

Community structure and abundance of small rodents at the wave front of agroforestry and forest in Alto Beni, Bolivia

Estructura de la comunidad y abundancia de pequeños roedores frente al inicio de cultivos agroforestales y en bosque en Alto Beni, Bolivia

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Abstract

Studies on the distribution of species and community structure are essential to understand the effects that environmental change may have on them, regardless of whether it was climatic or human-induced. These studies are particularly important in the case of rodent communities, as they are highly diverse and can often serve as biodiversity indicators. The study area, Unión Ipiri (La Paz, Bolivia) is a representative of several communities at the front end of human disturbance. The objective of the study was to determine the composition and diversity of rodent communities in two types of habitats, native forest and agroforestry crop, the latter as an anthropogenic disturbed habitat, during the dry season of 2014. We collected 256 individuals, belonging to 10 species of rodents and three species of marsupials. The most abundant species were *Oligoryzomys microtis chaparensis*, *Oligoryzomys* sp., *Euryoryzomys nitidus* and *Akodon dayi*. Both the richness and diversity showed no significant differences between the two habitats, while the abundance of rodents was higher in the agroforestry crops. *Oligoryzomys* sp. was the species with the highest proportion of males. And all the above-mentioned four species showed more adults individuals, as expected for the sampled season.

Key words: Abundance, Community, Crops, Diversity index, Forest.

Resumen

Los estudios sobre la distribución de las especies y la estructura de la comunidad son esenciales para comprender los efectos que el cambio ambiental puede producir en ellos, independientemente de si fue climático o inducido por el hombre. Estos estudios son particularmente importantes en el caso de las comunidades de roedores, ya que son muy diversas y a menudo pueden servir como indicadores de biodiversidad. El área de estudio, Unión Ipiri (La Paz, Bolivia) es un representante de varias comunidades frente al inicio de la perturbación humana. El objetivo del estudio fue determinar la composición y diversidad de las comunidades de roedores en dos tipos de hábitats, los bosques y los cultivos agroforestales como hábitat antropogénico perturbado, durante la estación seca de 2014. Se recolectaron 256 individuos, pertenecientes a 10 especies de roedores y tres especies de marsupiales. Las especies más abundantes fueron *Oligoryzomys microtis chaparensis*, *Oligoryzomys* sp.1, *Euryoryzomys nitidus* y *Akodon dayi*. Tanto la riqueza como la diversidad no mostraron diferencias significativas entre los dos tipos de hábitat, mientras que la abundancia de roedores fue mayor en los cultivos agroforestales. *Oligoryzomys* sp. fue la única especie con la mayor proporción de machos. Y todas las cuatro especies mencionadas mostraron más individuos adultos, como se esperaba para la temporada que muestreamos.

Palabras clave: Abundancia, Bosque, Comunidad, Cultivos, Índice de diversidad.

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Introduction

Research on natural history, systematics, and community ecology provide the necessary baseline to understand ecosystem changes following anthropogenic perturbations (Altrichter *et al.* 2004, Kufner *et al.* 2004). However, studies on the basic biology of rodents are scarce for most remote regions of world, where ecosystems are undergoing

the most rapid changes. This is even worse for Neotropical piedmont habitats (Landres *et al.* 1988, Hudson *et al.* 2016).

Rodents can serve as biodiversity indicators (Ostfeld *et al.* 1994, Kalcounis-Ruppell *et al.* 2002, Deitloff *et al.* 2010),

and commonly constitute a large portion of ecosystems' food chains. Diversity of food resources is generally positively associated with richer assemblage of rodents (Meserve 1981, Simonetti 1989, Windberg 1998, Cruz *et al.* 2010). A higher structural habitat complexity may also lead to coexistence of a larger number of species (MacArthur & MacArthur 1961, Brown & Munger 1985, Stevens & Tello 2011). Therefore, richness and diversity of rodents will vary according to habitat characteristics and within same type of environment will depend on local levels of disturbance (Marconi & Kravetz 1986, Brehme *et al.* 2011, Stevens & Tello 2011).

