Journal Pre-proof

Assemblage-level responses of Neotropical bats to forest loss and fragmentation

Santiago Gamboa Alurralde , M.Mónica Díaz

PII: S1439-1791(20)30091-8
DOI: https://doi.org/10.1016/j.baae.2020.09.001
Reference: BAAE 51274

To appear in: *Basic and Applied Ecology*

Received date: 20 April 2020
Accepted date: 3 September 2020

Please cite this article as: Santiago Gamboa Alurralde , M.Mónica Díaz , Assemblage-level responses of Neotropical bats to forest loss and fragmentation, *Basic and Applied Ecology* (2020), doi: https://doi.org/10.1016/j.baae.2020.09.001

Highlights

- The structure of Neotropical bat assemblages varies regardless of the disturbance level of the study sites.
- No differences in assemblage diversity and composition between well-preserved and disturbed sites of the Yungas Forests.
- The responses of bats to habitat alteration tend to be highly species-specific.

Assemblage-level responses of Neotropical bats to forest loss and fragmentation

Santiago Gamboa Alurralde[a,b,*] and M. Mónica Díaz[a,b,c]

[a]Programa de Investigaciones de Biodiversidad Argentina (PIDBA), Programa de Conservación de los Murciélagos de Argentina (PCMA), Facultad de Ciencias Naturales e IML, Universidad Nacional de Tucumán. Miguel Lillo 205, 4000. Tucumán, Argentina.

[b]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET). Crisóstomo Álvarez 722, 4000. Tucumán, Argentina.

[c]Fundación Miguel Lillo. Miguel Lillo 251, 4000. Tucumán, Argentina.

*Corresponding author. Tel.: (+54) 0381-154198128.

E-mail address: santigamboaalurralde@gmail.com

Highlights:

- The structure of Neotropical bat assemblages varies regardless of the disturbance level of the study sites.
- No differences in assemblage diversity and composition between well-preserved and disturbed sites of the Yungas Forests.
- The responses of bats to habitat alteration tend to be highly species-specific.

Abstract

Habitat loss and fragmentation are the most important causes of biological diversity loss, changing the properties of the remaining environment. The Neotropical Region is one of the most affected areas due to the conversion of natural habitats into agricultural activities and deforestation. In this region, bats represent almost 50% of all mammal species, reaching the highest taxonomic and functional diversity. Bats are valuable indicators of biodiversity and ecosystem health, but their response to habitat loss and fragmentation was poorly studied in Argentina. The aim of this study was to analyze the response of bat assemblages to habitat alteration in Northwestern Argentina. The specimens were collected in eight different localities, four well-preserved and four disturbed sites of the Yungas Forests. To describe the structure of bat assemblages, rank-abundance curves, species richness and Shannon (H') and Simpson (D') diversity indexes were calculated. To test the assemblage variations among sites, PCA and NPMANOVA analysis were performed. After 96 sampling nights, a total of 565 bats from 23 species were captured. A great variation in the assemblage structure was registered, regardless the disturbance level of the sites. These variations were not significantly different according to statistical analysis. The results support the hypothesis that areas with moderate fragmentation can sustain a high diversity of bat species. Moreover, these results showed that consistent responses to landscape composition at the assemblage level are harder to identify in fragmented Neotropical Forests. The responses of bats to habitat alteration tend to be highly species-specific.

Keywords: Assemblage diversity, Chiroptera, Community ecology, Habitat loss, Habitat fragmentation.

Introduction

Alteration in land use is one of the principal aspects of globlal environmental change and a key driver of biodiversity loss in terrestrial ecosystems (Meyer, Struebig & Willig 2016). Indeed, biodiversity impacts of land-use change are generally considered to be more immediate than those from climate change (Sala et al. 2000; Jetz, Wilcove & Dobson 2007; Pereira et al. 2010). However, human pressures on the natural environments are not uniformly distributed on the planet (Myers et al. 2000). In this sense, the Neotropics is one of the regions under stronger pressure for the conversion of its natural landscapes due to logging, creation of pastures and agricultural activities, mining or growing urbanization (Asner et al. 2009; Lewis et al. 2009; FAO 2011). This situation is alarming, considering that the Neotropics contain some of the highest levels of biodiversity, several centers of endemism, with rare and endangered species (Young et al. 2004; Schipper et al. 2008).

In the Neotropical Region, bats can represent more than 50% of the species in a mammalian fauna (Aguirre 2002; Sampaio et al. 2003). They exhibit the general mammalian pattern of greatest diversity in the tropics, from both a taxonomic and a functional perspective (Willig, Patterson & Stevens 2003). Bats also provide ecosystem services that are critically important in tropical ecosystems—as pollinators and seed dispersers for hundreds of plant species and as agents of suppression of arthropod herbivores and pest species (Muscarella & Fleming 2007; Kalka, Smith & Kalko 2008; Williams-Guillén, Perfecto & Vandermeer 2008; Kunz et al. 2011; Maas, Clough & Tscharntke 2013). Moreover, bats are valuable indicators of biodiversity and ecosystem health, and respond to a range of stressors related to environmental change (Jones et al. 2009).

Regarding the current understanding of tropical bat responses to anthropogenic disturbance, there was a general increase in the number of studies over the last 30 years (Fenton et al. 1992; Wilson, Ascorra & Solari 1996; Kalko 1998; Medellín, Equihua & Amin 2000; Soriano & Ochoa 2001; Gorresen & Willig 2004; Peters, Malcolm & Zimmerman 2006; Coutinho Cunto & Bernard 2012). However, despite these numerous attempts to detect consistent responses of tropical bats to habitat fragmentation, studies to date suggest relatively few generalizations (Meyer, Struebig & Willig 2016). At the assemblage level, studies that have compared fragmented and continuous forest in terms of species richness, diversity, and composition demonstrate inconsistent responses (Cosson, Pons & Masson 1999; Schulze, Seavy & Whitacre 2000; Estrada & Coates-Estrada 2002; Faria 2006).

With a few exceptions (Estrada et al. 2004; Estrada-Villegas, Meyer & Kalko 2010; Rodríguez-Durán & Otero 2011; Williams-Guillén & Perfecto 2011; Rodríguez-Durán & Feliciano-Robles 2016), Neotropical bat studies focused on the Phyllostomidae family, in turn largely reflecting the use of mist nets to capture bats (Meyer, Struebig & Willig 2016). Thus, little is still known about the effects of environmental disturbances in the Neotropics on bats of other poorly studied families, such as Molossidae and Vespertilionidae (Countinho Cunto & Bernard 2012). A similar pattern is observed regarding the studied trophic guilds. Most of the studies were conducted on frugivorous species, whereas the effects of environmental disturbances on bats of other trophic groups, such as arthropodophagous or carnivorous species, remain uncertain (Countinho Cunto & Bernard 2012). In America, the conducted studies included 11 countries (Countinho Cunto & Bernard 2012), with no previous information about bat response to fragmentation in Argentina. The Yungas Forests of Northwestern Argentina are the third most diverse area for bats in the country, containing 65% of the 67 species in the country (Díaz et al. 2016, 2019; Barquez & Díaz 2020). Moreover, these forests represent a biodiversity hotspot for being one of the richest and most diverse areas on Earth (Mittermeier et al. 1999; Ceballos & Ehrlich 2006). However, over the last decades, large areas of the Yungas Forests have been affected and altered by human activities through deforestation and cattle-raising in the piedmont areas (Brown et al. 2001); as well as energy and mining projects and exploitation of forest resources in the montane areas (Pacheco & Cristóbal 2009).

