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# Ecology of anurans inhabiting bromeliads in a saxicolous habitat of southeastern Brazil

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**Abstract.** We studied two anuran species that use bromeliads either during their entire life cycle (bromeligenous) or as a diurnal shelter (bromelicolous) near the municipality of Itarana, Espírito Santo State, southeastern Brazil. We collected 736 tadpoles and 56 adults of the bromeligenous species *Scinax perpusillus* and 63 adults of the bromelicolous *Thoropa miliaris*. Adults of *S. perpusillus* occurred throughout the year, without significant differences in numbers within the months sampled. Tadpoles of this hylid also occurred throughout the year, but showed significant differences in number over the year. *Thoropa miliaris* showed peaks of occurrence in July, August, January, February and March, with sharp significant differences during the months sampled. The area researched was characterised as being one of low anuran diversity due to certain restrictions imposed by the saxicolous habitat, such as the microclimate conditions on the inselberg.

Keywords: Hylidae, Thoropidae, *Scinax perpusillus*, *Thoropa miliaris*, *Alcantharea* sp., life history, Neotropis.

## Introduction

Anuran communities that inhabit tanks of bromeliad plants (Bromeliaceae) vary greatly in the community structure along geographic gradients, resulting in different relationship types among species (Dunn 1937, Smith 1941, Duellman 1978, Duellman & Toft 1979, Peixoto 1995, Teixeira et al. 1997, Schineider & Teixeira 2001, Teixeira et al. 2002), even in relatively close localities (e.g., Teixeira et al. 1997, Schineider & Teixeira 2001, Teixeira et al. 2002).

Bromeliads are characteristic plants of the American continent (Dejean & Olmsted 1997), providing habitats for a diversity of invertebrates and vertebrates that form real microcosms (Rocha & Bjornberg 1987, Domingues et al. 1989, Cotgreave et al. 1993, Oliveira et al. 1994, Teixeira et al. 1997, Richardson 1999, Sidoti 2000, Schineider & Teixeira 2001, Teixeira et al. 2002). Tadpoles of bromeliad-inhabiting anurans must be adapted to live in a confined space and low quality water stored in the leaf rosette or plant axil (Bokermann 1974, Lannoo et al. 1987, Altig & Johnston 1989, Hödl 1990, Caldwell & Araujo 1998; Lehtinen et al. 2004). Their epithelium needs to endure both the acidity of the stored water as observed in the present study and low oxygen concentration (Lannoo 1987).

Several hypotheses have been formulated in order to explain the number of species and individuals that make up anuran communities and the differences in species composition, especially in tropical and temperate regions (Duellman & Trueb 1994). Bromeliad anuran communities are generally composed of few species, suggesting strong limitations of space, contrary to those complex communities at temporary or permanent ponds (e.g., Cardoso et al. 1989, Drost & Fellers, 1996, Tocher et al. 1997, Bertoluci 1998, Bernarde et al. 1999, Silva et al. 2000, Feio & Caramaschi 2002, Toledo et al. 2003, and many others). However, we do not know the key factors that contribute to this low diversity. Availability of prey and predator threats may be important factors.

Saxicolous habits studied here are essentially isolated rock formations (inselbergs) generally surrounded by open plains. These habitats can be found in tropical, subtropical, and temperate regions that were geologically formed by granite or gneiss of the Precambrian. Inselbergs have been poorly explored, and their ecology is hardly known (Parmentier 2003). The aim of this study was (1) to determine the anuran species coexisting inside the tank bromeliad, *Alcantharea* sp. (Fig. 1), in a saxicolous habitat in Southeastern Brazil and (2) to assess the monthly occurrence of tadpoles and adults in bromeloids in this habitat.

Fig. 1. *Alcantharea* sp.

