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# Diversity and ecology of anuran communities in San Sebastián (Chiquitano region, Bolivia)

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**Abstract.** We studied species composition and diversity of anuran communities in different habitats in the eastern lowlands of Bolivia. Additionally, we investigated microhabitat selection, seasonal calling activity and call frequency segregation. The study site San Sebastián is a cattle ranch in a landscape consisting of a mosaic of different habitats (Cerrado savannas partially used as pasture, numerous temporary wetlands, ponds and artificial lakes, and endemic Chiquitano Dry Forest). We investigated five selected study areas in typical habitats using transect methods (visual encounter surveys, audio surveys). Diversity and similarity among sites were examined by using Shannon-Index, Evenness, and Jaccard cluster analysis. We based our calculations on 3,940 observations of 31 species in total. The most abundant species were *Dendropsophus minutus, D. nanus, Scinax* cf. *fuscomarginatus,* and *Phyllomedusa boliviana*. We found a high level of partitioning of the species according to microhabitat selection, seasonal calling activity and call frequency segregation. The endemic Chiquitano Dry Forest turned out to be species poor in comparison to the other study areas in open formations. The habitat structure complexity might be responsible for the high anuran α- and β-diversity of the relatively small study site. The results of the study emphasize the high value for conservation of the Chiquitano region. It is necessary to do further studies of the herpetofauna of that diverse but understudied region.

Key words: Anuran community, audio surveys, Bolivia, Chiquitano region, Chiquitano Dry Forest, diversity, microhabitat use, seasonal activity, transect method, visual encounter surveys.

**Resumen**. Estudiamos la composición de especies y la diversidad de las comunidades de anuros de diferentes hábitats en las tierras bajas del este de Bolivia. Adicionalmente, investigamos la selección de hábitat, y la actividad temporal y segregación de la frecuencia de las vocalizaciones. Este estudio se realizó en San Sebastián, un rancho ganadero que contiene un mosaico de diferentes hábitats (Cerrado – una sabana parcialmente usada para pastizales, numerosos humedales, estanques y lagos artificiales y el endémico bosque seco Chiquitano). Seleccionamos e investigamos cinco áreas de estudio en hábitats típicos usando un índice de Shannon, uno de Evenness, y un análisis de cluster de Jaccard. Basamos nuestros cálculos en 3.940 observaciones realizadas en un total de 31 especies. Las especies más abundantes son *Dendropsophus minutus, D. nanus, Scinax* cf. *fuscomarginatus,* y *Phyllomedusa boliviana*. Encontramos un alto nivel de subdivisión de las especies de acuerdo con la selección de hábitat, la actividad temporal de canto y la segregación de la frecuencia de canto. El bosque seco endémico Chiquitano tiene un bajo número de especies en comparación con las otras áreas de estudio en formaciones abiertas. La complejidad de la estructura del hábitat pudiera ser responsable de la elevada diversidad α y β de anuros de nuestra área de estudio, la cual es relativamente pequeña. Los resultados de este estudio enfatizan la gran importancia de conservar la región del Chiquitano. Es necesario realizar estudios adicionales herpetofaunísticos en esta diversa, aunque poco estudiada región.

## Introduction

There has been increasing interest in Bolivian anurans over the last decades (e. g. De la Riva et al. 2000, Köhler 2000, Reichle 2006). Most studies focused on the montane regions of the Andes. The eastern lowlands of Bolivia, however, have received comparatively little attention, thus especially the Chiquitano region turned out to be very diverse (De La Riva 1993, Jansen et al. 2007a, b). Furthermore, there are still only a few publications dealing with ecology or species composition of anuran communities in Bolivia compared to studies about anuran taxonomy (but see De La Riva 1993, Reichle & Köhler 1998).

To contribute to the knowledge about the ecology of anuran communities in Bolivia, a study was set up in the Chiquitano region. Aim of the study was to characterize the anuran communities at this site in different habitats (forest, savanna and artificial ponds) in terms of species composition and diversity. In addition, the partitioning of the species into different microhabitats, variation in seasonal calling activity and call frequency segregation was investigated.

## Methods

### Study site

The study site was the cattle ranch San Sebastián (16°21.732' S, 62°00. 135' W, 500 m asl), 24 km south of the town of Concepción, Province of Ñuflo de Chávez, Santa Cruz Department, Bolivia (Fig. 1). The site is located

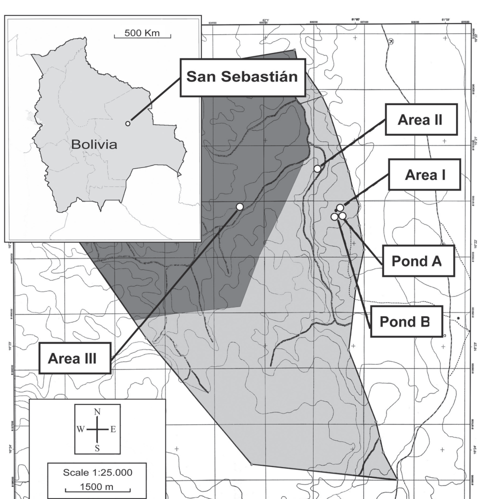


Fig. 1. Location of the study site San Sebastián in Bolivia (upper map) and detailed map of San Sebastián (lower map) with Areas I-III and Ponds A and B. Dark grey indicates the private reserve (RPPN) of 1800 ha.

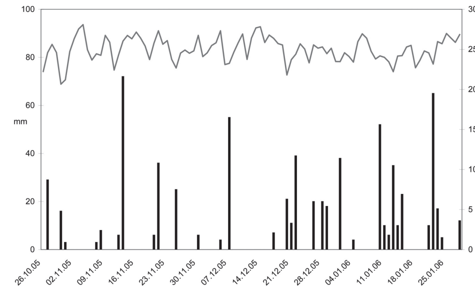


Fig. 2. Rain fall and temperature in San Sebastián between October 2005 and February 2006.

in a region locally known as the Chiquitano region. Zoogeographically, this region lies between the Amazon rainforest, the Cerrado and the Gran Chaco. According to Ibisch et al. (2003), the region is composed of the ecoregion Chiquitano Dry Forest and the subecoregion Cerrado of the Chiquitano region.

San Sebastián covers an area of 3,265 ha. The landscape is a mosaic of various habitats, such as Chiquitano Dry Forest, Cerrado savannas, which are partly used as pasture, and numerous temporary wetlands, ponds and artificial lakes. In 2002, a private reserve (RPPN = Reserva Privada de Patrimonio Natural) of 1,800 ha was established at San Sebastián in order to protect the endemic Chiquitano Dry Forest. Climatically, a distinction is made between a dry season from May to September and a rainy season from October to April, 60-80% of the rain falls between December and March. For temperature and rain fall data during the study period see Fig. 2. Average annual precipitation in San Sebastián from 1998 to 2006 is 1223 mm/a (Werding, pers. data).