In the present study, we analyzed the response of bat assemblages to habitat alteration in Northwestern Argentina. According to this, we described the structure of bat assemblages in terms of composition, species richness and diversity, and evaluated their differences between well-preserved and disturbed sites from the Yungas Forests. Because a greater degree of disturbance is associated with drastic changes in the floristic composition and structure of vegetation (Castro-Luna, Sosa & Castillo-Campos 2007), we hypothesized that well-preserved sites would support greater bat species richness, composition, and abundance in comparison to disturbed sites. In accordance to similar studies (Medellín, Equihua & Amin 2000), we expected to observe in well-preserved sites assemblages characterized by higher number of total and rare species and low relative abundance of the most common species, while the reverse combination of values is expected to be found in disturbed sites of Yungas Forests.

Materials and methods

Study area

The study area belongs to the Yungas Forests ecoregion (Burkart et al. 1999), which is distributed from the borderline with Bolivia to the north of the province of Catamarca, including three neighboring provinces, namely, Jujuy, Salta and Tucuman (Brown et al. 2001). The area is represented by typical vegetation dominated by tall trees such as *Cedrela lilloi* (cedar), *Enterobium contortisiliquum* (earpod tree) and *Cinnamomun porphyrium* (laurel). There are also smaller trees that do not exceed 20 m such as *Allophyllus edulis* (chalchal), *Celtis boliviensis* (tala), among others. Bushes such as *Urera baccifera, Piper tucumanum,* and *Solanum* sp. are present, as well as herbs which range from smaller forms to taller than two meters (Cabrera 1976); epiphytes are abundant, and lichens, ferns, bromeliads, and mosses are dominant (Brown et al. 2001). The climate in the area is warm and humid; the annual precipitation varies between 900 and 1000 mm, and the rainfalls are concentrated mainly in summer, 750 mm aproximatelly from October to March (Burkart et al. 1999).

Sampling

The specimens were collected in eight different localities (Fig. 1), four well-preserved and four disturbed sites of the Yungas Forests (see Appendix), during ten field surveys of three nights each, between September 2012 and October 2015. The sites were selected from pairs at different latitudes, and the separation distance between each pair ranged from three to 18 km. In well-preserved sites, the vegetation is typical of the montane forest district, where all vegetation strata were recorded; whereas in disturbed sites, the structure of the vegetation is modified and some strata are missing, usually bushes and small trees. In the study sites, deforestation for cattle raising and croplands, as well as selective cutting, are the main causes of habitat alteration. Over the last decades, these actions generated a strong retraction of the Yungas Forests, transforming natural forests in isolated patches (Gamboa Alurralde et al. 2016). The conversion of natural habitat to pastoral land is registered mainly in the southern portion of the Yungas Forests (Cabrera 1976), where the typical vegetation form patches separated by open grassland areas (Fig. 1, localities 5–8). In the middle portion of the Yungas Forests (Fig. 1, localities 3 and 4), the patches of old-growth forests are separated by huge extensions of cropland, mainly soybean crops (Gamboa Alurralde 2017). At the northern study sites (Fig. 1, localities 1 and 2), the commercial logging is also a major force of forest degradation (Brown et al. 2001), where the native tree species were completely replaced by exotic timber species, such as eucalyptus and pines. We used ArcGIS 10.1 (ESRI 2011) to calculate the proportion of native forest in the landscape as a measure of forest loss, and the density of edge habitat as a measure of fragmentation (Rodríguez-San Pedro & Simonetti 2015). Forest amount ranged from 98 to 100% in well-preserved sites and from 79 to 88% in disturbed sites. The bats were captured using six 12-m mist nets, set after sunset inside the forest and over streams or rivers, and kept open for periods of six hours. External measurements, age, sex, and reproductive condition were recorded from all collected specimens following Díaz, Flores and Barquez (1998). Bats were grouped by trophic guilds following Aguirre (2002).

Statistical analysis

To determine whether the surveys were representative of the bat assemblages, we calculated and plotted the species accumulation curves using the surveyed years as a sampling unit. The curves were calculated using the non-parametric estimators Chao 1 to estimate the number of species present in the area. Chao 1 is based on the number of rare species in a sample as a way to calculate the percentage of completeness of an inventory (Colwell 2005). To describe the structure of bat assemblages, in terms of composition and diversity, we calculated rank-abundance curves, species richness and Shannon (H') and Simpson (D') diversity indexes (Medellín, Equihua & Amin 2000). These analyses were conducted using the free software EstimateS (Colwell 2005). We used Principal Components Analysis (PCA; Legendre & Legendre 1998) to analyze the assemblage variation among sites. Additionally, to test for significant differences in assemblage structure, we performed a Nonparametric Multivariate Analysis of Variance (NPMANOVA; Anderson 2001). We determined species richness and diverstity indexes as the response variables, and the disturbance level of capture site (well-preserved/disturbed), the proportion of native forest and the density of edge habitat as explanatory variables. For each run, we used the Bray-Curtis similarity index for 10,000 permutations. These analyses were conducted using the free software PAST 3.11 (Hammer, Harper & Ryan 2001).

Results

After 96 survey nights and a total sampling effort of 41,472 m × h, we captured 565 specimens of bats belonging to 13 genera and 23 species, representing three families (Table 1). The most abundant species was *Sturnira lilium* (40% of the total captures), followed by *Artibeus planirostris* (12%), and *Myotis dinellii* (9%). Regarding the trophic guilds, we registered assemblages dominated by slow-flying arthropodophagous species, in terms of their species richness. We recorded 10 species of slow-flying arthropodophagous bats, eight fast-flying arthropodophagous, and three species of frugivorous bats. The remaining guilds, carnivorous and sanguivorous, were represented by only one species each (Table 1). In terms of abundance, we observed assemblages to be dominated by frugivorous species, such as *S. lilium* and *A. planiostris.* The species accumulation curves reached values close to the asymptote, and Chao 1 estimated a total number of species close to the species numbers recorded from the different sites. Based on this estimator, the assemblages represented between 69 and 100% (Table 1), indicating that the number of recorded species was optimal for most of the study sites.

The structure of bat assemblages, in terms of their composition, was described calculating the range-abundance curve for each study site; a great variation in the assemblage structure among sites (Fig. 2) was observed, regardless the disturbance level of the site (well-preserved vs. disturbed). Some of the studied sites, both well-preserved and disturbed ones, showed assemblages of bats with high species richness, high number of rare species, and no dominant species in terms of abundance. On the contrary, in some of the other sites the opposite situation was recorded, showing assemblages with lower species richness, low number of rare species and few dominant species (Fig. 2). These results were also observed with the diversity indexes, with high values in both well-preserved and disturbed sites (Table 1).

The variation among assemblages of the different sites was studied using a Principal Components Analysis. The first two principal components (PC1 and PC2) summarized 97.32% of the variation in the sample (Fig. 3, Table 2). PC1 (88.83% of explained variation) represented mainly the proportion of native forest (NF) in the study sites. Positive scores on PC1 are associated with higher amount of forests found in well-preserved sites. On the other hand, PC2 (8.42% of explained variation) was highly correlated with species richness (SR) and moderately associated with the Simpson diversity index (D'). Positive scores on PC2 were correlated to assemblages with higher number of species and higher diversity. Finally, to test for significant differences in the assemblage structure among sites we performed a NPMANOVA. According to this analysis, the registered variations were not significantly different, neither based on the species richness (P = 0.797) nor the diversity indexes (P = 0.714).

