VARIATION IN VEGETATION COVER AFFECT THE HERPETOFAUNA ASSEMBLY COMPOSITION AT THE SERRA AZUL, EASTERN AMAZON

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Abstract: The impacts of landscape alteration on herpetofauna assemblages can have negative consequences in the fauna composition, related to changes in the distribution and species diversity. In this study was evaluated the effect of vegetation in the composition of the herpetofauna community in a fragmented landscape of eastern Amazon, specify in the Serra Azul region, located in the Lower Amazon, municipality of Monte Alegre on Pará State. We used two sampling methods: time-constrained searches and pitfall traps with drift fences. Sampling occurred in four localities with different land use history and vegetation cover. The sampling occurred during the rainy and dry seasons between the years 2013-2014, twice on begin rainy and once on begin dry, totaling a sampling effort of 120 hours-catcher and traps 1.912 hours-bucket. We record 23 species of anurans and 27 species of reptiles (12 lizards, 12 snakes, two turtles and one alligator). The species accumulation curve tended to stabilize. The richness of species estimated in this study was 71 (± 4.74). The richness of the community was higher in weir localities and crops area and lower in forest and primary forest edge localities.

Keywords: Amazonian forest, Amphibian, Lower Amazon, Reptiles, Species richness.

A variação na cobertura da vegetação afeta a composição da estrutura da herpetofauna na Serra Azul, Amazônia Oriental

Resumo: O efeito da alteração da paisagem sobre a herpetofauna pode gerar consequências negativas na composição da fauna, relacionadas a mudanças na distribuição e diversidade de espécies. Neste estudo foi avaliado o efeito da vegetação sobre composição da comunidade de herpetofauna na floresta tropical, em paisagem fragmentada na Amazônia Oriental, especificamente na região da Serra Azul, localizada no município de Monte Alegre, no Estado do Pará. Utilizamos dois métodos de amostragem: busca visual limitada por tempo e armadilha de interceptação e queda com cerca guia. A amostragem ocorreu em quatro localidades de coleta com diferentes históricos de uso da terra, durante as duas estações anuais chuva e seca entre os anos 2013-2014, totalizando um esforço de amostragem de 120 horas-coletor e armadilhas de 1.912 horas-balde. Registramos 23 espécies de anfíbios (anuros) e 27 espécies de répteis (12 lagartos, 12 cobras, duas tartarugas e um jacaré). A curva de acumulação das espécies tendeu a estabilizar. A riqueza de espécies estimada neste estudo foi de 71 (± 4,74). A riqueza da comunidade foi maior nas localidades do açude e área de cultivo e menor em localidades de florestas e bordas de florestas primárias.

Palavras-chave: Anfíbios, Baixo Amazonas, Floresta amazônica, Riqueza de espécies, Répteis.

Introduction

The effects of habitat loss as a result from environmental changes and the fragmentation of tropical forest are a major threat to local biodiversity. There are several factors that can lead to the extinction of populations (Turner, 1996; Gascon 1999 & Brooks et al., 2002) and cause changes in the composition, dominance patterns and relative abundance of species (Neckel-Oliveira et al., 2000; Gardner et al., 2007; Silva et al., 2014).

Several studies carried out in tropical forests related to effect landscape changes on herpetofauna assemblages infer negative consequences in the fauna composition related to changes in the distribution and species diversity (Beirne et al., 2013; Dixo & Martins, 2008; Schlaepfer & Gavin, 2001). The discontinuity of the forest canopy is enhanced by edge effects that act as barriers for the dispersal of amphibians and reptiles (Dixo et al., 2009; Clark et al., 2010; Maynard et al., 2016).

The knowledge of the herpetofauna of the eastern Amazon increased in the last decade as a result of a number of faunal studies (Ávila-Pires et al., 2010; Mendes Pinto et al., 2011; Bernardo et al., 2012; Pinheiro et al., 2012; Prudente et al., 2013; Vaz-Silva et al., 2013). Many studies are specific to this region and some areas are still poorly known, especially for areas located north of the Amazon River, which was called the forgotten region of zoogeographical unit of the Guianas (Ávila-Pires et al., 2010).

As evidenced here, there are few studies in this region of Pará State, specifically in the municipality of Monte Alegre, a region which experienced an accelerated deforestation process as a result of the expansion of the agricultural and livestock frontiers. The faunal studies of composition, richness and diversity of species of reptiles and amphibians are elementary and basic parameters to describe biological communities, which in turn define conservation and monitoring strategies consistent with the reality of the studied site (Pereira Júnior et al., 2013). Therefore, the goal in this study is to compare herpetological richness in four collection localities with different land use history and vegetation cover, and analyze their structure of assembly in the Serra Azul region, eastern Amazon.