### Study areas

Three study areas (Areas I-III) were selected in habitats not or only little influenced by cattle farming. Additionally, two artificial ponds (Pond A and B) were examined for comparative analyses (Fig. 1). In the following, we give a brief description of the chosen study areas:


Fig. 3. View of the study areas in San Sebastián during the rainy season. (a) Area I; (b) Area II; (c) Area III and (d) Pond A.

Area I: This area is located in a depression, which is used as pasture. The depression is dominated by open grassland with occasional trees, cacti and some small groups of shrubs. During September to October heavy rains create some flooded areas (Fig. 3 A).

Area II: This area is situated at the contact zone between open savannas and Chiquitano Dry Forest with palms. The area is also partially flooded during the rainy season, but is not used as pastures during these months (Fig. 3 B).

Area III: This area is a natural clearing in the dense Chiquitania Dry Forest of the RPPN. The clearing is dominated by several types of grasses and perennial herbs reaching a height of approximately 1.6 m at the peak of the rainy season. Here, wetland did not develop until December (Fig. 3 C).

Pond A and Pond B: The two artificial ponds are located between pastures and used to water the cattle. Pond A was surrounded by only a few shrubs and banks partly overgrown with grasses (Fig. 3 D). Pond B showed denser vegetation consisting of grass and scattered small bushes at the shore.

## Field methods

A comprehensive inventory of the herpetofauna of the study area was done during several field trips in the rainy seasons from 2004/2005 to 2007/2008 by the second author. Results of this study will be published elsewhere (Jansen, pers. data). Field work for this study was carried out by the first author between 17 October 2005 and 29 January 2006.

Each study area was investigated using Visual Encounter Surveys (VES) along transects and Audio Strip Transects (AST) according to Heyer et al. (1994). At Area I and II, two 100 m transects were set up, in Area III one 130 m and one 30 m transect were used. Ponds A and B were circumnavigated by foot along the shore. Here it was not possible to set up consistent transect lengths due to the ponds' changing water levels.

The VES was conducted in a width of two meters to each side of the transects. For the AST, transect width was extended to five meters to each side. The surveys were done in consecutive nights alternating the study areas. Area II and III where studied each in one night, whereas Area I, Pond A and Pond B were sampled in the same night because of their proximity to each other. Field work started between 22:00 and 22:30 hrs. and ended between midnight and 2:00 hrs. In each survey VES and AST were conducted simultaneously thereby walking slowly in one direction along the transect and searching and listening meticulously to detect as far as possible all visible and audible individuals along the transect. Density of anurans at Areas I, II and III was defined as follows: Individuals/m = (observations in total/number of surveys)/(length of transect 1 + length of transect 2).

During the VES, various parameters of the perches were recorded for each observed frog. These included chosen substrate by the observed individual, density of the vegetation in the immediate proximity of the perch, and its height. For the substrate parameters the following categories were chosen: open water, bank, soil, flooded hoof prints, grass, trunk/branch of shrub, shrub leaf, trunk/branch of bush, bush leaf, trunk/branch of tree and tree leaf. Density of vegetation was differentiated into four categories: without plant cover, sparsely covered with plants, light vegetation and densely covered with vegetation. Vertical height was measured in ranks of 10 cm from ground.

In addition to the VES and AST, we measured calling intensities with Audio Surveys (AS) to detect variations of seasonal activities. The AS were done from fixed positions next to the transects immediately before the start of the transect surveys. In a time-frame of 10-15 minutes, calling intensities were estimated using the following categories: 0 = no calling activity, 1 = call of a single individual, 2 = several divided calls, 3 = several overlapping calls, 4 = full chorus.

A HOBO Pendant temperature 64 K data logger (HOBO Data Logger Company, MA, USA) was situated in study Area I. At the beginning of every VES, AST and AS, air temperature and air humidity were measured with analog and digital instruments. For species determination we used Marquez et al. 2002, and De La Riva et al. (2000) with the nomenclature of Faivovich et al. (2005), Frost et al. (2006) and Chapparo et al. (2007).

## Measurements of α- and β-diversity

For measurements of diversity, Shannon index values were calculated (Townsend et al. 2003, Magurran 2004). This standard method includes the number of species at one site as well as the number of individuals at this site. The index shows a higher value at a high number of species and an even statistical distribution (of the species at one site) whereas a lower number of species and an uneven distribution results in a lower value.

The index ($H_s$) is calculated with the following formula:

$$H_s = -\sum_{i-1}^{s} p_i \ln p_i \qquad p_i = \frac{n_i}{N} \qquad \sum_{i-1}^{s} p_i = 1$$

where $p_i$ is the observed relative abundance of species *i* and $n_i$ its number of individuals. N denotes the total number of individuals and S the total number of species.

To check if the calculated value results from the number of species or the equal distribution, the Evenness ($E_s$) according to Shannon is used:

$$E_s = \frac{H_s}{H_{max}} = \frac{H_s}{I\,S\,n}$$

where $H_s$ denotes the diversity related to the number of species and $H_{max}$ the highest possible diversity in each area. Evenness is calculated as the ratio between the value of the Shannon and the highest possible diversity at the same number of species. This is reached when every species shows the same part of the total abundance of all species. Therefore the Evenness is defined between 0-1.

To determine the similarity of the areas and the ponds according to their species composition, the Jaccard cluster analysis was used. This analysis is based on a present-absent-matrix of species in each area. All calculations were done by using the BioDiversity Pro software (McAleece et al. 1997).

### Bioacoustics

Calls were recorded with a Sony Hi-Mini-Disc-Walkman (MZ-NH90) and a ME80 microphone by Sennheiser electronic GmbH, Wedemark, Germany. Recordings were analysed with Adobe Audition 1.5, using 256 sampling points.

## Results

In all five study sites, a total of 31 anuran species were found during the study period (Tab. 1). A total of 3,940 observations in all study sites were protocolled. The most abundant species were *Dendropsophus nanus* (828 observations), *D. minutus* (555), *Scinax* cf. *fuscomarginatus* (384), and *Phyllomedusa boliviana* (344). For further results see Tab. 1. Of all species, 19 (61%) belong to the family Hylidae, 9 (29%) to the family Leptodactylidae, 2 (7%) to the family Microhylidae, and 1 (3%) species belongs to the Bufonidae. See Fig. 4 for total numbers of species in the Areas I-III and Pond A and B and their species composition by families.