Discussion

In this study, we analyzed the response of bat assemblages to habitat alteration in Northwestern Argentina. We described the structure of bat assemblages in terms of composition, species richness and diversity, and evaluated their differences between well-preserved and disturbed sites in the Yungas Forests. Our results showed no significant differences between bat assemblages from well-preserved and disturbed sites. In general terms, we registered bat assemblages characterized by few abundant common species, along with a high number of rare and less abundant species. This structure is similar to those obtained in other studies conducted in the Yungas Forests in Argentina (Bracamonte 2010; Jayat & Ortiz 2010; Gamboa Alurralde et al. 2016; Sánchez 2016).

Although most species of bats are arthropodophagous (Shiel et al. 1997), in tropical environments they are usually not the dominant guild, whereas at higher latitudes the importance of arthropodophagous species increases in the bat communities (Gamboa Alurralde, Barquez & Díaz 2017), as was recorded in this study. These results were also consistent with other studies carried out in the Neotropical Region (Aguirre 2002; Flores-Saldaña 2008). In terms of abundance, the high abundance of frugivorous species such as *Sturnira lilium* is in line with bat studies conducted in tropical (Kalko & Handley 2001) and subtropical environments (Moya et al. 2008; Gamboa Alurralde et al. 2016).

In contrast with our expectations, the structure of bat assemblage composition was not directly related to the disturbance level of the study sites. We expected to observe in well-preserved sites a greater bat species richness, diversity and abundance than in disturbed sites. However, based on the rank-abundance curves, we observed both well-preserved and disturbed sites with high and low species richness of bats and high and low values of diversity indexes. Except for one of the well-preserved sites which showed the highest diversity of all, the disturbed sites were equal or more diverse than well-preserved sites. These results support the hypothesis that areas with moderate amounts of fragmentation, associated with conversion of forest habitat, can sustain a high diversity of bat species (Gorresen & Willig 2004; Clarke, Pio & Racey 2005; Clarke, Rostant & Racey 2005; Bernard & Fenton 2007; Willig et al. 2007; Klingbeil & Willig 2009; Rodríguez-Durán & Otero 2011; Rodríguez-Durán & Feliciano-Robles 2016). The tolerance of bats to habitat loss and fragmentation woud be related to their capacity to traverse open areas between forest fragments or between fragments and continuos forest (Meyer, Struebig & Willig 2016), and to exploit all the resources of the landscape matrix, including roosts and food (Law, Anderson & Chidel 1999; Schulze, Seavy & Whitacre 2000; Presley et al. 2009; Trevelin et al. 2013).

A clear example of this was the pattern observed in *Chrotopterus auritus*. This species is usually collected in undisturbed forests (Fenton et al. 1992; Medellín, Equihua & Amin 2000; Gorrensen & Willig 2004), but is also present in disturbed forests, as was recorded in our study (Wilson, Ascorra & Solari 1996; dos Reis et al. 2007). Although *C. auritus* depends on primary forests to find roost (Medellín 1989), human pressure on natural environments makes this species use disturbed areas as foraging habitats within its large home range (Brooke 1988), taking advantage of the high abundance of food that this type of area offers (Moras 2011). Another example of bat tolerance to habitat fragmentation, observed in this study, was showed by *Artibeus planirostris.* This frugivorous bat species was very abundant in disturbed sites, in line with several previous studies (Cosson, Pons & Masson 1999; Pinto & Keitt 2008; Chambers et al. 2016). The species of *Artibeus* have large home ranges (Morrison 1978), allowing them to be generalists in terms of the areas used (Bonaccorso 1979) and to occur in both well-preserved and disturbed forests (Pinto & Keit 2008; Mena 2010; García-García & Santos-Moreno 2014).

The analysis of the assemblage variation among sites included environmental variables and assemblage variables. In this study, temporal variables to analyse the dynamics of the bat assemblages over time were not included. But it is known that, while the total number of species belonging to a community is often relatively constant in time, species composition is likely to change as some populations become extinct and are replaced by others (Russel et al. 1995). Moreover, it has been shown for bats that species relying on food resources that change over time (e.g. fruits) were more likely to be absent in particular years, due to temporal availability of the preferred food resource (Bonaccorso 1979). In contrast, species relying on more permanent food supplies (such as aerial insects) were present all year round. Because most of the species reported in this study belong to aerial insectivorous guild, we strongly believe that the assemblages evaluated would be characterized by low rates of species turnover, in line with previous studies (Aguirre et al. 2003).

Regarding the spatial variables analysed here, and in accordance with other studies, forest amount, a measure of habitat loss, was the best feature to separate the different assemblages of bats (Klingbeil & Willig 2009; Ethier & Fahrig 2011). This supported the use of habitat loss measures as a reliable factor to evaluate the bat response to habitat alteration (Meyer & Kalko 2008; Henry, Cosson & Pons 2010; Rodríguez-San Pedro & Simonetti 2015). Based on all variables, we conducted a NPMANOVA and no significant results were obtained. Similar results were observed in previous studies, showing that consistent responses to landscape composition at the assemblage level are harder to identify in studies conducted in fragmented Netropical Forests (Gorrensen & Willig 2004; Klingbeil & Willig 2009, Montaño-Centellas et al. 2015; Meyer, Struebig & Willig 2016). A difficulty facing bat fragmentation studies is that responses tend to be highly species-specific, wich is often overlooked by diversity metrics applied at the assemblage level (Klingbeil & Willig 2009). In addition to this, recent studies provide evidence for widespread scale dependence in associations between landscape metrics and bat responses at the assemblage, population, and species level (Gorresen & Willig 2004; Meyer & Kalko 2008; Pinto & Keitt 2008; Cisneros, Fagan & Willig 2015). Thus, future research should focus on the mechanisms behind responses of the individual bat species to fragmentation in mutliple-scale assesments.

This study provides baseline research in Argentina and adds important information about the assemblage ecology of bats in the Yungas Forests. These are the first data about the response of bat to northwestern forests fragmentation, one of the most diverse areas for bats in the country. Considering that large areas of the Yungas Forests have been altered by human activities in the last decades, more studies are needed to understand the effect of these changes on bats.

Acknowledgements

We wish to acknowledge all the members of PIDBA for extending their support during our field collection trips. We also thank Annia Rodriguez-San Pedro for her help with the analysis of ecological data with ArcGis. We acknowledge support from Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina.

Appendix

Collection localities. The localities from the Yungas Forests are listed from north to south and according to its numbers in Fig. 1. For each locality is provided the acronym, specific site, department and province in brackets, coordinates and altitude in meters above sea level, and type of site.

1 – LCP. Las Capillas, 15 km al N de Las Capillas (Dr. Manuel Belgrano, Jujuy). 24º02'37'' S, 65º07'55'' W, 1061 m. Well-preserved site.

2 – FLC. Finca Las Capillas, 3 km al E del cruce entre río Las Capillas y ruta provincial nº 20 (Dr. Manuel Belgrano, Jujuy. 24º05'35.77'' S, 65º09'07.86'' W, 1141 m. Disturbed site.

3 – RLCH. Metán, 6 km al O, sobre río Las Conchas (Metán, Salta). 25º28'09'' S, 65º02'11.58'' W, 986 m. Well-preserved site.

4 – MET. Metán, 3.5 km al W (Metán, Salta). 25º29'34.76'' S, 65º00'29.95'' W, 1019 m. Disturbed site.

5 – AGCH. Reserva Provincial Aguas Chiquitas, sobre río Aguas Chiquitas (Burruyacú, Tucumán). 26º36'32.40'' S, 65º10'36.60'' W, 605 m. Well-preserved site.

6 – ELC. El Cadillal, camping La Curva (Burruyacú, Tucumán). 26º37'52.08'' S, 65º11'10.87'' W, 555 m. Disturbed site.

7 – ESC. Villa de Batiruana (La Cocha, Tucumán). 27º38'11.61'' S, 65º44'40.29'' W, 515 m. Disturbed site.

