Universidade Federal de Uberlândia

Instituto de Biologia

Programa de Pós-graduação em Ecologia e Conservação de Recursos Naturais

HISTÓRIA NATURAL DE ESPÉCIES DE ANUROS DO CERRADO: Corte, vocalização e girino de *Epipedobates flavopictus* (Anura: Dendrobatidae) e Predação de duas espécies de anuros por *Procyon cancrivorus*, no Cerrado Brasileiro.

Ronan Caldeira Costa

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Orientador

Prof. Dr. Ariovaldo Antonio Giaretta

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Capítulo 01

Courtship, vocalization, and tadpole description of *Epipedobates flavopictus* (Anura: Dendrobatidae) in southern Goiás, Brazil

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ABSTRACT

Epipedobates flavopictus is a diurnal, aposematic dendrobatid with a wide distribution in seasonal wet tropical regions of Brazil. We describe the daily period of vocalization, advertisement call, courtship behavior, and tadpole of *E. flavopictus* from a previously unknown population in southern Goiás and compare theses features with that of other populations. Studies were carried out in November (2004) and February (2005). We counted the number of calling males and duration of calling bouts in the morning and evening periods. The advertisement call was recorded with a digital recorder. Tadpole description was based on specimens collected in pools. Males called from well-illuminated sites such as rocky fields, rain channels, and borders of riverine forests. In November, males vocalized daily during two distinct periods, between 0430 and 1000 h and between 1630 and 2000 h. Morning temperature varied between 20-23ºC and humidity from 79-89%; during evening varied between 24-27ºC and 54-82%. In the middle of the day, temperature reached 36ºC and humidity 40%. During the morning, call activity was almost uninterrupted, in the evening calling bouts lasted around 9 min. In February, even with the occurrence of rainfall and temperatures similar to that of November no frog vocalized. The advertisement call is composed by a single note with 7–8 pulses with frequency ascending slightly from 3.20 to 4.05 kHz. Note duration was 144 ms, and between note intervals is 292 ms. Notes are given at a rate of 139 per minute. Upon observing the female, the male began to emit courtship call. The female approached the male and touched him laterally with her snout. The male moved forward and raised his hindquarters by stretching his hind legs. While leading the female, the male continued to give courtship and advertisement calls. The male clasped the female in axillary amplexus, and the pair entered a hole in a bank. The female deposited eggs on the surface of the soil, spreading them in groups. The egg clutches had eggs in at least two developmental stages, recently deposited and with embryos. Tadpoles were found in small, shallow rocky pools along a permanent stream, in well-illuminated sites at the forest border. The tadpole had the dorsal fin arched, not extending onto body. *E. flavopictus* appears to be unique among dendrobatids by using open areas subject to high temperatures and low humidity. Reproductive activity of the species ends before the end of the rainy season, possibly to avoid loss of tadpoles during months with unpredictable rainfall. The studied call had more notes and shorter between-call intervals than those described from other populations. The free-living tadpoles we describe differ from those of other populations by having the dorsal fin reduced.

Key-words: populational variation, Brazilian Cerrado, habitat, pattern of activity, behavior, reproduction, advertisement call.

RESUMO

Epipedobates flavopictus é um dendrobatídeo diurno, aposemático que tem ampla distribuição em regiões tropicais do Brasil. Descrevemos o período diário de atividade de canto, canto de anúncio, comportamento de corte e girino de *E. flavopictus* de uma população previamente desconhecida do sul de Goiás e comparamos essas características às de outras populações. O estudo foi realizado em novembro de 2004 e fevereiro de 2005. Comparamos o número de machos em atividade de canto e a duração dos períodos de canto da manhã e da tarde. O canto foi gravado com aparelho digital. A descrição dos girinos foi feita com base em espécimes coletados em poças. Os machos vocalizavam em sítios bem iluminados tais como ambientes rupestres e borda de matas ribeirinhas. Em novembro, os machos vocalizavam diariamente em dois períodos diferentes do dia; entre 0430 e 1000 h e entre 1630 e 2000 h. Durante a manhã, a temperatura variou entre 20 e 23 ºC e a umidade entre 79 e 89%; durante a tarde variou entre 24 e 27 ºC e 54 e 82%. No meio do dia, a temperatura chegou a 36 ºC e a umidade a 40%. Durante a manhã, a atividade de canto era quase ininterrupta, e a tarde os períodos de canto duravam cerca de 9 min. Em fevereiro, apesar da ocorrência de chuvas e temperatura/umidade similares as de novembro, não houve atividade de canto. O canto de anúncio é composto por uma única nota com 7-8 pulsos, com freqüência ascendente de 3,20 a 4,05 kHz. A duração da nota é de 144 ms com intervalos de 292 ms. As notas são emitidas a uma taxa de 139 notas por minuto. Uma vez visualizada a fêmea, o macho começa a emitir canto de corte. A fêmea se aproxima do macho e o toca na lateral do corpo com o focinho. O macho se move pra frente e levanta o seu quarto traseiro esticando suas pernas. Enquanto conduzindo a fêmea, o macho continuava a emitir cantos de corte e de anuncio. O macho amplexou a fêmea axilarmente, e o par entrou num buraco no barranco. A fêmea depositou os ovos na superfície do solo, espalhando-os em grupos. Uma desova examinada tinha ovos em dois estágios diferentes de desenvolvimento: recém depositados e com embriões. Os girinos foram encontrados em pequenas poças rasas em rochas ao longo de um riacho permanente, em sítios bem iluminados na borda da floresta. Os girinos tinham a nadadeira dorsal arqueada, a qual não se estendia para o corpo. Aparentemente, *E. flavopictus* é o único entre os dendrobatídeos por usar áreas abertas sujeitas a altas temperaturas e baixas umidades. A atividade reprodutiva da espécie termina antes do fim da estação chuvosa, possivelmente para evitar perda de girinos durante meses com chuvas imprevisíveis. O canto estudado tinha mais notas e intervalos de cantos mais curtos que aqueles descritos de outras populações. O girino de vida livre que descrevemos difere do de outras populações ter a nadadeira dorsal reduzida.