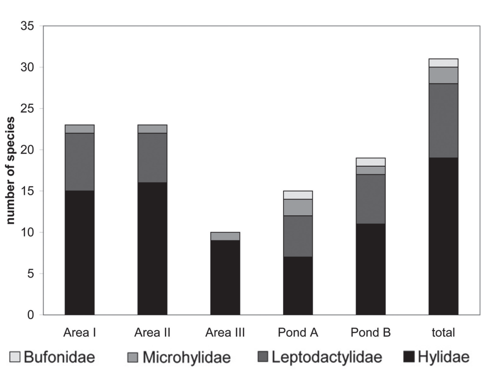


Fig. 4. Total numbers of species in the study areas and species composition, by families.

### α- and β-Diversity

Area I and II show the highst numbers of species (23 species each), whereas in Area III the lowest number of species was detected (see Tab. 1, Fig 4). Dominant species according to their relative abundances along the transects were as follows:

Area I (savanna wetland, 823 observations in total): *Dendropsophus nanus* (357 observations); *Scinax* cf. *fuscomarginatus* (122); Area II (savanna wetland at forest edge, 876 observations in total): *D. nanus* (358); *S.* cf. *fuscomarginatus* (201); Area III (forest, 344 observations in total): *D. nanus* (93), *D. bifurcus* (85); *Phyllomedusa boliviana* (53), *D. minutus* (43); Pond A (artificial pond, 747 observations in total): *P. boliviana* (287), *Eupemphix nattereri* (261); Pond B (artificial pond, 1202 observations in total): *Dendropsophus minutus* (459); *D. rubicundulus* (141); *P. centralis* (115).

Summarising all 3,940 observations in all sites, the most abundant species were *Dendropsophus nanus, D. minutus, Scinax* cf. *fuscomarginatus,* and *Phyllomedusa boliviana*. From these species, *D. nanus* had the widest range of micro- and macrohabitats. One further species, *S. nasicus,* occurred at all study sites, showing a wide range of macrohabitats.

Density in the study sites were calculated as follows: Area I = 0,129 individuals/m; Area II = 0,258 individuals/m; Area III = 0,195 individuals/m. Highest Shannon Index values were calculated at Pond B ($H_s$ = 2.16) and Area I ($H_s$ = 2.106), the lowest diversity was measured at Pond A ($H_s$ = 1.38). The calculation of the Evenness according to Shannon showed the highest value at Area III ($E_s$ = 0.78), whereas the lowest value was determined at Pond A ($E_s$ = 0.51) (see Tab. 2).

Tab. 1. Presence and abundance (number of observations of each species) of 31 anuran species in the study areas, San Sebastián, Bolivia.

| species | Area I | II | III | Pond A | Pond B | observations |
|---|---|---|---|---|---|---|
| Bufonidae | | | | | | |
| *Rhinella schneideri* (Lutz, 1925) | | | | × | × | 14 |
| Hylidae | | | | | | |
| *Dendropsophus bifurcus* (Anderson, 1945) | × | × | × | | | 119 |
| *Dendropsophus leali* (Bokermann, 1964) | | × | × | | × | 50 |
| *Dendropsophus leucophyllatus* (Beireis, 1783) | × | × | × | | | 105 |
| *Dendropsophus melanargyreus* (Cope, 1862) | × | × | | × | × | 110 |
| *Dendropsophus minutus* (Peters, 1872) | | × | × | | × | 555 |
| *Dendropsophus nanus* (Boulenger, 1889) | × | × | × | × | × | 828 |
| *Dendropsophus rubicundulus* (Reinhardt, 1962) | × | × | | | × | 182 |
| *Hypsiboas punctatus* (Schneider, 1799) | × | × | | | | 66 |
| *Hypsiboas raniceps* (Cope, 1862) | × | × | | | | 44 |
| *Osteocephalus taurinus* Steindachner, 1862 | × | × | | | | 13 |
| *Phyllomedusa boliviana* Boulenger, 1902 | | × | × | × | × | 344 |
| *Phyllomedusa azurea* Cope, 1862 | × | × | | × | × | 37 |
| *Pseudis paradoxa* (Linnaeus, 1758) | | | | | × | 32 |
| *Scinax* cf. *fuscomarginatus* (Lutz, 1925) | × | × | | | × | 384 |
| *Scinax fuscovarius* (Lutz, 1925) | × | × | × | × | × | 85 |
| *Scinax nasicus* (Cope, 1862) | × | × | × | × | × | 69 |
| *Scinax* cf. *nebulosus* (Spix, 1824) | × | | | | | 12 |
| *Scinax ruber* (Laurenti, 1768) | × | | | | | 2 |
| *Trachycephalus venulosus* (Laurenti, 1768) | × | × | × | × | | 50 |
| Leptodactylidae | | | | | | |
| *Leptodactylus* cf. *diptyx* Boettger, 1885 | × | | | | | 1 |
| *Leptodactylus elenae* Heyer, 1978 | | × | | | | 1 |
| *Leptodactylus fuscus* (Schneider, 1799) | × | × | | × | × | 106 |
| *Leptodactylus labyrinthicus* (Spix, 1824) | × | | | | | 1 |
| Leiuperidae | | | | | | |
| *Eupemphix nattereri* Steindachner, 1863 | × | × | | × | × | 282 |
| *Physalaemus albonotatus* (Steindachner, 1863) | × | × | | × | × | 23 |
| *Physalaemus centralis* Bokerman, 1962 | × | × | | × | × | 160 |
| *Physalaemus cuvieri* Fitzinger, 1826 | × | × | × | | × | 85 |
| *Pseudopaludicola mystacalis* (Cope, 1887) | | | | × | × | 96 |
| Microhylidae | | | | | | |
| *Chiasmocleis albopunctata* (Boettger, 1885) | | | | × | | 1 |
| *Elachistocleis* sp. (Schneider, 1799) | × | × | | × | × | 83 |
| Total number of species: 31 | **23** | **23** | **10** | **15** | **19** | **3,940** |

According to species composition, the cluster analysis showed the highest similarity between Area I and II. Area III showed a distinct dissimilarity to the other areas and ponds (Fig. 5).

