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Crab burrows and termite thermal chimneys as refuges for anurans in a Neotropical wetland

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Abstract. In this study, we report on shelter use by anurans during the dry season in the Pantanal, a large wetland in mid-western Brazil that is subject to periodical floods, dry periods, and sporadic fires. Field observations were made in the northern Pantanal from 2010 to 2013. We documented the use of underground burrows by seven frog species (about 20% of the known local anuran richness), including representatives of Hylidae, which tend to be arboreal. Most shelters used were galleries similar to those built by the crab *Dilocarcinus pagei* (Trichodactylidae). We also report on experimental and opportunistic observations on the use of termite thermal chimneys by the toad *Rhinella bergi*. Due to the prevalence of open areas in the Pantanal and absence of overlapping rocks and other types of shelter, underground galleries and tunnels in termite mounds may often be important refuges for anurans during the dry season and fires. Therefore, these tunnels may contribute significantly to the structuring of ground-dwelling anuran communities, which requires further studies. These studies should also address the indirect impacts of potential threats to the availability and integrity of underground burrows in the Pantanal, such as land management practices, uncontrolled crab exploitation, and extended extreme climatic events.

Key words. Trichodactylidae, Isoptera, Pantanal, subterranean habitats, diurnal shelter, drought, dry season, fire refuge, murundu.

Introduction

Shelters may often be important abiotic limiting factors for animals (Gotelli 2009), and their availability can influence the survival of individuals, persistence of populations and communities, and biological diversity (Magoulick & Kobza 2003, Mènard et al. 2012). Physical refuges are not only effective to avoid predators, but may also minimize excessive fluctuations in body temperature, thereby reducing evaporative water loss and risks of desiccation. These characteristics are important for anurans (and other amphibians) because they have a semi-permeable skin (Seebacher & Alford 2002, Rosset & Alcade 2004, Wells 2007).

A few anuran species have adapted to digging themselves into soil or burrowing (Hoffman & Katz 1989, Denton & Beebee 1993, Rosset & Alcade 2004). In most species, however, individuals occupy burrows excavated by other animals, which presumably reduces the high energetic costs associated with burrowing (Wells 2007). Anurans use burrows excavated by crustaceans, spiders, tortoises, lizards, birds, mammals, and other animals (Conner et al. 1997, Tozetti & Toledo 2005, Wells 2007, Roznik & Johnson 2009, Ferreira & Tonini 2010; also see a recent review in Nunes & Costa 2011). Although usually facultative, burrow use may be obligatory in some species, such as the crawfish frog (*Lithobates areolatus*, Ranidae), native to the prairies and grasslands of the central United States, which depends on crayfish burrows as primary retreats during non-breeding period (Heemeyer et al. 2012).

Termite (Isoptera) nests (or termitaria) are another important source of shelter and of nesting sites for several invertebrates and vertebrates, including frogs. Termites, and therefore termitaria, are widespread and abundant in Neotropical savannas (Moreira et al. 2009). Frogs may also use other forms of shelter, such as cracks and crevices in dry soil (Nunes & Costa 2011).

In ecosystems subject to periodic disturbances (e.g., fire, flooding, logging, cropping), permanent shelters may be scarce, and the role of temporary refuges in such places may be even more important in the structuring of biological communities than in more stable environments (e.g., Heemeyer et al. 2012). In flood-pulsed wetlands, where seasonal and spatial variation in hydrological conditions are the main drivers of variation in aquatic biodiversity and natural ecosystem function (Junk et al. 2006, Davidson et al. 2012), shelters might be of fundamental importance, particularly during periods of hydrological stress.

In the Pantanal, the largest inland wetland in the world, encompassing parts of Brazil, Bolivia, and Paraguay, the flood pulse is an important factor that determines the structuring of communities of several organisms, including anurans (Valério-Brun & Strüssmann 2010). At least in the Brazilian Pantanal, population densities of these vertebrates are much greater in the floodplain that in the surrounding elevated plateaus that also form part of the Upper Paraguay River Basin (Strüssmann et al. 2011). Soils in the floodplain comprise unconsolidated sediments, with no rocks and a general scarcity of potential surface shelters for amphibians – including logs and leaf litter that are restricted to patchy forested formations interspersed in a grassland matrix (Nunes da Cunha et al. 2010). Frogs must then rely on alternative shelters for periods of inactivity or habitat disturbance. Surprisingly, both the dynamics of stress avoidance and habitat shelters for sensitive amphibians are unknown in the Pantanal.