## Material and methods

### Study site

The saxicolous habitat has a maximum altitude of 1039 m in a region called Pedra da Onça (19º 31'S, 39º 18'W), located about 3 km from Praça Oito County, Municipality of Itarana, Espírito Santo State, Southeastern Brazil. The floristic composition of inselbergs in the Atlantic forest is dominated by Bromeliaceae, Velloziaceae, Cactaceae and Cyperaceae, mainly due to their edaphic and microclimate constraints (Porembski et al. 1998). The predominant plants at the studied site were *Stilingia dichotoma* (Euphorbiacea), *Vellozia variegata* (Velloziaceae), *Pleurostima pabstiana* (Velloziacea), *Pseudolaelia drudae* (Orchidaceae), and *Hoffmanseggella mixta* (Orchidaceae). Around the entire area water was found only on the hilltop, where a permanent pond (ca. 5 $m^2$) is able to store water from rainfall. Railroads are present on the rock surface, suggesting that they contribute to a rapid drainage during the rainfall (Fig. 2). Our research concentrated on randomly chosen areas estimated at 2500 $m^2$, with an Alcantharea density of 15 plants per 2500 $m^2$, and focused on bromeliads that were easy to reach, in places where the sloping angle was up to 110 degrees. Itarana has hot and wet climate and mean temperatures range from 24.2 to 27.0 ºC during the year (data from Incaper – Instituto Capixaba de Pesquisa e Extensão Rural). The entire Itarana region shows hardly any temperature fluctuations throughout the year. The city of Itarana has a well-defined rainy season starting in November and lasting throughout March (Fig. 3). The sparse vegetation of these rocky habitats is exposed to a relatively high insolation during the day as a result of temperature and a loss of moisture.

### Samples

Anurans were manually collected each month from August 2002 to July 2003, from 9:00 to 13:00 h during the daytime. The samples were taken in terrestrial bromeliads located at altitudes ranging from 800 to 850 m, since in previous surveys we detected a decline of anurans at higher elevations. Ten bromeliads per month were examined. They were cut near the ground and shaken upside down in a plastic vase (0.8 m diameter). Whenever possible, bromeliads were replanted. Rainfall data (mm) were obtained from Incaper. The pH of the water inside bromeliads was measured using digital field equipment, and the water temperature was measured using a mercury stick thermometer

| | pH | | | | Temperature (°C) | | | |
|---|---|---|---|---|---|---|---|---|
| **Month** | **Mean** | **Min** | **Max** | **$s^2$** | **Mean** | **Min** | **Max** | **$s^2$** |
| Jul/02 | 6.4 | 6.4 | 6.5 | 0.0 | 21.2 | 21.0 | 21.5 | 0.2 |
| Aug/02 | 6.5 | 6.4 | 6.6 | 0.1 | 21.3 | 21.0 | 22.0 | 0.3 |
| Sep/02 | 6.4 | 6.0 | 6.6 | 0.2 | 21.9 | 21.0 | 22.5 | 0.5 |
| Oct/02 | 5.9 | 5.8 | 6.0 | 0.1 | 22.6 | 21.0 | 23.0 | 0.7 |
| Nov/02 | 6.3 | 6.0 | 6.4 | 0.2 | 22.5 | 22.0 | 22.5 | 0.2 |
| Dec/02 | 5.7 | 5.5 | 6.0 | 0.1 | 23.0 | 22.5 | 23.5 | 0.3 |
| Jan/03 | 5.5 | 5.4 | 5.8 | 0.1 | 23.0 | 22.5 | 23.5 | 0.2 |
| Feb/03 | 5.6 | 5.4 | 5.6 | 0.1 | 22.9 | 22.5 | 23.0 | 0.2 |
| Mar/03 | 5.7 | 5.6 | 5.8 | 0.1 | 23.1 | 22.5 | 23.5 | 0.3 |
| Apr/03 | 6.4 | 6.3 | 6.5 | 0.1 | 22.2 | 22.0 | 22.5 | 0.3 |
| May/03 | 5.9 | 5.4 | 6.0 | 0.2 | 22.2 | 22.0 | 23.0 | 0.3 |
| Jun/03 | 6.0 | 5.8 | 6.1 | 0.1 | 21.6 | 21.0 | 22.5 | 0.5 |
| **Total** | 6.0 | 5.4 | 6.6 | 0.4 | 22.3 | 21.0 | 23.5 | 0.7 |

Tab. 1. Mean values, minimum (Min), maximum (Max), and standard deviation ($s^2$) of pH and temperature of bromeliads axil water recorded between July 2002 and June 2003 at an inselberg of southeastern Brazil.

