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Article

DIVERSITY AND SEASONAL CHANGES OF PHYLLOSTOMID BATS ASSEMBLAGES IN MONTANE AND PREMONTANE FORESTS IN THE CENTRAL PERUVIAN YUNGAS

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ABSTRACT. The Yungas of central Peru constitutes an ecosystem with an interesting diversity of wildlife species, among which the communities of phyllostomid bats are not yet well known. Phyllostomid bats are considered a good bioindicator, due to their abundance and taxonomic stability. In this study, we provide a better understanding of patterns of phyllostomid assemblages at two elevations and during two seasons in the Central Peruvian Yungas. We sampled phyllostomid bats with ground-level mistnets at one site in the montane forest (the higher elevation) and at one site in the premontane forest (the lower elevation) in Chanchamayo, Junín, during the dry and wet seasons. We captured 297 individuals belonging to 31phyllostomid species and five guilds. Species richness was higher overall at the premontane site. The species richness and relative abundance at the premontane site were higher in the dry season, while the montane site did not show seasonal differences. Phyllostomid assemblages at the two sites shared four species, while 20 species were captured only at the premontane site, and seven only at the montane site. Further studies are needed to obtain a better understanding of the entire bat community and species with altitudinal movements. We recommend a special focus on aerial insectivores. Our study contributes to a better understanding of phyllostomid bat assemblages and their distribution in the Central Peruvian Yungas. We hope this information will become an important piece of biodiversity information for the region that will lead to improved decision-making. The richness and relative abundance of the bat species recorded in this study as well as the presence of *Vampyressa melissa* and *Gardnerycteris koepckeae*, which are categorized by the Peruvian Government as Vulnerable and Critically Endangered, respectively, demonstrate the need for conservation efforts to protect the forest of Chanchamayo, Junín, especially in the montane areas. In addition, the information generated by this study can serve as a baseline for future comparisons to examine possible effects of climate change on species distributions that may force some species to move to higher elevations.

RESUMEN. DIVERSIDAD Y CAMBIOS ESTACIONALES DE ENSAMBLAJES DE MURCIÉLAGOS FILOSTÓMIDOS EN BOSQUES MONTANO Y PREMONTANOS EN LAS YUNGAS CENTRALES DEL PERÚ. Las Yungas del centro del Perú constituyen un ecosistema con una interesante diversidad de especies de fauna, entre las cuales aún no se conocen bien las comunidades de murciélagos filostómidos, que son considerados como buenos bioindicadores debido a su abundancia y estabilidad taxonómica. En este estudio brindamos una mejor comprensión de los patrones de los ensamblajes de filostómidos en dos elevaciones y durante dos temporadas en las Yungas Centrales en Perú. Muestreamos murciélagos filostómidos con redes

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de niebla a la alturadel suelo en un sitio de bosque montano (elevación más alta) y en un sitio de bosque premontano (elevación más baja) en Chanchamayo, Junín, durante las estaciones seca y húmeda. Hemos capturado 297 individuos que pertenecieron a 31 especies de filostómidos y cinco gremios. La riqueza de especies fue mayor en el bosque premontano en general. La riqueza y la abundancia relativa en el bosque premontano fueron mayores durante la estación seca, mientras que el bosque montano no mostró diferencias estacionales. Los ensamblajes de filostómidos en ambos sitios compartieron cuatro especies, mientras que 20 especies solo fueron capturadas en el bosque premontano y siete solo en el bosque montano. Se necesitan más estudios para obtener una mejor comprensión de toda la comunidad de murciélagos y de los movimientos altitudinales de las especies. Recomendamos un enfoque particular en los insectívoros aéreos. Nuestro estudio contribuye a una mejor comprensión de los ensamblajes de murciélagos filostómidos y su distribución en las Yungas del centro del Perú. Esperamos que esta información se convierta en una pieza importante de información sobre biodiversidad para la región que conduzca a una mejor toma de decisiones. La riqueza y abundancia relativa de las especies de murciélagos registradas en este estudio así como la presencia de *Vampyressa melissa* y *Gardnerycteris koepckeae*, clasificadas por el Gobierno peruano como Vulnerable y En Peligro Crítico, respectivamente, demuestran la necesidad de esfuerzos de conservación para proteger el bosque de Chanchamayo, Junín, especialmente en las zonas montañosas. Además, la información generada por este estudio puede servir como línea de base para futuras comparaciones para examinar los posibles efectos del cambio climático en la distribución de especies que pueden obligar a algunas especies a trasladarse a elevaciones más altas.

Key words: Chanchamayo, Chiroptera, elevational gradient, guilds, Junín.

