

VERTICAL SEGREGATION IN *PRISTIMANTIS* SPECIES FROM A BAMBOO FOREST IN SOUTHEAST OF AMAZONIA, BRAZIL

Jhon Jairo LÓPEZ-ROJAS¹

1 Universidad Nacional de San Martín, Facultad de Ecología. lopezrojasjj@gmail.com

ABSTRACT

In this work, the vertical stratification in *Pristimantis* species was studied in a remanescent forest dominated by bamboo in the southwest region of the Amazon. The field work was carried out between December 2012 and May 2013. The differences in height of the perch were analyzed interspecifically, and intraspecific in relation to the structure of the vegetation. A total of four species were recorded, *Pristimantis fenestratus* being the most abundant and occurring in all sampling units. There was significant interspecific difference in perch height, as well as between adults and juveniles. For *P. fenestratus*, there was no differentiation of segregation between sampling units. The structure of the vegetation did not explain the preference of heights; however, leaf litter depth influenced its vertical stratification. More data and occurrences are needed in all sampling units to infer better explanations.

KEYWORDS: Vertical segregation, *Pristimantis*, bamboo forest, structure of the vegetation.

DISTRIBUCIÓN VERTICAL EN ESPECIES DE *PRISTIMANTIS* EN UN BOSQUE DOMINADO POR BAMBÚ EN LA REGIÓN SUROESTE DE LA AMAZONÍA, BRASIL

RESUMEN

En este trabajo, se estudió la distribución vertical en especies de *Pristimantis* en un bosque dominado por bambú en la región suroeste de la Amazonía. Los muestreos se realizaron entre diciembre del 2012 y mayo del 2013. Las

diferencias de la altura de percha fueron analizadas inter e intra-específicamente en relación a la estructura de la vegetación. Un total de cuatro especies fueron registradas, *Pristimantis fenestratus* fue la más abundante ocurriendo en total las unidades de muestreo. Hubo una diferencia significativa en la altura de percha, tanto en adulto como en juveniles. Para *P. fenestratus* no hubo diferencia de segregación entre las unidades de muestreo. La estructura de vegetación no explicó la preferencia vertical, sin embargo, la profundidad de la hojarasca explicó su estratificación. Mas datos y ocurrencias son necesarios en todas las unidades para inferir mejores explicaciones.

PALABRAS CLAVES: Segregación vertical, *Pristimantis*, bosque dominado por bambú, estructura de la vegetación.

INTRODUCTION

Niche theory suggests that coexisting species will reduce the effects of interspecific competition through the segregation of shared resources (Chesson, 2000), these coexisting species often use different tactics without causing a competitive exclusion of resources occupying different habitats (Caramashi, 1981; Hauer and Stanford, 1986; Kiszka et al., 2011).

Several studies have focused vertical stratification in Anura (Arroyo et al., 2008; Muñoz-Guerrero, 2007; Guayasamin and Funk, 2009; de Menezes Gondim, 2013; Fonseca-Pérez, 2017). To explain this behavioral and ecological activity, different strategies are used by the anuran species to coexist in the same habitat: ontogenetically (Eterovick et al., 2010, de Menezes Gondim, 2013), foraging sites and competition inter and intraspecific (Duellman and Pyles, 1983; Toft, 1985), and by attracting females during the breeding season by strategic vocalization frequencies in males (Miyamoto, 1982). However, until now there have been no approaches that relate vertical intra-specific segregation (de Menezes Gondim, 2013) and interspecific segregation with variables that structure the vegetation.

The focus on anuran species of the genus *Pristimantis* Jiménez de la Espada, 1870, has involved particularities in their natural history of direct development (Pombal and Haddad, 2007), as sensitive indicators of anthropogenic disturbances (Pearman, 1997), and present vertical stratifications in vegetation (Lynch and Duellman, 1997; Guayasamin and Funk, 2009; Blair and Doan, 2009). This genus is one of the most diverse groups of amphibians in the Neotropics, with 38 species occurring in Brazil (Segalla et al., 2017). The southwestern region of the Brazilian Amazon is characterized by the presence of patches of bamboo (Silveira, 2005).