Most environmental changes are accompanied by fluctuations in biodiversity, which in turn lead to alterations in the ecological organization of mammal communities (Luévano *et al.*, 2008, Bledsoe *et al.* 2010, Cruz *et al.* 2010, Brehme *et al.* 2011). Most rodent species have several young per litter, which tends to favor their resilience to environmental changes (Aplin *et al.* 2003). Thence, in disturbed habitats (i.e. agroforestry systems) it may be reasonable to expect that the rodent community will be a subsample of that present in surrounding forests (García-Estrada *et al.* 2002). Likewise, it is expected that some species, in particular generalist species, will be more abundant in crops than in undisturbed forests.

Changes in tropical forest due to agricultural activities reduce tree density and lower canopy height, which may in turn lead to an increase in understory vegetation cover (Assenaar *et al.* 2005, Luévano *et al.* 2008, Bledsoe *et al.* 2010, Brehme *et al.* 2011). Responses of rodent communities to these kinds of environmental disturbances may also include changes in sex ratio and age structure. In undisturbed environments, a 1:1 sex ratio is expected, assuming that parents were investing equally in average offspring of either sex (García-Estrada *et al.* 2002, Leturque & Rousset 2003, Santos *et al.* 2007, Fontúrbel 2012). Changes in sex ratio may be due to changes in nutrients assimilation by females due to environmental variation (Cockburn *et al.* 2002), and thus, a biased sex ratio may be an indicator of population stress brought about by habitat disturbance. Age structure is another population parameter potentially regulated by factors such as habitat type, resource availability, amount of carbohydrates in food, and predation pressure (Rosi *et al.* 1992, Rosenfeld *et al.* 2003, Cameron *et al.* 2008). In tropical regions, where there is no marked seasonality, reproduction of rodents is more opportunistic, and strongly influenced by nutrients availability, allowing for a larger number of annual reproductive events. This might indicate that reproductive output, characterized by a juvenile-biased structure, is a result of changes in distribution and supply of food resources (Bomford 1987, Kemp 2001, Hoehn *et al.* 2009, Hirsch *et al.* 2012).

Under this framework, the main objective of our study was to compare the composition and diversity of rodent assemblages in two habitats with different degrees of human disturbance. As a secondary objective, we wanted to establish a baseline of the rodent community from a previously poorly known region of Bolivia recently colonized by a peasant community, as a tool for future comparisons.

Study site

Research was conducted at Union Ipiri (Ipiri for short), located in the municipality of Palos Blancos, La Paz Department, Bolivia (15° 46'00.01" S - 66°52'59.88" W). Ipiri is within the biogeographic province of southwestern Amazonian, in a zone of Yungas, and characterized by its high precipitation (2,000-3,000 mm/year) with diverse vegetation (Navarro & Maldonado 2002, Paniagua *et al.* 2003). The sampling sites were restricted to an elevation range of 830–1,000 m.

Ipiri was established in 2009 and is owned by 80 peasant families, which live in nearby (10 to 30 km straight line) towns. Every family owns 35 to 50 ha, of which 1- 2 ha were cultivated during the study, while most of the area was still primary forest. Canopy height is > 20 m with 3-4 canopy strata and a ground cover < 10%. Agriculture is mainly agroforestry including products like cacao, coffee, bananas, orange, coca, rice or corn. Crops are placed alongside the single dirt access road and were established 3-4 years before this study began. Trees at crop areas are all < 3 m in height. The main economic activity in rest of the region is selective logging. People visited their fields for about 4-10 days per month. In most fields, only bananas were actively harvested.

Methods

Sampling: Sampling was carried out during the dry season (July to August 2013), including agroforestry systems (crops) and primary forest. The sampling consisted of 12 plots, each plot had one grid placed on a crop field and another in the adjacent primary forest; four plots were sampled for five consecutive nights (based in Cárdenas *et al.* 2006). Sampling procedure was repeated to complete 12 plots.