(0.5 °C precision). Anurans that were found in every bromeliad were readily killed in Chlorobutanol and stored in 10 % alcohol. After this procedure, they were transferred to 10 % formalin. Tadpoles were counted and released in other bromeliads far from our study site. Throughout this text we have been using Peixoto´s (1995) terminology that defines organisms spending their entire life cycle inside the plants as bromeligenous, and those using the plants occasionally, mainly as a diurnal shelter, as bromelicolous.

Fig. 2. View of the site studied, evidencing its inclination and its typical saxicolous vegetation.

## Statistical procedures

The numbers of anurans collected were examined in reference to their monthly variation using one-way analysis of variance (ANOVA). The month was the independent variable, and the numbers of individuals (adults and tadpoles) the dependent one. Before applying ANOVA, we used the Levene's test to evaluate the homocedasticity of variances, and the Kolmogorov-Smirnov test to evaluate normality, in order not to violate ANOVA's assumptions (Zar 1999). In those cases in which differences were significant ($\alpha$ = 0.05), we used the Newman-Keuls *a posteriori* test to detect where the differences occurred. Whenever necessary, data were log transformed ($\log_{10}$ x + 1) before applying the tests.

## Results

The water inside the bromeliads was slightly acidic, ranging from pH 5.4 to 6.6 (Table 1),

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Feb** | 0.57 | | | | | | | | | | |
| **Mar** | 0.58 | 0.27 | | | | | | | | | |
| **Apr** | 0.95 | 0.34 | 0.71 | | | | | | | | |
| **May** | 0.39 | 0.07 | 0.78 | 0.42 | | | | | | | |
| **Jun** | 0.39 | 0.07 | 0.83 | 0.41 | 0.91 | | | | | | |
| **Jul** | 0.45 | 0.11 | 0.78 | 0.51 | 0.79 | 0.92 | | | | | |
| **Aug** | 0.35 | 0.21 | 0.96 | 0.57 | 0.86 | 0.88 | 0.89 | | | | |
| **Sep** | 0.44 | 0.13 | 0.62 | 0.52 | 0.90 | 0.95 | 0.86 | 0.84 | | | |
| **Oct** | 0.22 | ***0.02** | 0.69 | 0.23 | 0.86 | 0.68 | 0.86 | 0.73 | 0.87 | | |
| **Nov** | ***0.01** | ***0.01** | ***0.01** | ***0.01** | ***0.01** | ***0.01** | ***0.01** | ***0.01** | ***0.01** | ***0.01** | |
| **Dec** | 0.64 | 0.86 | 0.25 | 0.50 | 0.06 | ***0.05** | 0.09 | 0.21 | 0.11 | ***0.02** | ***0.01** |

Tab. 2. Probabilities of the Newman-Keuls a posteriori test evidencing significant differences (*) among months, related to the monthly number of *Scinax perpusillus* tadpoles found between July 2002 and June 2003 at an inselberg of southeastern Brazil.

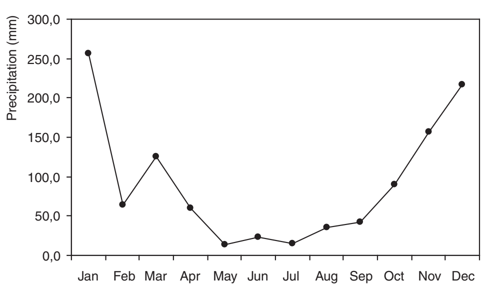


Fig. 3. Mean values of precipitation (mm) in the municipality of Itarana, Espírito Santo, from January 1997 to December 2002 (source: Incaper).

and the temperature fluctuated little throughout the year, varying from 21.0 to 23.5 °C.

