HERPETOLOGICAL JOURNAL, Vol. 16, pp. 15-20 (2006)

SEASONAL AND HOURLY PATTERNS OF REPRODUCTIVE ACTIVITY IN *SCINAX TRAPICHEIROI* (ANURA, HYLIDAE), RIO DE JANEIRO STATE, SOUTH-EASTERN BRAZIL

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We examine the temporal pattern of reproduction of the hylid *Scinax trapicheiroi* and evaluate how environmental factors affect the calling activity of males and the reproductive activity of females. Fieldwork was carried out at a small stream inside the Atlantic Rainforest of Ilha Grande, an island off the coast of south-eastern Brazil. The study area was sampled monthly from October 2000 to September 2001. Periods for quantifying males' calling activity were alternated with periods of observing female presence. Calling activity occurred mainly during the night. Males called during all months of the year, but activity was higher during the warm wet season. The number of calling males positively influenced the number of calls emitted per male. Fewer females appeared at the stream to reproduce than males. The presence of females was affected only by rainfall during the previous day.

Key words: Atlantic Rainforest, behaviour, calling activity, environmental factors, frog

INTRODUCTION

In anuran species with long reproductive seasons, the reproductive success of males typically depends on their ability to attract females to their calling site because female arrival is unpredictable (Wells, 1977). Knowing the temporal patterns of vocalization of anuran species (e.g. continuous, opportunistic, explosive) helps us to understand how variations in environmental factors (such as temperature, humidity or rainfall) might affect their reproductive activity. Several studies have shown that calling activity of anurans is influenced by local environmental factors, including relative humidity (e.g. Cree, 1989), air temperature (e.g. Pough *et al.*, 1983; Navas, 1996; Boquimpani-Freitas *et al.*, 2002), light intensity (Hatano *et al.*, 2002), photoperiod (e.g. Hatano *et al.*, 2002), rainfall (e.g. Donnelly & Guyer, 1994), or a combination of environmental factors (Oseen & Wassersug, 2002; Murphy, 2003). However, the relative importance of local and microscale variation in physical and environmental conditions on calling activity of males may differ among species (Brooke *et al.*, 2000).

In this study we investigate calling and reproductive activity of *Scinax trapicheiroi*. The genus *Scinax* is presently divided into five groups of species, the *S. rubra*, *S. rostrata*, *S. catharinae*, *S. staufferi* and *S. perpusilla* groups (Faivovich, 2002). *Scinax trapicheiroi* (B. Lutz, 1954) is a small hylid frog from the *S. catharinae* group which inhabits mountainous areas in the Atlantic Rainforest region of southeastern Brazil (Carvalho-e-Silva & Carvalho-e-Silva, 1994; Faivovich, 2002). In these areas, *S. trapicheiroi* reproduces in clear waters of small and shallow rivulets (either standing or slow moving water) or temporary ponds (Rico *et al.*, 2004). Studies on *S. trapicheiroi* are limited to the species and tadpole description, taxonomy and geographic distribution (Lutz, 1954, 1973; Carvalho-e-Silva & Carvalho-e-Silva, 1994). Information on ecological aspects of *S. trapicheiroi* is restricted to its breeding biology (Rico *et al.*, 2004). Our specific aim was to address the effects of air temperature, relative humidity, photoperiod and rainfall on hourly and monthly reproductive activity of both males and females in our study area.

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MATERIAL AND METHODS

The study was carried out from October 2000 to September 2001 at a small stream in the Atlantic Rainforest of Ilha Grande (23°12'S, 44°13'W). Ilha Grande is located in southern State of Rio de Janeiro and is one of the largest islands on the Brazilian coast. The landscape of the island is rugged, and the highest peaks reach 1000 m. The island is covered by Atlantic Rainforest with different levels of regeneration due to disturbance by human activities (Araújo & Oliveira, 1988). Our study site was a creek whose origin was a steep forested hillside. Water levels in the creek were highly variable, and during periods of no rainfall the stream was reduced to a linear series of disjunct pools fed by subsurface flow.