Tab. 2. Values of the Shannon calculations including the Shannon diversity value ($H_s$), the maximum possible value in each area ($H_{max}$) and the value for the Evenness ($E_s$) for the study areas in San Sebastián, Bolivia.

| Index | Area I | Area II | Area III | pond A | pond B |
|---|---|---|---|---|---|
| Shannon ($H_s$) | 2.106 | 1.974 | 1.797 | 1.382 | 2.16 |
| Shannon ($H_{max}$) | 3.178 | 3.135 | 2.303 | 2.708 | 2.944 |
| Evenness ($E_s$) | 0.663 | 0.629 | 0.78 | 0.51 | 0.734 |

## Microhabitat selection, seasonal calling activity, and bioacoustics

A wide range of substrates were used as perches, but most anurans preferred grass (Fig. 6). Preferred perch heights of the anuran species are presented in Fig 7. A schematic illustration of the spatial partitioning is presented in Fig 8. For summary of seasonal calling activity see Appendix I-V. A comparison matrix for all species including favored subtrat and vegetation density, average perch height, seasonal calling activity patterns and dominant frequency of advertisement calls is presented in Tab. 3.

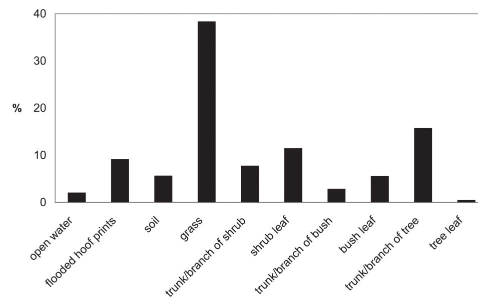


Fig. 6. Microhabitat use of anurans (3,940 observations in total) between October 2005 and February 2006, San Sebastián, Bolivia.

## Discussion

We found a high α-diversity at the study sites, as well as significant differences in species composition and diversity in between the study sites. As major factor influencing the diversity of the study areas we assume differences in habitat structure complexity.

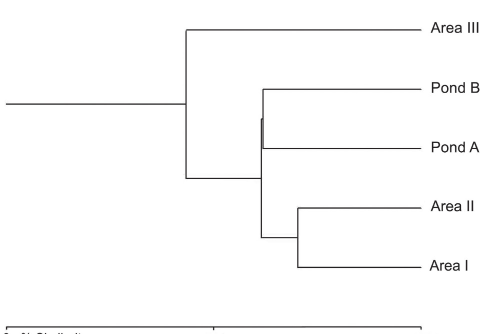


Fig. 5. Jaccard cluster analysis for similarity of study areas in San Sebastián, Bolivia.

Presence respectively absence of species can be explained by micro- and macrohabitat requirements of the involved species.

Highest species richness and high Shannon and Evenness values were measured in the savanna-wetland (Area I) and the savanna/forest contact zone (Area II). As described above, Area I is located in a depression, which forward partitional flooding through ponded surface water and rainfall. A mosaic of trees, bushes and grassland result in a very complex structure of habitat. Area II at the contact zone between forest and savanna, showed the highest density (individuals per meter on transect) compared to Area I and III. This might be due to the predominance of grass, the most favored microhabitat of the anurans in San Sebastián. It is remarkable that the highest Shannon value of all areas showed the artificial Pond B, although it is a water whole not very frequently used by cattle and relatively poor in structure. An explanation for this could be the fact, that here grass is the predominant microhabitat. Pond A is much more frequently used by cattles.

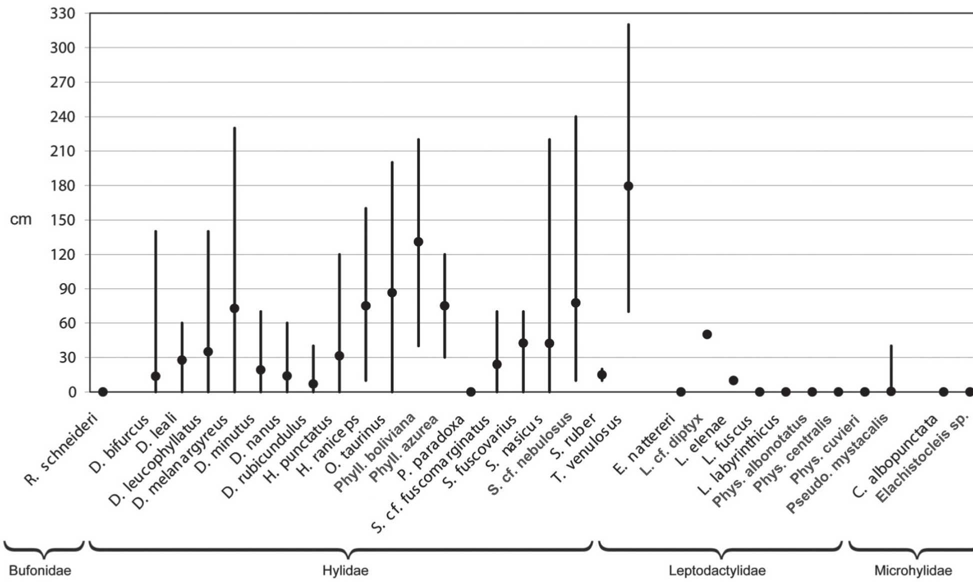


Fig. 7. Vertical microhabitat partitioning of anurans (3,940 observations in total) between October 2005 and February 2006, by families. Dots mark the average preferred perch height above ground.

Poor habitat structure und grass vegetation density in this study area results in poor anuran diversity.

The results from this study let assume positive effects of extensive cattle farming on the anuran fauna in the Chiquitano region under certain aspects. Most important is the supply of artificial water bodies in the dry savannas. In addition, pasture can lead to the regularly aerating of the ground by the hoofs of the cattle and horses. As a result, the ground keeps moist for a longer time, small ponds in wholes of hoofs are created, vegetation is kept small, and the area keeps its open character, as observed in Area I. However, it must be emphasized that cattle farming in San Sebastián can be characterized as not extensive, as there are only about 500 cattle on about 1,400 ha for pasture.

The wetland in the Chiquitano Dry Forest (Area III) was relatively poor in species numbers and regarding its species composition it is significant dissimilar to the other areas. The composition of the anuran community in Area III can be characterized by the absence of pure open formation species on one hand, such as *Scinax* cf. *nebulosus*, *Leptodactylus elenae, Dendropsophus melanargyrea,* and *Eupemphix nattereri*, and on the other hand by the absence of pure forest species (species solely occurring in this area). According to this, we could only find species present in at least two other sites. Therefore, the recorded species found at Area III can be understood as opportunistic or occasional invaders into the forest, which, however, seem to find a suitable habitat which is shown by high Evenness values, as well as high densities.