Palavras-chave: variação populacional, Cerrado brasileiro, habitat, padrão de atividade, comportamento, reprodução, canto de anúncio.

INTRODUÇÃO

Epipedobates flavopictus Lutz, 1925 é um dendrobatídeo diurno, aposemático (preto, laranja, e vermelho) com uma ampla distribuição em regiões tropicais úmidas e sazonais dos estados brasileiros de Minas Gerais, Goiás, Tocantins, norte do Pará e nordeste do Maranhão (Haddad & Martins 1994). Algumas variações interpopulacionais no tamanho do adulto e coloração são reconhecidas (Haddad & Martins 1994). Haddad et al. (1988) e Haddad & Martins (1994) descreveram o canto e o girino e Toledo et al. (2004) descreveram a desova e o cuidado parental em populações de Minas Gerais. Apesar destes estudos prévios, alguns aspectos do comportamento de *E. flavopictus* permanecem desconhecidos e diferenças interpopulacionais em morfologia e parâmetros de canto são pouco conhecidas. No presente estudo, descrevemos o período diário de vocalização, o canto de anúncio, o comportamento de corte e o girino de *E. flavopictus* de uma população previamente desconhecida no sul de Goiás.

INTRODUCTION

Epipedobates flavopictus A. Lutz, 1925 is a diurnal, aposematic (black, orange, and red) dendrobatid with a wide distribution in seasonal wet tropical regions in the Brazilian states of Minas Gerais, Goiás, Tocantins, northern Pará and northeastern Maranhão (Haddad & Martins 1994). Some interpopulational variation in adult size and color has been recognized (Haddad & Martins 1994). Haddad et al. (1988) and Haddad & Martins (1994) described the call and the tadpole, and Toledo et al. (2004) described egg clutches and parental care in populations from Minas Gerais. In spite of these previous studies, some aspects of the behavior of *E. flavopictus* remain unknown, and interpopulational differences in morphology and call parameters are only partly documented. In the present study, we describe the daily period of vocalization, the advertisement call, courtship behavior, and tadpole of *E. flavopictus* from a previously unknown population in southern Goiás.

MATERIAL AND METHODS

Study Site and Procedures

This work was conducted during five days in November (2004) and in three days in February (2005) at Parque Estadual da Serra de Caldas Novas (PESCAN) (17° 46' 8.7" S and 48° 39' 39" W; ca. 800 m altitude), southern Goiás, Brazil. The PESCAN encompasses an area of 12500 ha of Cerrado Biome. The climate is AW type, according to Köppen classification, corresponding to rainy/hot humid tropical climate with rains concentrated in summer (Santos 2003). Water bodies include permanent forest streams, seasonal small (<5 liters) pools along rocky streams, and rocky rain channels. Around the administration facilities there is a stone garden with shallow (<20 cm) cement-bottomed pools.

Epipedobates flavopictus (Figure 1) was relatively common at the study site. We preliminarily determined the daily pattern of vocal activity of males of *E. flavopictus* for a 24 h period by visiting reproductive sites. Subsequently, the number of calling males was quantified along three 50 m transects of similar vegetational aspect. Site I was a rocky field (Cerrado Rupestre) (Figure 2-A); sites II and III were two segments of a rain channel (ca. 300 m apart) (Figure 2-B). Each transect was walked in the morning (between 0400 and 1000 h) and evening (between 1600 and 2000 h). During sampling, air temperature and relative humidity were measured each hour with a thermo-hygrometer (Hanna Instruments HI 8564). To compare the number of calling males in the morning and evening periods, we used the Wilcoxon matched pairs test (Zar 1999), performed considering the maximal number of males in each period. While sampling transects (mornings and evenings), we measures the duration of calling bouts with a stopwatch; bouts were arbitrarily considered different from one another if more than one minute elapsed between them. To check for site fidelity, males were recognized by their individual pattern of dorsal yellow spots (see Fig. 18, pg. 37 in Eterovich & Sazima 2004). On February 26, 27, and 28, we visited the same transects and surrounding areas to determine the presence of calling males.