Four sampling points (separated by at least 30 m) were established along 150 m of the creek. Male calling activity was quantified monthly at each point, during 5 min/point/hr over a 24-hr sampling regime. We included all males calling from within an imaginary circle with 10 m radius and tallied calls by hand. To reduce the probability of pseudoreplication (Hulbert, 1984), we recorded calling activity in eight, 3-hr sessions, so as to cover the 24 hrs of a day, in each of these four points. These 3-hr sessions were alternated during one week of

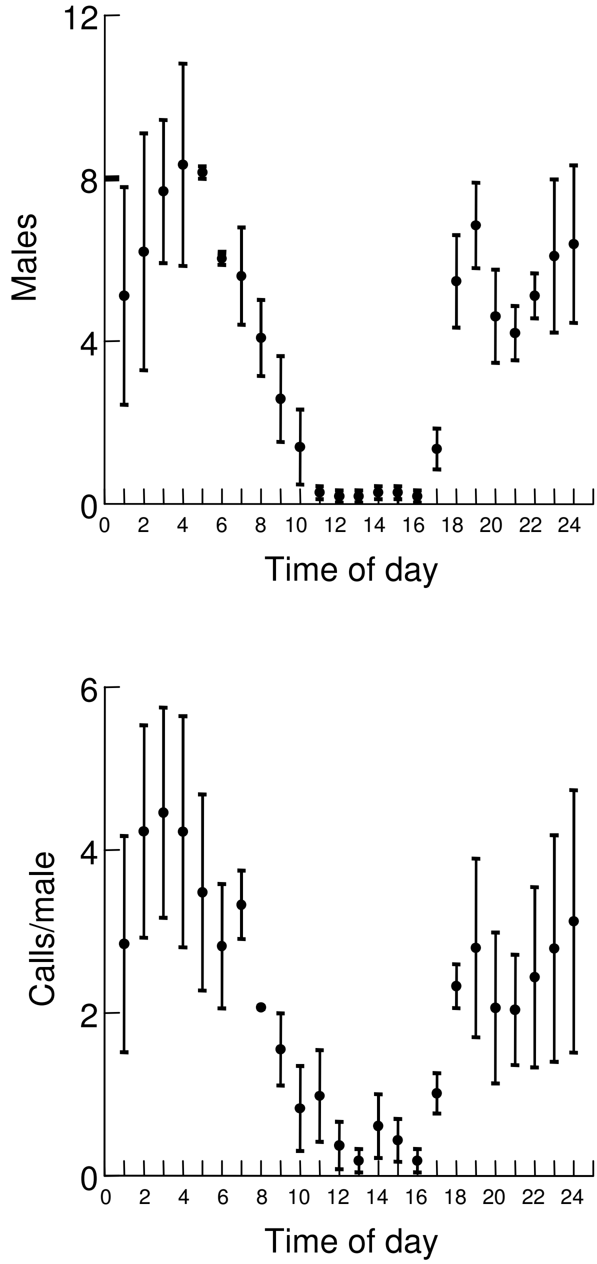

FIG. 1. Hourly pattern of calling activity of males *Scinax trapicheiroi* along a stream in Ilha Grande. Figures represent the mean numbers (±1 SD) of males calling (a), and calls/male (b), during 5 minutes/hour per point, from October 2000 to September 2001.

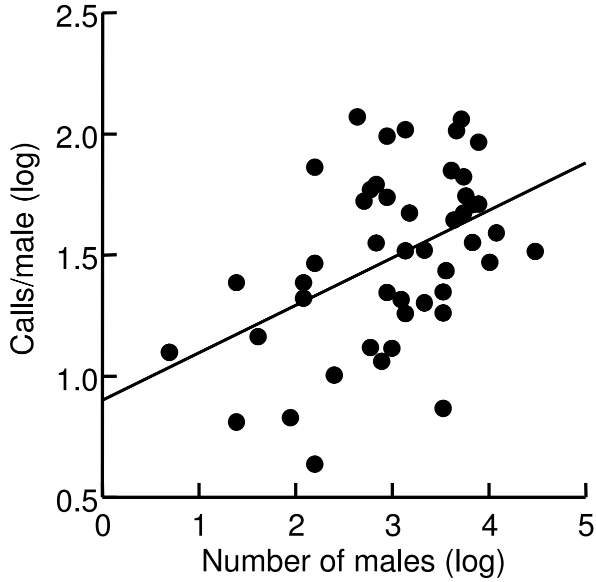

Fig. 2. Number of calls emitted per male in relation to the number of males of *S. trapicheiroi* calling in the chorus along a stream in Ilha Grande.