The dynamics of bamboo growth is crucial in influencing vegetation structure in richness and abundance in this assemblage, differentiating certain habitats of targeted species (López-Rojas et al., 2015).

In this study the vertical distribution of species of the genus *Pristimantis* occurring in syntopy in a fragmented forest dominated by bamboo, needs to address questions regarding vertical stratification and interspecific differences between adults and juveniles. Additionally, does the vegetation structure influence the vertical segregation of the various species?

MATERIAL AND METHODS

The work was carried out in a forest fragment known as Fazenda Experimental Catuaba (10°04'S, 67°37'W), in the municipality of Senador Guiomard, Acre State, Brazil. It comprises an area of 1200 ha, dominated by bamboo, *Guadua weberbaueri* Pilger (Smith and Nelson, 2011). Distribution of plots in Catuaba, measurements and analysis of vegetation structure variables are detailed in López-Rojas et al. (2015). Field work was conducted for a total of 70 days of sampling, largely during the rainy season, between November 2012 and May 2013, with twice monthly visits, each five days in length, totaling 180 hours of observations, with an average of 12 repetitions for each plot.

The sampling of *Pristimantis* was carried out at night using active visual and auditory survey (Crump and Scott 1994). Two researchers surveyed each plot for approximately 90 minutes, searching the trail to an extent of two meters wide on both sides of the central line, up to a height of three meters between 17:00 h - 23:00 h. For each individual frog observed, I recorded the perching height above ground level using metric measurements. Snout-vent-length (SVL) was

measured with a digital caliper to differentiate adults from juveniles, under the criteria of Lehr and Duellman and Lehr (2009), Padial de la Riva (2009). All specimens encountered were identified in the field or in the laboratory, by comparison with specimens deposited in the Herpetological Collection of the Universidade Federal do Acre.

After analysis of homoscedasticity and normality of the data, an analysis of variance (ANOVA) was performed to identify the differences in the use of the perching height among the species. The significance of the differences between pairs of means was calculated by the Tukey-Kramer method. The intraspecific difference between adults and juveniles was done through a T-test.

P. fenestratus was present in all plots, so it was possible to infer if there was an intraspecific difference in all the sampling units by ANOVA. Likewise, the vegetation structure variables and the first axis of the PCA (see, López-Rojas et al., 2015) were used to relate them to the mean height in each plot by linear regression. All analyzes were performed in RStudio 1.0.153 (R, 2015) and Statistic 10 (StatSoft Inc., 2011).

RESULTS

Perching height above ground level was recorded in 229 individuals of four species of *Pristimantis*. There was interspecific difference in relation to