Only two anuran species were collected inside the bromeliads of the inselberg researched: *Scinax perpusillus* (Fig. 4) (Hylidae) and *Thoropa miliaris* (Fig. 5) (Thoropidae). We collected 736 tadpoles and 56 adult individuals of the bromeligenous *S. perpusillus*, and 63 individuals of the bromelicolous *T. miliaris* in the course of one year. Tadpoles of *T. miliaris* were observed on the rocky surface, their mature habitat, in November and December only. Other anurans found were *Dendropsophus elegans*, breeding in an artificial pond (ca. 5 $m^2$) at the hilltop, and one specimen of *Eleutherodactylus binotatus* sitting on the ground in the vegetation.

Tadpoles of *S. perpusillus* occurred in bromeliads throughout the year, but were clearly more abundant during summer, with the highest value in November (Fig. 6A). The number of tadpoles differed significantly among the months studied (ANOVA: $F_{[1, 108]} = 6.59$; $P < 0.01$). However, the number of tadpoles most different compared to the other months was found in November 2002 (Table 2). Adults of *S. perpusillus* also occurred in bromeliads throughout the year, although the highest abundance was found in September 2002, February and April 2003 (Fig. 6B). There was no significant difference in abundance of adults of this hylid frog among the months sampled (ANOVA: $F_{[1, 108]} = 1.84$; $P > 0.06$). *Thoropa miliaris* adults showed peaks of occurrence in bromeliads during summer in January, February, March and during winter in July and August (Fig. 6C). The number of individuals differed significantly throughout the year (ANOVA: $F_{[1, 108]} = 3.82$; $P > 0.01$). February 2003 was the most divergent month in relation to the others (Table 3). Contrary to *S. perpusillus* *T. miliaris* was found mainly on the base and the dry bromeliad axils where little or no water was stored.

The percentage of occupied plants in each

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Feb** | 0.35 | | | | | | | | | | |
| **Mar** | 0.71 | 0.15 | | | | | | | | | |
| **Apr** | 0.40 | ***0.01** | 0.79 | | | | | | | | |
| **May** | 0.35 | ***0.01** | 0.71 | 1.00 | | | | | | | |
| **Jun** | 0.30 | ***0.01** | 0.61 | 1.00 | 1.00 | | | | | | |
| **Jul** | 0.69 | 0.40 | 0.49 | 0.10 | 0.08 | 0.07 | | | | | |
| **Aug** | 0.49 | 0.60 | 0.45 | 0.11 | 0.10 | 0.08 | 0.90 | | | | |
| **Sep** | 0.26 | ***0.01** | 0.52 | 1.00 | 1.00 | 0.97 | 0.07 | 0.07 | | | |
| **Oct** | 0.55 | 0.17 | 0.85 | 0.74 | 0.67 | 0.59 | 0.49 | 0.40 | 0.52 | | |
| **Nov** | 0.73 | 0.11 | 0.82 | 0.84 | 0.76 | 0.63 | 0.44 | 0.42 | 0.49 | 0.90 | |
| **Dec** | 0.37 | ***0.02** | 0.56 | 0.99 | 0.98 | 0.92 | 0.13 | 0.13 | 0.73 | 0.61 | 0.43 |

Tab. 3. Probabilities of the Newman-Keuls a posteriori test evidencing significant differences (*) among months, related to the monthly number of *Thoropa miliaris* individuals.

month was calculated based on a total of 120 bromeliads. Tadpoles of *S. perpusillus* occurred in 69 bromeliads (57.5 %) and occupied more plants between November and April (Fig. 7A). Adults of *S. perpusillus* occurred in 43 bromeliads (35.8 %) and its frequency did not suggest any seasonal trend in the occupation of bromeliads throughout the year (Fig. 7B). *Thoropa miliaris* occurred in 44 bromeliads (36.7 %), with peaks of occurrences in July and August 2002, as well as in January and March 2003 (Fig. 7C).