TABLE 1. Partial regression values (coefficients and significance) of the environmental variables of photoperiod and rain of the previous day for the mean number of males of *Scinax trapicheiroi*, and mean number of calls/male along the year along a stream of Ilha Grande.

	Photoperiod	Rain during previous day
No. of males	0.055,*P*=0.716	-0.010,*P*=0.949
No. of calls/male	0.661,*P*<0.001	0.186,*P*=0.086

fieldwork (for example, on day 1 we sampled the periods 0100-0400 hrs; 0900-1200 hrs; and 1500-1800 hrs; on day 2 we sampled the periods 0400-0700 hrs; 1200-1500 hrs, and so on). Calling activity was expressed as the total number of males calling and as the mean number of calls per male (Heyer *et al.*, 1994).

Female annual activity was estimated based on their presence at the study area, on three nights each month (see Rico *et al.*, 2004 for details). These nights (*n*=36) were not the same as those of the calling activity samplings and were not consecutive. Because we did not recapture any female, even within a month, we assume that each sampling night was independent of the others. The number of females observed and the number of clutches deposited in the stream during those nights were used as an index of their reproductive activity.

Air temperature and relative humidity were recorded every hour, and rainfall and photoperiod were recorded daily. Daily rainfall data were obtained from a tipping bucket pluviometer (Davies Rain™) that was placed approximately 1 km from the study area. For our analyses, we used amount of rainfall of the day before each sampling.

To test the effect of the environmental variables on the monthly calling activity of males and reproductive activity of females of *S. trapicheiroi* we used multiple linear regression (Zar, 1999). Male monthly calling activity was related to photoperiod and rainfall considering each sampling point separately (*n*=48), and female activity (number of females present at the creek each sampling night) was related to air temperature and rainfall. We tested whether the hourly activity of calling males (mean of all months and sampling point) differed along the 24-hr period using Repeated Measures ANOVA (Zar, 1999). We assessed the effect of chorus size (log-transformed number of males) on calling intensity (log-transformed number of calls emitted per male) using linear regression. We considered each sampling point separately.

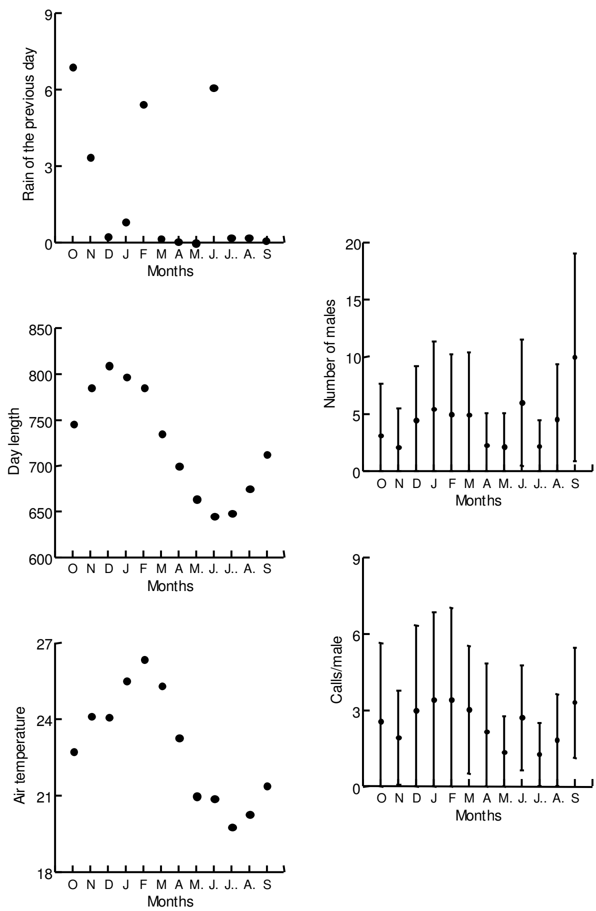

FIG. 3. Annual pattern of rainfall (of the previous day, in mm – upper left), photoperiod (in seconds – middle left), air temperature (in °C – lower left) and mean numbers (±1 SD) of male *Scinax trapicheiroi* calling (upper right), and calls/male (lower right), during 5 min/point/hr, at four points along a stream in Ilha Grande from October 2000 to September 2001.