Palabras clave: Chanchamayo, Chiroptera, gradiente altitudinal, gremios, Junín.

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INTRODUCTION

Bats are one of the most diverse groups of mammals, with 192 species reported for Peru (Pacheco et al. 2009; Velazco et al. 2010; Medina et al. 2014; Velazco et al. 2014; Medina et al. 2016; Velazco & Patterson 2019; Velazco 2021). Among bats, phyllostomids have been considered good bioindicators because of their abundance, taxonomic stability, and responses to environmental disturbances (Fenton et al. 1992; Medellín et al. 2000; Jones et al. 2009; García-Morales et al. 2013). They are important for ecosystem function, and provide ecological services such as seed dispersal by frugivores, pollination by nectarivores (Castro-Luna & Galindo-González 2012; Kasso & Balakrishnan 2013; Lacher et al. 2019), and pest control by insectivores, saving millions of dollars annually in the agricultural industry (Mass et al. 2015; Lacher et al. 2019).

Variation in diversity across elevational gradients has been widely reported for different taxa (Terborgh 1977; Graham 1983; Patterson et al. 1996, 1998; Sánchez-Cordero 2001; Linden et al. 2014; Dreiss et al. 2015; Willig & Presley 2015; Montaño-Centellas & Garitano-Zavala 2015; Capaverde et al. 2018; Montaño-Centellas et al. 2021). For bats, the highest species richness and relative abundances have been generally reported at low elevations, declining with increased elevation (Graham 1983; Patterson et al. 1996, 1998). Patterson et al. (1998) found highly nested assemblages across elevations in southeastern Peru. Factors related to elevation, such as food availability and habitat complexity, are known to limit the occurrence of the species (Graham 1983; Capaverde et al. 2018). In addition, the bat abundance, guild richness, and assemblage composition across elevational gradients have been attributed to climatic variation as well as to historical factors (e.g., speciation, immigration, and extinction) and contemporary ecological influences (Graham 1983; Lomolino 2001; McCain 2007; Mancini et al. 2019). Specifically, bat species richness variation with elevation has been found to correlate with temperature and water availability, showing increased richness when both factors increase, as well as a mid-elevation richness peak when the environment is dry at the lowest elevation (McCain 2007). Only highly adaptable species have been found to live in

areas with low temperatures. Living in such areas necessarily involves a higher energetic cost of thermoregulation (Graham 1983; Patterson et al. 1996).

Seasonality, in the form of dry and wet seasons, has been found to affect the diversity and composition of bat communities (Sánchez-Cordero 2001; García-García & Santos-Moreno 2014; Cisneros et al. 2015), as well as their geographic distribution and ecological interactions (MacArthur 1984; Beja et al. 2010; Cisneros et al. 2015; Ferreira et al. 2017). Frugivorous and insectivorous bats show increased capture rates and richness during the wet season (Williams-Guillén et al. 2008; Ferreira et al. 2017). The increase in frugivorous bat species during the wet season is thought to coincide with fruiting peaks (between July and December in Peru, Reynel 2012). The scarcity of food resources during the dry season presents a challenge to species with specialized diets (e.g., *Artibeus* and *Ficus* fruits Handley & Leigh 1991), affecting their movement patterns and resulting in altitudinal migrations (Montalvo 1997; Hsiung et al. 2018).

The Peruvian Yungas, occupying approximately 14% of the land area of Peru, is an area biologically rich region and a sensitive ecosystem with one of the highest rates of endemism in flora and vertebrates in the country (Koopman 1978; Patterson et al. 1996; Aguilar & Reynel 2009; Pacheco et al. 2009; Tovar Narváez et al. 2010). Despite this, the biodiversity of the Central Peruvian Yungas is not well known. According to Tovar Narváez et al. (2010), the Central Peruvian Yungas include areas of premontane (800–1 500 meters above sea level, hereafter m.a.s.l.) and montane forest (1 500–3 500 m.a.s.l.). In terms of forest vegetation, the premontane forest does not differ significantly from what is found in lowland forest areas, unlike montane forest vegetation, which is characterized by the presence of several endemic species (Aguilar & Reynel 2009). The Central Peruvian Yungas are characterized by two seasons based on variations in rainfall. The premontane forest exhibits differences in vegetation composition and diversity between seasons, while these differences are diffuse in the montane forest (Reynel 2012). Unfortunately, the Central Peruvian Yungas are experiencing high deforestation pressure (Antón & C. Reynel 2004). Between 2000 and 2013, 93 000 hectares were deforested in Junín (MINAGRI & MINAM 2014). This pattern has continued, with 21 900 hectares of forest lost in 2020 (Global Forest Watch 2021).