## Discussion

Four anuran species were found at the studied site and only two species live in the tank bromeliads in a saxicolous habitat in Southeastern Brazil. Generally, the diversity of species is greater in the tropics than at higher latitudes, but in the case of amphibians, the variable moisture may be a restrictive factor (Duellman & Trueb 1994). The vegetation of inselbergs is relatively sparse offering few shelters to vertebrates and restricted to those species adapted to live on rocks or in bromeliads. Competition for spawning sites between anurans breeding in this habitat type seems to be weaker than between species using ponds as breeding sites due to lower diversity. No competition for oviposition sites was observed between *Scinax perpusillus* and *Thoropa miliaris* because *S. perpusillus* use bromeliad axils as breeding sites and *T. miliaris* spawn on wet rock surfaces (reproductive mode 6 and 19 sensu Haddad & Prado 2005). Giaretta & Facure (2004) observed strong intraspecific competition for oviposition sites in *T. miliaris* and suggested, that strong territoriality, paternal care and aggressive behavior in *T. miliaris* evolved due to a limitation of water flooded rocks. However, we have no data on aggressive interactions between *T. miliaris* and *S. perpusillus*.

Apparently, both species compete for shelter, a limited resource in this habitat. *T. miliaris* seems to favor dry axils whereas *S. perpusillus* occupy water filled axils. The rosette of the bromeliad *Alcantharea* sp. is wide enough to provide shelter for many individuals, and at the site studied it can reach up to a diameter of 1.5 m, but the occupation of a rosette by one adult individual may restrict its use by others. Teixeira et al. (1997) have found only *Phyllodytes luteolus* (Wied-Neuwied, 1824) inhabiting the tank bromeliad *Aechmea blanchetiana* in the sandy coastal plain (= restinga) in Northeastern Espírito Santo state. Schineider & Teixeira (2001) have found five anuran species living in four different species of tank

Fig. 4. *Scinax perpusillus.*

Fig. 5. *Thoropa miliaris.*

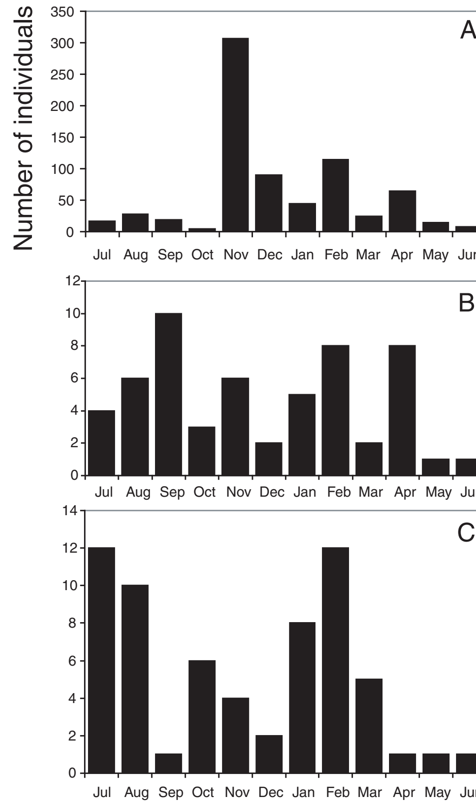


Fig. 6. Number of individuals according to each month sampled: (A) tadpoles of *Scinax perpusillus*; (B) adults of *Scinax perpusillus*; (C) adults of *Thoropa miliaris*.

bromeliads in a restinga habitat of Linhares, in the center of Espírito Santo. In a restinga habitat of Southern Espírito Santo, Teixeira et al. (2002) also found five anuran species living inside several bromeliad species. Those studies evidenced a percentage of one adult anuran per plant in most cases.