RESULTS

HOURLY ACTIVITY

Males of *Scinax trapicheiroi* called mainly during the night, with sporadic vocalizations during the day (Fig. 1). Calling began at sunset (1700-1800 hrs) and quickly increases in activity. In the following three hours, calling activity decreased slightly. Peak activity occurred between 0200 and 0500 hrs, which was followed by a steady decrease after sunrise (0500-0600 hrs). Calling activity significantly differed along the day (Repeated Measures ANOVA: number of males; $F_{23,253}$=9.19, P<0.001; mean number of calls per male; $F_{23,253}$=11.09, P<0.001)

The number of calls per male increased as the number of males calling in the chorus increased (R^2=0.22, $F_{1,46}$=13.18, P=0.001; Fig. 2). When more than 15-20 males were calling in the chorus, the number of calls per male no longer increased, but male aggregations usually had fewer than 20 individuals.

MONTHLY ACTIVITY

Calling activity of *S. trapicheiroi* varied during the year (Fig. 3). The highest number of males calling occurred in September 2001, but the mean numbers of calls/male were usually higher from December to February. The number of males calling was not affected by the environmental variables tested (photoperiod and rainfall; R^2=0.003; $F_{2,45}$=0.067, P=0.935) but the intensity of male calling activity was affected by these variables (R^2=0.509, $F_{2,45}$=23.28, P<0.001; Table 1). Photoperiod explained (P<0.001) an additional part of the variation in number of calls emitted per male (Fig. 4).

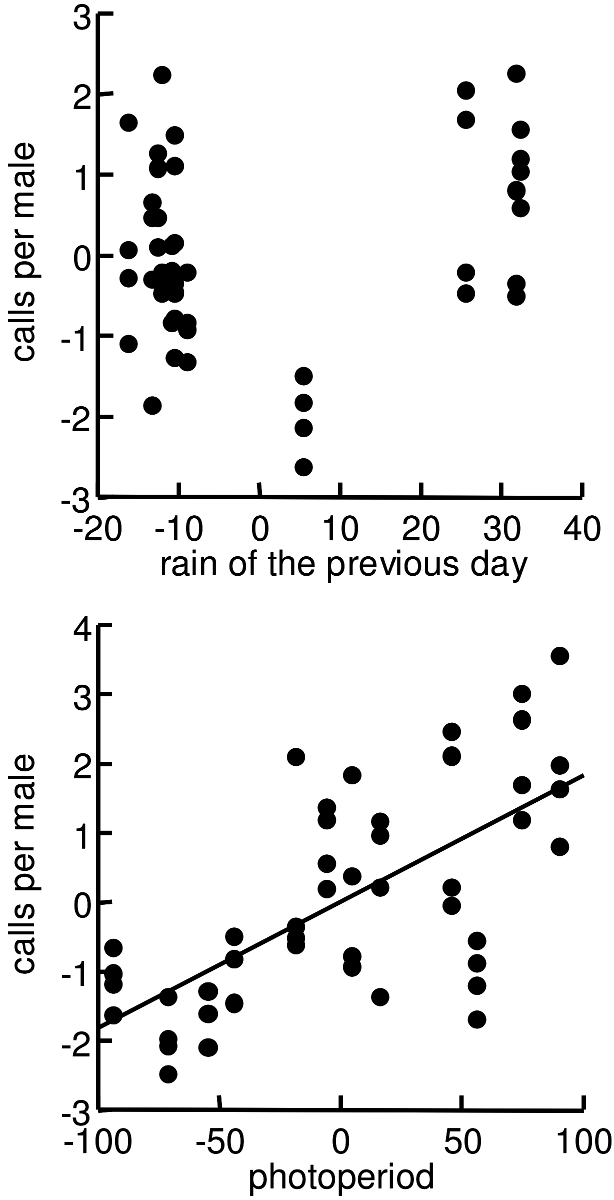

FIG. 4. Partial regression plots depicting the relationship between two environmental variables (rain of the previous day and photoperiod) and the monthly number of calls/male of *Scinax trapicheiroi* at four points along a stream in Ilha Grande.

