset of the one found in the grassland (Fig 3.)(Fig. 5). Conversely, beta diversity observed between FO and EU was predominantly due to species turnover, with few species co-occurring in both habitat patches (Fig. 3). Finally, GR and EU presented a relatively lower difference in species composition (Fig. 3), with a statistically significant dissimilarity value of 32% (PERMANOVA F= 10.45, P < 0.001). This dissimilarity was highly influenced by a nestedness process, indicating that the species composition of the *Eucalyptus* sp. assemblage constitutes a subset of the grassland community (Fig. 3).

The rank-abundance distribution was more even in the grassland assemblage, with three species accounting for over 50% of all individuals registered in this habitat (Fig. 4). In GR, *Hermeuptychia* sp. Forster, 1964 (Nymphalidae: Satyrinae) was the most abundant species (21.7%), followed by *Biblis hyperia nectanabis* (Fruhstorfer, 1909) (Nymphalidae: Biblidinae) (19.6%), and *Cybdelis petronita* Burmeister, 1861 (Nymphalidae: Biblidinae) (11.5%). The EU also presented three species summing more than 50% of the individuals registered in this habitat (Fig. 4): *H.* sp., was again the most abundant species in the assemblage (28.7%), followed by *C. petronita* (12.8%), and *B. hyperia nectanabis* (11.2%). In contrast, FO presented two dominant species, which accounted for 90% of the individuals registered for this habitat: *Pedaliodes palaepolis*, (Hewitson, 1878) (Nymphalidae: Satyrinae) (53.2%), and *Eunica tatila bellaria* Fruhstorfer, 1908 (Nymphalidae: Biblidinae) (36.8%) (Fig. 4). The Kolmogorov-Smirnov test showed a statistically significant shift in species rank-abundance distribution between the three habitat patches (FO vs. GR: D= 0.72, P

<0.001, FO vs. EU: D= 0.22, P= 0.002, and GR vs. EU D= 0.42, P <0.001).

Discussion

In this study, we documented the diversity of a diurnal butterfly community across habitat patches with different land-use within a sector of the subtropical montane forest of NW Argentina (Yungas ecoregion). Our results suggest that the impacts of land-use change have a strong effect on the diurnal butterfly assemblage of the area. Contrary to our initial expectations, the butterflies assemblage did not show a reduction in species richness with increased land-use change. Instead, we observed the opposite trend, revealing clear differences in alpha diversity among the three habitat patches, where GR emerged as the most diverse habitat, followed by EU and, lastly, FO. The highest diversity registered in GR can be attributed to the structure of the vegetation found in this patch, which includes a small remnant of native forest and open areas with a variety of herbaceous plants. This habitat heterogeneity likely provides a large amount of resources and niches for several species.

Previous studies established that species belonging to the Satyrinae and Biblidinae subfamily can display diverse responses to habitat disturbances, with some species being highly sensitive to such changes, while others became more abundant following alterations (Shahabuddin & Terborgh 1999; Fermon et al. 2005; Barlow et al. 2007ab; Barlow et al. 2009; Uehara-Prado et al. 2007; Ribeiro et al. 2012; Vasconcelos et al. 2019). This aligns with our results, where *Hermeuptychia* sp. emerged as the principal satirine species successfully occupying patches of altered habitat compared to the more conserved secondary native forest. Modified environments appeared to be suitable for opportunistic species tolerant to structural changes in the vegetation. The genus *Hermeuptychia*, has been geographically expanding in recent years due to its great adaptability, the capacity of larvae to feed on a variety of pioneer plant species belonging to grasses, such as *Poa*, *Paspalum*, and *Stenotaphrum* (Nuñez-Bustos et al. 2010). Therefore, these modified habitats may not only host more satyrins species, but also support a higher abundance per species (Brown 1992). This is consistent with previous studies that identified the genus, *Hermeuptychia* and *Biblis* as typical invasive species of open areas (Ramos 2000). In addition to *B. hyperia nectanabis*, *C. petronita* was also abundant in GR and EU habitat patches, probably due to the association with the type of host plant used during larval development. These butterfly species feed mainly on herbaceous plants of the

genus Tragia (Freitas et al. 1997; Bauza 2000; Nuñez-Bustos 2010), which are perennials and typically inhabit open areas, such as cultivated fields or stream banks (Romero & Sanguinetti 1989).