Other species found in the Chiquitano Dry Forest but not at Area III include *Rhinella* cf. *margeritifera*, *Leptodactylus leptodactyloides*, and *Epipedobates pictus* (pers. data). However, these species were found in open formations as well. Similar results like ours were shown by De La Riva et al. (2000). From all 36 species listed as inhabitants of the Chiquitano Dry Forest, only *Phyllomedusa camba* is an exclusively inhabitant of forest formations (including Amazonian Rainforests and other), whereas the other inhabit each open and forest formations, and moreover, 28 species (78 %) of those species are listed as species

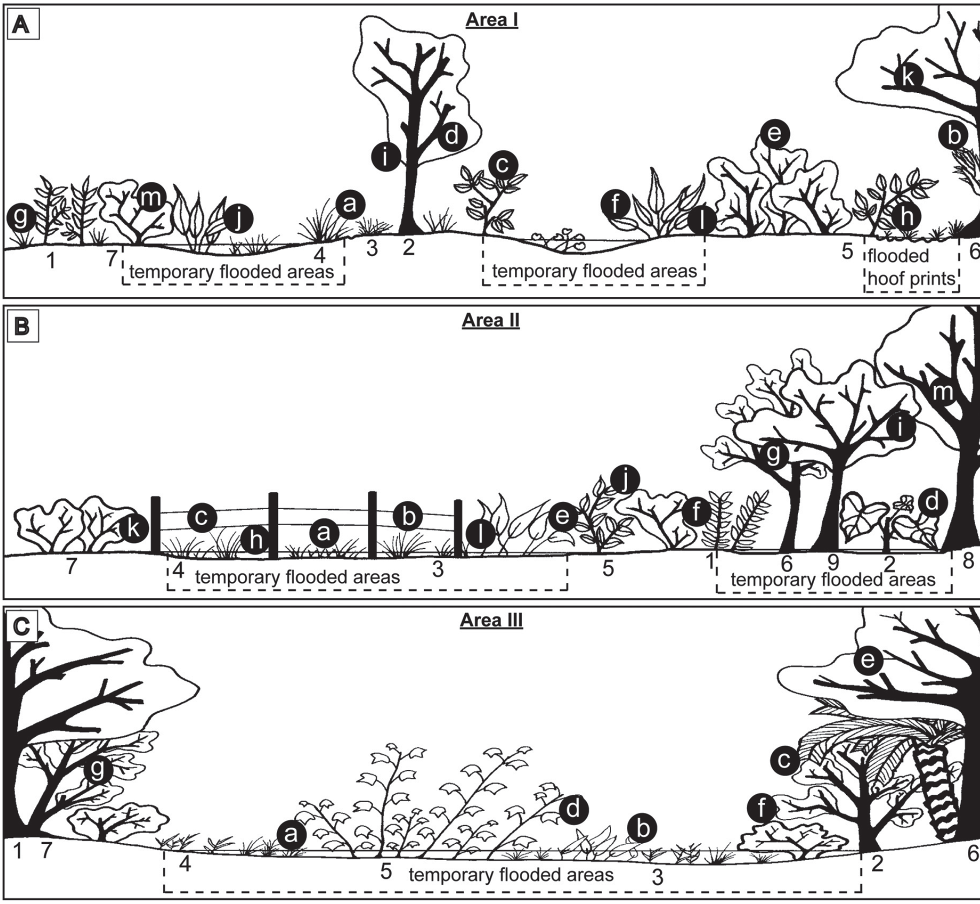


Fig. 8. Schematic illustration of the spatial partitioning of the anurans in Area I-III, San Sebastián, Bolivia (species with mainly equal microhabitats combined): (A) Area I: (a) *D. nanus, S.* cf. *fuscomarginatus* (b) *T. venulosus* (c) *D. leucophyllatus, D. bifurcus* (d) *H. raniceps, S. nasicus* (e) *D. melanargyreus, Phyll. azurea* (f) *H. punctatus, S. fuscovarius* (g) *L. fuscus, E. nattereri* (h) *E. ovalis, Phys. cuvieri, Phyll. centralis, Phys. albonotatus* (i) *S.* cf. *nebulosus* (j) *D. rubicundulus, S. ruber* (k) *O. taurinus* (l) *L. labyrinthicus* (m) *L. diptyx*. vegetation: [1] Lamiaceae [2] Moraceae [3] Cyperaceae [4] Graminae [5] Compositaceae [6] Anacardiaceae [7] Acanthaceae. (B) Area II: (a) *D. nanus, D. rubicundulus, L. elenae* (b) *S.* cf. *fuscomarginatus* (c) *D. minutus, S. nasicus* (d) *D. leucophyllatus, H. punctatus, Phyll. azurea* (e) *D. bifurcus* (f) *D. leali* (g) *O. taurinus* (h) *Phys. centralis, Phys. cuvieri* (i) *H. raniceps* (j) *D. melanargyreus* (k) *L. fuscus* (l) *S. fuscovarius, Phys. albonotatus* (m) *T. venulosus*. vegetation: [1] Lamiaceae [2] Moraceae [3] Cyperaceae [4] Graminae [5] Compositaceae [6] Combretaceae [7] Acanthaceae [8] Ulmaceae [9] Papillionoideae. (C) Area III: (a) *D. nanus, D. minutus, Phys. cuvieri* (b) *D. bifurcus* (c) *Phyll. boliviana* (d) *D. leali*, *D. leucophyllatus* (e) *T. venulosus* (f) *S. nasicus* (g) *S. fuscovarius*. vegetation: [1] Bombacaceae [2] Moraceae [3] Cyperaceae [4] Graminae [5] Cucurbitaceae [6] Anacardiaceae [7] Meliaceae.

of predominantly open formations. Possible reasons for the limitation of species numbers in the Chiquitano Dry Forest might be the lack of waterbodies as breeding sites.

To summarize the results of this study, the anuran communities of San Sebastián can be characterized as highly specialized according to microhabitat use, seasonal calling activity

Tab. 3. Comparison matrix of favoured substrate and vegetation density, average perch heights, seasonal calling activity pattern and dominant frequency of encountered frog species in San Sebastián, Bolivia. Data result from VES, AST and AS. Abbrevation: n.d. = no data. Categories for substrate: A = open water, B = flooded hoof prints, C = soil, D = grass, E = trunk/branch of shrub, F = shrub leaf, G = bush leaf, H = trunk/branch of tree. Categories for vegetation density: I = without plant cover, II = sparsely covered with plants, III = light vegetation, IV = densely covered with vegetation. Perch height values are given as average with range in parentheses. Categories for main calling activity (during study period): 0 = no pattern of activity, 1 = during or after rainfalls 2 = at the beginning of study period, 3 = at the end of study period, 4 = in the middle of study period, s.h. = scarcely heard.