Materials And Methods

Study Area

The study was carried out on Sustainable Development Plan (PDS) Serra Azul, a territory with a total area of 78,000 hectares in the municipality of Monte Alegre, located in the lower Amazon region, State of Pará, Brazil (Fig. 1). The region is in the northern area of the city, reached through the PA-254 highway, about 82 kilometers from the municipal seat (1.1787 ° S, 54.1868 ° W; WGS84). It still has a well preserved forest area with predominantly dense tropical submontane rainforest and a rugged topography. Its climate is characterized by an annual rainfall of around 2,000 mm, average annual temperature of 25.6ºC and two well defined seasons: one marked by abundant rains from December to July and a dry season from August to November (Frota et al., 2005).

Field Data Collection

To carry out the sampling, four localities were chosen, categorized in open (farming mixed areas and forest edge), semi-open (weir) and forest (primary forest), defined as follows:

Farming mixed areas, 1°15'27.61"S 54°08'28.90"W: areas near streams that border the road with mainly citrus, cereals, banana and papaya crops.

Forest edge, 1°10'43.30"S 54°11'12.60"W: characterized by its vegetation of secondary forest or training "coops", with little to no remaining natural vegetation (e.g. road, sidings and tracks following bank vegetation fragments).

Weir, 1°15'30.10"S 54°08'34.70"W: a small dam, a stream which is surrounded by a fragment of natural forest used for fish farming and crop irrigation.

Primary forest, 1°09'51.23"S 54°11'54.90"W: primary forest with large trees and dense canopy, especially trees of the Fabaceae, Sapotaceae and Lauraceae families.

Three field trips were made during the years 2013-2014, lasting an average of seven days for a total of 21 days, comprising two annual seasons, twice on begin rainy and once on begin dry. The sampling methods used were as follows:

Time-constrained searches (Crump & Scott, 1994) complemented by the hearing location (Zimmerman, 1994). The effort took place at

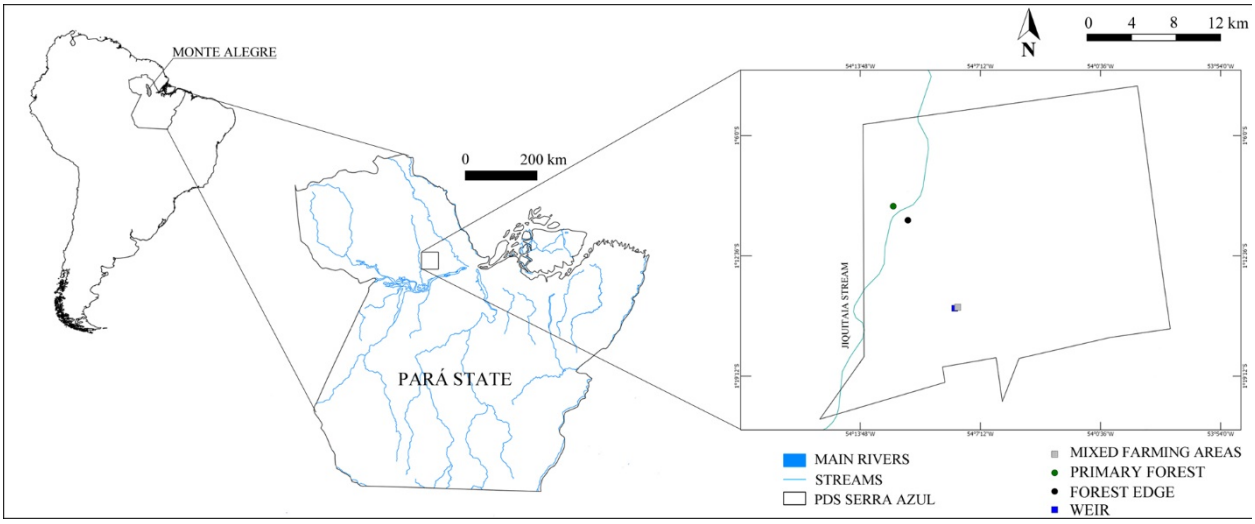

Fig. 1. Location of the herpetological collection area in the Serra Azul region, Monte Alegre, Pará, Brazil.

all times of the day with two researches hiking an average of three hours, which resulted in a total 120 hours-catcher.