Species from the Pieridae family, such as *Abaeis albula albula* (Cramer, 1775), *Teriocolias deva deva* (E. Doubleday, 1847), *Phoebis sennae marcelina* (Linnaeus, 1758), *Pyrisitia nise floscula* (Cramer 1775), *Anteos clorinde* (Godart 1824), *Abaeis arbela arbela* (Geyer 1832), and *Pseudopieris nehemia prasina*, Hayward, 1949 (Nuñez-Bustos 2010; Klimaitis et al. 2018a; Klimaitis et al. 2018b, Warren et al. 2023), recorded in the habitat patches with the most remarkable land-use intensification, suggest adaptations that enable them to colonize different environments. Their rapid flight, the use of a variety of nutritional plants, and preference for open or edge areas contribute to their capability to occupy extensive modified areas (Ospina López et al. 2010). Other species tolerant to modified environments, such as "jumping" hesperids *Burnsius orcus* (Stoll, 1780), *Burnsius orcynoides* (Giacomelli, 1928), *Urbanus proteus proteus* (Linnaeus, 1758), and certain nymphalids of the subfamily Nymphalinae, represented by heliophilous species of open areas such as *Junonia genoveva hilaris* C. Felder & R. Felder, 1867, *Chlosyne lacinia saundersi* (E. Doubleday, [1847]), *Tegosa claudina* (Eschscholtz, 1821), *Telenassa berenice drusinilla* (Röber, 1913), and *Vanessa carye* (Hübner, 1812), may colonize different habitats due to their lack of specific habitat requirements (Pastrana et al. 2004; Nuñez-Bustos 2010; Volkmann & Nuñez-Bustos 2010; Klimaitis et al. 2018a; Klimaitis et al. 2018b, Warren et al. 2023). We also recorded species from the Charaxinae subfamily in the modified habitats patches (GR and EU). These lepidopterans, with their large bodies and high mobility, can move long distances (Barlow et al. 2009; Freire et al. 2021), allowing them to occupy various habitat types.

The absence or reduced abundance of *P. palaepolis* and *E. tatila bellaria* in the GR and EU habitats suggests that these diurnal frugivorous lepidopterans, can respond sensitively to habitat disturbances. *P. palaepolis*, was recognized as a typical species of montane forest of the Yungas region (F. Moschioni, pers. comm.). Consequently, the heightened species richness in GR could be attributed to an increase in species tolerant to modified habitats and open areas, resulting in a mechanism of compensatory dynamics, which likely masks the negative effect of land-use change on diversity (Supp & Ernest 2014; Filgueiras *et al*. 2019). Similarly, we considered EU a heterogeneous habitat despite exhibiting a simplified vegetation structure, including small portions of native forest and open areas, the latter used

as cattle pasture. Consequently, species richness in this habitat could also be compensated by common and abundant species, such as *H. sp*., *Yphthimoides celmis*, Godart, (1824), and *Cissia phronius* Godart (1824). These findings were consistent with studies carried out in different regions of Brazil, such as the Amazon Region and the Brazilian Atlantic Forest in Southeast Brazil (Ramos 2000; Ribeiro *et al*. 2012; Vasconcelos *et al*. 2019), where the same genera were registered as abundant and common.

Despite the structural simplification observed in EU the presence of tree canopy coverage may enable certain species associated with canopy habitats to tolerate land-use changes, explaining the occurrence of species linked to the forest canopy (DeVries 1987). However, this structural simplification could lead to biotic homogenization, often acting as a filter for those species with specific habitat requirements (Steffan-Dewenter & Tscharntke 2000), particularly understory butterflies associated with the vertical stratification of a forest, and favoring species capable of using a new spectrum of plants (Ekroos *et al*. 2010; Borschig *et al*. 2013). Furthermore, the absence or decline of certain dominant forest species in EU suggests that some land uses may not adequately preserve local diversity.

Studying species composition through beta diversity measures revealed significant changes in butterfly assemblages, with a concerning reduction of forest-related species. GR and EU, representing higher land-use intensification, exhibited greater similarities to each other, and both differed significantly in community composition from the FO. A nestedness process mainly determined the observed difference in species composition of butterfly assemblages between GR and FO. This suggests that while GR maintains a set of butterfly species relatively similar to the FO, new structural conditions might facilitate the occurrence of a new set of species capable of exploiting highly modified habitats. This may result in a butterfly community increasingly dominated by species adapted to modified environments and open areas, leading to biota homogenization with significant consequences for ecosystem functioning and services of the Yungas forest. On the other hand, the beta diversity observed between FO and EU was mainly driven by a species turnover process.