Calls of one male were recorded with a Boss 864 digital recorder coupled to a Sennheiser ME67 microphone (44000 Hz; 16 bit resolution). Sound analysis was performed with Sound Ruler software (Gridi-Papp 2003). Tadpoles were collected in pools along permanent streams where males where heard. The tadpoles were described base on specimens preserved in 5% formalin immediately after collection. Nomenclature for tadpole anatomy follows Altig & McDiarmid (1999). A sample of tadpoles was kept in laboratory until metamorphosis to confirm identification; those used for description were between stages 25 and 37 (Gosner 1960). Measurements were taken with a caliper to the nearest 0.1 mm.

Voucher specimens are housed at the frog collection of the Museu de Biodiversidade do Cerrado, at the Universidade Federal de Uberlândia. Adult AAG-UFU 2526; newly metamorphosed AAG-UFU 3157; tadpoles AAG-UFU 3151 (a lot with six tadopes).

Figure 1. Adult male *Epipedobates flavopictus*. Municipality of Caldas Novas, Goiás, Brazil.

Figure 2. Calling sites of *E. flavopictus*. A - Rocky field (Cerrado Rupestre); B - Rain channel. Municipality of Caldas Novas, Goiás, Brazil (08/11/2004).

RESULTS

Males called from well-illuminated sites such as rocky fields, rain channels, borders of riverine forests, and at the rocky garden. In November, males vocalized daily during two distinct periods, between 0430 and 1000 h and between 1630 and 2000 h. During the morning, temperature varied from 20 ºC to 23 ºC and humidity from 79% to 89%; in the evening, temperature ranged from 24 ºC to 27 ºC and from 54% to 82%. In the middle of the day, when no male called, (1200 to 1500 h), temperature reached 36 ºC and humidity 40%.

In the transects, the number of males calling during the morning (Median = 5) were not different from that calling during the evening (Median = 2) (Wilcoxon Z = -1.6; p = 0.11). During the morning, call activity was almost uninterrupted, with bouts lasting as long as 60 min and the interval between bouts were short (ca. 1 min). In the evening calls bouts lasted about 9 min (Mean = 503 s; SD = 254; N = 5 males); with intervals between bouts ranging from 10 to 20 min. In hot (Mean = 25 ºC; SD = 0.8; N = 3 days) rainy (humidity 92%) days of February no male vocalized or was saw along transects.

The advertisement call of one male was composed by a single note whit 7–8 pulses (Figure 3) that ascended slightly from 3.20 to 4.05 kHz. Note duration was 144 ms (SD = 2.8, N = 5), and between note intervals were 292 ms (SD = 5.61, N = 5). Notes were given at a rate of 139 per minute.