Each sampled plot was chosen at random, but ensuring a minimum distance of 500 m between pairs. Each grid was composed of 6 lines and 10 columns, spaced about every 10 m (Monge-Meza 2011). At each sampling point (within each line), also separated by 10 m, we placed one Sherman trap and at points 3, 6 and 9 one additional Museum Special trap, making a total of 13 traps per sampling line (78 traps per plot). Total sampling effort was 312 traps / night per plot. Traps were baited with a mixture of tuna, oats, and vanilla essence (Santos *et al.* 2007, Luévano *et al.* 2008, Cruz *et al.* 2010).

Captured individuals were preliminarily identified, with standard body measurements, body weight, sex, and reproductive condition obtained in the field (Santos *et al.* 2007). All specimens were preserved in alcohol 96% and stored at Colección Boliviana de Fauna (CBF) in order to corroborate their identifications at the laboratory. For their identification, we extracted the skull and compare it with literature and voucher specimens of CBF. Later, with a stereomicroscope the age was assessed by the degree of molar wear according to five age-classes (Myers & Carleton 1981, Myers and Patton 1989, Myers *et al.* 1990); however, those age categories were later grouped into two age classes: the first three age categories were classified as juveniles, and the last two as adults.

Analyses: We used species accumulation curves (Chao 1 and Chao 2) to determine representativeness of sampling for both habitat types (crops and forest). Chao 1 estimator considers the abundance, whereas the second estimator (Chao 2) is based on species incidences (Escalante 2003).

We estimated species richness (species number for habitat type) and relative abundance (number of individuals per species). Diversity and evenness were estimated by the Inverse Simpson index (Moreno 2001) using R 2.15.1. We also draw abundance range curves to determine if there are differences in abundance of species at each site of study. Species richness and relative abundances were compared between forests and crops using Mann-Whitney U tests, using SPSS19. For species with > 10 individuals, we estimated sex ratios and tested whether they differed from a hypothetical 1:1 using a Chi-square goodness of fit test (Lahoz-Beltrá *et al.* 1994). We only carried out qualitative comparisons for age structure between crops and forest, because of small sample sizes.

Results

Trapping effort was 4368 trap-nights and resulted in 256 captures, 253 rodents and three marsupials. We captured 2.95 as many individuals in crops as in the forest, representing trapping success rates of 8.65% and 2.93%, respectively (Fig. 1).