To date, studies of bats in the Central Peruvian Yungas have focused on issues such as diversity inside and outside of natural protected areas (Vivar 2006; Mena 2010; MINAM 2012; Refulio 2015; Arias et al. 2016; Arias & Pacheco 2019; Guevara-Torres et al. 2021), reproductive patterns (Rivero-Monteagudo et al. 2021), trophic ecology (Arias & Pacheco 2019; Pellón et al. 2021) mineral concentrations in tissue (Ramos-H et al. 2021), and the influence of seasonality on bat diversity and composition (Arias et al. 2016; Zegarra 2019). The present study addresses the following issues in the Central Peruvian Yungas: (1) the taxonomic diversity, assemblage, and guild composition of phyllostomid bats in premontane versus montane forests, and (2) the seasonal effects on phyllostomid bat species diversity and composition in premontane versus montane forests. We hope this information will become an important piece of biodiversity information for the Central Peruvian Yungas that will serve as base line information for future studies and lead to improving decision-making in this region.

MATERIALS AND METHODS

Study sites

Our study took place at two locations, one in the premontane forest and one in the montane forest, 6.5 km apart on different mountains in the Central Peruvian Yungas. Both sites are located in the district of San Ramon, Chanchamayo Province, Junín Department (**Fig**. 1), and have large expanses of forest adjacent to agricultural lands. Vegetation at both sites has been monitored and described by Antón & C. Reynel (2004).

The montane site, Puyu Sacha Forest (75° 25’ 44” W, 11° 5’ 44” S), is a private conservation concession owned and managed by the Peruvian conservation NGO Asociación Peruana para la Promoción del Desarrollo Sostenible (APRODES). Vegetation plots of one hectare at this site show that the most abundant tree species belong to the Lauraceae, Melastomataceae, Moraceae, Myrtaceae, and Burseraceae families (Antón & C. Reynel 2004). Puyu Sacha is considered to have some of the highest tree diversity in the Andean region of Peru, with 147 species per hectare (Antón & C. Reynel 2004). Our sampling transect was located on a hillside trail at an altitude of 2 200 m.a.s.l.

The premontane site, Fundo La Génova (75° 22’ 15” W, 11° 5’ 9” S), is a research station of the Universidad Nacional Agraria La Molina. The vegetation plots in Fundo La Génova have shown that the most abundant and species-rich tree families are Lauraceae and Moraceae (Antón & C. Reynel 2004). Our sampling transect at in Fundo La Génova was located on the hilltop of a well-conserved part of the forest in the area, at 1 200 m.a.s.l.

In the Peruvian Yungas there isa dry season and a wet season. The months with the highest precipitation in the district of San Ramón are October to March, according to the National Service of Meteorology and Hydrology of Peru (SENAMHI). We considered these months as the wet season, although a strict timeline for the two seasons is not practical due to bioclimatic variations, as well as large-scale events

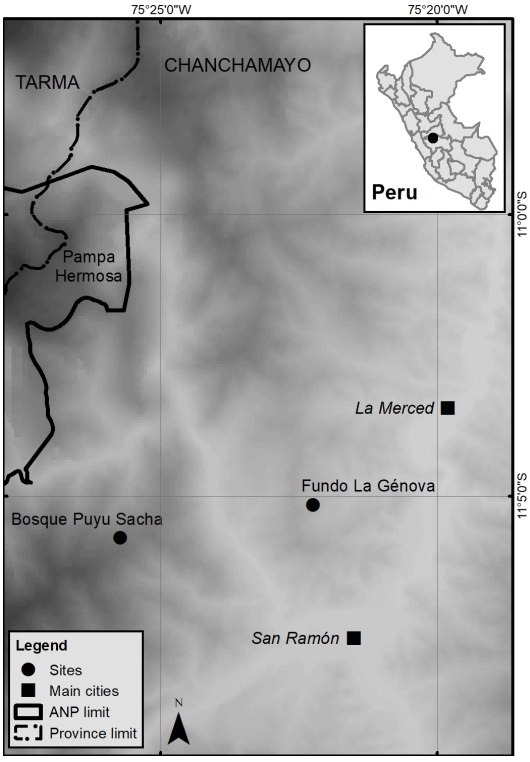

Fig. 1. Location of the study sites.

such as El Niño and the Intertropical Convergence Zone, and only general trends can be described (Reynel 2012). We conducted data collection during the dry season (May and June) and the wet season (November and December) of 2010. The seasonal sampling periods per site were separated by approximately five months. We completed a total of 36 sampling nights during this study, with a varying number of nights at each sampling site and in each season due to inclement weather (**Table** 1).