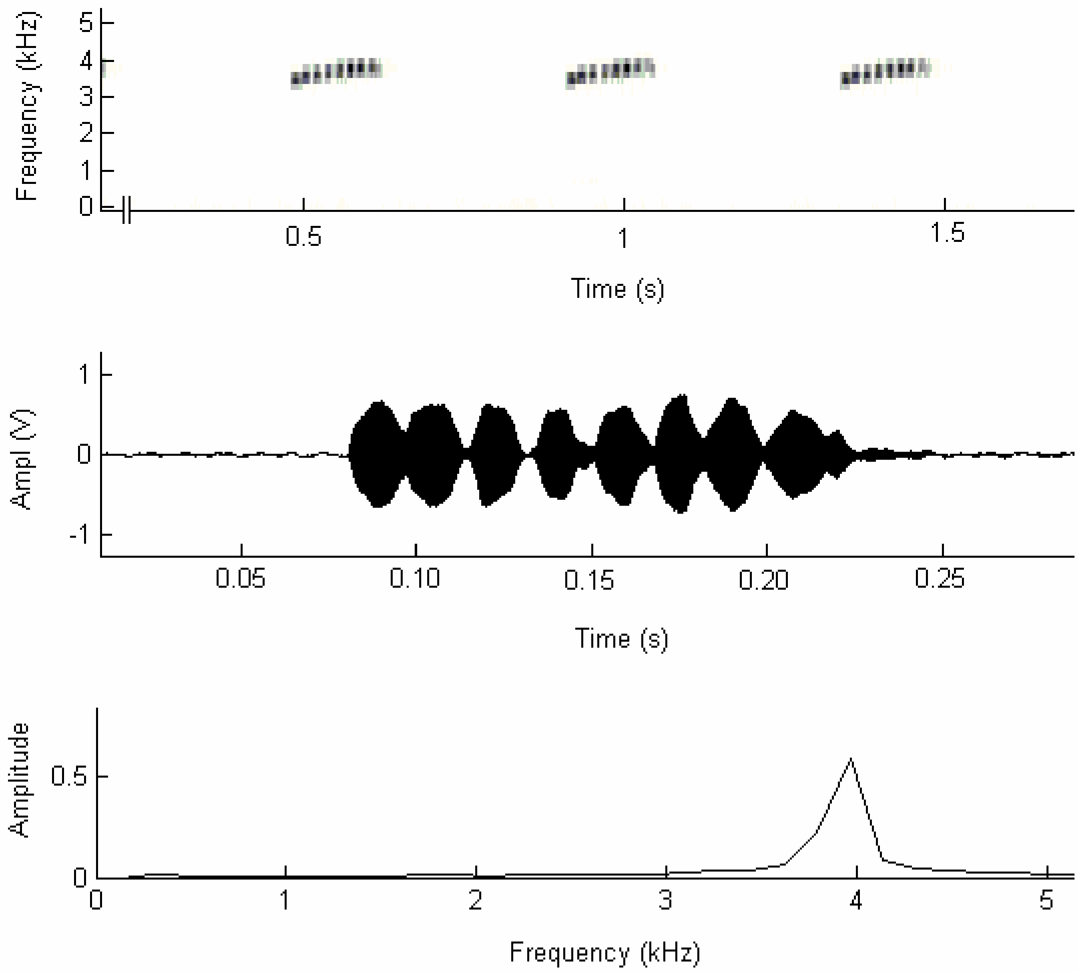

Figure 3. Advertisement call of *Epipedobates flavopictus*. Above- Spectrogram, Middle-Oscilogram of a single call. Below- Power Spectrum. Call recorded in November 2004. Air temperature, 23.5^{o}C, water temperature, 22.7^{o}C. Sound file EpipedflavopAAGd. Unvouchered record. Municipality of Caldas Novas, Goiás, Brazil.

One complete courtship sequence that culminated in egg deposition and two partial events were observed at the rain channel (Site II), all during the morning. In the complete sequence, the female approached a calling male. Upon observing the female, the male began to emit a low, peeping courtship call (not recorded). The female approached the male and touched him laterally with her snout. The male moved forward and raised his hindquarters by stretching his hind legs, thus revealing the orange coloration on his legs. The male continued to move, usually in about 30 cm increments, stopping to raise his cloacae. The female followed him, touching his flanks when he stopped, eventually completely turning around him. The male moved 2 m from the contact point while repeating this behavior; the female was never more than 20 cm apart from him. While leading the female, the male continued to give courtship and advertisement calls. The pair reached a small hole in the bank, where the male called from the entrance. The male clasped the female in axillary amplexus, and the pair entered the hole. After about 10 min, the female began to deposit eggs on the surface of the soil, spreading the eggs in groups within a circle of ca. 10 cm diameter. It took 85 minutes from the beginning of the courtship to beginning of egg deposition.

Examination of the egg deposition site the following afternoon revealed the presence of 20 eggs in at least two developmental stages, recently deposited and with developing embryos. Including the gelatinous capsules, the eggs with embryos measured between 4.4 and 4.7 mm in diameter (N = 4). In the two other courtships observed the pairs also were near (< 1 m) holes in the ground.

Seven tadpoles were found in two in small, shallow (2 liters; 15 mm deep) rocky pools along a fast-moving permanent stream, in well-illuminated sites at the forest border. A male carrying tadpoles was seen near the pool in the stone garden. Syntopic frog species at the garden were *Physalaemus cuvieri*, *Hyla* sp. (gr. *marmorata*), *Scinax fuscovarius*, *Leptodactylus syphax*, and *L. labyrinthicus*.

Tadpole (Figure 4). Body ovoid in lateral and dorsal views. Nostril same distance from tip of snout as to eye; both nostril and eye positioned dorsolaterally. Spiracle sinistral, located equidistant at height and length of body, posterodorsally directed. Anal tube dextral, broad, without a free border. Dorsal fin arched, not extending onto body; tail tip rounded. Oral disc positioned ventrally, emarginated. Labial tooth row formula 2(2)/3(1); A-2 gap well defined and P-1 gap barely discernable; P-3 slightly shorter or same length as P-1 and P-2. Oral disc surrounded by papillae except for a broad anterior gap; papillae rounded. Papillae in a single row, although appearing alternated; some submarginal papillae laterally on disc and on posterior labium. Upper jaw sheath arc-shaped; lower jaw sheath U-shaped. Maximal observed length 29 mm (Gosner stage 41). Body 38% the total length. In life, dorsal surface silver on a gray background; translucent tail with some black mottling; translucent belly, with some silver mottling. Snout-vent length 11.1 mm at metamorphosis (N = 1).