FEMALE ACTIVITY

Females were observed in 20 out of 36 sampling nights (55.6%) during the study. The number of new clutches laid per night was highly correlated to the number of females observed that night at the rivulet

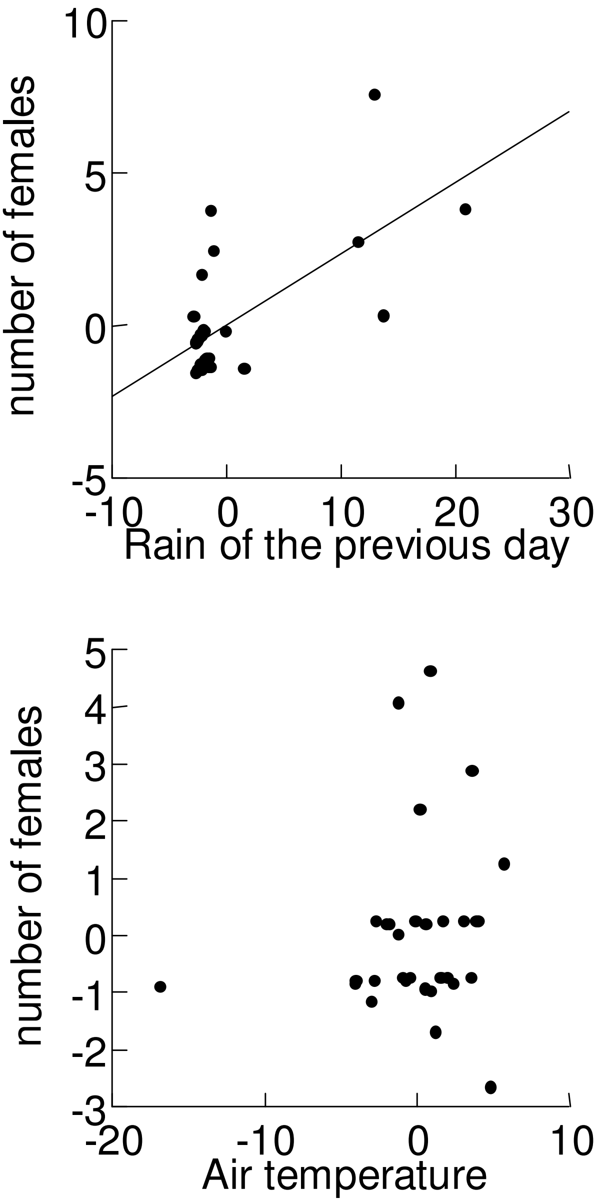

FIG. 5. Partial regression plots depicting the relationship between two environmental variables (air temperature and relative humidity) and the number of females of *Scinax trapicheiroi* along a stream in Ilha Grande, during three nights each month from October 2000 to September 2001.

(R^2=0.13, $F_{1,34}$=5.24, P<0.001). The number of females present at the rivulet was significantly affected by the environmental variables (rain of the previous day and air temperature; R^2=0.45, $F_{2,30}$=12.20, P<0.01). Only the rain of the previous day (partial coefficient = 0.66; P<0.001) explained an additional part of female activity (Fig. 5).

DISCUSSION

There was considerable variation in the number of males *Scinax trapicheiroi* calling and in the number of calls per male, both on a seasonal and on a diurnal scale, which is similar to results of other studies of anuran calling activity (Brooke *et al.*, 2000 and references therein, Murphy 2003). Males of *S. trapicheiroi* called almost exclusively during the night, as is true for most treefrog species (Duellman, 1989). Sunset and sunrise seem to play an important role in the regulation of the start and of the end of the calling activity. During days with high reproductive activity (inferred from the number of females and of clutches laid at the rivulet), males also called during the first sunlight hours, a behaviour similar to that of other opportunistic hylid species (Bastos, 1996; Pombal, 1997). Differences in hourly activity trends among anuran species can result from differences in foraging schedules (Cardoso & Haddad, 1992), differences in strategies used to avoid predation, dehydration and high temperatures (Cardoso & Haddad, 1992; Pombal, 1997), division of acoustic space (Pombal, 1997; Garcia-Rutledge & Narins, 2001), or phylogenetic history (Bridges & Dorcas, 2000).