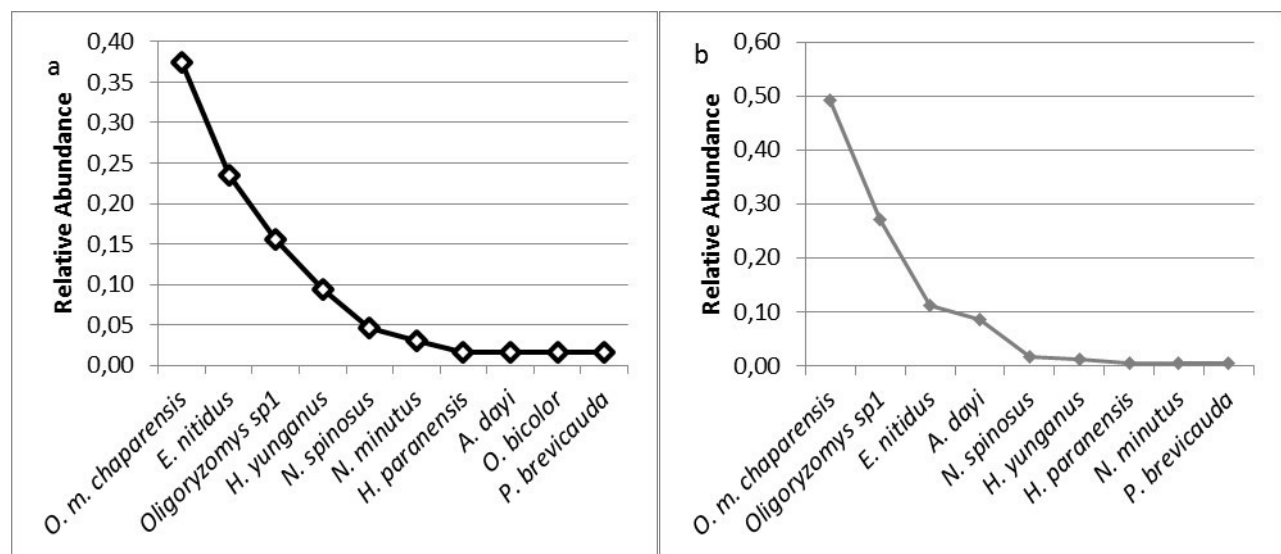


Figure 1. Rank abundance curves for rodent species in a. forest and b. crops.

Only three captures were non-rodent species: one *Marmosops noctivagus* and one *Monodelphis glirina* in forest, and one *Monodelphis peruviana* in crops. The remaining captures included 10 rodent species; nine were Cricetidae (99.2 % of individuals) and one Echimyidae (Table 1). All analyzes were performed only for rodents. The two most abundant species were *Oligoryzomys microtis chaparensis* and *Oligoryzomys sp.*, while *Oecomys bicolor* represented the least common species (Table 1), with only one specimen collected in the forest area. All nine species found in crops were also found in forest, but species richness was slightly higher in forest (S=10), than in crops (S=9), however this difference was not significant (U = 43,

N = 12, p = 0.084); the same result was found at each plot. A plot of a cumulative number of species vs. sample size suggested an adequate sampling effort (Fig. 2). The estimated number of species in Ipiri, according to Chao 1 and 2 estimators, is about 13 species in forest and 12 in crops.

The most abundant species for both habitats belong to genera *Oligoryzomys* and *Euryoryzomys* (Table 1, Fig. 3), with *Oligoryzomys sp.* being slightly more abundant than *Euryoryzomys nitidus* (Fig. 3) in crop areas. Only for the two species of *Oligoryzomys* there was a significant difference between habitats (Table 1)

Table 1. List of rodent species captured in two habitat types (crops and forest) at Unión Ipiri. U Mann-Whitney tests is for comparison between forest and crops.

Family	Species	N° of captured individuals (%)			U – Mann-Whitney
		Total	Forest	Crops	
Cricetidae	<i>Oligoryzomys microtis chaparensis</i>	117 (46.24)	24 (37.50)	93 (49.21)	$U=34$; $P=0.02$
	<i>Oligoryzomys</i> sp.1	61 (24.11)	10 (15.63)	51 (26.98)	$U=11,5$; $p=0$
	<i>Euryoryzomys nitidus</i>	36 (14.22)	15 (23.44)	21 (11.11)	$U=61$; $p=0.53$
	<i>Akodon dayi</i>	17 (6.72)	1 (1.56)	16 (8.47)	$U=27$; $p<0.01$
	<i>Hylaeamys yunganus</i>	8 (3.16)	6 (9.38)	2 (1.06)	$U=59$; $p=0.32$
	<i>Neacomys spinosus</i>	6 (2.37)	3 (4.68)	3 (1.59)	
	<i>Neacomys minutus</i>	3 (1.19)	2 (3.13)	1 (0.53)	
	<i>Hylaeamys paranensis</i>	2 (0.79)	1 (1.56)	1 (0.53)	
	<i>Oecomys bicolor</i>	1 (0.40)	1 (1.56)	-	
Echimyidae	<i>Proechimys brevicauda</i>	2 (0.80)	1 (1.56)	1 (0.53)	