Figure 4. Left, dorsal, and ventral views of a tadpole of *Epipedobates flavopictus*. The left-sided picture shows that the dorsal fin does not extend onto the body. Gosner stage 27; 21.4 mm TL. Tadpole slightly stained with iodine. Municipality of Caldas, Novas, Goiás, Brazil.

DISCUSSION

Among dendrobatids, choice of egg-laying sites is variable, with some species depositing eggs on the ground (Wells 1978, 1980a, 1980b, Roithmair 1994, Lima et al. 2002). Toledo et al. (2004) depicted a clutch of eggs of *Epipedobates flavopictus* in a mass; however, we found that eggs were spread in small groups. Dendrobatids are known to reproduce in primary or secondary forests (Rodriguez & Duellman 1994), even those from the Cerrado (Haddad et al. 1988, Haddad & Martins 1994). *Epipedobates flavopictus* appears to be unique among dendrobatids by using open areas subject to high temperatures and low humidity. Reproductive activity of *Epipedobates flavopictus* ends before February, prior the end of the rainy season, possibly to avoid loss of tadpoles during months with unpredictable rainfall.

Environmental variables such as humidity, temperature and photoperiod may determine anuran breeding period (Navas 1996, Navas & Bevier 2001, Hatano et al. 2002). As in other diurnal frogs, the daily calling pattern of *E. flavopictus* may be related to moderate temperatures and higher humidity (Wells 1980a, 1980b, Navas 1996, Narvaes 1997, Heying 2001, Hatano et al. 2002); although we did not measure light intensity, it seems that this factor was of secondary importance, since vocal activity occurred during full-night hours. We predict that on rainy mid-summer days the call activity may occur throughout the day. The two-phase calling period of *E. flavopictus* is similar to that described for *E. macedo* (Rodriguez & Myers 1993) and *E. parvulus* (Rodriguez & Duellman 1994). As indicated by the larger time the males spent calling and the number of observed courtship events, *E. flavopictus* is more active during the morning period.

Males of several species of dendrobatids lead females to egg-laying sites (Rodriguez & Duellman 1994, Caldwell & De Oliveira 1999, Lima et al. 2002); we observed this behavior in *E. flavopictus* as well. Among dendrobatids, multiple clutches at the same site have been reported for *E. flavopictus* by Toledo et al. (2004; present study) and for

Colostethus nidicola (Caldwell & Lima, 2003). This association between the male and the egg laying site may be indicative of the existence of parental care in the egg phase in these species, as already recognized in other species of the family (Weygoldt 1987; Pröhl & Hödl 1999).

Good quality territories usually result in access to more females (Heying 2001) and in greater offspring survival (Pröhl & Hödl 1999). Territoriality, as evidenced by site fidelity in *E. flavopictus,* is expected in those prolonged-breeding frogs, and egg deposition usually occurs in defended areas (Wells 1977).

Geographic variation in call parameters, color pattern, and size of adults and larvae are known for several anurans (Wilczynski et al. 1992, Aresco 1996, Gascon et al. 1998). The call of *E. flavopictus* from our study area had more notes and shorter intercall intervals than those described from populations from Minas Gerais (Haddad & Martins 1994, Haddad et al. 1988). Haddad & Martins (1994) described *E. flavopictus* tadpoles based on specimens collected from a male's back and Martins & Sazima (1989) presented a photo of a late-staged tadpole. The free-living tadpoles we describe here differ from those of Haddad & Martins (1994) by having the dorsal fin reduced (not extending onto the body), a shorter P-1 gap, and, apparently, more numerous oral papillae. The specimen depicted by Martins & Sazima (1989) also showed an extended dorsal fin. A reduced dorsal fin is a feature of several *Epipedobates* species, including *E. braccatus*, *E. pictus,* and *E. hahneli* (Haddad & Martins 1994, Rodriguez & Duellman 1994).

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Capítulo 2

Crab-eating raccoon (*Procyon cancrivorus*) predation on dwarf frogs (*Physalaemus nattereri*) and granular toads (*Bufo granulosus*) in a Cerrado area of southeastern Brazil

ABSTRACT

We report on crab-eating raccoon (*Procyon cancrivorus*) predation on dwarf frogs (*Physalaemus nattereri*) and granular toads (*Bufo granulosus*), and describe some defensive behaviors presented by this toad species. Remains of adult individuals, being six *P. nattereri* (including at least one female) and eight *B. granulosus* (six males and two females) were found in association with recent footprints of crab-eating raccoons at three anuran breeding sites in Uberlândia, MG, Brazil. All individuals were found inside water. Based on carcasses, anurans were bitten in the belly, but not in the dorsal region. The toxic prey skins were not ingested. Male toads tested for defensive behaviors emitted releasing calls and one of them displayed the defensive posture known as crouching. Males of *B. granulosus* were more preyed than females probably because they are more numerous at breeding sites and their choruses turn them more easily detected by crab-eating raccoons. Besides exposing more efficiently the parotoid glands, the crouching posture may also hinder the access to the vulnerable toad underside. However, the defensive display of *B. granulosus* can be performed only in terrestrial environments, not providing protection against predators that catch their prey inside water, such as the crab-eating raccoon. The behavior of removing the prey skin before eating allows the crab-eating raccoon to avoid dermal toxins when preying upon poison anurans.

