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Calling activity of *Crossodactylus gaudichaudii* (Anura: Hylodidae) in an Atlantic Rainforest area at Ilha Grande, Rio de Janeiro, Brasil

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ABSTRACT. The calling activity in anuran amphibians can be influenced by several environmental variables that can affect such activity in different ways. In the present study we investigated the relationship of the daily calling activity of males of the diurnal frog *Crossodactylus gaudichaudi* with some environmental variables. The study was carried out between July 2003 and June 2005 in an area of Atlantic forest in Ilha Grande, an island located on the southern coast of the State of Rio de Janeiro. The observations were made in three fixed points in the forest, adjacent to streams, always from 05:00 to 19:00h, one day per month. We verified that the males of *C. gaudichaudii* have strictly diurnal calling activity, staying active during all months of the year. The highest counts of emitted calls were registered, in general, at the beginning and at the end of each day sampled. Air temperature, relative humidity and light intensity affected the daily rate of calling activity in different ways, with air temperature and light intensity seeming to be the factors that influence most importantly the activity of the species. The photoperiod seemed to be the main factor regulating the extension of the calling activity along the year in males of *C. gaudichaudii*.

KEY WORDS : Calling activity, Atlantic Rainforest, streams, *Crossodactylus gaudichaudii*.

INTRODUCTION

Calling behaviour in anurans constitutes the main form of communication for these organisms, followed by visual signals (Wells, 1977; Duellman & Trueb, 1986). In most anuran species the calls are essential to guarantee the reproductive success, being used to attract females (mainly), to defend a territory, and to display distress (e.g. Duellman & Trueb, 1986; Wells, 1988; Haddad & Giaretta, 1999; Guimarães & Bastos, 2003). However, calling activity involves energetic costs and increased exposure to predation by calling males (Duellman & Trueb, 1986; Judge & Brooks, 2001; Wong et al., 2004).

Calling activity of frogs is influenced by environmental factors such as photoperiod (e.g. Jaeger et al., 1976; Whittier & Crews, 1987), light intensity (e.g. Hatano et al., 2002), relative humidity (e.g. Cree, 1989; Hatano et al., 2002) and air temperature (e.g. Licht, 1969; Navas, 1996). However, the relative importance of these factors on calling activity of males may differ among species (Brooke et al., 2000). For the Atlantic Rainforest biome of eastern Brazil, there are few studies relating the calling activity to local environmental factors (Boquimpani-Freitas et al., 2002; Hatano et al., 2002; Van Sluys et al., 2006).

Frogs of the genus *Crossodactylus* are diurnal and live in rocky streams inside the forest (Weygoldt & Carvalho-e-Silva, 1992; Izecksohn & Carvalho-e-Silva, 2001; Jordão-Nogueira et al., 2006). C*rossodactylus gaudichaudii* Duméril & Bibron (1841) is commonly found associated with streams inside the forest in the states of Rio de Janeiro and São Paulo (Izecksohn & Carvalho-e-Silva, 2001). During the day, males of *C. gaudichaudii* communicate by acoustic and visual signals (Weygoldt & Carvalho-e-Silva, 1992). However, the lack of studies specifically addressing aspects of the biology of *C. gaudichaudii* limits our understanding of parameters of the species ecology and natural history. In the present study we investigate the calling activity of *C. gaudichaudii* in the Atlantic Rainforest of Ilha Grande and try to evaluate how some local environmental factors affect the calling activity of males.

MATERIALS AND METHODS

Study area

Data was gathered from July 2003 to June 2005 in the Atlantic rainforest of Ilha Grande (23°11’ S, 44°12’ W), a large continental island (aproximately 19000ha) on the southern coast of Rio de Janeiro state, southeastern Brazil. The forest exhibits different levels of disturbance caused by human activities during the last century (Araújo & Oliveira, 1988). Annual rainfall at Ilha Grande is about 2200mm, and mean annual temperature is about 23°C (Hatano et al., 2002). The study site is located on a trail between Vila Dois Rios and the Caxadaço beach, at the seaward side of the island.

Collecting methods and analysis

We established three observation sites to record frog activity at three small forest streams located > 100m apart. The observations were made always from 05:00 to 19:00h, one day per month, between July 2003 and June 2005. We considered only the individuals that were calling within a perimeter of approximately five meters around the three sampling sites.

At hourly intervals, we registered for five minutes, at each point, the number of individuals calling and the number of calls emitted (with a hand counter and a chronometer). At the beginning of each hour we measured the light intensity (in lux, with a luxmeter), and the air temperature (°C) and the relative humidity (%) (with a thermohigrometer). Besides, we obtained the photoperiod (in minutes) for the respective days of sampling (Hatano et al., 2002). Frog calling activity is expressed as the mean number of calls at the sites and as the mean number of active individuals per hourly and monthly intervals.