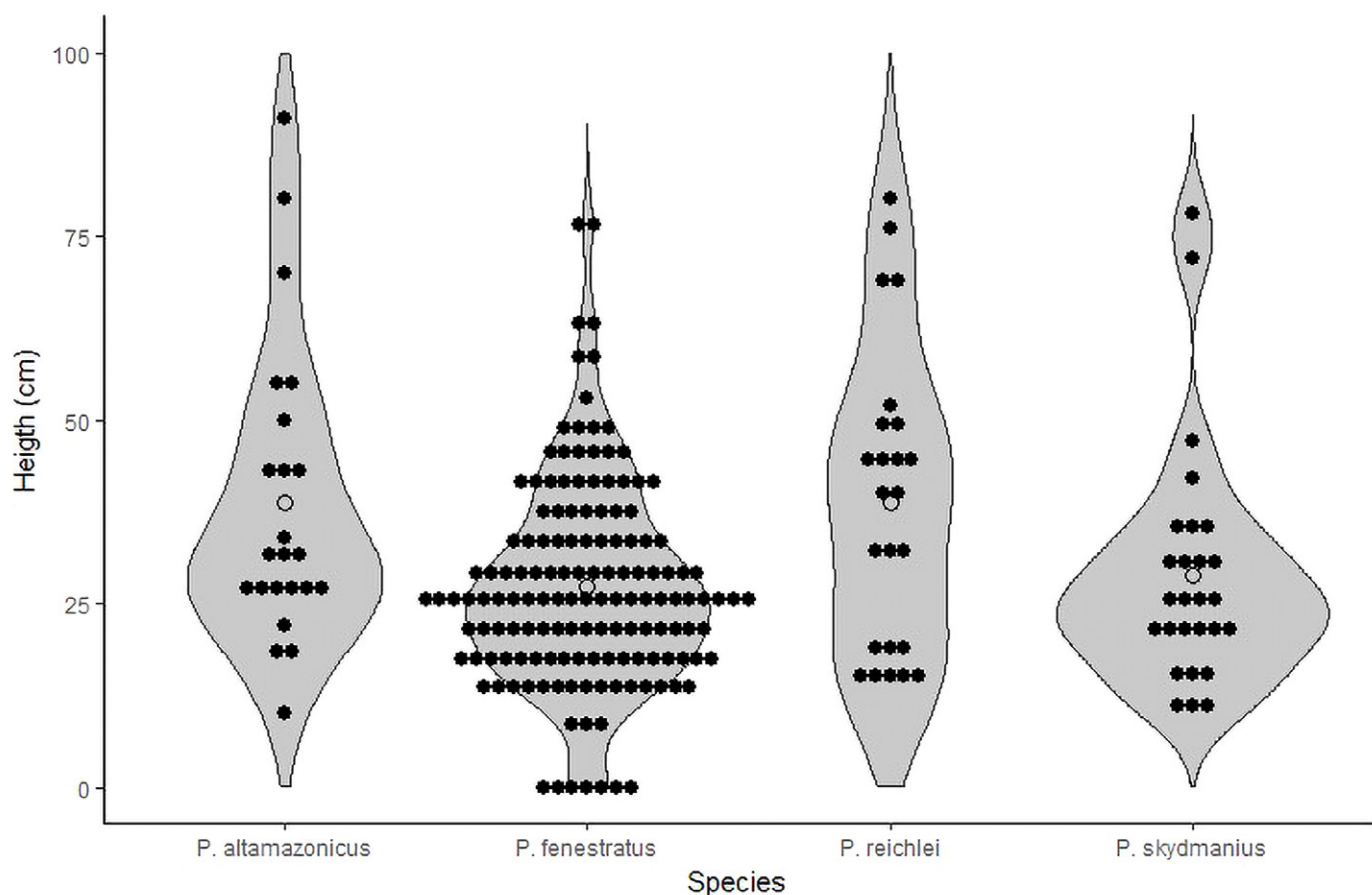


Fig 1. Vertical distribution of four species of *Pristimantis* in Catuaba, Acre, Brazil.

Table 1. Descriptive data and ontogenetic differences in four species of *Pristimantis* observed in Catuaba, Acre State, Brazil. N=Number of individuals; M=Mean; SD=Standard Deviation; t=Student t-test; p=Propability.

Species	N	M	SD	t	p
<i>P. altamazonicus</i>					
Adults	16	35.8	18.2	-2.76	< 0.01
Juveniles	10	69.5	43.1		
<i>P. fenestratus</i>					
Adults	56	22.3	10.0	-3.29	0.00
Juveniles	91	34.2	25.8		
<i>P. reichlei</i>					
Adults	15	32.0	23.7	-2.88	< 0.16
Juveniles	13	65.8	35.9		
<i>P. skydmainus</i>					
Adults	12	23.8	7.1	-2.3	<0.01
Juveniles	16	43.0	32.6		

the hanger height (ANOVA, $F_{3,225}=8.02$, $p<0.01$, Fig 1). *P. altamazonicus*, *P. fenestratus* and *P. skydmainus* occupied ranges of heights between 20 and 39 cm, whereas *P. reichlei* was more common between 40 and 59 cm (Fig. 1).