Key-words: *Bufo granulosus*, defensive behavior, *Physalaemus nattereri*, predation, *Procyon cancrivorus*

RESUMO

Nós relatamos predação por mão-pelada (*Procyon cancrivorus*) da rã de Natterer (*Physalaemus nattereri*) e do sapo comum (*Bufo granulosus*) e descrevemos alguns comportamentos defensivos apresentados por essa espécie de sapo. Restos de indivíduos adultos, sendo seis *P. nattereri* (incluindo pelo menos uma fêmea) e oito *B. granulosus* (seis machos e duas fêmeas) foram encontrados em associação com pegadas recentes de mãos-peladas em três locais de reprodução de anuros em Uberlândia, MG, Brasil. Todos os indivíduos foram encontrados dentro da água. Com base nas carcaças, os anuros foram mordidos na barriga, mas não na região dorsal. As peles tóxicas das presas não foram ingeridas. Os sapos machos testados para comportamentos defensivos emitiram cantos de libertação e um deles exibiu a postura defensiva conhecida como "crouching" (agachamento). Os machos de *B. granulosus* foram mais predados que as fêmeas provavelmente porque eles são mais numerosos nos locais de reprodução e suas vocalizações os tornam mais facilmente detectáveis pelos mãos-peladas. Além de expor as glândulas parotóides mais eficientemente, a postura de agachamento também pode dificultar o acesso à região ventral, mais vulnerável, dos sapos. Entretanto, a exibição defensiva de *B. granulosus* pode ser executada apenas em ambientes terrestres, não conferindo proteção contra predadores que capturam suas presas dentro da água, como o mão-pelada. O comportamento de remover a pele das presas antes de comer permite ao mão-pelada evitar as toxinas dérmicas ao atacar anuros venenosos.

Palavras-chave: *Bufo granulosus,* comportamento defensivo, *Physalaemus nattereri*, predação, *Procyon cancrivorus*

INTRODUÇÃO

Os animais possuem uma variedade de características morfológicas, fisiológicas e comportamentis que atuam na proteção contra predadores (Alcock 1993, Krebs & Davies 1993). Em anfíbios, um dos principais mecanismos de defesa é a presença de glândulas de veneno na pele (Toledo & Jared 1995). Em algumas espécies, estas glândulas estão concentradas em certas áreas do corpo formando macroglândulas como as glândulas inguinais de alguns leptodactilídeos e glândulas parotóideas de bufonídeos, as quais podem estar associadas a comportamentos defensivos (Martins 1989).

A rã *Physalaemus nattereri* tem porte grande (CRC aproximadamente 45 mm), distribui-se nas regiões central e sudeste do Brasil e no leste do Paraguai (Frost 2004). É uma espécie que possui glândulas inguinais pigmentadas de preto que são exibidas na presença de predadores potenciais (Sazima & Caramaschi 1986). Rodrigues & Oliveira-Filho (2004) relataram duas tentativas mal sucedidas de predação de *P. nattereri* pela rã *Leptodactylus ocellatus*. Outros predadores como a serpente *Helicops infrataeniatus* e a rã-pimenta *Leptodactylus labyrinthicus* costumam predar adultos dessa espécie (Cardoso & Sazima 1977, Martins & Duarte 2003, França et al. 2004) e a mosca *Beckeriella niger* (Diptera, Ephedridae) infesta seus ninhos de espuma, consumindo ovos e embriões (Menin & Giaretta 2003).

O sapo *Bufo granulosus* é um bufonídeo de tamanho pequeno (CRC aproximadamente 50 mm), ocorre do sul do Brasil até as Guianas, nordeste do Peru, Bolívia e nordeste do Paraguai e da Argentina, (Frost 2004). Apesar de sua distribuição ampla, *B. granulosus* raramente é relatado como presa, um fato provavelmente relacionado à presença das glândulas paratóideas (Toledo & Jared 1995). Os únicos registros de predação que encontramos referem à ave *Theristicus caudatus* (Sick 1984), e os anuros *Bufo paracnemis* (Guix 1993a) e *L. labyrinthicus* (França et al. 2004). O comportamento defensivo exibido por essa espécie ainda permanece desconhecido.