| Species | Substrate | Vegetation Density | Average Perch Height (cm) | Main calling activity (during study period) | Dominant Frequency (Hz) |
|---|---|---|---|---|---|
| *Rhinella schneideri* | A | I | 0 | s.h. | 701.4 ± 23 |
| *Dendropsophus bifurcus* | D | IV | 13.7 (0-140) | 5 | 2,893.7 ± 42 |
| *D. leali* | D | III | 27.6 (0-60) | 3 | 6,400.8 ± 105 |
| *D. leucophyllatus* | D | IV | 34.9 (0-140) | 5 | 2,680.9 ± 52.4 |
| *D. melanargyreus* | E | III | 72.6 (0-230) | 1 | 1,763.8 ± 108.9 |
| *D. minutus* | D | III | 19.2 (0-70) | 5 | 2,335.4 ± 76.7 |
| *D. nanus* | D | IV | 13.9 (0-60) | 5 | 4,236.2 ± 138.6 |
| *D. rubicundulus* | D | III | 7 (0-40) | 5 | 3,439.1 ± 48.2 |
| *Hypsiboas punctatus* | D | III | 31.4 (0-120) | 4 | 839 ± 33.3 |
| *H. raniceps* | H | II | 75 (10-160) | 4 | 696.9 ± 22.4 |
| *Osteocephalus taurinus* | H | II | 86.7 (0-200) | 0 | 716.7 ± 32.4 |
| *Phyllomedusa boliviana* | H | III | 130.89 (40-220) | 5 | 1,306.1 ± 43.2 |
| *P. hypochondrialis* | D/F | IV/II | 75 (30-120) | s.h. | 1,973.7 ± 46.3 |
| *Pseudis paradoxa* | A | IV | 0 | 4 | n.d. |
| *Scinax* cf. *fuscomarginatus* | D | IV | 24 (0-70) | 3 | 4,129.6 ± 222.8 |
| *S. fuscovarius* | H | III | 42.5 (0-70) | 0 | 872.9 ± 34.1 |
| *S. nasicus* | H | II | 42.5 (0-220) | 0 | 962.2 ± 3.4 |
| *S.* cf. *nebulosus* | D/F | IV/II | 77.5 (10-240) | s.h. | 3,071.6 ± 84.1 |
| *S. ruber* | H | II | 15 (10-20) | 1 | 1,578.5 ± 179.7 |
| *Trachycephalus* venulosus | D | II | 179.4 (70-320) | 5 | 484.8 ± 27.3 |
| *Leptodactylus* cf. *diptyx* | D | IV | 50 (50-50) | 4 | 4,672.8 ± 56.6 |
| *L. elenae* | D | III | 10 (10-10) | s.h. | 963.6 ± 9.7 |
| *L. fuscus* | C | I | 0 | 2 | 2,497.6 ± 72.2 |
| *L. labyrinthicus* | B | IV/III | 0 | 0 | 376.7 ± 6.2 |
| *Eupemphix nattereri* | H | III | 0 | 5 | 641.1 ± 9.5 |
| *Physalaemus albonotatus* | A | III | 0 | 5 | 2,203.3 ± 41 |
| *P. centralis* | A | III | 0 | 5 | 486.7 ± 49.9 |
| *P. cuvieri* | D | III | 0 | 5 | 562.3 ± 10.9 |
| *Pseudopaludicola mystacalis* | C | I | 0 | n.d. | n.d. |
| *Chiasmocleis albopunctata* | C | I | 0 | s.h. | 5,404.9 ± 26.9 |
| *Elachistocleis* sp. | B | III | 0 | 0 | 3,677.8 ± 202.3 |

and call frequency segregation. The high anuran α- and β-diversity at the study site might be caused by complexity of micro- and macrohabitat structures of the Chiquitano region. Positive effects of extensive cattle farming could be found in at least two sites due to supply of water and landscape structure conservation by perching. We assume that the endemic Chiquitano Dry Forest functions as a suboptimal habitat for most of the amphibian species of the region, as most of them seem to be more adapted to open formations. The results show the high value for conservation concerns of this unique region, which is threatened by deforestation for forestry, agriculture and intensive cattle farming.

## Future prospects

We are far away from understanding the factors that influence diversity and ecology of the anuran communities in the Chiquitano region. A more thorough comprehension might be achieved in long-term studies. In San Sebastián the following rainy season 2006/2007 showed a significant smaller amount of rainfall, which resulted in a different species richness as well as composition of species (Jansen et al. in press). Some species occurred with drastically lower numbers (e.g., *Hypsiboas raniceps, Physalaemus cuvieri*) than in this study, and some others did not appear at all (e.g., *Leptodactylus labyrhinticus*). The analysis of those fluctuations and their reasons would help completing the dynamic image of this anuran population.

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**Appendix I.** Seasonal calling activity of the anurans at Area II between October 2005 and February 2006, based on Audio Surveys. Categories: 1 = call of a single individual, 2 = several divided calls, 3 = several overlapping calls, 4 = chorus. An empty space indicates no calling activity.

| species / date | *Dendropsophus bifurcus* | *D. leucophyllatus* | *D. melanargyreus* | *D. minutus* | *D. nanus* | *D. rubicundulus* | *Hypsiboas punctatus* | *H. raniceps* | *Osteocephalus taurinus* | *Phyllomedusa boliviana* | *Scinax* cf. *fuscomarginatus* | *S. fuscovarius* | *S. nasicus* | *Trachycephalus venulosus* | *Eupemphix nattereri* | *Leptodactylus fuscus* | *Physalaemus albonotatus* | *P. centralis* | *P. cuvieri* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26.10.05 | | | 2 | | | | | 1 | 1 | 1 | | | | | 2 | 3 | | | 1 |
| 02.11.05 | | | | | | | | | | 2 | | | | 1 | | 2 | | | |
| 08.11.05 | | | | | | | | | | 1 | | | | 2 | | 3 | | | 3 |
| 13.11.05 | | | 3 | | 4 | | | | | | | 2 | 3 | | 2 | 2 | 4 | 4 | |
| 17.11.05 | | | | | | | 3 | | | 2 | | | 3 | 2 | | 3 | 3 | 3 | |
| 28.11.05 | | 2 | | 2 | 4 | 3 | | | | | | | | | | | 2 | 3 | |
| 04.12.05 | | 3 | | | 4 | | 2 | 3 | | | | | | | | 2 | | 3 | 2 |
| 08.12.05 | | 2 | | | 4 | 3 | | 2 | | | | | | | | | 4 | 3 | |
| 15.12.05 | | 2 | | | 4 | | 3 | 3 | | | | | | | | | | 2 | |
| 25.12.05 | 1 | 2 | | 2 | 4 | | | 2 | | | | | | 1 | | | 3 | 3 | |
| 06.01.06 | 2 | | | 3 | 4 | | 3 | 3 | | | | | | | | | | | 3 |
| 09.01.06 | 3 | 3 | | 2 | 4 | | 3 | 2 | 3 | | 2 | | | | | | | 3 | |
| 12.01.06 | 4 | 3 | | 3 | 4 | | 2 | 2 | | | | | | | | 3 | | 2 | |
| 17.01.06 | 3 | 3 | | 2 | 3 | | | | | | 3 | | | | | | 3 | 2 | |
| 24.01.06 | | 3 | | 3 | 4 | | 3 | 2 | 1 | | 3 | | | | | | 2 | 2 | |