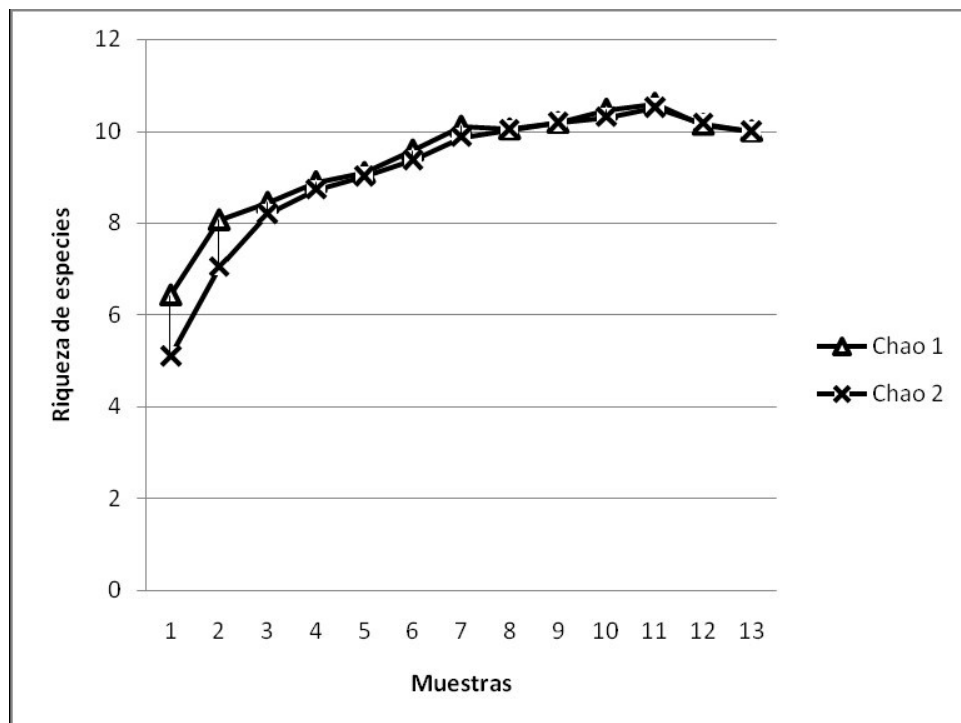


Figure 2. Species accumulation curves for rodents at Ipiri, Bolivia, considering all sampling sites.

Relative abundances were higher in crops (median = 14 individuals, range 1-36) than in adjacent forest (median = 5.5 individuals; range 1-13; $U = 30$, $N = 12$, $p = 0.015$). We found same results when we carried out the analysis on a per plot basis (Fig. 4).

Abundances of *Oligoryzomys microtis chaparensis*, *Oligoryzomys* sp. and *Akodon dayi* were significantly higher in crops (Table 1). Forest's species diversity ($D_{inv} = 4.29$) was not significantly different from that in crops ($D_{inv} = 2.99$) ($U = 0.00$, $N = 12$, $p = 0.317$). A similar trend was found for evenness, which was 0.43 in forest, and 0.33 in crops ($U = 0.00$, $N = 12$, $p = 0.317$).

Four species (*Oligoryzomys* sp., *O. microtis chaparensis*, *Euryoryzomys nitidus*, and *Akodon dayi*) with more than 10 individuals in total (crops plus forests) were taken into account to analyze sex ratio (Table 1). Only for *Oligoryzomys* sp. the sex ratio deviated significantly from 1:1, in crops ($\chi^2 = 5.667$, $df. = 1$, $p = 0.017$) but not in forest ($\chi^2 = 0.4$, $df. = 1$, $p = 0.527$; Fig. 5).

Most of individuals collected for the four species with more than 10 captures were adults. However, both species of *Oligoryzomys* showed a high proportion of juveniles in crops (6.49 % and 7.36 %) than in forest (0.43 % and 1.3 %), and also in comparison with the other species (Fig. 6).