O mão-pelada (*Procyon cancrivorus*) é um procionídeo noturno distribuído nas Américas Central e do Sul, da Costa Rica até o sul do Panamá, Uruguai e Argentina (Emmons & Feer 1997, Eisenberg & Redford 1999). Esta espécie aparentemente é restrita a locais próximos a corpos d’água e a sua dieta onívora, inclui muitos animais aquáticos como crustáceos e peixes (Bisbal 1986). Estudos prévios descrevem que o mão-pelada ocasionalmente consume anuros (Guix 1993), apesar da presença de glândulas de veneno na pele dessas presas. Neste trabalho relatamos pela primeira vez casos de predação de *P. nattereri* e de *B. granulosus* por *P. cancrivorus*. Descrevemos também alguns comportamentos defensivos apresentados por *B. granulosus*.

INTRODUCTION

Animals possess a variety of morphological, physiological, and behavioral features that provide some protection against predators (Alcock 1993, Krebs & Davies 1993). In amphibians, one of the principal mechanisms of defense is the presence of venom glands in their skin (Toledo & Jared 1995). In some species, these glands are concentrated in certain areas of the body, forming macroglands, such as the inguinal glands of some leptodactylids and parotoid glands of bufonids, which may be associated with defensive behaviors (Martins 1989).

The dwarf frog (*Physalaemus nattereri*) is a large (snout-vent length of around 45 mm) species of the genus, distributed in central and southeastern Brazil and eastern Paraguay (Frost 2004). This species presents black pigmented inguinal glands, which are displayed in the presence of potential predators (Sazima & Caramaschi 1986). Rodrigues & Oliveira-Filho (2004) reported two unsuccessful attempts of predation on *P. nattereri* by the spotted thin-toed frog (*Leptodactylus ocellatus*). The water snake *Helicops infrataeniatus* and the South American pepper frog (*Leptodactylus labyrinthicus*) prey upon adults (Cardoso & Sazima 1977, Martins & Duarte 2003, França et al. 2004) and *Beckeriella niger* flies (Diptera, Ephedridae) infest foam nests and consume egg/embryos (Menin & Giaretta 2003).

The granular toad (*Bufo granulosus*) is a small-sized bufonid (snout-vent length of around 50 mm), found from Panama to the Guianas, south through the Amazon Basin to northeastern Peru, non-Andean Bolivia, northwestern Paraguay, northeastern Argentina, and southern Brazil (Frost 2004). Despite its wide distribution, *B. granulosus* is rarely reported as prey, a fact probably related to the presence of the parotoid glands (Toledo & Jared 1995). The only records of predation we found refer to the buff-necked ibis (*Theristicus caudatus*) (Sick 1984), to the cururu toad (*Bufo paracnemis*) (Guix 1993a), and to the South American pepper frog (França et al. 2004). The defensive behavior of this species is still unknown.

The crab-eating raccoon (*Procyon cancrivorus*) is a nocturnal procyonid distributed in Central and South America from east Costa Rica and Panama south to Uruguay and north Argentina (Emmons & Feer 1997, Eisenberg & Redford 1999). This species is apparently restricted to waterside habitats and its omnivore diet includes many aquatic animals, such as crustaceans and fish (Bisbal 1986). Previous studies suggest that crab-eating raccoons occasionally consume anurans (Guix 1993), despite the presence of venom glands in the prey skin. Herein, we report for the first time on the crab-eating raccoon predation on *P. nattereri* and *B. granulosus*, and describe some behaviors presented by this toad species that may be used in an antipredatory context.

MATERIAL AND METHODS

Data on predation of *P. nattereri* and *B. granulosus* were obtained by examining individuals that were found dead between 15 October and 5 November 2004 at three anuran breeding sites in the outskirts of Uberlândia (18º55'S - 48º17'W, approx. 750 m altitude), State of Minas Gerais, southeastern Brazil. The local climate is characterized by a wet/warm season from September to March, when many anuran species are reproducing (Giaretta & Kokubum 2004, Giaretta & Menin 2004, Silva et al. 2005), and a dry/mild season from April to August. The monthly mean temperature ranges from 19 to 30 ºC, and the annual rainfall is about 1,550 mm (Rosa et al. 1991). Remains of natural vegetation near the breeding sites include low land Cerrado environments, such as gallery forests and palm swamps (Araújo et al. 2002).

Predator species was identified based on footprints (Becker & Dalponte 1990) found near carcasses and checked throughout visual encounters. Prey remains were examined for bite marks and refused body parts. Toads were sexed based on the presence of a yellow vocal sac and nuptial pads in males. Five live individuals (four males and one female) were tested for defensive behaviors. We tested each individual by gently tapping it on the back and turning it with the belly upward. Voucher specimens of *P. nattereri* and *B. granulosus* are deposited in Museu de Biodiversidade do Cerrado, Universidade Federal de Uberlândia and photos of live individuals are available on AmphibiaWeb.