**Appendix II.** Seasonal calling activity of the anurans at Area I between October 2005 and February 2006, based on Audio Surveys. Categories: 1 = call of a single individual, 2 = several divided calls, 3 = several overlapping calls, 4 = chorus. An empty space indicates no calling activity.

| species / date | *Dendropsophus bifurcus* | *D. leucophyllatus* | *D. melanargyreus* | *D. nanus* | *D. rubicundulus* | *Hypsiboas punctatus* | *H. raniceps* | *Phyllomedusa boliviana* | *P. azurea* | *Scinax* cf. *fuscomarginatus* | *S. fuscovarius* | *S. nasicus* | *S.* cf. *nebulosus* | *S. ruber* | *Trachycephalus venulosus* | *Eupemphix nattereri* | *Leptodactylus* cf. *diptyx* | *L. fuscus* | *L. labyrinthicus* | *Physalaemus albonotatus* | *P. centralis* | *P. cuvieri* | *Elachistocleis* sp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21.10.05 | | | | | | | | | | | | | | | 2 | 4 | | 3 | | | | 2 | |
| 24.10.05 | | | | | | | | | | | | | | | | | | 3 | | | | 3 | |
| 26.10.05 | | | 4 | 4 | | | 2 | | | | | 1 | | | | 4 | | 2 | | 1 | 4 | | 3 |
| 27.10.05 | | 1 | 4 | 4 | | | 2 | | | | 2 | 1 | | | 2 | | | 2 | | | 4 | 2 | |
| 30.10.05 | | | | | | | | 1 | | | 3 | | | | | | | | | | | 3 | |
| 01.11.05 | | | | | | | | | | | | | | | | | | 3 | | | | 4 | |
| 04.11.05 | | | | 4 | | | | | | | | | | | | | | 3 | | | | 3 | |
| 06.11.05 | | | | | | | | | | | | | | | | | | 3 | 1 | | | 3 | |
| 07.11.05 | | | | 2 | | | | | | | | | | | 1 | | | 3 | | | | 3 | |
| 11.11.05 | | | 4 | 3 | | | | | | | | | | | 2 | | | | | | 3 | | |
| 12.11.05 | 1 | | 4 | 3 | | | 2 | | | | 2 | 3 | | | 3 | | | 3 | 1 | 3 | | 3 | 2 |
| 14.11.05 | | | 3 | 4 | | | 2 | | | | | | | | | | | 3 | 2 | 3 | 3 | 2 | 3 |
| 20.11.05 | | 2 | 3 | 4 | | | 2 | | | | 2 | 3 | | 2 | | | | 3 | | 3 | 3 | 2 | 2 |
| 26.11.05 | | | | 4 | | | 1 | | | | | | | | 1 | | | 3 | | | 2 | 3 | |
| 29.11.05 | | 2 | | 3 | | | 1 | | | | | | | | | | | 2 | | | | | |
| 30.11.05 | | 2 | | 4 | | | 3 | | | | | | | | 1 | | | 1 | | | | 3 | |
| 05.12.05 | | 3 | | 4 | | | 2 | | | | | 2 | | | | | | 2 | | | | 3 | |
| 09.12.05 | | 2 | | 3 | | 2 | | 1 | | | | | | | | | 3 | | | | 3 | 3 | |
| 10.12.05 | | 3 | | | | | | | | | | | | | 2 | | 3 | | | | | 3 | |
| 13.12.05 | | 2 | | 4 | | 3 | | | | | | | | | | | 2 | | | | | 2 | |
| 16.12.05 | | 2 | | 3 | | 2 | | | | | | 1 | | | | | 3 | | | | 3 | | |
| 18.12.05 | | 2 | | 4 | | 3 | | 1 | | | | | | | | | 3 | | 2 | | | 3 | |
| 19.12.05 | 2 | 2 | | 4 | | 3 | 1 | | | | | 2 | | | | 3 | 1 | | 3 | | 3 | 3 | |
| 23.12.05 | | 2 | | 3 | | 3 | | | | | | | | | 3 | | 3 | | | | | 3 | |
| 26.12.05 | 2 | 2 | | 4 | | 3 | | | | 2 | | | | 2 | | 3 | | | | | | 3 | |
| 05.01.06 | | 2 | | 3 | | 3 | | | | | | | | | | | 2 | | | | 2 | | |
| 08.01.06 | | 2 | | 4 | 1 | 1 | | | 2 | | | 2 | | | 3 | 2 | | | | | | 3 | |
| 11.01.06 | | | | 3 | 2 | | | | | | | | | 2 | 3 | 2 | | | | | | 2 | |
| 13.01.06 | | 2 | | 4 | | 2 | | | | | | | | | 3 | | | | | | 3 | | |
| 17.01.06 | | 3 | | 4 | 3 | | | | | | | 2 | 3 | | | | | | | | | 2 | |
| 18.01.06 | | 3 | | 4 | 2 | | | | | | | | | 2 | 3 | | | | | | | 3 | 1 |
| 21.01.06 | | 3 | | 4 | 2 | | | | | | | | | | 3 | 3 | | | | | 3 | 3 | |
| 23.01.06 | | 2 | | 4 | 2 | | | | | | | | 2 | | 3 | | | | | | | | |
| 27.01.06 | | 3 | | 4 | 2 | | | | | | | | | | 3 | | | | | | 3 | | |

**Appendix III.** Seasonal calling activity of the anurans at Area III between October 2005 and February 2006, based on Audio Surveys. Categories: 1 = call of a single individual, 2 = several divided calls, 3 = several overlapping calls, 4 = chorus. An empty space indicates no calling activity.