8 – PAC. Villa de Escaba, 22 km al SE, sobre ruta provincial nº 9 (Paclín, Catamarca). 27º47'48.48'' S, 65º46'56.70'' W, 538 m. Well-preserved site.

References

Aguirre, L. F. (2002). Structure of a Neotropical savanna bat community. *Journal of Mammalogy, 83*, 775–784. https://doi.org/10.1644/1545-1542(2002)083%3C0775:SOANSB%3E2.0.CO;2.

Aguirre, L. F., Lens, L., van Damme, R., & Matthysen, E. (2003). Consistency and variation in the bat assemblages inhabiting two forest islands within a netropical savanna in Bolivia. *Journal of Tropical Ecology, 19*, 367–374. https://doi.org/10.1017/S0266467403003419

Anderson, M. J. (2001). A new method for non-parametric multivariate analysis of variance. *Austral Ecology, 26*, 32–46. https://doi.org/10.1111/j.1442-9993.2001.01070.pp.x.

Asner, G. P., Rudel, T. K., Aide, T. M., Defries, R., & Emerson, R. (2009). A contemporary assessment of change in humid tropical forests. *Conservation Biology, 23*, 1386–1395. https://doi.org/10.1111/j.1523-1739.2009.01333.x.

Barquez, R. M., & Díaz, M. M. (2020). *Nueva guía de los murciélagos de Argentina*. San Miguel de Tucuman: Publicación Especial Nº 3 PCMA (Programa de Conservación de los Murciélagos de Argentina).

Bernard, R., & Fenton, M. B., 2007. Bats in a fragmented landscape: species composition, diversity and habitat interactions in savannas of Santarem, Central Amazonia, Brazil. *Biological Conservation, 134*, 332–343. https://doi.org/10.1016/j.biocon.2006.07.021.

Bonaccorso, F. J. (1979). Foraging and reproductive ecology in a Panamian bat community. *Bulletin of the Florida State Museum, 24*, 359–408. https://www.floridamuseum.ufl.edu/wp-content/uploads/sites/35/2017/03/Vol-24-No-4.pdf

Bracamonte, J. C. (2010). Murciélagos de bosque montano del Parque Provincial Potrero de Yala, Jujuy, Argentina. *Mastozoología Neotropical, 17*, 361–366.

Brooke, A. P. (1988). Pray selection, foraging and habitat use by *Chrotopterus auritus* in Costa Rica. *Bat Research News, 29*, 44.

Brown, A. D., Grau, H. R., Malizia, L. R., & Grau, A. (2001). Argentina, In M. Kappelle, & A. D. Brown (Eds.), *Bosques nublados del Neotrópico* (pp. 623–659). Santo Domingo de Heredia: Editorial Instituto Nacional de Biodiversidad (INBio).

Burkart, R., Bárbaro, N. O., Sánchez, R. O., & Gomez, D. A. (1999). *Eco-regiones de la Argentina*. Buenos Aires: Administración de Parque Nacionales.

Cabrera, A. L. (1976). *Regiones Fitogeográficas Argentinas*. Buenos Aires: ACME.

Castro-Luna, A. A., Sosa, V. J., & Castillo-Campos, G. (2007). Bat diversity and abundance associated with the degree of secondary succession in a tropical forest mosaic in south-eastern Mexico. *Animal Conservation, 10*, 219–228. https://doi.org/10.1111/j.1469-1795.2007.00097.x.

Ceballos, G., & Ehrlich, P. R. (2006). Global mammal distributions, biodiversity hotspots, and conservation. *Proceedings of the National Academy of Sciences of the United States of America, 103*, 19374–19379. https://doi.org/10.1073/pnas.0609334103.

Chambers, C. L., Cushman, S. A., Medina-Fitoria, A., Martínez-Fonseca, J., & Chávez-Velásquez, M. (2016). Influences of scale on bat habitat relationships in a forested landscape in Nicaragua. *Landscape Ecology, 31*, 1299–1318. https://doi.org/10.1073/pnas.0609334103.

Cisneros, L. M., Fagan, M. E., & Willig, M. R. (2015). Effects of human modified landscapes on taxonomic, functional, and phylogenetic dimensions of bat biodiversity. *Diversity and Distribution, 21*, 523–533. https://doi.org/10.1111/ddi.12277.

Clarke, F. M., Pio, D. V., & Racey, P. A. (2005). A comparison of logging systems and bat diversity in the Neotropics. *Conservation Biology, 19*, 1194–1204. https://doi.org/10.1111/j.1523-1739.2005.00086.x-i1.

Clarke, F. M., Rostant, L. V., & Racey, P. A. (2005). Life after logging: postlogging recovery of a Neotropical bat community. *Journal of Applied Ecology, 42*, 409–420. https://doi.org/10.1111/j.1365-2664.2005.01024.x.

Colwell, R. K. (2005). *EstimateS: statistical estimation of species richness and shared species from samples*. Version 7. Available at: purl.oclc.org/estimates.

Cosson, J. F., Pons, J. M., & Masson, D. (1999). Effects of forest fragmentation on frugivorous and nectarivorous bats in French Guiana. *Journal of Tropical Ecology, 15*, 515–534. https://doi.org/10.1017/S026646749900098X.

Coutinho Cunto, G., & Bernard, E. (2012). Neotropical bats as indicators of environmental disturbance: what is the emerging message? *Acta Chiropterologica, 14*, 143–151. https://doi.org/10.3161/150811012X654358.

Díaz, M. M., Flores, D. A., & Barquez, R. M. (1998). *Instrucciones para la preparación y conservación de mamíferos*. San Miguel de Tucuman: PIDBA Publicaciones Especiales.

Díaz, M. M., Romero, M. N., Ramos Barreira, M. M., Morales Soler, J. J., & Barquez, R. M. (2019). *Peropteryx macrotis* (Wagner, 1843) (Mammalia, Chiroptera, Emballonuridae), a newly recorded family, genus, and species of bat for Argentina. Check List, 15, 945–949. https://doi.org/10.15560/15.5.945.

Díaz, M. M., Solari, S., Aguirre, L. F., Aguiar, L. M. S., & Barquez, R. M. (2016). *Clave de identificación de los murciélagos de Sudamérica*. San Miguel de Tucuman: Publicación Especial Nº 2 PCMA (Programa de Conservación de los Murciélagos de Argentina).

dos Reis, N. R., Peracchi, A. L., Pedro, W. A., & de Lima, I. P. (2007). *Morcegos do Brasil*. Londrina: Universidade Estadual de Londrina.

ESRI (2011). *ArcGIS Desktop: Release 10*. Redlands: Enviromental Systems Research Institute.

Estrada, A., & Coates-Estrada, R. (2002). Bats in continuous forest, forest fragments and in an agricultural mosaic habitat-island at Los Tuxtlas, Mexico. *Biological Conservation, 103*, 237–245. https://doi.org/10.1016/S0006-3207(01)00135-5.

Estrada, A., Jiménez, C., Rivera, A., & Fuentes, E., 2004. General bat activity measured with an ultrasound detector in a fragmented tropical landscape in Los Tuxtlas, Mexico. Animal *Biodiversity and Conservation*, *27*, 1–9. https://doi.org/56789.

Estrada-Villegas, S., Meyer, C. F. J., & Kalko, E. K. V. (2010). Effects of tropical forest fragmentation on aerial insectivorous bats in a land-bridge island system. *Biological Conservation, 143*, 597–608. https://doi.org/10.1016/j.biocon.2009.11.009.