In the present work, we report on the use of underground crab burrows and termite mounds as shelters for anurans in the northern Pantanal. We also briefly discuss the potential of their use in assuring individual survival and population persistence in an environment subject to both predictable (i.e., annual floods) and stochastic (i.e., fire, land management) disturbances.

Materials and methods

While studying anuran communities in seasonally inundated areas in the Brazilian Pantanal wetlands – a UNESCO Natural World Heritage Site, a Biosphere Reserve, and also a Ramsar site, comprising approximately 140,000 km² (Junk et al. 2011) – we recorded several anurans using underground burrows or termite mounds as refuges. Field observations were made in different parts of the northern portion of the Pantanal, in the state of Mato Grosso: in the "RPPN SESC Pantanal" Nature Reserve (16–17° S, 56–57° W, left margin of the Cuiabá River, municipality of Barão de Melgaço); "SESC Baía de Pedras" Ranch (16°30' S, 56°24' W; near the Cuiabá River, municipality of Poconé); Malhada Ranch (16°39' S, 57°10' W, Poconé); Retiro Novo Ranch (16°15' S, 56°22' W, district of Pirizal, municipality of Nossa Senhora do Livramento). At all four localities, the landscape has a predominantly open aspect, with few trees and no fallen tree trunks, overlapping rocks, brush piles (Nunes da Cunha et al. 2010), or other potential refuges for small vertebrates.

The rainy season in the Pantanal extends from October through April and the dry season from May through September, when the region suffers unpredictable fires (Junk et al. 2011). Field observations were made between October 2010 and February 2013. At Retiro Novo Ranch, we also carried out a short-term experiment on the nature and location of daytime shelters for *Rhinella bergi* (Bufonidae). At this location, seasonally flooded fields are covered by grasses and sparse Cerrado woody vegetation, interspersed with mounds (Nunes da Cunha et al. 2010). Locally called murundus, these mounds are formed by intense termite activity and erosive processes (Furley 1986) and are subject to sporadic fires during the dry season. During the experiment, 17 individuals of *R. bergi* were captured in pitfall traps in the morning of 12 November 2012, ten of them on recently burned mounds and five on unburned mounds. We recorded the total lengths of the toads with a digital Vernier calliper and weighed them with a hand-held dynamometer (Pesola®). A thread bobbin, unwound until it weighed less than 5% of the toad's weight, was attached to each specimen with an elastic waist band (Fig. 1). The toads were then released at their point of capture at 20:00 h, and the free end of each thread was tied to a nearby bush. On 13 November 2012 at 10:00 h, the path of each individual was followed by the thread from the point of initial capture.

Results

Seven anuran species of three families were found using underground burrows (Tab. 1). On two occasions, one burrow was occupied by more than one individual of the same species (three *Leptodactylus chaquensis,* Fig. 2A) or of different species (one *L. chaquensis* and one *Hypsiboas raniceps*). Most burrows appeared to have been built by the

Figure 1. *Rhinella bergi* (Bufonidae) with an unwound thread bobbin attached to its waist, to allow following the individual to its burrow.

Table 1. Frog species and number of individuals, found in burrows during the non-flooded season in the northern Pantanal (Mato Grosso, Brazil), date and habitat (habitat characterisation following Arieira et al. 2011). September is the peak of the dry season.