To estimate the extension (in minutes) of the calling activity, we recorded the time of the beginning and the end of frog activity in each day sampled. The onset and end of frog activity were considered as the time when the first and last calls were recorded, respectively.

The mean number of calls and the mean number of active individuals per hour was regressed against air temperature, air humidity and light intensity recorded at the same period using multiple regression analysis (fixed model). In this case, we analyzed data for the dry (April to September) and rainy (October to March) seasons separately. To test for differences between the mean number of calls emitted during the months of the dry and rainy seasons we used a one-way ANOVA (Zar, 1999).

The photoperiod was regressed against the extension of the calling activity using regression analysis (Zar, 1999). To evaluate the effect of light on the onset and end of *C. gaudichaudii* calling activity, we related the precise time of the start and the end of frog activity to the hour of sunrise and sunset of the same day, respectively, using regression analysis (Zar, 1999). In order to evaluate if any nocturnal activity occurred, observations were made for 24h during two months of a dry season (July and August 2003) and two months of a rainy season (December 2003 and March 2004).

RESULTS

We did not record nocturnal activity by males of *Crossodactylus gaudichaudii*. The males called during all months of the study period at Ilha Grande. The daily calling activity was most intense, generally, at the beginning (from 05:00-06:00h) and at the end (from 17:00-18:00h) of the light period (Figs 1 and 2). The daily calling activity usually started between 05:00 and 06:30h and ended between 17:00 and 18:30h, depending on the period of the year (Figs 3 and 4). At Ilha Grande, the photoperiod differs about 2.5h between the longest and the shortest days, a value similar to that observed for the difference between the smallest and the highest values of calling activity extension in *C. gaudichaudii* (Fig. 5).

In the dry season, a multiple regression analysis showed an overall significant effect of environmental parameters on the mean number of calls during the day (R^2=0.101; $F_{3,164}$=4.813; P=0.003). However, only air temperature (t=1.969; P=0.05) and light intensity (t=3.394; P=0.001) explained an additional part of the mean number of calls after removing the effect of the other variables. The multiple regression analysis did not show an overall significant relation to mean number of calling individuals (R^2=0.1; $F_{3,164}$=0.512; P=0.674). In the rainy season, the environmental factors showed a significant effect on mean number of calls (R^2=0.070; $F_{3,164}$=3.651; P=0.014), but only air temperature (t=2.544; P=0.005) and relative humidity (t=2.943; P=0.003) explained an additional part of the relationship after removing the effect of the other variables. Similarly, the environmental factors interacted to affect the mean number of calling individuals (R^2=0.071; $F_{3,164}$=3.721; P=0.013), with air temperature (t=2.997; P=0.003) and relative humidity (t=3.108; P=0.002) showing an additive effect. The mean number of calls and the mean number of calling individuals on each month did not differ between the rainy and wet seasons (ANOVA: $F_{1,22}$=1.011; P=0.326 and $F_{1,22}$=1.021; P=0.322, respectively).

The start and the end of *Crossodactylus gaudichaudii's* activity in each month were usually coincident with the sunrise and sunset, respectively. The start of calling activity was positively related to the time of sunrise (R^2=0.645; $F_{1,22}$=40.013; P<0.001). Similarly, the end of frog activity was positively related to the time of sunset (R^2=0.703; $F_{1,22}$=52.145; P<0.001). The relationship between day length and extent of frog activity was positive and significant (R^2=0.879; $F_{1,22}$=159.211; P<0.001).

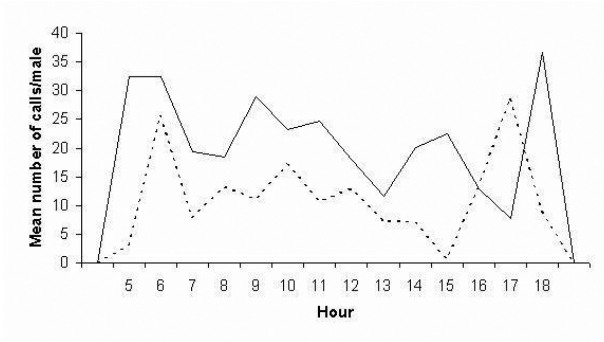

Fig. 1. – Mean number of calls emitted by males of *Crossodactylus gaudichaudii* in the three sampled points in the forest between 05:00 and 19:00h in months of dry (broken line) and rainy (continuous line) seasons in a Atlantic Rainforest area at Ilha Grande.