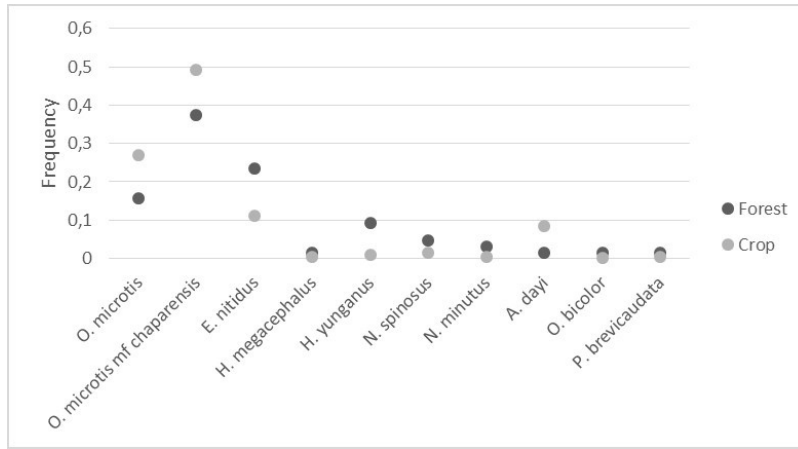


Figure 3. Relative abundance for species in crop and forest.

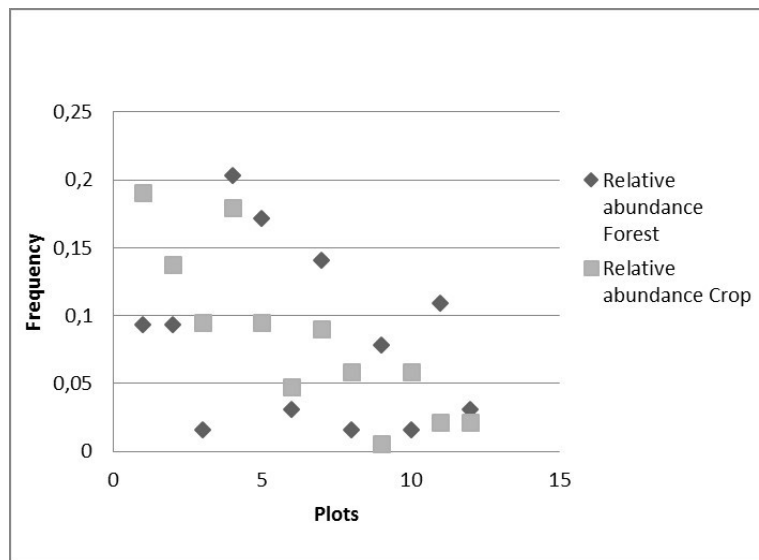


Figure 4. Relative abundance for species in crop and forest per individual plots.

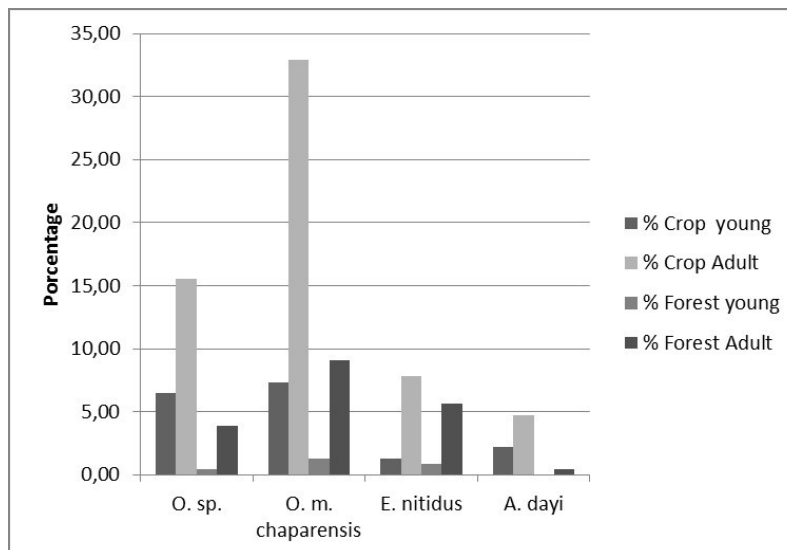


Figure 5. Number of individuals by sex, for four species of rodents with > 10 individuals, considering captures in both types of habitat.