Study design

The study design included repeated measurements, using the season as a within-site factor and premontane versus montane forest as site categories. For bat captures, we used a combination of 6 m x 2.5 m and 12 m x 2.5 m mistnets, for a total of 225 m^2 of mistnets area per night. Mistnets were placed equally 60 m apart along a transect of 300 m length and 20 m apart in a transect of 100 m in length at Puyu Sacha and Fundo La Génova, respectively. We established transects of different lengths at the two sites due to differences in forest structure and topography at each site. We kept the mistnets active from 18:00 to 24:00 and checked them every hour. We followed Costa Straube & Bianconi (2002) to calculate the capture effort, resulting in a total of 48 600 m^2 per hour for the entire study. Mistnets are known to provide an accurate representation of the phyllostomid community, but not for species of other bat families (Kalko 1998). Both study sites had anthropogenically modified areas in their surroundings, with greater intensity in the premontane forest (Fig. S1) and the presence of agricultural areas ranging in size from 0.4 to 3.94 hectares, while patches of deforested and agricultural areas near Puyu Sacha, mostly on the west side, ranged in size from 1.1 to 6.4 hectares (Fig. S2).

Bat captures

The field team checked the mistnets, measured the captured individuals (forearm length, weight), and recorded their age, sex, and reproductive status. To avoid including recaptures in the analysis, we marked the individuals in a non-permanent way with a hairclip on the dorsal area (Harvey & Gonzalez Villalobos 2007; Klingbeil & Willig 2009; Helbig-Bonitz et al. 2014). Species were identified in the field using identification guides and taxonomic keys (Pacheco & Solari 1997; Giannini & Barquez 2003; Giannini & Kalko 2004; Gardner 2008; Aguirre et al. 2009). Each captured individual was assigned to a guild based on habitat type (background cluttered space, highly cluttered space, uncluttered space), feeding mode (aerial or gleaning), and diet (carnivores, frugivores, insectivores, nectarivores, omnivores, piscivores, or sanguivores) using the categorization presented by Kalko (1997), also presented in Schnitzler and Kalko (1998). The term clutter refers to "mechanical as well as perceptual problems for bats" (Kalko 1997). If a species we recorded was not listed in either Kalko (1997) or Schnitzler & Kalko (1998), we based our guild assignment on species of the same genus and guilds assigned by Scheiner et al. (2017). Individuals that could not be identified in the field were collected following guidelines provided by the American Society of Mammalogists (Gannon et al. 2007) and preserved in alcohol. We compared the specimens with collections of the Museums of Natural History at both the Universidad Nacional Mayor de San Marcos (MUSM) and the Universidad Nacional San Agustín in Arequipa (MUSA). This research and collection of specimens were conducted under the permit provided by the Peruvian government Resolución Directoral No. 0555- 2010-AG-DGFFS-DGEFFS.

Data analysis

We generated accumulation curves plotting recorded species against the cumulative number of individuals captured to evaluate the completeness of the sampling per site and season. We estimated phyllostomid species richness using the Chao1 index. We performed the curves in the R environment (R Core Team 2020) and relied on the R package "vegan" (Oksanen et al. 2005) and its "specaccum" function.

We estimated the capture rate (number of individuals captured per square meter and hour) for each site and season as a standard measure of relative abundance. We also generate drank abundance curves using species capture rates for analyzing species abundance distribution. Seasonal rank abundance curves per site were compared with Kolmogorov-Smirnov two-sample tests. We analyzed the shared and unique species between sites and seasons to evaluate the difference in the bat assemblage.

RESULTS

We recorded 31 species of phyllostomid bats and 297 individuals in this study (**Table** 1). We col-

lected 46 specimens deposited in the collections of the Universidad Nacional Mayor de San Marcos (MUSM), the Universidad Nacional San Agustín in Arequipa (MUSA), and the Centro de Ornitología y Biodiversidad (CORBIDI). The premontane site showed greater species richness 27.1 + 3.64 (Chao1 richness estimator + standard error) and relative abundance (0.009 ind/h.m^2) than the montane site (15.46 + 7.13 species and 0.0035 ind/h.m^2). We registered one individual recaptured from the species *Sturnira oporaphilum* at the montane site. The species *Carollia perspicillata*, *Glossophaga soricina*, and *Carollia brevicauda* were the most frequently captured species across sites and seasons. Species belonged to five guilds: 1) highly cluttered space gleaning insectivores, hereafter insectivores; 2) highly cluttered space gleaning sanguivores, hereafter sanguivores; 3) highly cluttered space gleaning frugivores, hereafter frugivores; 4) highly cluttered space gleaning nectarivores, hereafter nectarivores, and 5) highly cluttered space gleaning omnivores, hereafter omnivores. Accumulation curves for phyllostomid species per site approached the asymptote by the end of the sampling period, showing that capture effort allowed a strong representation of the phyllostomid bat assemblages present (**Fig**. 2). The number of species registered during this study represents 83.5% of the expected species richness estimated using the Chao1 index (37.1 species + 6.06 standard error).