Pitfall traps with drift fences, following the guidelines by Cechin & Martins (2000). Two series of pitfall traps were installed in a radial disposition in two sampling localities: the crop area and the primary forest. The pitfall traps were active during expeditions, totaling 1.912 hours-bucket, and checked twice a day, at 6am and 6pm.

Animal's collection was made under permanent license authorization to collect zoological material - SISBIO Number 32401 and 65141. The collected specimens were deposited in the Coleção de Vertebrados do Laboratório de Zoologia – LZA in the Altamira campus of the Federal University of Pará under the numbers LZATM – 920-1060. The nomenclature used herein followed Frost (2016), for amphibians, and Uetz (2016), for reptiles.

Data Analyzes

The localities were compared regarding the composition and species richness. The software used for the estimation of species richness was EstimateS 8.2 with 1000 randomizations in the order of samples, which removes any unwanted effect by averaging the surplus randomizations (Colwell, 2006).

The nonparametric first-order Jackknife richness estimator was used to calculate species richness in non-homogeneous environments (Magurran, 2004) and sampling small animals with the use of traps (Burnham & Everton, 1979). According to Palmer (1990), among the tested estimators, the Jackknife was the most accurate and less biased estimator. A similar result was observed by Tobler et al. (2008).

To identify the relationship between the species and study sites, we conducted a principal component analysis (PCA) using the composition matrix transformed by Hellinger procedure, thereby correcting the effect of the arc (Legendre & Galenger, 2001) and scores of local species categorized by type of environment. Since the PCA does not test the significance of the groups, the difference in the structure of herpetofauna of the four localities was tested through the analysis of randomized multivariate variance (PERMANOVA) (Anderson, 2001) and community variation within localities with test multivariate homogeneity groups (PERMDISP) (Anderson, 2006). Both analyzes were based on the Jaccard similarity matrix in the software R 3.2.4 (R Development Core Team, 2015), using the Adonis and Betadisper functions, both implemented in vegan package (Oksanen et al., 2016).

Results

This study recorded 337 individuals, resulting in a total of 23 species of amphibians (frogs) and 27 species of reptiles (12 lizards, 12 snakes, two turtles and an alligator) (Fig. 2 and 3). Amphibians (frogs) are distributed in seven families, of which Hylidae has the greatest number of species (7 spp.). Snakes are represented by four families, with Colubridae as the family with the greatest number of species (9 spp.). In the case of lizards, Teiidae was the largest of the eight families (3 spp.). Turtles comprise only two families: Geomydidae (1 sp.) and Testudinidae (1 sp.). Alligators consist of only one family: Alligatoridae (1 sp.) (Tab. 1).

In the degraded areas, the most abundant species of anurans were *Ameerega hahneli*, *Rhinella marina*, and *Scinax ruber*, while in less de-