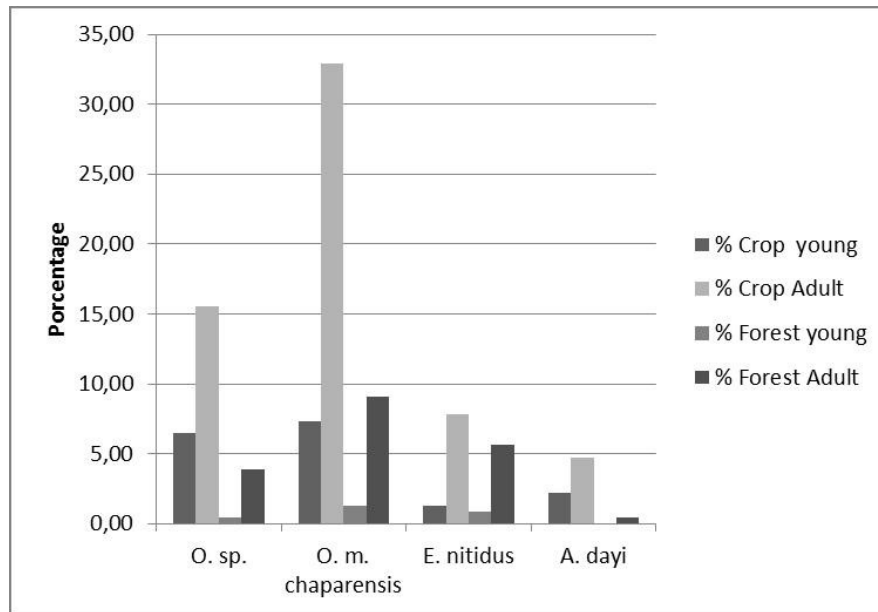


Figure 6. Age distribution of species with more than 10 individuals, per habitat.

Discussion

We carried out the first comparison of composition, abundance, and population characteristics of rodent communities in two habitats with different disturbance degree. Our results suggest that rodent assemblages in crops do not differ from those in adjacent forests, except in the abundance of some of the species. Sex ratio deviated from hypothetical 1:1 only for *Oligoryzomys* sp. Finally, for the four most abundant species, the majority of individuals trapped were adults.

Capture success (crop: 8.65%, forest: 2.93%) was similar to other studies of rodents in tropical forests (0.97% in Ramirez & Pérez 2007, 1.5 % to 7.4 % in Ferro & Barquez 2008, 2 % to 36 % in Mulungu *et al.* 2008, 3,19 % in Ashton *et al.* 2000) and species accumulation curves suggested a good sampling effort for both habitat types in our study area. It is important to notice that occurrence of species at any particular location can be biased due to unequal species detectability (Boulinier *et al.* 1998, Pollock *et al.* 2002, Kéry & Royle 2008); however, our results showed a similarity in species detectability.

Species richness is one of the most extensively used measures for biodiversity monitoring, because it can be related to environmental factors, like climate change, or environmental degradation (Yoccoz *et al.* 2001, Pollock *et al.* 2002). One likely explanation for the lack of differences in species diversity between crops and forests at our study site may be that agricultural activities had only begun 3-4 years before our study started. This fact suggests that the degree of disturbance in crops may have not reached levels that were detectable by the approach and methods we used, or may not be large enough for rodents. Effect of time since disturbance and vegetation heterogeneity is of

primary importance in determining community composition and population structure in small mammals. For example, Malcolm (1988) showed that small mammal communities in patches of different size and distinct times since disturbance were significantly different, particularly for generalist species. Likewise, in a study in eastern Paraguay, de la Sancha (2014) found that 40 years of deforestation events had changed the community structure, and this was because medium-sized forest remnants had highest species diversity; most likely because of a proportionally larger contribution of the border effect.