Ethier, K., & Fahrig, L. (2011). Positive effects of forest fragmentation, independent of forest amount, on bat abundance in eastern Ontario, Canada. *Landscape Ecology, 26*, 865–876. https://doi.org/10.1007/s10980-011-9614-2.

FAO (Food and Agriculture Organization) (2011). *The state of the tropical rainforest in the Amazon Basin, Congo Basin and Southeast Asia*. Rome: FAO.

Faria, D. (2006). Phyllostomid bats of a fragmented landscape in the nort-eastern Atlantic forest, Brazil. *Journal of Tropical Ecology, 22*, 531–542. https://doi.org/10.1017/S0266467406003385.

Fenton, M. B., Acharya, L., Audet, D., Hickey, M. B. C., Merriman, C., Obrist, M. K., & Syme, D. M. (1992). Phyllostomid bats (Chiroptera: Phyllostomidae) as indicators of habitat disruption in the Neotropics. *Biotropica, 24*, 440–446. https://doi.org/10.2307/2388615.

Flores-Saldaña, M. G. (2008). Estructura de las comunidades de murciélagos en un gradiente ambiental en la reserva de la biosfera y tierra comunitaria de origen Pillón Lajas, Bolivia. *Mastozoología Neotropical, 5*, 309–322.

Gamboa Alurralde, S. (2017). *Ensambles de murciélagos (Mammalia, Chiroptera) en zonas con distinto grado de perturbación de las Yungas de Argentina*. San Miguel de Tucuman: Universidad Nacional de Tucuman.

Gamboa Alurralde, S., Barquez, R. M., Díaz, M. M. (2017). New records of bats (Mammalia: Chiroptera) for a southern locality of the Argentine Yungas. *Check List, 13*, 2105. http://dx.doi.org/10.15560/13.3.2105.

Gamboa Alurralde, S., López Berrizbeitia, M. F., Barquez, R. M., & Díaz, M. M. (2016). Diversity and richness of small mammals at a well-conserved site of The Yungas in Jujuy Province, Argentina. *Mammalia, 80*, 253–262. https://doi.org/10.1515/mammalia-2014-0157.

García-García, J. L., & Santos-Moreno, A. (2014). Efectos de la estructura del paisaje y de la vegetación en la diversidad de murciélagos filostómidos (Chiroptera: Phyllostomidae) de Oaxaca, Mexico. *Revista de Biología Tropical, 62*, 217–239. https://doi.org/10.15517/rbt.v62i1.12094.

Gorresen, P. M., & Willig, M. R. (2004). Landscape responses of bats to habitat fragmentation in Atlantic forest of Paraguay. *Journal of Mammalogy, 85*, 688–697. https://doi.org/10.1644/BWG-125.

Hammer, Ø., Harper, D. A. T., & Ryan, P. D. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica*, *4*, 9. http://palaeo-electronica.org/2001_1/past/issue1_01.htm.

Henry, M., Cosson, J. F., & Pons, J. M. (2010). Modelling multi-scale spatial variation in species richness from abundance data in a complex neotropical bat assemblage. *Ecological Modelling*, *221*, 2018–2027. https://doi.org/10.1016/j.ecolmodel.2010.05.011.

Jayat, J. P., & Ortiz, P. E. (2010). Mamíferos del pedemonte de Yungas de la alta cuenca del río Bermejo en Argentina: una línea de base de diversidad. *Mastozoología Neotropical, 17*, 69–86.

Jetz, W., Wilcove, D. S., & Dobson, A. P. (2007). Projected impacts of climate and land-use change on the global diversity of birds. *PLoS Biol*, *5*, e157. https://doi.org/10.1371/journal.pbio.0050157

Jones, G., Jacobs, D. S., Kunz, T. H., Willig, M. R., & Racey, P. A. (2009). Carpe noctem: the importance of bats as bioindicators. *Endangered Species Research*, *8*, 93–115. https://doi.org/10.3354/esr00182.

Kalka, M. B., Smith, A. R., & Kalko, E. K. V. (2008). Bats limit arthropods and herbivory in a tropical forest. *Science, 320*, 71. https:doi.org/10.1126/science.1153352.

Kalko, E. K. V. (1998). Organization and diversity of tropical bat communities through space and time. *Zoology, 101*, 281–297.

Kalko, E. K. V., & Handley Jr., C. O. (2001). Neotropical bats in the canopy: diversity, community structure and implications for conservation strategies. *Plant Ecology*, *153*, 319–333. https://doi.org/10.1023/A:1017590007861.

Klingbeil, B. T., & Willig, M. R. (2009). Guild-specific responses of bats to landscape composition and configuration in fragmented Amazonian rainforests. *Journal of Applied Ecology, 46*, 203–213. https://doi.org/10.1111/j.1365-2664.2008.01594.x.

Kunz, T. H., Braun de Torrez, E., Bauer, D., Lobova, T., & Fleming, T. H. (2011). Ecosystem services provided by bats. *Annals of the New York Academy of Sciences, 1223*, 1–38. https://doi.org/10.1111/j.1749-6632.2011.06004.x.

Law, B. S., Anderson, J., & Chidel, M. (1999). Bat communities in a fragmented landscape on the south-west slopes of New South Wales, Australia. *Biological Conservation, 88*, 333–345. https://doi.org/10.1016/S0006-3207(98)00118-9.

Legendre, P., & Legendre, L. (1998). *Numerical Ecology*. Amsterdam: Elsevier.

Lewis, S. L., Lloyd, J., Stich, S., Mitchard, E. T. A., & Laurance, W. F. (2009). Changing ecology of tropical forests: evidence and drivers. *Annual Review of Ecology, Evolution and Systematics, 40*, 529–549. https://doi.org/10.1146/annurev.ecolsys.39.110707.173345

Maas, B., Clough, Y., & Tscharntke, T. (2013). Bats and birds increase crop yield in tropical agroforestry landscapes. *Ecology Letters, 16*, 1480–1487. https://doi.org/10.1111/ele.12194.

Medellín, R. A. (1989). *Chrotopterus auritus*. *Mammalian Species, 343*, 1–5.

Medellín, R. A., Equihua, M., & Amin, M.A. (2000). Bat diversity and abundance as indicators of disturbance in neotropical rainforests. *Conservation Biology, 14*, 1666–1675. https://doi.org/10.1111/j.1523-1739.2000.99068.x.

Mena, J. L. (2010). Respuestas de los murciélagos a la fragmentación del bosque en Pozuzo, Perú. *Revista Peruana de Biología, 17*, 277–284.

Meyer, C. F. J., & Kalko, E. K. V. (2008). Assemblage-level responses of phyllostomid bats to tropical forest fragmentation: land-bridge islands as model system. *Journal of Biogeography*, *35*, 1711–1726. https://doi.org/10.1111/j.1365-2699.2008.01916.x.

Meyer, C. F. J., Struebig, M. J., & Willig, M. R. (2016). Responses of tropical bats to habitat fragmentation, logging, and deforestation. In C. C. Voigt, & T. Kingston (Eds.), *Bats in the Anthropocene: conservation of bats in a changing World* (pp. 63–103). New York: Springer Open.

Mittermeier, R. A., Myers, N., Robles Gil, P., & Mittermeier, C. G. (1999). *Hotspots: earth's biologically richest and most endangered terrestrial ecoregions*. Mexico D. F.: Cemex.

Montaño-Centellas, F., Moya, M. I., Aguirre, L. F., Galeón, R., Palabral, O. et al. (2015). Community and species-level responses of phyllostomid bats to disturbance gradient in the tropical Andes. *Acta Oecologica*, *62*, 10–17. https://doi.org/10.1016/j.actao.2014.11.002.