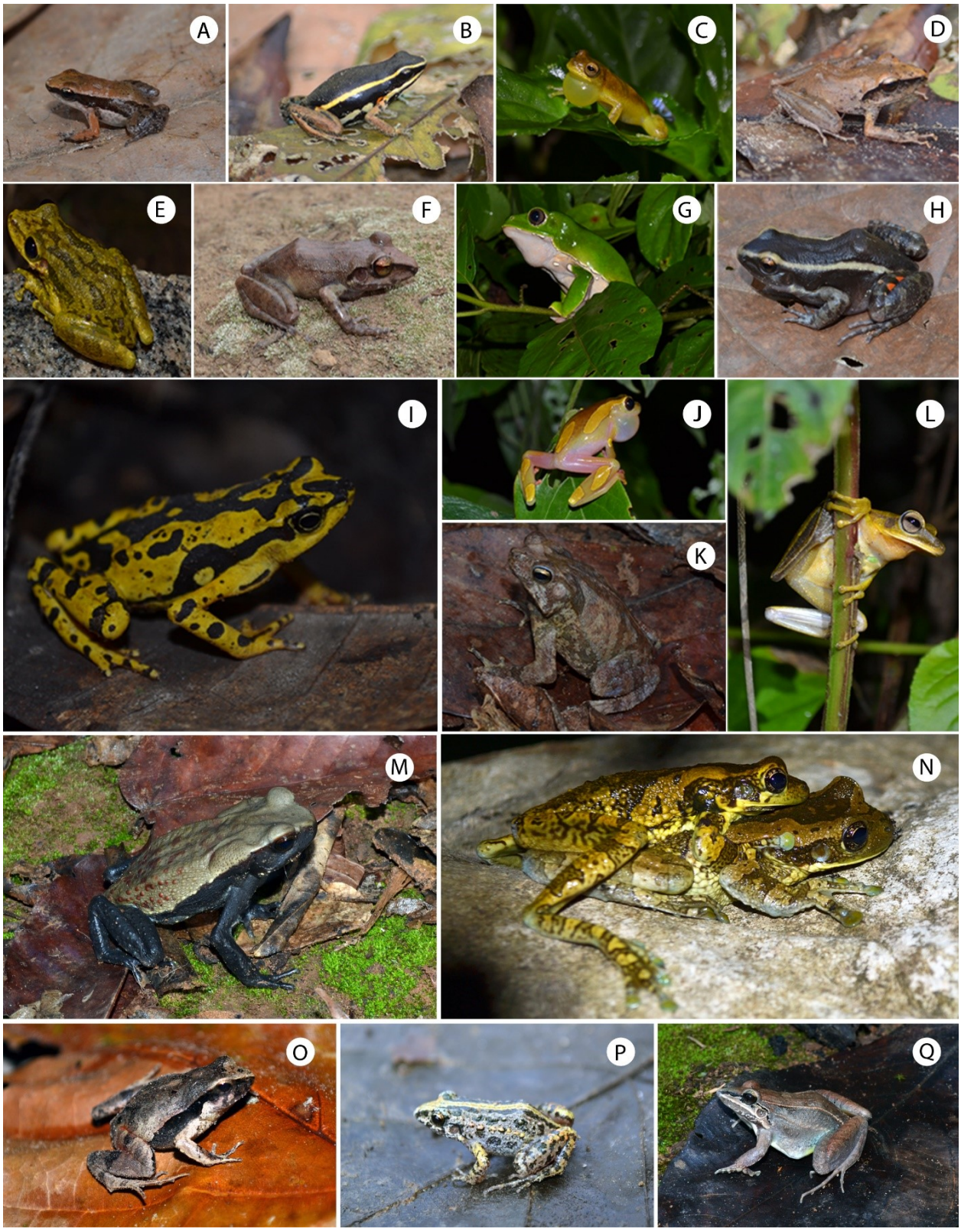

Fig. 2. Some amphibians anuran recorded at the study site. A) *Allobates sumtuosus*; B) *Ameerega hahneli*; C) *Dendropsophus minutus*; D) *Pristimantis chiastonotus*; E) *Scinax ruber*; F) *Pristimantis zeuctotylus*; G) *Phyllomedusa bicolor*; H) *Lithodytes lineatus*; I) *Atelopus hoogmoedi*; J) *Dendropsophus leucophyllatus*; K) *Rhinella* gr. *margaritifera*; L) *Hypsiboas multifasciatus*; M) *Rhaebo guttatus*; N) *Trachycephalus typhonius*; O) *Physalaemus ephippifer*; P) *Adenomera andreae* e Q) *Leptodactylus longirostris*.

Fig. 3. Some reptiles recorded at the study site. A) *Rhinoclemmys punctularia*; B) *Anolis fuscoauratus*; C) *Tupinambis teguixin*; D) *Plica plica*; E) *Leptodeira annulata*; F) *Gonatodes humeralis*; G) *Thecadactylus rapicauda*; H) *Dipsas variegata*; I) *Epicrates cenchria*; J) *Xenopholis scalaris*; K) *Erythrolamprus typhlus*; L) *Typhlophis squamosus* e M) *Mastigodryas boddaerti*.

Tab. 1. Herpetofauna recorded at Serra Azul region, Monte Alegre, Pará, Brazil. Collection methods: (PT) pitfall traps; (TC) time-constrained searches.