Comparison of the community structure among the three land-use areas showed not only a significant difference in species composition but, a variation in the dominant species within each habitat type. Species that were abundant in GR and EU, such as *H.* sp. (Satyrinae), *B. hyperia nectanabis* (Biblidinae), and *C. petronita* (Biblidinae), were practically absent in the secondary native forest. Conversely, dominant species in FO,

such as *P. palaepolis* (Satyrinae) and *E. tatila bellaria* (Biblidinae) were less abundant or even absent in more modified habitats. *E. tatila bellaria*, is characteristic of humid forests associated with habitats of a complex vegetation structure. Its larvae feed on a native tree from the Euphorbiaceae family, specifically the genus *Sebastiania* (Nuñez-Bustos 2010), dominant in the Montane forest strata of the Yungas (Cabrera 1994). Cavanzón-Medrano et al. (2003), showed that *E. tatila* is a neotropical species identified as a bioindicator with significant relevance in undisturbed areas of the Yucatan Peninsula in Mexico. The species predominantly associates with the arboreal stratum, providing essential food resources for the adults (Salazar 2009). Consequently, the dominance of *P. palaepolis* and *E. tatila bellaria* in FO could be considered indicative of low levels of habitat alteration in forest habitats. Montane forest likely serves as a source of host plants, fleshy fruits, and organic matter for larvae and adult stages of these frugivorous species. Our results suggest that, alongside these two species, other forest-dependent butterflies present in the area like *Taguaiba ypthima* (Hübner, 1821), may also be affected by land-use changes. Although its classification as a forest species (DeVries 1987), coincides with our results given that it was only recorded in FO.

To our knowledge, our work represents the first study on the response of diurnal butterflies to land-use changes in the Southern AndeanYungas ecoregion of Argentina. This research constitutes a first step for future regional-scale studies in this field. Additional studies are needed to assess the impacts of habitat composition and configuration on species diversity in the studied region. Further research into the mechanisms driving the effects of land-use changes on forest-dependent butterfly diversity could provide insights into which mitigation strategies are most likely to succeed in conserving butterfly diversity in theYungas of Argentina. To establish the amount of forest vital to protect even a fraction of the original biodiversity holds value for local butterfly conservation. The dispersal abilities of most species and the distances they travel, crucial for species to cope with alterations in habitat conditions, are still poorly known in the region. Additionally, specific habitat requirements and functional traits of the species, such as body size or mobility, may determine whether a particular species benefits from or is adversely affected by intense land-use changes.

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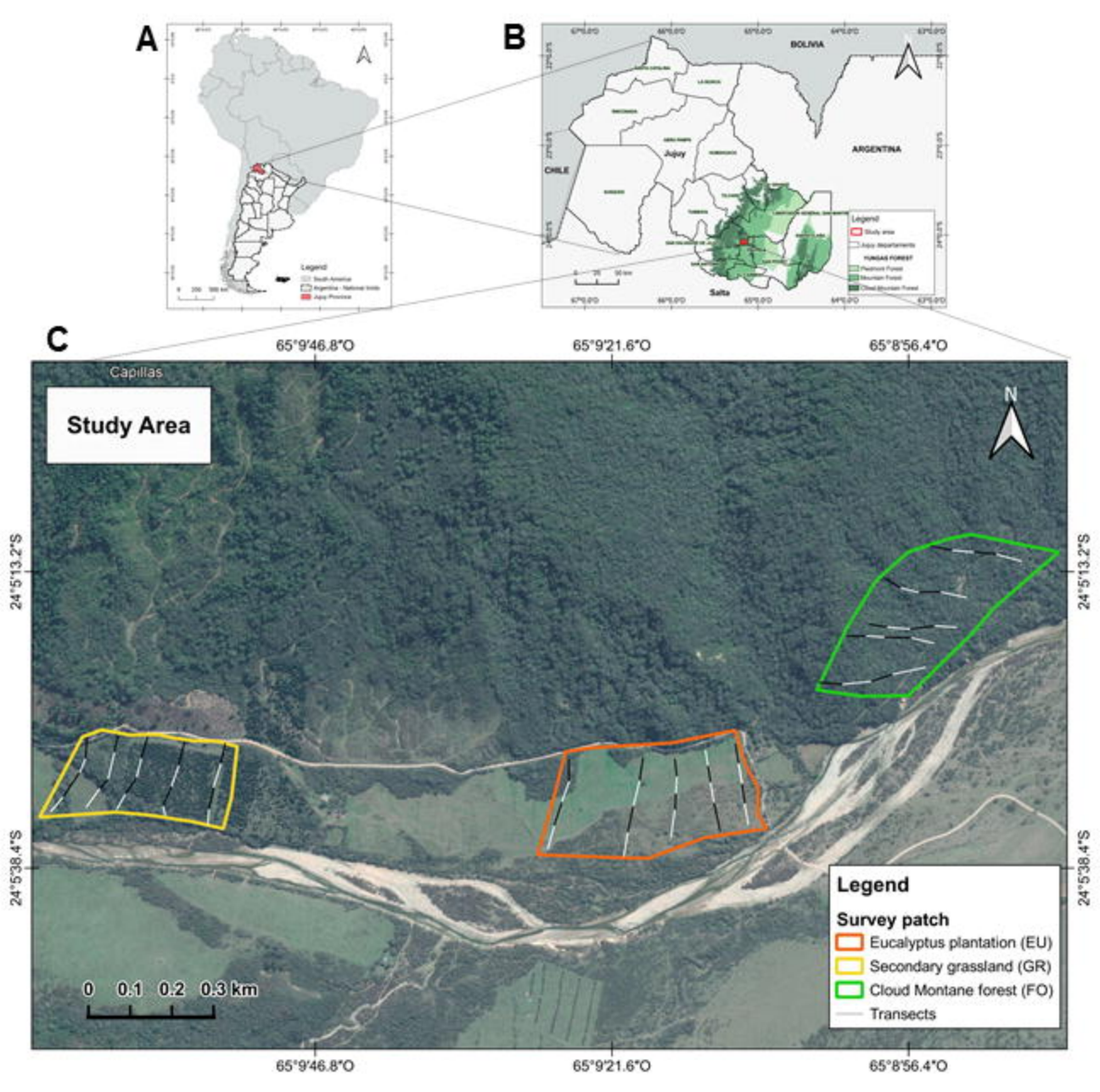
Table 1. List of butterfly species recorded at three habitat patches of Finca "Las Capillas", (24° 05 34'' S; 65° 09 32'' W, 1160 m asl), Jujuy, Argentina. **FO=** Secondary native forest; **EU**= *Eucalyptus* plantation; GR= Secondary grassland.