Moras, L. M. (2011). *Assembleia do morcegos (Mammalia, Chiroptera) e estrutura da paisagem: composição e uso de habitat em uma região de elevada altitude no sul de Minas Gerais*. , Lavras: Universidade Federal de Lavras.

Morrison, D. W. (1978). Foraging ecology and energetics of the frugivorous bat *Artibeus jamaicensis*. *Ecology, 59*, 716–723. https://doi.org/10.2307/1938775.

Moya, M. I., Montaño-Centellas, F., Aguirre, L. F., Tordoya, J., Martínez, J., & Galarza, M. I. (2008). Variación temporal de la quiropterofauna en un bosque de yungas en Bolivia. *Mastozoología Neotropical, 15*, 349–357.

Muscarella, R., & Fleming, T. H. (2007). The role of frugivorous bats in forest succession. *Biological Reviews, 82*, 573–590. https://doi.org/10.1111/j.1469-185X.2007.00026.x.

Myers, N., Mittermeier, R. A., Mittermeier, C., Fonseca, G. A. B., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature, 403*, 853–858. https://doi.org/10.1038/35002501.

Pacheco, S., & Cristóbal, L. (2009). Cambio de uso de la tierra y fragmentación en la Reserva de Acambuco. In A. D. Brown, P. G. Blendinger, T. Lomáscolo, & P. García Bes (Eds.), *Selva pedemontana de las Yungas. Historia natural, ecología y manejo de un ecosistema en peligro* (pp. 319–332). San Miguel de Tucuman Ediciones del Subtrópico.

Pereira, H. M., Leadley, P. W., Proença, V., Alkemade, R., Scharlemann, J. P. W. et al. (2010). Scenarios for global biodiversity in the 21st century. *Science, 330*, 1496–1501. https://doi.org/ 10.1126/science.1196624.

Peters, S. L., Malcolm, J. R., & Zimmerman, B. L. (2006). Effects of selective logging on bat communities in the South-eastern Amazon. *Conservation Biology, 20*, 1410–1421. https://doi.org/10.1111/j.1523-1739.2006.00526.x.

Pinto, N., & Keitt, T. H. (2008). Scale-dependent responses to forest cover displayed by frugivore bats. *Oikos, 117*, 1725–1731. https://doi.org/10.1111/j.1600-0706.2008.16495.x.

Presley, S. J., Willig, M. R., Saldanha, L. N., Wunderle Jr., J. M., & Castro-Arellano, I. (2009). Reduced-impact logging has little effect on temporal activity of frugivorous bats (Chiroptera) in Lowland Amazonia. *Biotropica, 41*, 369–378. https://doi.org/10.1111/j.1744-7429.2008.00485.x.

Rodríguez-Durán, A., & Feliciano-Robles, W. (2016). Conservation value of remnant habitat for Neotropical bats on islands. *Caribbean Naturalist, 35*, 1–10. http://ciudadanocientifico.org/dl/05-C158-Rodriguez.pdf

Rodríguez-Durán, A., & Otero, W. (2011). Species richness and diversity of a West Indian bat assemblage in a fragmented ecosystem. *Acta Chiropterologica*, *13*, 439–445. . https://doi.org/10.3161/150811011X624929.

Rodríguez-San Pedro, A., & Simonetti, J. A. (2015). The relative influence of forest loss and fragmentation on insectivorous bats: does the type of matix matter? *Landscape Ecology, 30*, 1561–1572. https://doi.org/10.1007/s10980-015-0213-5.

Russel, G. J., Diamond, J. M., Pimm, S. L., & Reed, T. M. (1995). A century of turnover: community dynamics at three timescales. *Journal of Animal Ecology*, *64*, 628–641. https://doi.org/10.2307/5805

Sala, O. E., Chapin III, F. S., Armesto, J. J., Berlow, E., Bloomfield, J. et al. (2000). Global biodiversity scenarios for the year 2100. *Science*, *287*, 1770–1774. https://doi.org/10.1126/science.287.5459.1770.

Sampaio, E., Kalko, E. K. V., Bernard, E., Rodríquez-Herrrera, B., & Handley Jr., C. O. (2003). A biodiversity assessment of bats (Chiroptera) in a tropical lowland rainforest of central Amazonia, including methodological and conservation considerations. *Studies on Neotropical Fauna and Environment*, *38*, 17–31. https://doi.org/10.1076/snfe.38.1.17.14035.

Sánchez, M. S. (2016). Structure of three subtropical bat assemblages (Chiroptera) in the Andean rainforests of Argentina. *Mammalia, 80*, 11–19. https://doi.org/10.1515/mammalia-2014-0084.

Schipper, J., Chanson, J. S., Chiozza, F., Cox, N. A., Hoffmann, M. et al. (2008). The status of the World's land and marine mammals: diversity, threat, and knowledge. *Science, 322*, 225–230. https://doi.org/10.1126/science.1165115.

Schulze, M. D., Seavy, N. E., & Whitacre, D. F. (2000). A comparison of the phyllostomid bat assemblages in undisturbed neotropial forest and in forest fragments of a slash-and-burn farming mosaic in Petén, Guatemala. *Biotropica*, *32*, 174–184. https://doi.org/10.1111/j.1744-7429.2000.tb00459.x.

Shiel, C., McAney, C., Sullivan, C., & Fairley, J. (1997). *Identification of arthropod fragments in bat droppings*. London: The Mammal Society.

Soriano, P. J., & Ochoa, J. G. (2001). The consequences of timber exploitation for bat communities in tropical America. In A. Fimbel, A. Grajal, & J. Robinson (Eds.), *The cutting edge: conserving wildlife in logged tropical forests* (pp. 153–166). New York: Columbia University Press.

Trevelin, L. C., Silveira, M., Port-Carvalho, M., Homem, D. H., & Cruz-Neto, A. P. (2013). Use of space by frugivorous bats (Chiroptera: Phyllostomidae) in a restored Atlantic forest fragment in Brazil. *Forest Ecology and Management, 294,* 36–143. https://doi.org/10.1016/j.foreco.2012.11.013.

Williams-Guillén, K., & Perfecto, I. (2011). Ensemble composition and activity levels of insectivorous bats in response to management intensification in coffee agroforestry systems. *PLoS One, 6*, e16502. https://dx.doi.org/10.13713332Fjournal.pone.0016502.

Williams-Guillén, K., Perfecto, I., & Vandermeer, J. (2008). Bats limit insects in a Neotropical agroforestry system. *Science, 360*, 70. https://doi.org/10.1126/science.1152944.

Willig, M. R., Patterson, B. D., & Stevens, R. D. (2003). Patterns of range size, richness, and body size in the Chiroptera. In T. H. Kunz, & M. B. Fenton (Eds.), *Bat Ecology* (pp. 580–621). Chicago: University of Chicago Press.

Willig, M. R., Presley, S. J., Bloch, C. P., Hice, C. L., Yanoviak, S. P. et al. (2007). Phyllostomid bats of Lowland Amazonia: effects of habitat alteration on abundance. *Biotropica*, *39*, 737–476. https://doi.org/10.1111/j.1744-7429.2007.00322.x.

Wilson, D. E., Ascorra, C. F., & Solari, S. (1996). Bats as indicators of habitat disturbance. In D. E. Wilson, & A. Sandoval (Eds.), *Manu, the biodiversity of southeastern Peru* (pp. 613–625). Lima: Editorial Horizonte.

Young, B. E., Stuart, S. N., Chanson, J. S., Cox, N. A., & Boucher, T. M. (2004). *Disappearing jewels: the status of New World amphibians*. Arlington: NatureServe.