Taxon	Collection Method	LOCALITY			
		Weir	Mixed Farming Areas	Primary Forest	Forest Edge
Anura					
Arombatidae					
Allobates femoralis (Boulenger, 1884)	TC			X	X
Allobates sumtuosus (Morales, 2002)	TC	X	X	X	
Bufonidae					
Atelopus hoogmoedi Lescure, 1974	TC			X	
Rhaebo guttatus (Schneider, 1799)	TC		X		X
Rhinella major (Müller and Helmich 1936)	TC	X	X		X
Rhinella gr. *margaritifera* (Laurenti, 1768)	TC		X		X
Rhinella marina (Linnaeus, 1758)	TC	X	X		X
Craugastoridae					
Pristimantis zeuctotylus (Lynch and Hoogmoed, 1977)	TC		X		
Pristimantis chiastonotus (Lynch and Hoogmoed, 1977)	TC			X	
Dendrobatidae					
Ameerega hahneli (Boulenger, 1884)	TC	X	X	X	X
Hylidae					
Dendropsophus leucophyllatus (Beireis, 1783)	TC	X			
Dendropsophus minutus (Petrs, 1872)	TC	X			
Hypsiboas multifasciatus (Günther, 1859)	TC	X	X		X
Phyllomedusa bicolor (Boddaert, 1772)	TC	X			
Pithecopus hypochondrialis (Daudin, 1800)	TC	X	X		X
Scinax ruber (Laurenti, 1768)	TC	X	X		X
Trachycephalus typhonius (Linnaeus, 1758)	TC		X		X
Leptodactilydae					
Adenomera andreae (Müller, 1923)	TC and PT		X	X	X
Leptodactylus longirostris Boulenger, 1882	TC	X	X		X
Leptodactylus mystaceus (Spix, 1824)	TC				X
Lithodythes lineatus (Schneider, 1799)	TC		X		
Physalaemus ephippifer (Steindachner, 1884)	PT		X		

Tab. 1 - Continuação

Microhylidae					
Chiasmocleis hudsoni Parker, 1940	PT			X	
SQUAMATA					
SAURIA					
Dactyloidae					
Anolis chrysolepis Duméril & Bibron, 1837	TC			X	
Anolis fuscoauratus D' Orbginy, 1837	TC			X	
Gekkonidae					
Hemidactylus mabouia (Moreau Jonnès, 1818)	TC				X
Gymnophtalmidae					
Loxopholis guianense (Ruibal, 1952)	TC and PT				X
Phyllodactylidae					
Thecadactylus rapicauda (Houttuyn, 1782)	TC		X		X
Scinidae					
Copeoglossum nigropunctatum (Spix, 1825)	TC	X	X	X	X
Sphaerodactylidae					
Gonatodes humeralis (Guichenot, 1855)	TC		X	X	
Chatogekko amazonicus (Andesson, 1918)	TC	X		X	X
Teiidae					
Ameiva ameiva (Linnaeus, 1758)	TC	X	X		X
Kentropyx calcarata (Spix, 1825)	TC	X			
Tupinambis teguixin (Linnaeus, 1758)	PT			X	X
Tropiduridae					
Plica plica (Linnaeus, 1758)	TC and PT			X	
OPHIDIA					
Anomalepidae					
Typhlophis squamosus (Schlegel, 1839)	TC		X		
Boidae					
Epicrates cenchria (Linnaeus, 1758)	TC		X		X
Colubridae					
Dipsas variegata (Duméril, Bibron & Duméril, 1754)	TC	X			
Erythrolamprus miliaris (Linnaeus, 1758)	TC	X			
Erythrolamprus typhlus (Linnaeus, 1854)	TC	X			
Leptodeira annulata (Linnaeus, 1758)	TC	X			X
Leptophis ahaetulla (Linnaeus, 1758)	TC				X

Tab. 1 - Continuação

Mastigodryas boddaerti (Sentzen, 1746)	TC			X	
Oxybelis aeneus (Wagler, 1824)	TC				X
Oxyrhopus melanogenys (Tschudi, 1845)	TC		X		
Xenopholis scalaris (Wucherer, 1861)	TC			X	
Viperidae					
Bothrops atrox (Linnaeus, 1758)	TC	X	X		X
TESTUDINATA					
Geomydidae					
Rhinoclemmys punctularia (Daudin, 1801)	TC			X	
Testudinidae					
Chelonoidis carbonarius (Spix, 1824)	TC			X	
CROCODYLIA					
Alligatoridae					
Paleosuchus sp.	TC	X			
TOTAL		**21**	**23**	**18**	**25**

graded areas, such as near streams, the most common species in both annual periods were *Pithecopus hypochondrialis* and *Hypsiboas multifasciatus*. Regarding lizards, the most common species in the degraded areas were *Ameiva ameiva* and *Copeoglossum nigropunctatum*, whereas in forested areas the most abundant species were *Chatogekko amazonicus* and *Loxopholis guianense*. The snakes comprise the most abundant species in degraded areas, mostly represented by *Leptodeira annulata*, all observed at night in foraging activity, and *Bothrops atrox*, but some of them were found dead by local residents.

The species accumulation curve tended to an asymptote (Fig. 4), however, the jackknife estimation of the first order indicated a richness of up to 71 (± 4.74).