Family	Subfamily	Species	FO	EU	GR
Hesperiidae	Eudaminae	*Urbanus proteus proteus* (Linnaeus, 1758)		x	x
	Eudaminae	*Spicauda teleus* (Hübner, 1821)			x
	Pyrginae	*Burnsius orcus (Stoll, 1780)*		x	x
	Pyrginae	*Burnsius orcynoides* (Giacomelli, 1928)			x
Lycaenidae	NA	*sp1*			x
	Theclinae	*Chlorostrymon simaethis* (Drury, 1773)			x
	Theclinae	*Micandra sylvana* (Jörgensen, 1934)			x
	Theclinae	*Pseudolycaena marsyas* ((Linnaeus, 1758)			x
Nymphalidae	Apaturinae	*Doxocopa cyane burmeisteri* (Godman & Salvin, 1884)	x	x	x
	Biblidinae	*Hamadryas epinome* (C. Felder & R. Felder, 1867)		x	x
	Biblidinae	*Hamadryas fornax fornax* (Hübner, [1823])		x	
	Biblidinae	*Biblis hyperia nectanabis* (Fruhstorfer, 1909)	x	x	x
	Biblidinae	*Mestra hersilia apicalis* (Staudinger, 1886)			x
	Biblidinae	*Callicore sorana sorana* (Godart, [1824])			x
	Biblidinae	*Diaethria neglecta neglecta* (Salvin, 1869)		x	x
	Biblidinae	*Haematera pyrame pyrame* (Hübner, [1819])		x	x
	Biblidinae	*Cybdelis petronita* Burmeister, 1861	x	x	x
	Biblidinae	*Eunica tatila bellaria* Fruhstorfer, 1908	x	x	x
	Biblidinae	*Epiphile orea negrina* C. Felder & R. Felder, 1862	x		x
	Charaxinae	*Fountainea glycerium cratais* (Hewitson, 1874)	x		x
	Charaxinae	*Fountainea nessus* (Latreille, [1813])		x	x
	Charaxinae	*Memphis moruus morpheus* (Staudinger, [1886])		x	x
	Charaxinae	*Archaeoprepona chromus chromus* (Guérin-Méneville, [1844])			x
	Charaxinae	*Archaeoprepona demophoon thalpius* (Hübner, [1814])			x
	Danainae	*Danaus eresimus plexaure* (Godart, 1819)			x
	Danainae	*Danaus erippus* (Cramer, 1775)			x
	Danainae	*Lycorea halia pales* C. Felder & R. Felder, 1862			x
	Danainae	*Episcada hymenaea hymenaea* (Prittwitz, 1865)		x	x
	Danainae	*Mechanitis lysimnia elisa* (Guérin-Méneville, [1844])		x	x
	Danainae	*Pteronymia ozia tanampaya* Haensch, 1909		x	x
	Danainae	*Thyridia psidii ino* C. Felder & R. Felder, 1862			x
	Heliconiinae	*Actinote pellenea pellenea* Hübner, [1821]			x
	Heliconiinae	*Euptoieta hortensia* (Blanchard, 1852)		x	x
	Heliconiinae	*Dione vanillae* (Linnaeus, 1758)			x
	Heliconiinae	*Dione moneta moneta* Hübner, [1825]		x	x
	Heliconiinae	*Dryas iulia* (Cramer, 1779)			x
	Heliconiinae	*Heliconius erato phyllis* (Fabricius, 1775)			x
	Libytheinae	*Libytheana carinenta carinenta* (Cramer, 1777)		x	x