In terms of seasonal variation, the premontane site showed four additional species and a higher capture rate during the dry season (**Fig**. 3). At the montane site, we registered only one additional species and similar capture rates between seasons. We did not detect any differences between the seasonal rank-abundance curves at the two sites (Kolmogorov-Smirnov two-sample tests, premontane: D = 0.37, p = 0.16, montane: D = 0.43, p = 0.5; Table S1).

When we analyzed bat assemblages at the premontane and montane sites, we found that four phyllostomid species were shared by both sites (**Fig**. 4), representing 16.7% of the species at the premontane site and 36.4% at the montane site. Twenty species were captured only in the premontane forest and seven species were captured only in the montane forest (**Fig**. 4). In the premontane site, some species such as *Enchisthenes hartii*, *Sturnira erythromos*, *Sturnira giannae* (previously *Sturnira lilium*), and *Carollia brevicauda,* all of which have at least four individuals registered, were captured only during one season. At the montane site, seven of the eleven species occurred only during one season. *Anoura aequatoris* and *Platyrrhinus masu,* each with more than four individuals, were only captured during the wet season. *Gardenycteris koepckeae* (previously *Mimon koepckeae*) was only captured during the dry season.

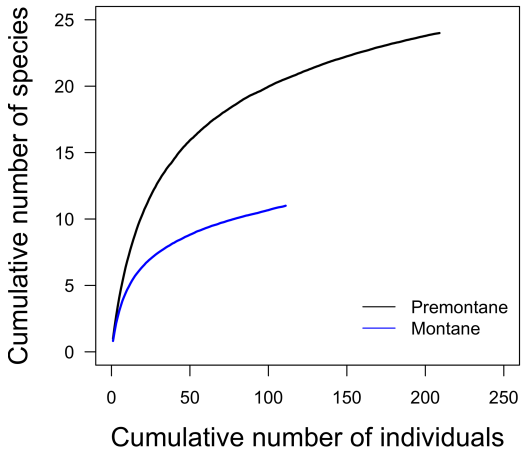

Fig. 2. Accumulation curves (individual-based) for both seasons in Fundo La Génova (premontane forest) and Bosque Puyu Sacha (montane forest).

In terms of guild richness and capture rates between sites and seasons, we found that frugivores and nectarivores were the most captured groups at both sites in terms of richness (**Fig**. 5A) and capture rate (**Fig**. 5B). The sanguivore *Desmodus rotundus* was only recorded in the montane forest, and the omnivore *Phyllostomus hastatus* was only recorded in the premontane forest (**Fig**. 5). The capture rate was higher in the premontane than the montane site for most guilds (**Fig**. 5). In terms of seasons, we found fewer species at the premontane site during the wet season and lower capture rates for nectarivores in the dry season. In contrast, we found a higher richness of frugivores and nectarivores at the montane site in the wet season than in the dry season (**Fig**. 5A). We are not able to draw strong conclusions about other guilds because their capture rates per season were very low.

DISCUSSION

Our study sites had some similarities with other areas of the Central Peruvian Yungas in terms of the species present at the two elevations (Mena 2010; Vivar 2006; MINAM 2012; Hurtado et al. 2014a; Refulio 2015). Our results fit a pattern of reduction of species richness and relative abundance with increased elevation found in previous studies (Graham