The localities that have the lowest similarity with respect to faunal composition were the weir and the primary forest (11%). The edge of the forest and the mixed farming areas have the greatest similarity in species composition (53%) (Tab. 2).

The composition PCA (Fig. 5) explained 34.08% of the variation in the first two axes. The first axis related negatively to the primary forest locality, and the species *Atelopus hoogmoedi, Allobates sumtuosus, Gonatodes humeralis, Plica plica, A. hahneli, L. guianense, Pristimantis chiastonotus,* which had great importance in the composition of that assembly. The other localities had a positive relation, just as the species *Dendropsophus leucophyllatus, H. multifasciatus, S. ruber, R. marina, P. hypochondrialis, A. ameiva, Rhinella major* and *Leptodactylus longirostris* did. Since the weir locality is set apart from the edge localities and mixed farming areas by the second axis of the PCA, the resulting pattern shows that the species *Dendrophsophus leucophyllatus, H. multifasciatus, S. ruber* and *R. marina* are related to the weir, and *A. ameiva, Rhinella major, L. longirostris,* and *P. hypochondrialis* to the mixed farming areaslocality and forest edge species.

The pattern observed in the PCA, the composition difference between the sampled sites, was confirmed by PERMANOVA (F (3, 36) = 5.936, P = 0.001), and 33% of the variation in composition is related to the locality type. Still, we note that the heterogeneity of the assemblages is greater in weir localities and mixed farming area and lower in forest edge localities and primary forest (F (3, 36) = 3.483, P = 0.001), and the forest edge locality consists of a subset of species in the mixed farming area (Fig. 6).

Discussion

The results presented here represent the first data regarding the herpetofauna of Serra Azul. Other results of nearby areas obtained similar levels of species richness: State Florest Paru, located north, Ávila-Pires et al. (2010) recorded 53 species (29 reptiles and 24 amphibians), of which 20 are also present in this study, with a faunal similarity index of 26%. Brasil (2009), for the State Park Monte Alegre, obtained 49 species, 20 of which are common to both inventories, with a similarity index of 25%. Most of the species col-

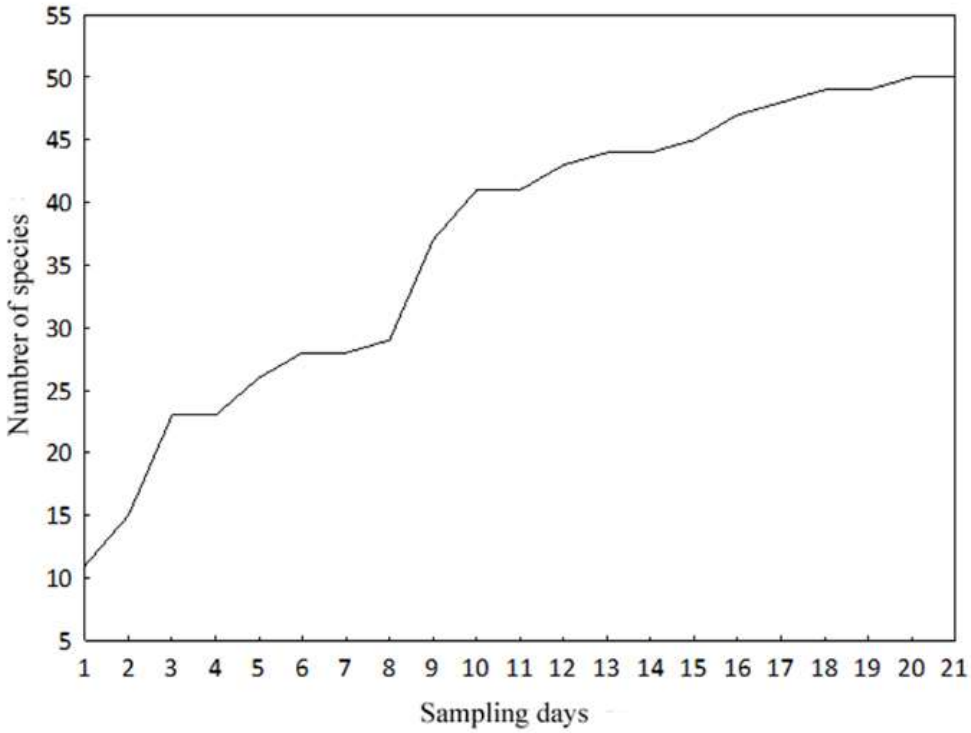

Fig. 4. Herpetofauna species accumulation curve of the Serra Azul region, Monte Alegre, Pará, Brazil.