	Limenitidinae	*Adelpha alala negra* (C. Felder & R. Felder, 1862)			x
	Limenitidinae	*Adelpha thessalia cesilas* Fruhstorfer, 1915		x	x
	Nymphalinae	*Junonia genoveva hilaris* C. Felder & R. Felder, 1867		x	x
	Nymphalinae	*Chlosyne lacinia saundersi* (E. Doubleday, [1847])			x
	Nymphalinae	*Dagon catula* (Hopffer, 1874)			x
	Nymphalinae	*Ortilia gentina* Higgins, 1981		x	x
	Nymphalinae	*Ithra ithra* (W. F. Kirby, 1900)		x	x
	Nymphalinae	*Tegosa claudina* (Eschscholtz, 1821)	x	x	x
	Nymphalinae	*Telenassa berenice* (Röber, 1913)			x
	Nymphalinae	*Hypanartia bella* (Fabricius, 1793)		x	x
	Nymphalinae	*Hypanartia lethe lethe* (Fabricius, 1793)		x	x
	Nymphalinae	*Smyrna blomfildia blomfildia* (Fabricius, 1781)			x
	Nymphalinae	*Vanessa braziliensis* (Moore, 1883)	x	x	x
	Nymphalinae	*Vanessa carye* (Hübner, [1812])	x		x
	Nymphalinae	*Anartia jatrophae jatrophae* (Linnaeus, 1763)		x	x
	Satyrinae	*Corades iduna procellaria* Thieme, 1907		x	x
	Satyrinae	*Hermeuptychia sp*. Forster, 1964	x	x	x
	Satyrinae	*Lasiophila orbifera pura* Thieme, 1907			x
	Satyrinae	*Cissia phronius* (Godart, [1824])		x	x
	Satyrinae	*Paryphthimoides poltys poltys* (Prittwitz, 1865)	x	x	x
	Satyrinae	*Pedaliodes palaepolis* (Hewitson, 1878)	x		x
	Satyrinae	*Pharneuptychia phares* (Godart, [1824])	x		x
	Satyrinae	*Physcopedaliodes physcoa* (Hewitson, 1862)	x		
	Satyrinae	*Taguaiba ypthima Hübner, [1821]*	x		
	Satyrinae	*Yphthimoides celmis* (Godart, [1824])	x	x	x
Papilionidae	Papilioninae	*Heraclides lamarchei* (Staudinger, 1892)			x
	Papilioninae	*Battus polydamas polydamas* (Linnaeus, 1758)		x	x
Pieridae	Coliadinae	*Anteos clorinde* (Godart, [1824])			x
	Coliadinae	*Abaeis albula* (Cramer, 1775)	x	x	x
	Coliadinae	*Abaeis arbela arbela* Geyer, 1832		x	x
	Coliadinae	*Abaeis salome salome* (C. Felder & R. Felder, 1861)		x	
	Coliadinae	*Teriocolias deva deva* (E. Doubleday, 1847)		x	x
	Coliadinae	*Phoebis neocypris neocypris* (Hübner, [1823])	x	x	x
	Coliadinae	*Phoebis sennae marcelina* (Cramer, 1777)		x	x
	Coliadinae	*Pyrisitia nise flóscula* (Weeks, 1901)		x	x
	Coliadinae	*Zerene cesonia cesonides* (Staudinger, 1894)		x	x
	Dismorphiinae	*Pseudopieris nehemia prasina* Hayward, 1949			x
Riodinidae	Riodininae	*Barbicornis basilis tucumana* Thieme, 1907			x
	Riodininae	*sp1*			x
	Riodininae	*Riodina lysippoides* Berg, 1882			x