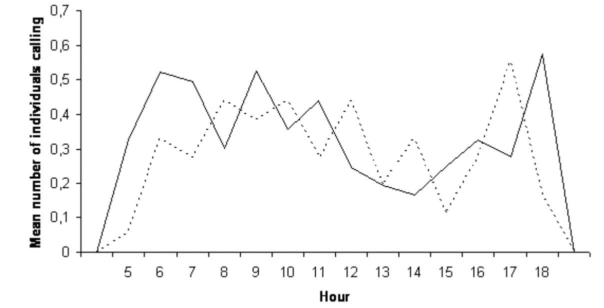

Fig. 2. – Mean number of calling individuals of *Crossodactylus gaudichaudii* in the three sampled points in the forest between 05:00 and 19:00h in months of dry (broken line) and rainy (continuous line) seasons in a Atlantic Rainforest area at Ilha Grande.

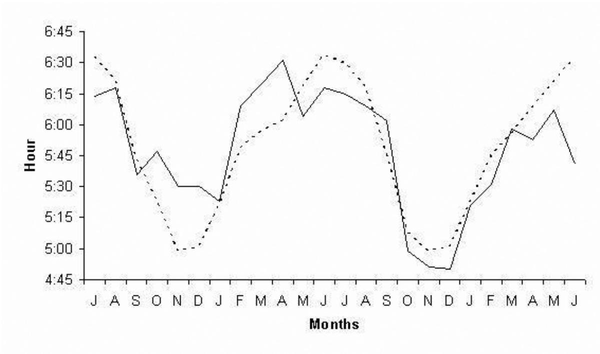

Fig. 3. – Time of beginning (continuous line) of *Crossodactylus gaudichaudii* calling activity and time of sunrise (broken line) between July 2003 and June 2005 in a Atlantic Rainforest area at Ilha Grande.

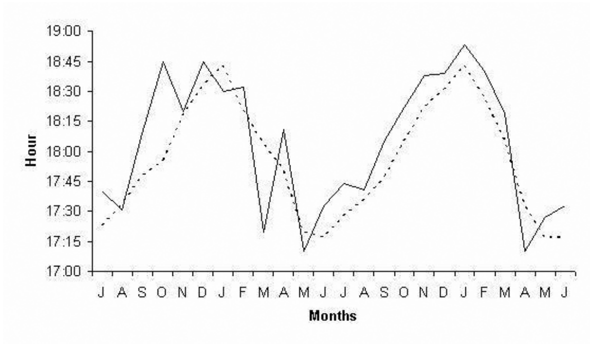

Fig. 4. – Time of end (continuous line) of *Crossodactylus gaudichaudii* calling activity and time of sunset (broken line) between July 2003 and June 2005 in a Atlantic Rainforest area at Ilha Grande.

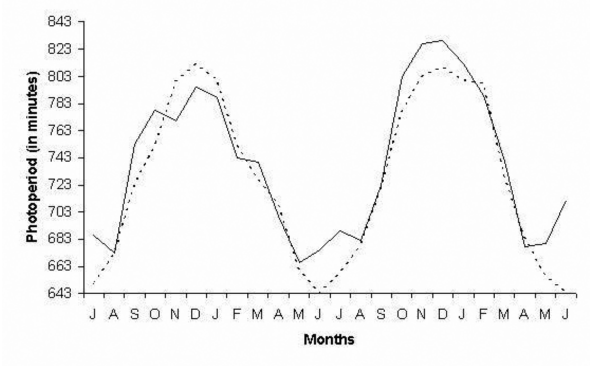

Fig. 5. – Calling activity extension, in minutes, of *Crossodactylus gaudichaudii* (continuous line) and daylength (broken line) between July 2003 and June 2005 in a Atlantic Rainforest area at Ilha Grande.

DISCUSSION

The data of the present study indicate a strictly diurnal calling activity for *Crossodactylus gaudichaudii*. This corroborates the previous available informations for the species, which are based on sporadic observations (Weygoldt & Carvalho-e-Silva, 1992; Izecksohn & Carvalho-e-Silva, 2001). Although most anuran species are nocturnal, males of *C. gaudichaudii* and of other species that live in habitats hypersaturated by humidity (having water available during throughout the year) would likely be less subjected to dehydration than other anurans. This may possibly have allowed the evolution of a diurnal activity pattern (Haddad & Giaretta, 1999; Boquimpani-Freitas et al., 2002).