Figure captions

Fig. 1. Studied localities in the Yungas Forests (shaded area), Northwestern Argentina. These included four well-preserved sites (white dots) and four disturbed sites (white squares). Localities: 1. Las Capillas (Jujuy); 2. Finca Las Capillas (Jujuy); 3. Río Las Conchas (Salta); 4. Metán (Salta); 5. Reserva Aguas Chiquitas (Tucumán); 6. El Cadillal (Tucumán); 7. Villa de Batiruana (Tucumán); 8. Villa de Escaba (Catamarca). For details see Appendix.

Fig. 2. Rank-abundance curves calculated as Log10(Pi) from the samples. The localities are listed from north to south and, for each of them, the type of site (well-preserved or disturbed) is indicated with superscript letters. Localities: LCP, Las Capillas; FLC, Finca Las Capillas; RLCH, Río Las Conchas; MET, Metán; AGCH, Aguas Chiquitas; ELC, El Cadillal; PAC, Villa de Escaba; ESC, Villa de Batiruana. Bat species: E.g, *Eumops glaucinus*; T.b, *Tadarida brasiliensis*; D.r, *Desmodus rotundus*; S.e, *Sturnira erythromos*; A.p, *Artibeus planirostris*; M.a, *Myotis albescens*; M.d, *Myotis dinellii*; D.e, *Dasypterus ega*; E.c, *Eptesicus chiriquinus*; E.f, *Eptesicus furinalis*; H.v, *Histiotus velatus*; L.b, *Lasiurus blossevillii*; L.c, *Lasiurus cinereus*; M.m, *Molossus molossus*; S.l, *Sturnira lilium*; M.r, *Myotis riparius*; C.a, *Chrotopterus auritus*; E.b, *Eumops bonariensis*; E.d, *Eptesicus diminutus*; P.n, *Promops nasutus*; M.k, *Myotis keaysi*; H.m, *Histiotus macrotus*; H.l, *Histiotus laephotis*.

Fig. 3. Principal component analysis of bat assemblages between well-preserved (black symbols) and disturbed sites (whithe symbols) in the Yungas Forests, Argentina. Localities: LCP, Las Capillas; FLC, Finca Las Capillas; RLCH, Río Las Conchas; MET, Metán; AGCH, Aguas Chiquitas; ELC, El Cadillal; PAC, Villa de Escaba; ESC, Villa de Batiruana. For details see Appendix.