RESULTS

We found the remains of six adults of *P. nattereri* (including at least two females) and eight adults of *B. granulosus* (six males and two females), which were associated with recent footprints of crab-eating raccoons. Two males of *B. granulosus* were found on 15 October and two males and one female on 5 November in an artificial lake and two males and one female were found on 21 October in a palm swamp pond. All toads were found inside water and their skins were not ingested, but turned inside out (Fig. 1). The two females were bearing mature eggs and were left by the predator almost intact. Based on carcasses, toads were bitten in the belly, but not in the dorsal region. All the six *P. nattereri* were found on 20 October in a temporary pond close to the palm swamp. Predators discarded prey skins and the female reproductive system (ovaries and oviducts) of this species (Fig. 2). Tracks of crab-eating raccoons were frequently found near the lake and the ponds during the study period. In three occasions, solitary crab-eating raccoons were seen foraging at night around the water bodies where anurans were aggregated for reproduction. One of them was observed using its front paws to hold a frog on the ground while eating.

Figure 1. Body remains of two males of *Bufo granulosus* that were preyed by *Procyon cancrivorus* in an artificial lake in Uberlândia, MG, Southeastern Brazil. Notice the intact parotoid glands and that the remains consist basically of the toad skins, which were turned inside out by the predator.

Figure 2. Body remains of two individuals of *Physalaemus nattereri* that were preyed by *Procyon cancrivorus* in a temporary pond in Uberlândia, MG, Southeastern Brazil. A- An almost entire discarded skin. B- A skin turned inside out and the ovaries filled with mature eggs.

Male individuals of *B. granulosus* tested for defensive behaviors emitted releasing calls and one of them displayed the defensive posture known as crouching, staying with the body flattened and the legs spread out. When turned with the belly upward, this individual immediately returned to its original position.

DISCUSSION

Our observations confirm that the crab-eating raccoon prey upon poison anurans, and suggest that individuals actively seek frogs and toads at their breeding sites. Dogs that bite toads present cardiotoxic symptoms, such as ventricular fibrillation, arrhythmia, lung edema, and death (Sakate & Oliveira 2000). Captive coatis (*Nasua nasua*) refused to consume offered *P. nattereri*, or rolled the prey on the ground to remove skin secretions prior to ingestion (Sazima and Caramaschi, 1986). The consumption of poison anurans by the crab-eating raccoon is probably related to its well-developed sense of touch and great manual dexterity to manipulate food sources (see Novak 1991), which allows this species to remove the prey skin before eating and to avoid dermal toxins. As far as we are aware, no other predator among South American carnivores skins prey before eating. Although some species may also consume anurans (Redford & Eisenberg 1992), the frequency of amphibians in the diet is generally low (e.g. Pardini 1998, Facure et al. 2003), and only the crab-eating raccoon seems to be a regular predator of anurans among carnivores in Brazil, at least in periods of greater abundance of this kind of prey, as during the reproductive season.

Since toad toxins are concentrated in dorsal skin and parotoid glands, predators must kill these anurans biting them in the belly. The crouching posture was also observed in another toad species, *B. paracnemis*, and was interpreted as a way of exposing the parotoid glands more efficiently (Toledo & Jared 1995), but our results indicate that it may also be helpful to hinder the predator access to the vulnerable toad underside. However, the defensive display of *B. granulosus* can be performed only in terrestrial environments, not providing protection against predators that catch their prey inside water, such as the crab-eating raccoon. The rejection of the toad females by the predator is probably due to the fact that *Bufo* eggs may be highly toxic (Crossland 2000). As frog ovaries and oviducts were also discarded, it is likely that *P. nattereri* eggs also present toxic substances.

Anurans are particularly susceptible to predation when aggregated around water bodies for reproduction (Ryan 1985, Duelmann & Trueb, 1986, Toledo 2003). The frequent encounters of crab-eating raccoons and their signs (footprints and prey remains) in the present study demonstrate intense exploitation of anuran breeding sites. In the study area, besides *P. nattereri* and *B. granulosus*, the crab-eating raccoon also skins and consumes adults of *Physalaemus* cf. *fuscumaculatus*, when they are aggregated for reproduction (Giaretta & Menin 2004). Mammalian predation on anurans at breeding sites has been commonly reported (e.g. Ryan 1985, Lodé 1996, Giaretta & Menin 2004, present study) and a factor that may contribute to attract and to orient these predators is the sound of male advertisement calls (Ryan et al. 1981, Tuttle et al. 1982). Males of *B. granulosus* were more preyed than females probably because they are more numerous at breeding sites (pers. obs.) and their choruses turn them more easily detected by predators.

In conclusion, our data shows that adult individuals of *P. nattereri* and *B. granulosus* are susceptible to predation by the crab-eating raccoon at laying sites throughout the breeding period and that male toads were more frequently eaten than females. Being a seasonal food resource, the occurrence of anurans in the diet may decrease during winter. Further studies are needed to better understand how the crab-eating raccoon select species and sex of anuran prey and if it adjusts its diet to the seasonal variation in the abundance of food items.

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