Males called every month during the study, but calling intensity varied during the year, being some what higher during months of the warmer wet season (December to February). September 2001 was the exception due to the exceptionally high number of males (more than 20) calling in the chorus in five sampling periods. Our results suggest that there is no direct effect of environmental factors on the number of active males of *S. trapicheiroi*, but rain and photoperiod affected the intensity of calling (expressed as the number of calls emitted per male). We can suppose that a frog species that maintains calling and reproductive activity throughout the year should be less susceptible to changes in environmental factors. Brooke *et al.* (2000) found differences in the effect of large-scale weather factors and small spatial ones. Seasonality in calling activity has also been pointed out for other anuran species (Pough *et al.*, 1983; Hatano *et al.*, 2002) that take advantage of seasonal environmental conditions (temperature, humidity, pluviosity, etc.) to facilitate their calling and reproductive activity. The impact of photoperiod, air temperature and relative humidity on the calling activity of anurans is well known (Whittier & Crews, 1987; Cree, 1989), and also in sympatric anurans at Ilha Grande (Boquimpani-Freitas *et al.*, 2002; Hatano *et al.*, 2002).

Rainfall is the main environmental variable influencing the calling activity of many anurans in tropical and subtropical regions (Aichinger, 1987; Donnelly & Guyer, 1994), due to increasing humidity and the number of water bodies in the habitat. In the study area, short-term rainfall positively influenced the presence of females at the creek, probably as a consequence of the presence of adequate oviposition sites in the habitat. However, heavy rains over several consecutive days significantly increased the creek current, risking the survival of clutches and tadpoles who depend on slow water for their development (Rico *et al.*, 2004). The unpredictability of temporary streams as places to reproduce can be compensated for by the length of the reproductive season (Diaz-Paniagua, 1990).

The observed increase in the number of calls per male as the number of males in the chorus increased, likely results from mutual stimulation among males. In *Hyla elegans*, males calling in a group emitted longer calls, with a significantly higher number of pulses than males not interacting with their neighbours (Bastos & Haddad, 1995). However, the mutual stimulation in male *S. trapicheiroi* occurred only up to a certain limit, above which the number of calls per male was independent of the number of males in the chorus. When many males are calling in a chorus, call overlap may disrupt information necessary for species recognition and female choice (Schwartz, 1987), so it may be advantageous for males to alternate calls. However, whether the threshold of 15-20 males observed for *S. trapicheiroi* results from avoidance of signal disruption or enhancement of female choice is not clear. Regardless, variation in calling rate is responsible for most of the variation in energy expenditure by calling frogs (Bevier, 1997).

In the study area, different factors seem to regulate reproductive activity for each sex, rainfall and photoperiod for males (on a monthly basis); short-term rainfall for females. Males were more constant than females at the creek. Females appeared only 56% of the nights with males at the creek. That value is comparable to 58% for *H. elegans* (Bastos & Haddad, 1995), and 42% for *Hyla faber* (Martins, 1993), but less than 84% for *Scinax rizibilis* (Bastos & Haddad, 1999). This difference may suggest that conditions for calling are less restrictive than conditions for egg laying, but may also result from the fact that those males who stay more time calling have higher reproductive success (Godwin & Roble, 1983).

We conclude that *Scinax trapicheiroi* at Ilha Grande is predominantly nocturnal. Calling activity of males was influenced by environmental factors on a monthly basis. Female presence in reproductive sites is affected by short-term rainfall.

ACKNOWLEDGEMENTS

This study is part of the results of the "Ecology, Conservation and Management of South-eastern Brazilian Ecosystems Program" and of the Southe-astern Brazilian Vertebrate Ecology Project (Vertebrate Ecology Laboratory), both of the Dept. Ecology, Universidade do Estado do Rio de Janeiro. We thank the Coordination of the CEADS/UERJ for local support and making many facilities available. During the development of this study MR received a graduate fellowship (Beca MUTIS) from Agencia Española de Cooperacion Internacional (AECI). R Fernandes, CG Murphy and an anonymous reviewer helped with the statistical analysis and gave valuable suggestions on the manuscript. MVS and CFDR receive Research Grants from Conselho Nacional do Desenvolvimento Científico e Tecnológico (CNPq, Processes # 302405/02-0 and # 307653/03-0, respectively). FAPERJ and CNPq partially supported the project (grants FAPERJ: # E-26/172.383/2000 and CNPq: # 477981/03-8). This study is also part of the BIOTA/FAPESP Project and was partially supported with a grant from this Agency (process No. 99/08291-5). Study was carried out under permit # 069/2001 from IBAMA.

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Accepted: 21.12.04