Figures

Fig. 1

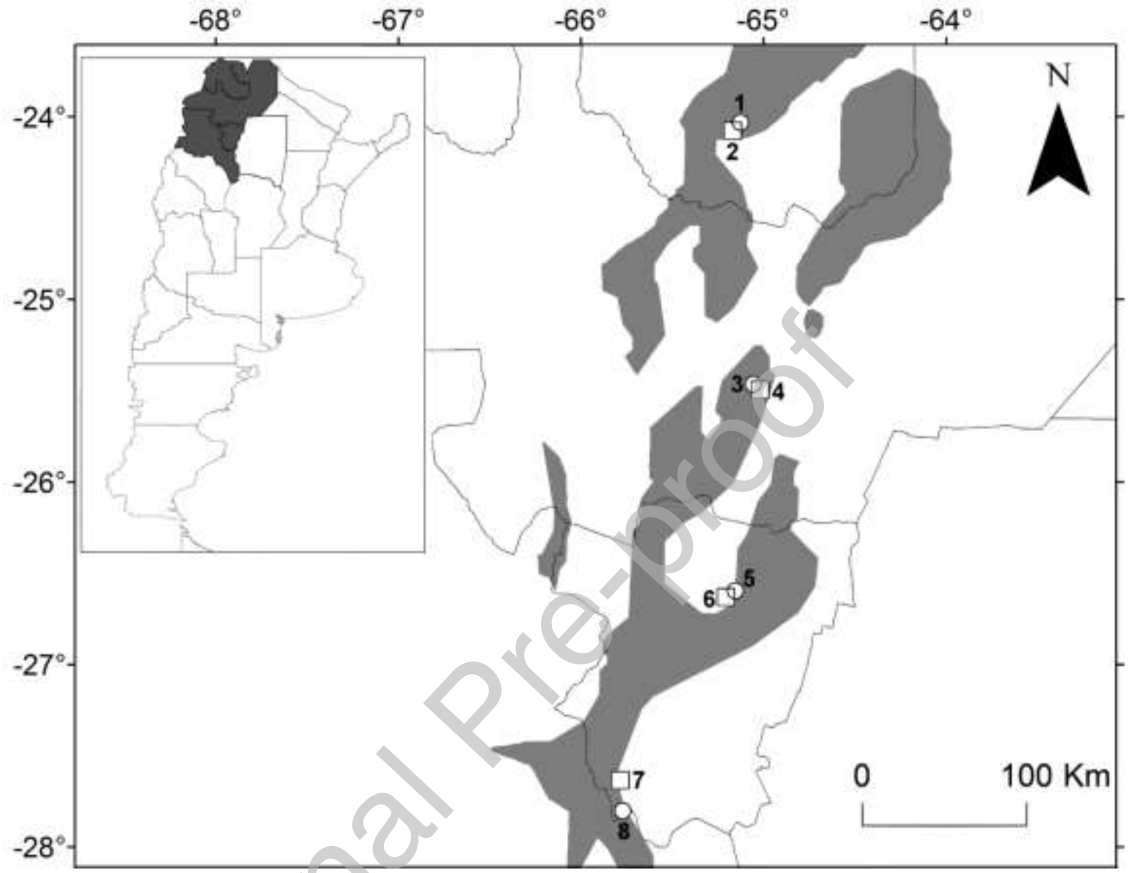


Fig. 2

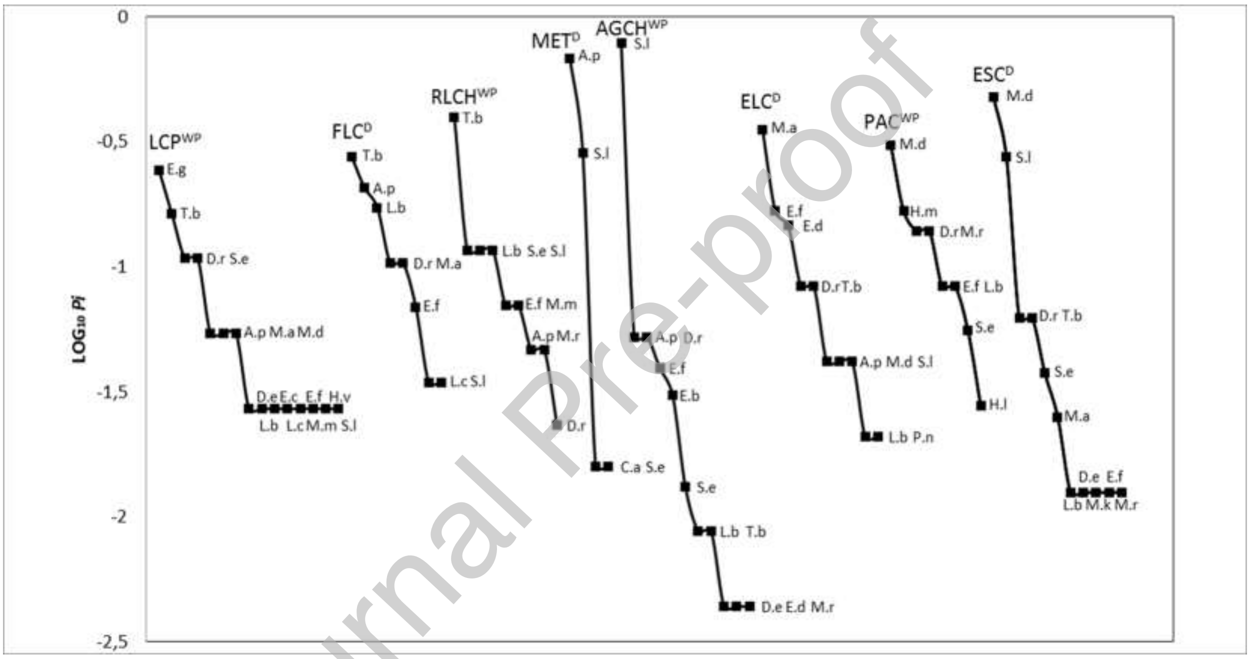
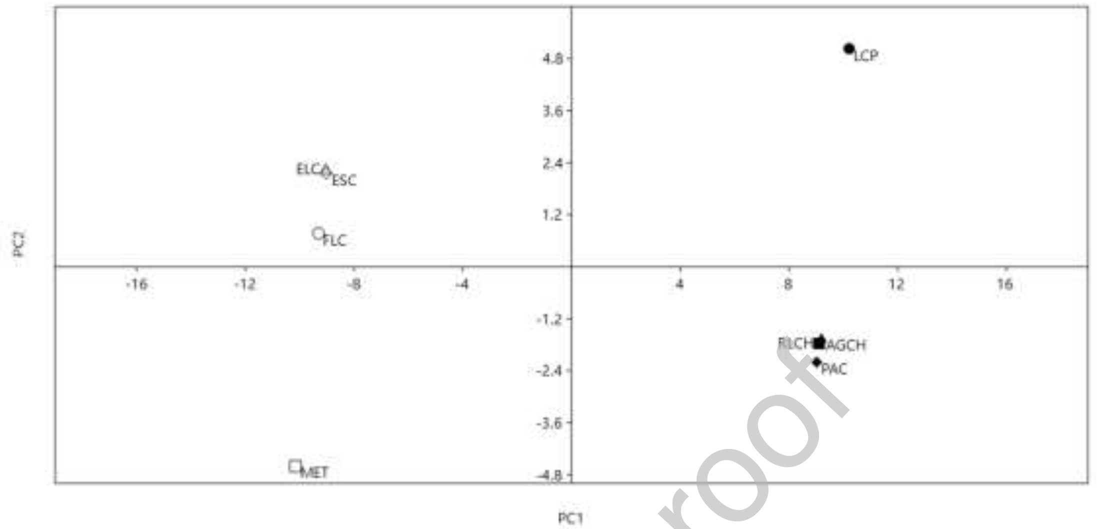

0
-0,5
-1
-1,5
-2
-2,5
LOG10 Pj
LCPWP
E.g
T.b
D.r S.e
A.p M.a M.d
D.e E.c E.f H.v
L.b L.c M.m S.l
FLCD
T.b
A.p
L.b
D.r M.a
E.f
L.c S.l
RLCHWP
T.b
L.b S.e S.l
E.f M.m
A.p M.r
D.r
METD
A.p
S.l
C.a S.e
AGCHWP
S.l
A.p D.r
E.f
E.b
S.e
L.b T.b
D.e E.d M.r
ELCD
M.a
E.f
E.d
D.r T.b
A.p M.d S.l
L.b P.n
PACWP
M.d
H.m
D.r M.r
E.f L.b
S.e
H.l
ESCD
M.d
S.l
D.r T.b
S.e
M.a
D.e E.f
L.b M.k M.r

Fig. 3


LCP
ELCA
ESC
FLC
ELCH
AGCH
PAC
MET
PC1
PC2
4.8
3.6
2.4
1.2
-1.2
-2.4
-3.6
-4.8
-16
-12
-8
-4
4
8
12
16

Tables

Table 1. Species of bats captured from eight sites of Yungas Forests, Argentina. The family, number of individuals in total and from each site, and the trophic guild are indicated for each species. The values of Chao 1, Shannon (H') and Simpson (D') diversity indexes are indicated for each site. The well-preserved sites are indicated in bold. Families: Phy, Phyllostomidae; Mol, Molossidae; Ves, Verpertilionidae. See the acronyms for the localities in Appendix. Trophic guilds are indicated as follows: Car, carnivorous; Fru, frugivorous; San, sanguivorous; F-F art, fast-flying arthropodophagous; S-F art, slow-flying arthropodophagous.

			Localities								
Species	Fam.	N	**LCP**	FLC	**RLCH**	MET	**AGCH**	ELC	ESC	**PAC**	TG
Chrotopterus auritus	Phy	1	-	-	-	1	-	-	-	-	Car
Artibeus planirostris	Phy	67	**2**	6	**2**	43	**12**	2	-	-	Fru
Sturnira erythromos	Phy	18	**4**	-	**5**	1	**3**	-	3	**2**	Fru
Sturnira lilium	Phy	228	**1**	1	**5**	18	**179**	2	22	-	Fru
Desmodus rotundus	Phy	34	**4**	3	**1**	-	**12**	4	5	**5**	San
Eumops bonariensis	Mol	7	-	-	-	-	**7**	-	-	-	F-F art
Eumops glaucinus	Mol	9	**9**	-	-	-	-	-	-	-	F-F art
Molossus molossus	Mol	4	**1**	-	**3**	-	-	-	-	-	F-F art
Promops nasutus	Mol	1	-	-	-	-	-	1	-	-	F-F art
Tadarida brasiliensis	Mol	42	**6**	8	**17**	-	**2**	4	5	-	F-F art
Dasypterus ega	Ves	3	**1**	-	-	-	**1**	-	1	-	F-F art
Eptesicus chiriquinus	Ves	1	**1**	-	-	-	-	-	-	-	S-F art
Eptesicus diminutus	Ves	8	-	-	-	-	**1**	7	-	-	S-F art
Eptesicus furinalis	Ves	27	**1**	2	**3**	-	**9**	8	1	**3**	S-F art
Histiotus laephotis	Ves	1	-	-	-	-	-	-	-	**1**	S-F art
Histiotus macrotus	Ves	6	-	-	-	-	-	-	-	**6**	S-F art
Histiotus velatus	Ves	1	**1**	-	-	-	-	-	-	-	S-F art
Lasiurus blossevillii	Ves	18	**1**	5	**5**	-	**2**	1	1	**3**	F-F art
Lasiurus cinereus	Ves	2	**1**	1	-	-	-	-	-	-	F-F art
Myotis albescens	Ves	24	**2**	3	-	-	-	17	2	-	S-F art
Myotis dinellii	Ves	53	**2**	-	-	-	-	-	38	**11**	S-F art

Myotis keaysi	Ves	1	-	-	-	-	-	-	1	-	S-F art
Myotis riparius	Ves	9	-	-	**2**	-	**1**	-	1	**5**	S-F art
Total individuals		565	**37**	29	**43**	63	**229**	48	80	**36**	
Total species		23	**15**	8	**9**	4	**11**	10	11	**8**	
Chao 1			**21.8**	8.5	**9**	4.98	**12**	10.2	15.9	**8**	
Shannon (H’)			**2.37**	1.87	**1.86**	0.75	**0.95**	1.92	1.54	**1.88**	
Simpson (D’)			**8.1**	5.64	**4.73**	1.82	**1.61**	5.14	3.21	**5.63**	

Table 2. Factor loadings of variables for the first two PCs. Variables: SR, species richness; H’, Shannon diversity index; D’, Simpson diversity index; NF, proportion of native forest; DE, density of edge habitat.

Variables	PC 1	PC 2
SR	0.147	0.858
H'	0.015	0.127
D'	0.064	0.472
NF	0.987	-0.160
DE	-0.002	0.0003
Total variance	88.83%	8.49%