Although we found the two species, *S. perpusillus* and *T. miliaris*, in every sampling month, the number of empty bromeliads was high. The number of tadpoles of *S. perpusillus* found was much higher than the number of adults, suggesting that the mortality rate is high during metamorphosis. Tadpoles represented 92.9 % of the *S. perpusillus* individuals collected. Based on the proportion of tadpoles and adults, probably 92.4 % of them do not reach adult stage. However, bromeliads are also broadly used by invertebrates, and some of them, such as arachnids (spiders and scorpions), grasshoppers, cockroaches and chilopods may prey upon or compete with anuran species. Predation on tadpoles in Phytotelmata is known from odonata larvae and belostomatid beetle (Duellman & Trueb 1994, Toledo 2003), and this may become critical in a confined bromeliad axil.

Suitable bromeliad microhabitats are likely to be seasonal. Therefore, the reproductive period of anurans is probably restricted to a time of the year in which large proportions of plants offer conditions for egg laying and tadpole development (Oliveira & Navas 2004), although we do not know precisely when metamorphosis occurs. Apparently, *S. perpusillus* reproduces during the entire year as we obtained tadpoles in every

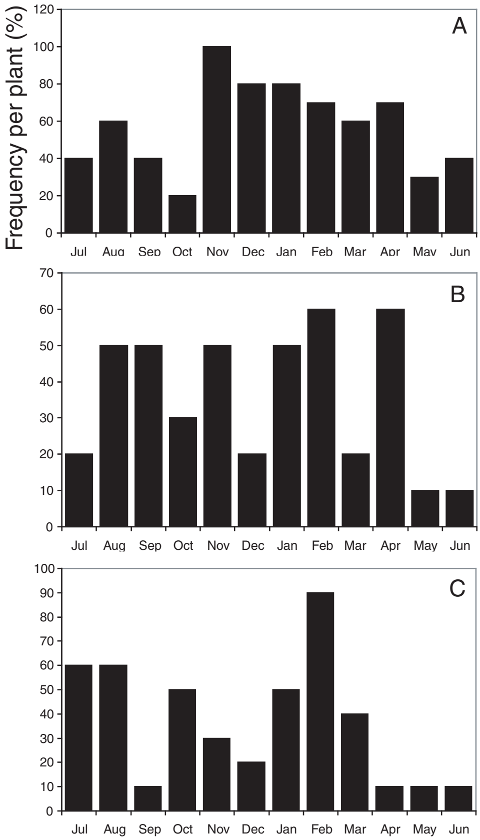


Fig. 7. Frequency of individuals per plant examined according to each month sampled: (A) tadpoles of *Scinax perpusillus*; (B) adults of *Scinax perpusillus*; (C) adults of *Thoropa miliaris*.

sampling month. However, as most tadpoles were collected during the rainy period, this suggests an increase in reproductive effort during the summer. In contrast, *T. miliaris* appears to concentrate its reproductive effort in the summer months (e.g., January, February and March), when water drains from the exposed rocky surfaces where the tadpoles live. Tadpoles of this species were obtained only in November and December and oriented in relation to the water flow as described by ROCHA et al. (2002). The reproductive period of *T. miliaris* is probably limited to these months at the site studied, restricted to the time when water is constantly flowing on the rock surface. Evidently, isolated rainfalls in other months are not sufficient to guarantee a good water supply at the site researched, reducing or limiting the reproductive period of *T. miliaris*.

The bromeliads of the inselberg studied here were characterized by the low anuran diversity due to certain restrictions imposed by the habitat. South American bromeliad community structures may vary according to plant size, axil numbers, quantity of debris, and volume of stored water (ARMBRUSTER et al. 2002). As cited previously, low moisture may play an important role limiting the colonization by other anuran species. Bromeliads represent the most important source of standing water in Pedra da Onça, which otherwise, due to the steep inclination of its terrain, flows quickly out of that region during rainfall. Also, low diversity of vegetation may not offer a good shelter for other bromelicolous species.

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