1. **Figure 1.** Study area and surveyed patches location at Finca "Las Capillas", (24° 05 34'' S; 65° 09 32'' W, 1160 m asl), Jujuy, NW Argentina. **FO=** Secondary native forest; **EU**= *Eucalyptus* plantation;GR= Secondary grassland.
2. **Figure 2.** Diversity profiles based on Hill numbers (^{q}D) for diurnal butterfly assemblages present in three surveyed habitat patches at Finca "Las Capillas", Jujuy, NW Argentina: **EU**: *Eucalyptus* plantation, **FO**: secondary native forest, and **GR**: Secondary grassland. The x axis represents the order *q.* Colored ribbons represent the 95% Confidence intervals.
3. **Figure 3.** Beta diversity partition into nestedness and species turnover components among the three surveyed habitat patches at Finca "Las Capillas", Jujuy, NW Argentina: **FO**: secondary native forest, **EU**: *Eucalyptus* plantation, and **GR**: Secondary grassland. Bars correspond to total beta diversity.
4. **Figure 4.** Species rank abundance curves based on the log-transformed relative abundances of butterfly species at each surveyed habitat patch at Finca "Las Capillas", Jujuy, NW Argentina. **FO**: secondary native forest; **EU**: *Eucalyptus* plantation, and **GR**: Secondary grassland. Only dominant species were identified by a name code. *Pedaliodes palaepolis* (**Pedpala**), *Eunica tatila bellaria* (**Euntati**), *Hermeuptychia sp.* (**Hersp**), *Cybdelis petronita* (**Cybpetr**), *Biblis hyperia nectanabis* (**Bibhype**).


A
B
C
BOLIVIA
ARGENTINA
CHILE
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Study area
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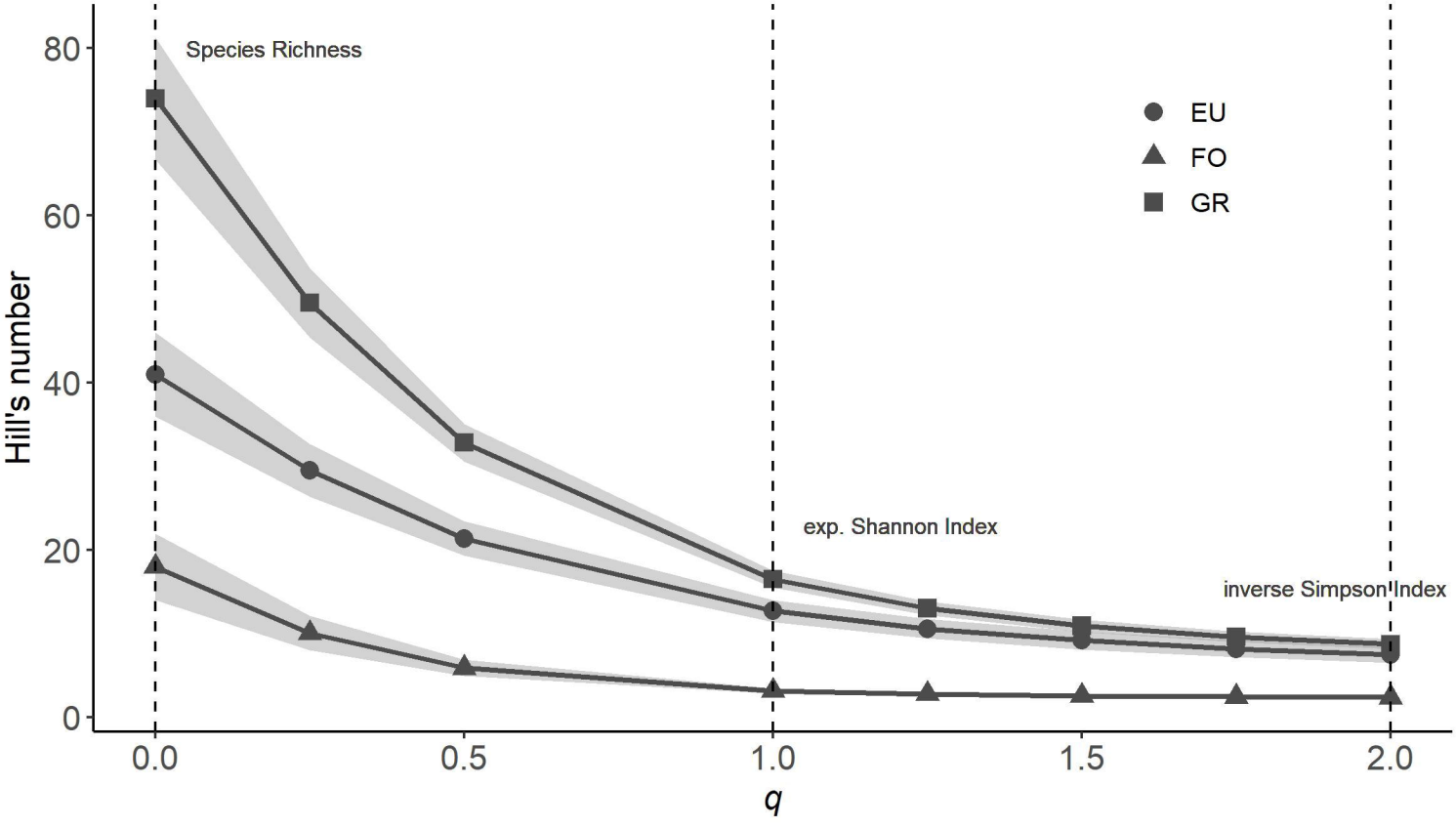
YUNGAS FOREST
Capillas
Study Area
N
65°9'46.8"O
65°9'21.6"O
65°8'56.4"O
24°5'13.2"S
24°5'38.4"S
0 0.1 0.2 0.3 km
Legend
Survey patch
Eucalyptus plantation (EU)
Secondary grassland (GR)
Cloud Montane forest (FO)
Transects