| species / date | *Dendropsophus bifurcus* | *D. leali* | *D. leucophyllatus* | *D. melanargyreus* | *D. minutus* | *D. nanus* | *Phyllomedusa boliviana* | *Scinax fuscovarius* | *S. nasicus* | *Trachycephalus venulosus* | *Leptodactylus elenae* | *Physalaemus albonotatus* | *P. centralis* | *P. cuvieri* | *Chiasmocleis albopuncatus* | *Elachistocleis* sp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28.10.05 | | | | | | | 2 | | | 3 | 1 | | | 1 | | |
| 10.11.05 | | | | | | | 2 | | | 1 | | | | | | |
| 15.11.05 | | | | | | | 3 | | | 2 | | | | | | |
| 01.12.05 | | | | | | | 2 | | | 2 | | | | | | |
| 07.12.05 | | | | | | | 2 | | | 2 | | | | | | |
| 14.12.05 | | | | | | | 2 | | | | | | | | | |
| 17.12.05 | | | | | | | 2 | | | 1 | | | | | | |
| 07.01.06 | 2 | | | | | 4 | 3 | | | | | 2 | | 4 | | |
| 10.01.06 | 2 | | 2 | | 3 | 4 | 3 | | | | | | 2 | | | |
| 15.01.06 | 4 | 3 | 2 | 3 | 3 | 4 | 3 | | 2 | | | | | | 3 | |
| 22.01.06 | 3 | 3 | 3 | 2 | 2 | 4 | 3 | 2 | 3 | 2 | | 3 | | 3 | | 2 |
| 26.01.06 | 3 | 3 | | | 3 | 4 | 3 | | | 2 | | | | | | |

**Appendix IV.** Seasonal activity of the anurans at pond A between October 2005 and February 2006, based on Audio Surveys. Categories: 1 = call of a single individual, 2 = several divided calls, 3 = several overlapping calls, 4 = chorus. An empty space indicates no calling activity.

| species / date | *Rhinella schneideri* | *Dendropsophus melanargyreus* | *D. nanus* | *Trachycephalus venulosus* | *Phyllomedusa boliviana* | *P. azurea* | *Scinax nasicus* | *S. fuscovarius* | *Leptodactylus fuscus* | *Physalaemus albonotatus* | *Eupemphix nattereri* | *Elachistocleis* sp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27.10.05 | | 2 | | | 3 | | | | | | 4 | |
| 30.10.05 | | | | | | | | | 1 | | 1 | |
| 01.11.05 | | | | | 1 | | | | 1 | | 4 | |
| 04.11.05 | | | | | 3 | | | | | | 4 | |
| 06.11.05 | | | | | 3 | | | | 3 | | 4 | |
| 07.11.05 | | 2 | | | 3 | | | | 1 | | 4 | |
| 11.11.05 | 1 | 4 | | 2 | 2 | | | | | | 4 | |
| 12.11.05 | | 3 | | | 3 | | | | | | 3 | |
| 14.11.05 | | | | | 2 | | | | | | 3 | |
| 20.11.05 | | 3 | | | 3 | | | | | | 4 | |
| 26.11.05 | | | | | 2 | | | | 2 | 2 | 4 | |
| 27.11.05 | | | | | 3 | | | | | | 4 | |
| 29.11.05 | | | | | 3 | | | | | | 4 | |
| 30.11.05 | | | | | 1 | | | | 2 | 2 | 4 | |
| 05.12.05 | | 1 | | | 3 | | | | | | 4 | |
| 06.12.05 | | 3 | | | 3 | | 2 | | | | 4 | |
| 09.12.05 | | | | | 3 | | | | | | 4 | |
| 10.12.05 | | | | | 3 | 1 | | | 1 | | 4 | |
| 13.12.05 | | | | | 1 | | | | | | 4 | |
| 16.12.05 | | | | | 3 | | | | | | 4 | |
| 18.12.05 | | | | | 2 | | | | | | 4 | |
| 19.12.05 | | 2 | 1 | | 3 | | | | | | 4 | |
| 23.12.05 | | | | | 2 | | | | | | 3 | |
| 26.12.05 | | 1 | | | 3 | | | | | 3 | 4 | |
| 05.01.06 | | | | | 3 | | | | | 2 | 4 | |
| 08.01.06 | | | | | 2 | | | | | | 4 | |
| 11.01.06 | | 3 | | | 3 | | 1 | 3 | | 3 | 4 | |
| 13.01.06 | | 3 | | | 3 | | | | | 2 | 4 | |
| 16.01.06 | | 2 | | | 3 | | | | | 3 | 4 | |
| 18.01.06 | | | | | 2 | | | | | 2 | | |
| 21.01.06 | | 4 | | 1 | 3 | | 3 | 2 | | 3 | 4 | 2 |
| 23.01.06 | | 3 | | | 3 | | 3 | 3 | | 3 | 3 | |
| 27.01.06 | | 2 | | | 3 | | | 1 | | 3 | 2 | |

**Appendix V.** Seasonal calling activity of the anurans at pond B between October 2005 and February 2006, based on Audio Surveys. Categories: 1 = call of a single individual, 2 = several divided calls, 3 = several overlapping calls, 4 = chorus. An empty space indicates no calling activity.

| species / date | *Rhinella schneideri* | *Dendropsophus melanargyreus* | *D. minutus* | *D. nanus* | *D. rubicundulus* | *Hypsiboas raniceps* | *Phyllomedusa boliviana* | *P. azurea* | *Pseudis paradoxa* | *Scinax* cf. *fuscomarginatus* | *S. fuscovarius* | *S. nasicus* | *Leptodactylus fuscus* | *Physalaemus albonotatus* | *P. centralis* | *Eupemphix nattereri* | *Elachistocleis* sp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30.10.05 | | | 1 | | | | | | | | | | 3 | | | 1 | |
| 01.11.05 | | | 2 | | | | | | | | | | 1 | | | | |
| 04.11.05 | | | 3 | | | | 1 | | | | | | | | | | |
| 07.11.05 | | | 2 | | | | | | | | | | 1 | | | | |
| 11.11.05 | 1 | 4 | 3 | 3 | | | | | | | 4 | 4 | | 4 | | 4 | |
| 20.11.05 | | 2 | 3 | | 3 | | | | | | | 1 | 2 | | 4 | | 1 |
| 25.11.05 | | | 4 | | | | | | | | | | | | | | |
| 27.11.05 | | | 4 | | 2 | | | | | | 2 | | 1 | | 3 | | |
| 02.12.05 | | | 4 | | 3 | 1 | 2 | | | | | | 3 | | | 4 | |
| 09.12.05 | | | 3 | 2 | 4 | | | 1 | 3 | | | 2 | 2 | 2 | | | 3 |
| 16.12.05 | | | 2 | | | 3 | | | 2 | | | 1 | | | | | |
| 05.01.06 | | | 3 | 3 | 3 | | | | 3 | | 3 | | | | | | 3 |
| 16.01.06 | | 3 | 3 | 4 | 3 | | | | 3 | 3 | 3 | | | 3 | 3 | | |

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