However, it may also be possible that crops and forest habitats at our study site offer the same quality of resources for rodents that could produce the similarity between the two habitats types, as reported by Cruz *et al.* (2010) in Chiapas – Mexico. This result could be explained by the fact that Ipiri is a very recently established community, plus the less labors in the settlement could not produce a change in the community structure of rodents. Another important characteristic of these habitats is that the proximity of forests to agroforestry crop systems (all crops had more than two species) may allow free movement from one type of habitat to the other, which could explain the lack of differences in species richness (Moguel & Toledo 1999, Rice & Greenberg 2002, Faria *et al.* 2006). Thus, the particular features of Ipiri agroforestry crops could be responsible for the similarities in richness. The increase of diversity in crops may be due to the increasing abundance of individuals in the crops, like some studies (for several groups birds, bats, and rodents) have also reported in other agroforestry systems, where cacao (*Theobroma cacao*) was one of main crops (Ashton *et al.* 2000, Cassano *et al.* 2009).

The absolute differences in diversity were higher, but were not statistically significant; the opposite was true for abundances, which were found to be higher in crops. A simple explanation for this result may be that crops contain a greater abundance of food resources, but only for some species (granivorous and omnivorous). Supporting this idea, three species that were significantly more abundant in crops (*O. m. chaparensis*, *Oligoryzomys* sp., and *Akodon dayi*) are omnivorous (Bergallo & Magnusson 1999, Veloso *et al.* 2004, Santos *et al.* 2007). It is reasonable to think that these species can make better use of abundant resources in crop areas, which would allow them to increase their reproductive output. This may result also from their capacity to take advantage of changes in their environment. Their demographic flexibility (Santos *et al.* 2007) might make those species more resistant to habitat changes (Veloso *et al.* 2004). On the other hand, other species in the study (i.e.: *Neacomys spinosus*, *O. bicolor*) that were less abundant could be more sensitive to the changes in the environment. In summary, crop areas at Ipiri might be offering more food resources than the adjacent primary forest for some species of rodents.

It has been reported that some rodent populations concentrate reproduction during the wet season, in response to a greater abundance of resources (Jackson & Van Aarde 2004, Santos *et al.* 2007). Because our sampling was carried out only during the dry season, we expected a larger number of adults at Ipiri. Our results agreed with expectations in the forest but results for crops were different. By providing more food resources crops, could support higher natality rates than forest; supporting the relationship between reproduction and abundance of resources (Spotorno *et al.* 2000). However, to fully test this hypothesis it is necessary to capture the whole seasonal variation, probably for several years. Another likely explanation to our findings could be that the area under crops is smaller than that covered by forest, which may positively affect the catchability of juveniles.

It has been suggested that females of some species tend to change their parental care efforts, in response to resource scarcity, particularly for mammals and birds, where females increase the parental care for their male offspring (Cockburn *et al.* 1985, Cockburn *et al.* 2002). Our findings of a higher abundance of *Oligoryzomys* sp., and positive sex bias towards males, may be a result of an inter-seasonal dynamics, sex differences in behavior and a seasonal variation in habitat availability, which may affect population structure, species composition, sex differences in mobility, among others (Zenuto *et al.* 2002). Only a more intense sampling may clarify this possibility.

Conclusions

We did not find differences in rodent species diversity between agroforestry crops and nearby forests.

Additionally, small differences in abundance, sex ratios and proportion of juveniles were evident only in 20 – 40% of species. The main factors potentially explaining our results are related to the fact that the disturbance (crops) are very recent and affecting a small proportion of the study area. Although it is tempting to suggest that our study provides a window into the early effects of human-induced disturbance on the community and composition of rodent assemblages, our conclusions are tempered by the need of further, more extensive sampling with the incorporation of additional trap types.

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