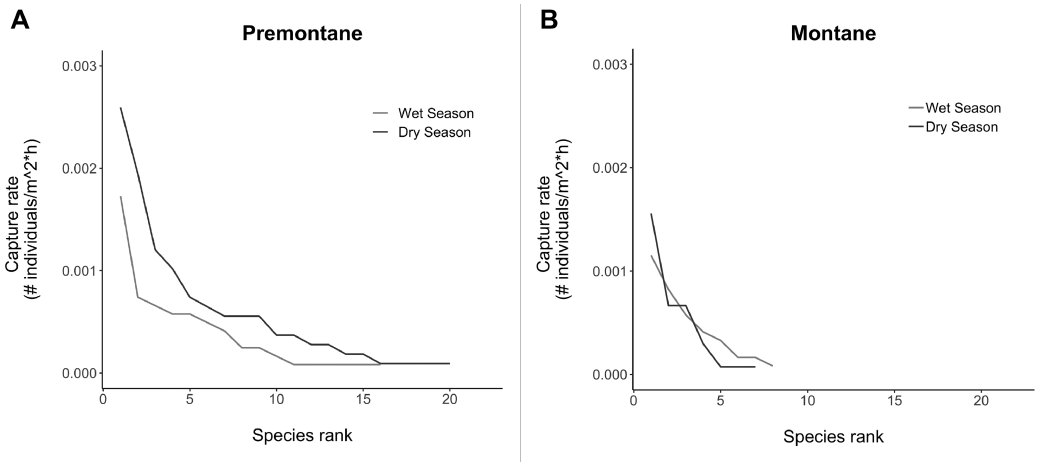

Fig. 3. Rank-abundance curves for each site and seasons.

Table 1

Capture effort, species richness, and number of individuals captured for the Phyllostomidae family, estimated richness, and capture rate during the sampling period. FG = Fundo La Génova; PS = Bosque Puyu Sacha; SE = standard error.

Locality	Replicates (sampling nights)	Capture effort ($h.m^2$)	Species richness	Number of captures	Chao1	SE	Capture rates ($ind/h.m^2$)
FG wet	9	12 150	16	77	33.77	23.33	0.0063
FG dry	8	10 800	20	129	26.21	7.50	0.0119
FG	17	22 950	24	206	27.11	3.64	0.009
PS wet	9	12 150	8	45	8.24	0.72	0.0037
PS dry	10	13 500	7	46	9.94	4.36	0.0034
PS	19	25 650	11	91	15.46	7.13	0.0035
Total	36	48 600	31	297	34.48	4.79	0.0061

1983; Patterson et al. 1996, 1998). In terms of seasonality, the premontane site showed higher species richness and capture rates during the dry season, while we did not find seasonal differences at the montane site.

In terms of capture rates, *Carollia perspicillata* and *Glossophaga soricina* were the most abundant species for the entire study; however, they were only captured at the premontane site. According to the scientific literature, these species are not distributed higher than 1700 and 1900 m.a.s.l., respectively, as previously reported for the Peruvian Yungas (Graham 1983; Patterson et al. 1996). *Sturnira erythromos*, the third most captured species, was present in both sites but with a higher number of captures at the montane site, similar to findings of Giannini (1999), where *S. erythromos* dominated higher elevations in an elevational gradient in Argentina. We also registered two species of the genus *Anoura* (*Anoura geoffroyi, A. aequatoris*) in the montane forest. These species are known to be nectarivores but were reported by Graham (1983) to feed on insects too providing them diet flexibility (Muchhala & Jarrin-V 2002) to fill their energetic requirements. In addition, the large body size of *A. geoffroyi* has been suggested as advantageous for thermoregulation at higher elevations and lower temperatures (Graham 1983; Aguirre et al. 2016).

The species assemblage from the montane site did not represent a subset of the premontane assemblage, and thus contrasted with the nested pattern found across the elevation gradient by Patterson et al. (1998). In our study, the sampling locations were not on the same slope side of the mountain, which represents an additional effect to consider in the differences in species composition. Because