Family / Species	N	Date	Habitat
Bufonidae			
Rhinella schneideri	1	Nov 2010	shrubland (burned)
Hylidae			
Scinax acuminatus	2	Oct 2010	shrubland (burned)
	1	Dec 2010	shrubland
	2	Dec 2010	open savanna
Hypsiboas raniceps	1	Dec 2010	shrubland
	1	Dec 2010	open savanna
Leptodactylidae			
Leptodactylus fuscus	2	Nov 2010	open savanna
Leptodactylus podicipinus	2	Oct 2010	monodominant forest of *Vochysia divergens* (burned)
	2	Nov 2010	monodominant forest of *Vochysia divergens* (burned)
	1	Dec 2010	open savanna
Leptodactylus chaquensis	1	Oct 2010	shrubland (burned)
	1	Dec 2010	shrubland
	1	Dec 2010	open savanna
	1	Sept 2011	monodominant forest of *Vochysia divergens*
	4	Oct 2010	open savanna
	1	Jul 2012	shrubland
	5	Oct 2010	"murundum" field
Leptodactylus elenae	1	Oct 2010	open savanna (burned)
	1	Oct 2010	monodominant forest of *Vochysia divergens* (burned)

crab *Dilocarcinus pagei* Stimpson, 1861 (Trichodactylidae). Active crabs or signs of their presence were recorded near the entrances of some of the burrows occupied by anurans (Fig. 2B).

In our string-tracking study, the threads with elastic waist bands previously tied to 17 individuals of *Rhinella bergi* were found the following morning with no toads at their free extremities. The elastic bands were found very near to the capture site or amidst vegetation in the middle of the mound. In two cases, threads were found leading inside termite nests amidst recently burned (November 2012) mounds. Another thread was found going inside a termite nest on an unburned mound (Fig. 3A). Additionally, on 09 February 2013, at 10:09 h, an individual of *Rhinella bergi* was found in the entrance of a thermal chimney of a termite mound (Fig. 3B).

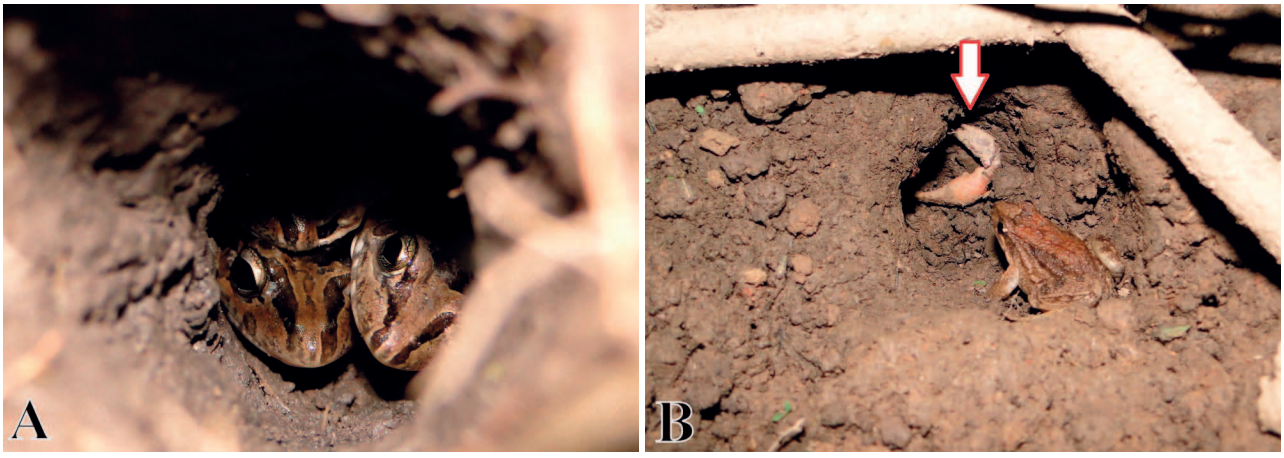

Figure 2. (A) Three *Leptodactylus chaquensis* (Leptodactylidae) in the same burrow; (B) *Leptodactylus podicipinus* (Leptodactylidae) about to enter a burrow in which a crab leg may be seen near the entrance (arrow).

Discussion

We herein recorded that 20% of the frog species that have been reported from the northern Pantanal (Valério-Brun et al. 2010) may use burrows during the dry season. Most burrows are apparently excavated in muddy sediments by the crab *Dilocarcinus pagei* in the beginning of the dry season, during which these organisms aestivate. On this occasion, when aquatic habitats are drying out, crabs become more conspicuous and are frequently caught by local fishermen to be sold as live bait for sport fishing (Wantzen et al. 2011). Estimates of annual capture rates of crabs in the region of Corumbá, in the southern Pantanal, added up to nearly 5.3 million individuals by the middle of the 1990's (Moraes & Espinoza 2001).