Species Richness
exp. Shannon Index
inverse Simpson Index
EU
FO
GR
Hill's number
q
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20
40
60
80
0.0
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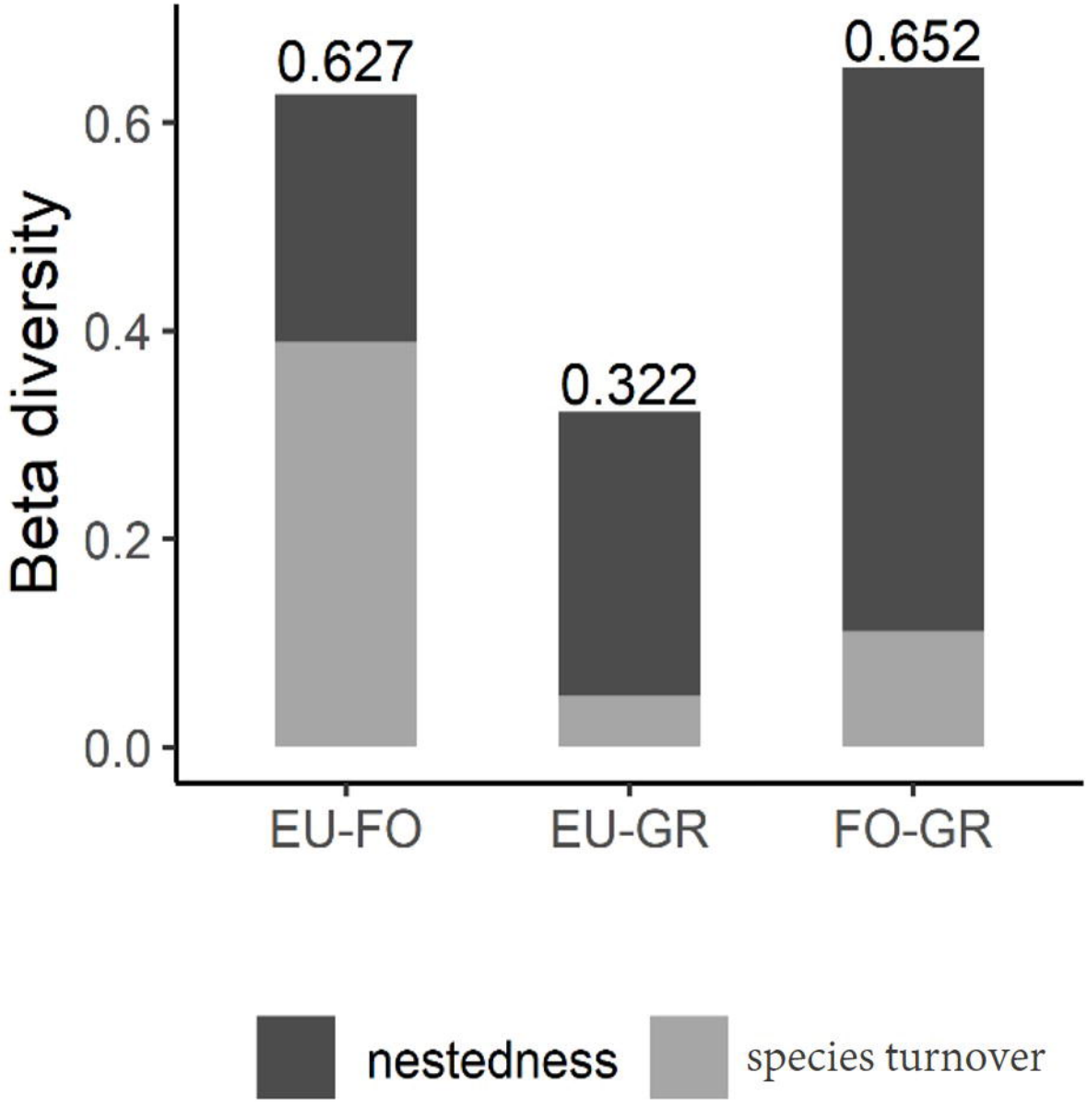
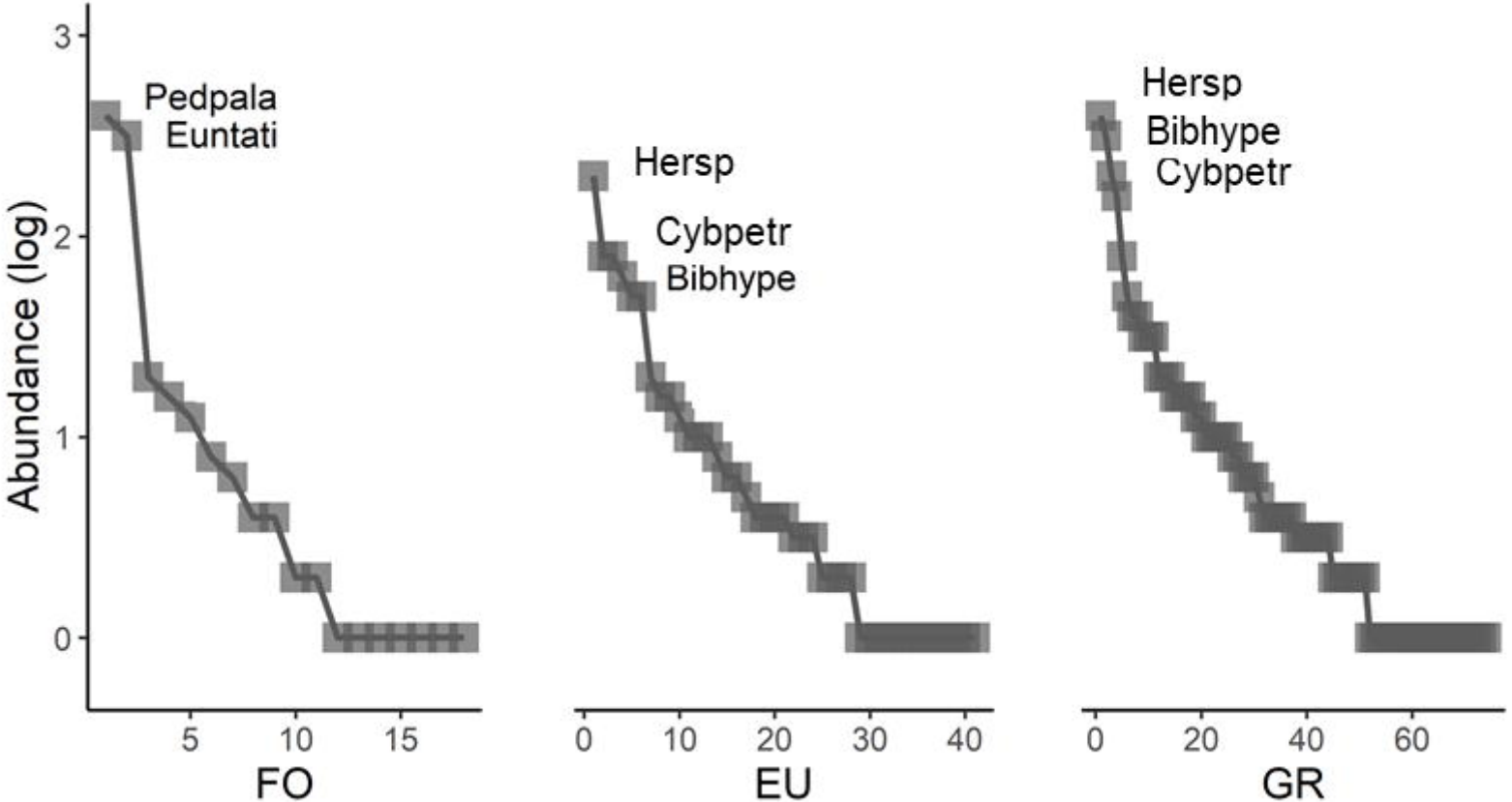
1.0
1.5
2.0


0.627
0.322
0.652
Beta diversity
0.0
0.2
0.4
0.6
EU-FO
EU-GR
FO-GR
nestedness
species turnover


Abundance (log)
3
2
1
0
Pedpala
Euntati
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Cybpetr
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Hersp
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FO
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EU
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