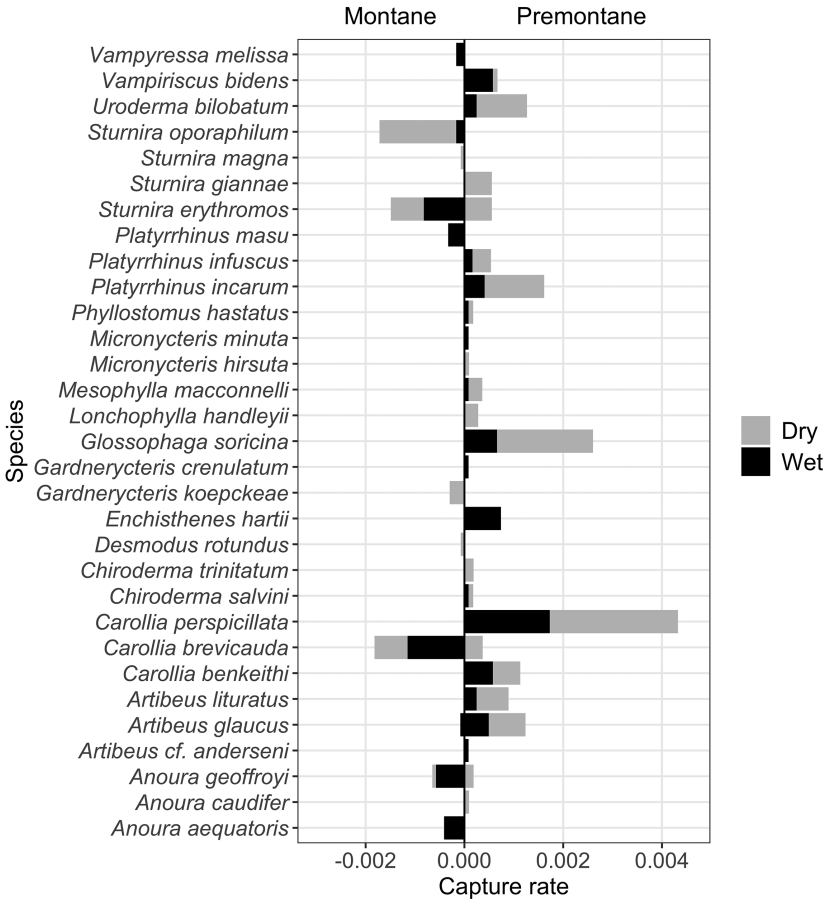

Fig. 4. Capture rates at each site and season.

the sites are 6.5 kilometers apart, it is very unlikely individuals would fly between sites, and therefore our results are unlikely to provide information about the altitudinal movements of the same population. However, our results are valuable in illustrating examples of characteristic phyllostomid bat assemblage at both elevation areas.

In terms of seasonal differences in richness and capture rates, the patterns we found differ from studies in México, Panamá, and Brazil, where seasonal effects were found with increases in species richness and capture rates during the wet season (Sánchez-Cordero 2001; Ferreira et al. 2017; Meyer & Kalko 2008). By paying attention to species-specific responses to seasonality, which can be obscured when analyzing community-wide parameters such as species richness and relative abundance, we found some particular patterns. Among the most captured species, some show a different pattern from the general pattern: *Carollia perspicillata* did not show strong differences in capture rates among seasons in the premontane forest (Table S1), and for *Enchisthenes hartii* there were no records during the dry season, and it was the second most captured species during the wet season. *Sturnira oporaphilum* went from being the most abundant species during the dry season to one of the least captured species during the wet season at the montane site. Previous work has reported that frugivorous phyllostomids can be flexible and follow changes in the availability of their preferred food resources across different temporal and spatial scales (Sánchez et al. 2012). Low capture rates or the absence of captures of some species during a season could be explained by their migratory ability. For the particular case of species of the genus *Sturnira*, Giannini (1999)