In the Neotropics, leptodactylid frogs are known to use burrows. In wetlands adjacent to streams in the Cerrado, small and medium-sized mammal burrows were used by *Leptodactylus labyrinthicus* (Tozetti & Toledo 2005). In mangroves, *Leptodactylus latrans* used abandoned crab burrows (Ferreira & Tonini 2010). The frogs of both species are terrestrial or semi-aquatic. Here, we are the first to describe burrow use by two sub-arboreal species of the family Hylidae. *Scinax acuminatu*s, which occurs mostly in the Chaco and Pantanal (Aquino et al. 2004), is primarily active in low vegetation or on the ground. *Hypsiboas raniceps*, on the other hand, has been found in higher perches, on tall grasses or even in woody vegetation (Uetanabaro et al. 2008).

In the Nearctic region, a study on the use of crayfish burrows by the ranid *Lithobates areolatus* showed that frog survival was favoured by the effective use of these burrows, located in grasslands up to 1 km distant from reproduction sites (Heemeyer et al. 2012). Crawfish Frogs tended to occupy primary burrows throughout the non-reproductive period and only left them for less than two months, during the breeding season (Heemeyer et al. 2012). When using crayfish burrows in winter, these frogs exhibited body temperatures that were 5.4°C higher than air temperature. In addition, predation rates on crawfish frogs using burrows were 12 times less than on individuals not using burrows during the non-reproductive period, but undertaking local migrations instead. We suggest that in the Pantanal (and in other environments subject to hydric stress during the dry season), underground burrows – especially those built by trichodactylid crabs – may constitute important refuges for several amphibian species, mainly during the dry season and during sporadic fires. Burrow use may be particularly important just before the breeding season because of the prevalence of open environments and lack of natural above-ground shelter, recurrence of heavy seasonal hydric stress, and occasional large fires (Junk et al. 2011). A large area of the RPPN SESC Pantanal was burned (in October–November 2010) prior to some of the observations of this study, which enabled us to see the crab gallery entrances and document the survival of frogs that found refuge inside. Survival of *L. areolatus* that used crayfish burrows during fires was also documented by Heemeyer et al. (2012).

The use of burrows as shelters may have a variety of consequences. By minimizing the effects of hydric stress during a critical period, burrows provide greater chances for survival and may be important criteria in habitat selection by individuals. On a larger scale, the local availability of these shelters may influence the number of reproducing adults and the population as a whole (sensu Sedell et al. 1990, and Lancaster & Belyea 1997). On a landscape level, spatial variation in the availability of burrows between different environments (thereby perhaps becoming a limiting resource) could cause populations to remain in some environments for longer periods of time than in others due to the diverse habitat (Nunes da Cunha et al. 2010) and different densities of crabs (*D. pagei*) in different environments (Rosa et al. 2009). The mean density of this crab species in a region near the study area was 0.56 ind./m^2 (Rosa et al. 2009).

Figure 3. (A) Opening of a thermal chimney at the base of a termite mound, in which can be seen the thread that shows where an individual of *Rhinella bergi* entered; (B) A *Rhinella bergi* found during the day at the entrance of a small thermal chimney in a termite mound.

The ploughing of burrows occupied by crawfish frogs leads to decreased survival rates of individuals displaced from their refuges (Heemeyer et al. 2012). As the intensity of the indirect association between anurans and crabs in the Pantanal is completely unknown, it is quite hard to even speculate on the possible impacts of land management practices, cattle trampling, uncontrolled crab exploitation, sediment deposition, permanent flooding, or any other plausible threat to the availability or integrity of underground refuges for anurans in the floodplain.

Finally, it is necessary to consider current global changes, which may intensify the effects of drought in the Pantanal, among other consequences. Therefore, there is an urgent need for additional studies on the diurnal and seasonal patterns of burrow use by anurans, to identify the importance of the association between anurans and crab burrows in the floodplain, and consequently, how these refuges may structure anuran communities.

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