At the Atlantic Rainforest of Ilha Grande, air temperature significantly affects the calling activity of *C. gaudichaudii*. This variable represents an important factor affecting the calling activity of anurans in general, and in some cases this is the most important factor regulating their activity (Pough et al., 1983; Navas, 1996). For the hylodid *H. phyllodes*, Hatano et al. (2002) found that air temperature also significantly affected the calling activity of males.

Relative air humidity can limit the activity of anuran amphibians both temporally and spatially (e.g. Cree, 1989). On the other hand, air humidity helps in transmission of the sound of the calls, as the resonant transmission is more efficient in humid air than in dry air (Harris, 1966). However, although air moisture affects activity of several anurans species, its effect should be less pronounced in species living permanently associated with streams such as *C. gaudichaudii* (Weygoldt & Carvalho-e-Silva, 1992; Izecksohn & Carvalho-e-Silva, 2001). In this case, even in the drier months, the atmosphere's own humidity would likely be enough to allow calling activity of the frogs without risks of desiccation.

The relative humidity also affected significantly the calling activity of *Hylodes phyllodes* (Hatano et al., 2002), which lives syntopically with *C. gaudichaudii* in some streams in the Atlantic forest of the Ilha Grande. Conversely, for the sympatric cyclorhamphid *Proceratophrys appendiculata* (Boquimpani-Freitas et al., 2002), the relative humidity of the air did not affect the calling activity in a significant way. This suggests that even for species living in streams air humidity has different effects.

The light intensity is as an important environmental variable which influences the calling activity of anuran amphibians (Jaeger et al., 1976; Pancharatna & Patil, 1997). For another strictly diurnal hylodid species of the Atlantic forest, the light intensity also constitutes an important factor affecting the calling activity (Hatano et al., 2002). In our study, light intensity also constitutes an important environmental variable affecting the calling of males of *C. gaudichaudii*. This indicates the importance of that environmental factor for the calling activity in diurnal frogs species.

The hourly calling activity of *C. gaudichaudii* at Ilha Grande was bimodal. The emission of calls by males involves energy expenses and exposes them to greater risks of predation (Duellman & Trueb, 1986; Judge & Brooks, 2001; Wong et al., 2004). The calling activity was more intense, in general, at the beginning and at the end of the day, periods in which the light intensity was comparatively reduced in our study. An increase in calling activity during the hours with smaller light intensity can be advantageous, because it can reduce the chances of desiccation of the skin and of a calling male to be detected by visually oriented predators (Oseen & Wassersug, 2002).

Because in our study light intensity significantly affected the calling activity in the dry season, we suggest that this variable (which had a clear effect in both seasons) and air temperature constitute the main factors affecting the calling activity of *Crossodactylus gaudichaudii* along the day. Those two variables have been suggested as important factors limiting or even suppressing the activity of anuran amphibians (Cardoso & Haddad, 1992).

Our data show that the males of *Crossodactylus gaudichaudii* in the Atlantic forest of the Ilha Grande emitted calls during all months of the year, indicating that the species has an extensive or even continuous reproductive activity, potentially allowing the occurrence of different reproductive events along the same year. Similar results were found for species of the genus *Hylodes* (e.g. Haddad & Giaretta, 1999), which is closely related to the genus *Crossodactylus*. Additionally, the absence of differences in calling activity between the dry and rainy seasons reinforces the suggestion that there is no seasonality in the reproductive activity of the species.

The coincidence among the times of sunrise and sunset with the start and the end of calling activity of males of *Crossodactylus gaudichaudii* is a clear indication of the strictly diurnal activity of this species. Day length also regulates the extent of calling activity of this frog. This has been observed for other hylodid species (Hatano et al., 2002), for which the extent of activity is regulated by the extent of the light period. The photoperiod is an important factor affecting the activity of several species of amphibians (Jaeger et al., 1976; Pancharatna & Patil, 1997). In our study, the photoperiod explained a considerable portion (approximately 88%) of the extent of the calling activity. The difference observed between the shortest and longest days was similar to that observed for the shortest and longest durations of calling activity, suggesting a narrow relationship between these two factors. As well as in other studies with diurnal species (Hatano et al., 2002), the extent of the calling activity thus seems to be regulated by the length of the day.

We conclude that males of *Crossodactylus gaudichaudii* have a strictly diurnal activity and are active during all months of the year. Air temperature, relative humidity and light intensity seems to interact in the dry and rainy seasons to affect the daily activity of this species, with air temperature and light intensity seeming to constitute the most important factors influencing calling frog activity. Photoperiod is the main factor regulating the extent of the calling activity along the year.

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