Tab. 2. Total species by collecting locality (diagonal line), number of common species (above the diagonal line), faunal Jaccard similarity index between each pair of localities (below the diagonal line).

	Weir	Mixed farming areas	Primary forest	Forest edge
Weir	**21**	11	4	12
Mixed farming areas	0.30	**23**	5	16
Primary forest	0.11	0.14	**18**	6
Forest edge	0.30	0.53	0.14	**25**

lected in this inventory are from areas with the typical vegetation of savanna or Cerrado. In all three studies, more than half of the species are different.

However, the list of species for the area is certainly not complete and remains subsampled, particularly for snakes, whose meeting is sporadic. Unlike most lizards and amphibians, which are easily sampled by visual search method, some species of snakes have more secretive habits and require the use of other methods, specific for this group of animals (Bernarde, 2008).

Through the similarity and principal component analysis statistically verified, the PERMANOVA and PERMDISP tests confirm that the locality has a direct influence on the composition of herpetofauna, showing the difference in the assemblies between open areas, semi-open and forest, as indicated in the literature (Hernández-Ruz et al., 2001; Vitt & Caldwell, 2014; Carvajal-Cogollo & Urbina-Cardona, 2015).

The primary forest has a distinct species composition, and lower variation in the assembly demonstrating that there is no species dominance, despite representing the lowest index richness, this fact can be explained by the difficulties of sampling nocturnes in this locality, nevertheless presented a greater number of exclusive species.

Such as *A. hoogmoedi* recorded a high density, whereas other species of *Atelopus* showed a population decline, probably due to infection by the chytrid fungus *Batrachochytrium dendroba-*

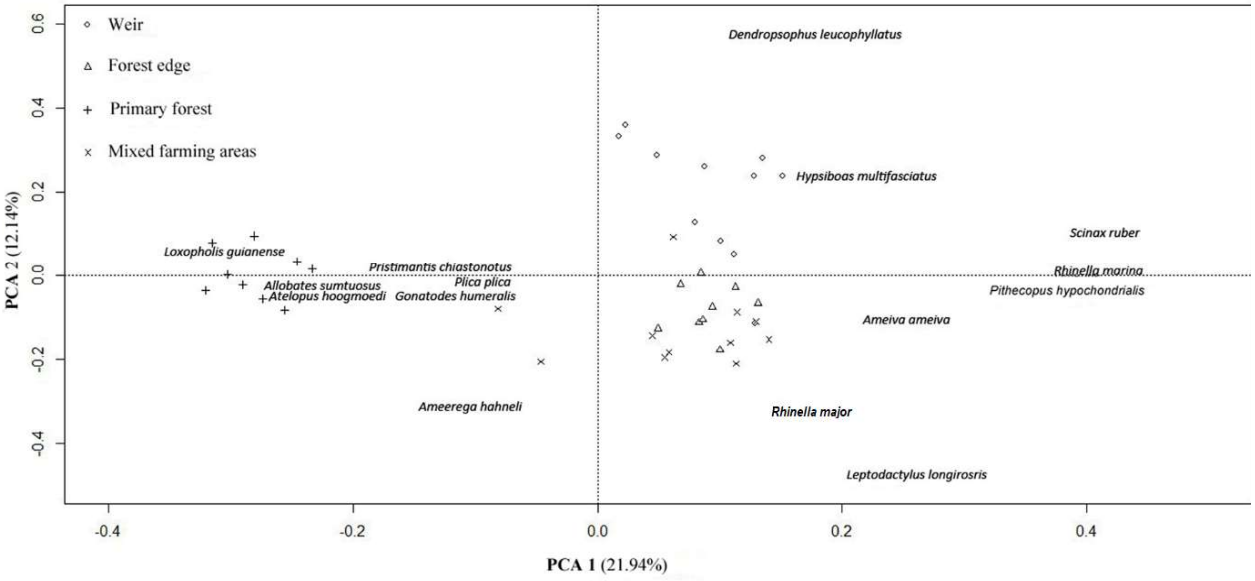

Fig. 5. The composition PCA for four collection localities in Monte Alegre Pará, Brazil.