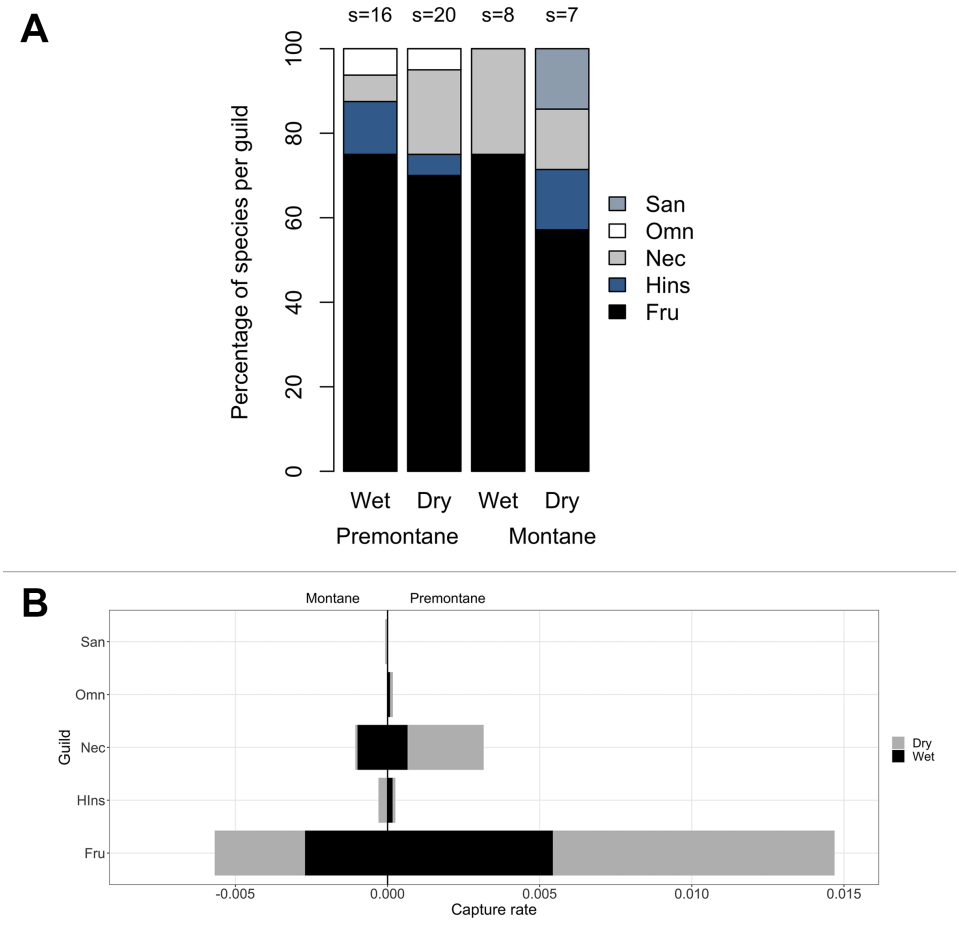

Fig. 5. (A) Richness of guilds and (B) guilds capture rates by season in study sites.s = species richness;HIns = highly cluttered space gleaning insectivores;San = highly cluttered space gleaning sanguivores; Fru = highly cluttered space gleaning frugivores; Nec = highly cluttered space gleaning nectarivores; Omn = and highly cluttered space gleaning omnivores.

reported migratory movements across the mountain range following fruiting plants, which could explain seasonal differences in captures. We did not find studies related to a seasonal difference in the number of captures for *Enchisthenes hartii*. In the case of *Carollia perspicillata*, although it has been reported as a suspected migrant species (Krauel & McCracken 2013), it has also been reported that its diet varies according to the food resources available at each season (Mello et al. 2004), so making it possible that the species remains in the same location throughout the seasons.

Some species we captured provide information on how habitat quality can affect bat communities. *C. perspicillata* and *G. soricina*, the two most abundant species in the study, are reported to be perturbation-tolerant species (Medellín et al. 2000). Their high capture rate in the premontane site may be a reflection of some degree of perturbation in this area since Fundo La Génova extensively uses for citric plantations and other agricultural activities (Fig. S1). In the montane forest (Fig. S2), we registered one individual of *Vampyressa melissa*, a species categorized as vulnerable by the IUCN (Ramirez-Chaves et al. 2015) and the Peruvian Government (N° 004-2014-MINAGRI). Insectivores, such as species of the genus *Gardnerycteris*, can be an indicator of a healthy ecosystem because they have been reported to be perturbation-sensitive species (Medellín et al. 2000) and occur in less modified landscapes (Cisneros et al. 2015). The three individuals of *Gardnerycteris koepckeae* registered in Puyu Sacha were identified

as *Mimon crenulatum* at the time of their capture. However, the lack of a dorsal line and the measurements of specimens coincide with the species description done after conducting fieldwork for this study (Hurtado et al. 2014a; Hurtado & Pacheco 2014b; Hurtado & D'Elia 2018). *G. koepckeae* is considered Data Deficient by the IUCN (Velazco & Aguirre 2019) and Critically Endangered by the Peruvian Government (D.S. N° 004-2014-MINAGRI). The record of these two protected species underscores the need to engage in conservation efforts to protect the forest areas in the district of San Ramón, especially in montane areas.

We recognize the limitations of our study due to the small number of spatial and temporal replicates. In addition, our sample size does not allow inferences about the effects of elevation and seasonality for most of the guilds found. Furthermore, future evaluations should include additional techniques such as acoustic monitoring (Yoh et al. 2020), harp trapping, and mist nets at the canopy level to provide a more comprehensive characterization of the entire bat community. To study possible migratory events and detect altitudinal movements with a higher level of certainty, future studies should sample the same mountainside. Also, the use of stable isotopes (Erzberger et al. 2011) would give new insights and information related to the altitudinal migration and species distribution in a montane and premontane forest.

CONCLUSIONS

The patterns of species richness, relative abundance, and assemblage composition observed in this study among two sites at different elevations and across seasons contribute to the available information about the diversity and seasonal variations in bat assemblage composition in areas of the Central Peruvian Yungas. The richness and relative abundance of the bat species registered in this study, as well as the presence of *Vampyressa melissa* and *Gardnerycteris koepckeae*, which are categorized as Vulnerable and Critical Endangered, respectively, by the Peruvian Government, indicate the need to undertake conservation efforts to protect the forest areas in the district of San Ramón district, especially in itsfor the montane areas. The information generated can be used to inform decision-makers in the region. It can also serve as a baseline for future comparisons to study possible effects of climate change in the montane areas that could generate changes in bat assemblages and species distribution along the elevational gradient, by forcing some species to move the mountains. We encourage others to continue to study the bat diversity in this important region of Peru, and expand methods to register aerial insectivores for which the information is scarce.

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