Perching height in *P. fenestratus* was significantly lower than *P. altamazonicus* and *P. reichlei* (Tukey-Kramer method, $p=0.04$ y $p=0.02$), but did not differ from *P. skydmainus* (Tukey-Kramer method, $p>0.05$). *P. reichlei* and *P. skydmanus* also showed differences in perch height (Tukey-Kramer method, $p=0.04$).

In the case of *P. fenestratus*, there was no significant difference of the hanger height distributed in the sampling units (ANOVA, $F_{9,199}=0.83$, $p>0.59$). The structure of the vegetation did not influence its vertical distribution ($R^2=0.27$, $p = 0.13$). Only leaf litter depth explained 51% of distribution ($R^2=0,51$, $p=0.02$).

DISCUSSION

This study showed a more quantitative subject regarding Lynch and Duellman (1997), and it was possible to find intraspecific differences in relation to the height of the substrate used for these nocturnally active frogs. *Pristimantis* exhibit a greater detectability in the rainy season (Arroyo et al., 2008; Waldez et al., 2011), and the present work was carried out during the majority of this five-month period, in contrast to the work of Miyamoto (1982) and Guayasamin and Funk (2009) which took two months and two years respectively.

Other authors have observed the vertical distribution of micro-habitats among *Pristimantis* species in other regions: western Ecuador (Guayasamani and Funk, 2009; Lynch and Duellman, 1997) and Costa Rica (Miyamoto, 1982). Here I show vertical segregation in the southwest region of the Amazon in a forest dominated by bamboo. This type of vegetation presents effects of the dynamics imposed by bamboo, affecting the structure of vegetation (Griscom and Ashton, 2003; Silveira, 2005; Griscom et al., 2007) and being able to influence vertical segregation for active anuran species. The complexity of the structure of vegetation of this type of forest accounts for some species of *Pristimantis* to be very low.

In López-Rojas et al. (2015), *P. altamazonicus* was detectable in areas with trees greater than 30 cm diameter at breast height with a closed canopy with abundant litter, while *P. fenestratus* prefers sites with bamboo and trees with a diameter at

breast height greater than 10. *P. skydmainus*, one of the species most sensitive to bamboo, was mostly restricted to heights of less than 45 cm, in some cases individuals were observed at heights higher than 200 cm concordant on the use of assemblage microhabitat of *Pristimantis* (Arroyo et al., 2008).

There was overlap in the location of the vertical zone among some species, although they differed in terms of abundance, ontogenetically and in habitat distribution. The differentiation between adults and juveniles may be due to the fact that adults position themselves at strategic sites during the night in search of food and sexual partners (Duellman and Pyles, 1983), males position themselves for optimal vocalization sites, while females, that are already gravid, can remain on the ground due to the increase in their body weight to avoid energetic wear (Crump, 1974). Juveniles, however will usually hide in leaf litter to avoid predators (Blair and Doan, 2009).

The height above ground level was analyzed for *P. fenestratus* in relation to environmental variables, since it is the most abundant species in the study area. In some instances, this species was found vocalizing at heights 20 and 39 cm during nighttime which could be interpreted as a search for sexual partners, or for surpassing the 150 cm height used to confuse possible predators i.e. bats (Duellman and Pyles, 1983; Blair and Doan, 2009). Females were also observed on the ground presumably in order to deposit their eggs in leaf litter (Crump, 1974).

Although vertical segregation it was related to the structure of the vegetation, it was not possible to explain variation, except that leaf litter was used to provide shelter, food, breeding, and oviposition sites (Slowinski et al., 1987). Because of this, a greater number of observational records of the other species is required, as well as assessment of additional biotic and abiotic

factors, that were not taken in this study, for a better understanding of the vertical variation of microsimpatric species (syntopics).

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