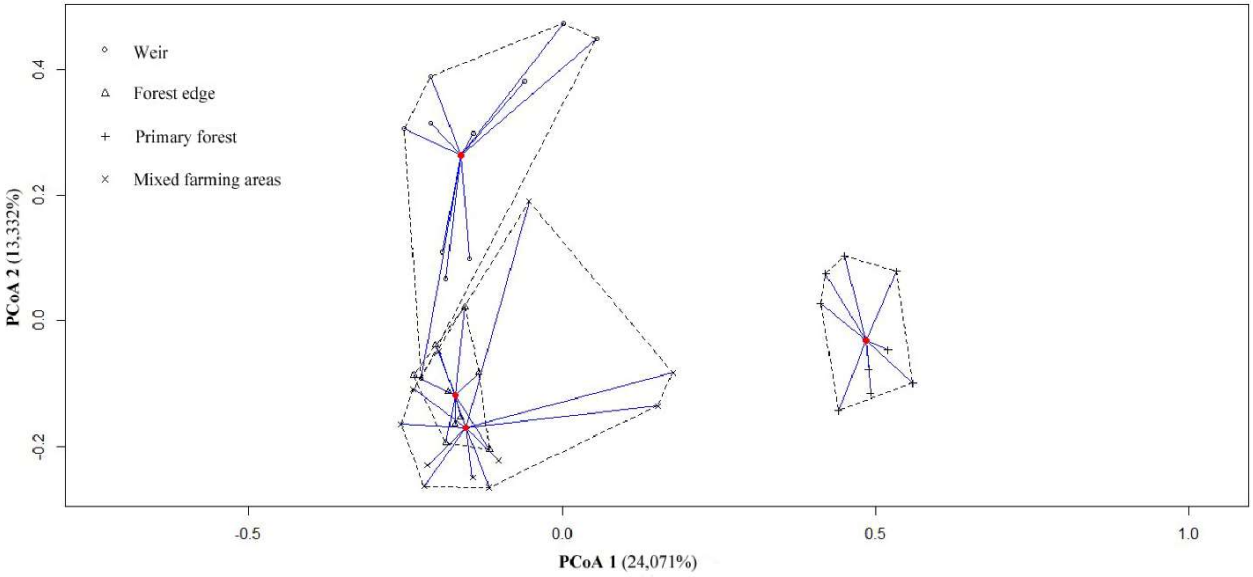

Fig. 6. PERMDISP analysis for the four collection localities, based on faunal composition in relation with sampling effort for the region of Serra Azul, Monte Alegre, Pará, Brazil.

tidis. Compared with other areas of the Amazon, such as the right bank of the Xingu River, this species is considered rare, since an effort of more than 1.200 hours collected only two specimens (unpublished date).

In contrast to what this study observed, in a small area near a rushing stream, in just one day during morning hours, more than 20 individuals, between adult males and females, which corroborates the observations of Ávila-Pires et al. (2010) regarding a population of the same species in the Estação Ecológica do Grão Pará, and Luger et al. (2008) regarding populations of Suriname and Guyana.

On the other hand, the forest edge and mixed farming area localities showed a high level of richness and faunal similarity. These high levels of richness, however, are misleading regarding the quality of the locality, as it is usual to find "trash species" known as opportunistic and common over disturbed areas in the Amazon (Duellman, 2005).

Weir had greatest importance for anuran species, it was observed that in the months with the highest rainfall levels in the region, from Decem-

ber to April, *Phyllomedusa bicolor*, which reproduces throughout the year and peaks in November, was commonly seen breeding in the surrounding bushes. Other species typical of areas altered by human action, such as a *R. marina* with a high density of individuals and other hylids also shared the same breeding site. During the dry season, on the other hand, no *P. bicolor* individual was found in the same location, even despite the fact that the weir is a permanent puddle. Only the species *R. marina, Dendropsophus* spp., *P. hypochondrialis* and *A. hahneli* remained active during both dry and rainy periods.

A major concern regarding the Brazilian Amazon is deforestation. The data of 2013 shows 29% of this deforestation is due to recurring settlements (IMAZON et al., 2014). In the Serra Azul settlement where this study took place, forest degradation is visible. The main factors are illegal logging and the introduction of new crops. Fortunately, distance and difficult access provide an initial barrier since this complicates transport and, consequently, prevents the increase of cattle and grazing areas.

However, it was observed that generalist species are dominant in areas where the native vegetation has been lost due to human activity. This indicates the degree of disruption in disturbed habitats. It is thus indisputable that forest conservation is of fundamental importance for the maintenance of local herpetofauna, since there are species ecologically dependent on forest localities, particularly with an intrinsic relationship to the primary forest. These species are strongly threatened, as they have lost their habitat due to an increase in human pressure.

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