Short-Term Movement and Retreat Sites of *Leptodactylus labyrinthicus* (Anura: Leptodactylidae) during the Breeding Season: A Spool-and-Line Tracking Study

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ABSTRACT.—Capture/recapture studies significantly increase our knowledge of the natural history of anuran amphibians. Many different methods have been employed in these studies, but a number of new techniques still require experimental validation. During two reproductive seasons in a Cerrado remnant in southeastern Brazil, we investigated the movement patterns and habitat use of the pepper frog, *Leptodactylus labyrinthicus,* using a spool-and-line device. This low-cost device did not appear to interfere with the activities of the frogs and allowed for constant monitoring, showing precise routes of movement and great predictability of relocations. Both sexes were active at night. During the day, males and females made use of retreat sites under vegetation or in burrows constructed by small- and medium-sized mammals. Males and females did not use standardized routes; there were no significant differences between their movements, and movements were not correlated with body size or environmental conditions. Individuals are able to move further than 100 m per day, a characteristic that may enable this species to colonize or recolonize open areas.

Movements of amphibians have been estimated with capture/recapture studies in which individuals were marked using a wide range of techniques, including toe-clipping (Martof, 1956; Dole, 1965a), branding or dyes (Daugherty, 1976), radioactive tags (Barbour et al., 1969; Kramer, 1973), fluorescent tags (Nishikawa and Service, 1988; Ovaska, 1992), passive integrated transponders (Jehle and Hödl, 1998), radio transmitters (Seebacher and Alford, 1999; Hodgkison and Hero, 2001; Lemckert and Brassil, 2003; Muths, 2003), and trailing devices or thread bobbins (Dole, 1965a,b; Duellman and Lizana, 1994; Lemckert and Brassil, 2000). Studies like these document aspects of natural history such as retreat and basking sites, feeding and breeding activities, short and long-term movement patterns (including home range estimations), and also approaches to genetic relationships within and between populations (Heyer et al., 1994).

The home-range size of anurans varies from 1–1900 m^2 (Pough et al., 1998), although there is one report of 6024 m^2 (Kramer, 1973). Home ranges are often directly correlated to species or individual body size, where larger sized species have greater home ranges than small species (references in Duellman and Trueb, 1994) and where, within a species, larger individuals move greater distances than smaller individuals (Ovaska, 1992). The distances moved can also vary among seasons of the year (Woolbright, 1985), age, (juveniles being more vagile than adults; Breden, 1987), and sex, where males move greater distances than females (Dole and Durant, 1974), or where females move greater distances than males (Ovaska, 1992). Hence, studies on movements should take these factors into account (Heyer et al., 1994).

Considering sheltering or retreat sites, arboreal species (e.g., hylid and some bufonid species) generally

use arboreal retreat sites, such as interior of bromeliads (Peixoto, 1995), fences on trees trunks (L. F. Toledo, pers. obs.), crevices and cavities of trees (Leary and Razafindratsita, 1998), or on leaves, branches, and trees trunks (Feio et al., 1998; Kwet and Di-Bernardo, 1999). Terrestrial species (e.g., dendrobatid, most of bufonid and leptodactylid species) generally use terrestrial shelters, such as fallen tree holes (Wells, 1977), ground vegetation (Stewart and Pough, 1983; Stewart and Rand, 1991; Bosman et al., 1996), rock crevices (Wells, 1977; Haddad and Martins 1994; Seebacher and Alford, 1999), and natural or constructed burrows (Svihla, 1953; Hoffman and Katz, 1989; Schwarzkopf and Alford, 1996). However, daytime or nighttime retreat sites have been described or identified in nature for only a few species (Schwarzkopf and Alford, 1996).

The pepper-frog, *Leptodactylus labyrinthicus,* is a terrestrial species typical of open biomes such as the Brazilian Cerrado and Caatinga, occurring in central and eastern of South America (Heyer and Maxon, 1982; Machado et al., 1999). Males usually calls for several months during the hot and rainy season of the year (Rossa-Feres and Jim, 1994; Blamires et al., 1997; Arzabe, 1999; Bernarde and Kokubum, 1999; Toledo et al., 2003; Prado et al., in press) and reproduction occurs in river margins (Blamires et al., 1997; Toledo et al., 2003), pond margins (Cardoso and Sazima, 1976; Blamires et al., 1997; Arzabe, 1999; Bernarde and Kokubum, 1999; Prado et al., in press), and swamps (Arzabe, 1999).

Recent studies have detailed the activities of *L. labyrinthicus* directly related to breeding, that is, calling behavior, courtship, mating, nest construction, spawning, and fights between males (see Silva et al., 200; Prado et al., in press). However, no information is available on the movement patterns and use of retreat sites by individuals during the reproductive season. In this study we describe the short-term patterns

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Fig. 1. (A) Adult male *Leptodactylus labyrinthicus* equipped with a thread-bobbin device at the Ecological Station of Itirapina, State of São Paulo, southeastern Brazil. (B) Spool-and-line device in detail.

of movements and diurnal sheltering of adult *L. labyrinthicus*.

MATERIALS AND METHODS

Fieldwork was conducted at Itirapina Ecological Station (IES: 2300 ha; 22°13′24″S; 47°54′03″W; approximately 700 m elevation), Municipality of Itirapina, State of São Paulo, southeastern Brazil. Regular sampling was conducted during two consecutive reproductive seasons, from February 2002 to February 2004. The study site represents one of the last remnants of protected Cerrado (Brazilian grasslands and shrublands) in the State of São Paulo. It consists of gallery forests, swamps, flooded areas, grasslands, grasslands with shrubs, and grasslands with shrubs and trees. The climate is mesothermic, with two well-defined seasons, a dry-cool (April through August) and a wet-warm season (September through March).

We monitored temporary ponds and flooded areas adjacent to streams for individuals of *L. labyrinthicus*. We toe-clipped each individual following Waichman (1992), and recorded gender, body mass, and snout–vent length (SVL). To obtain data on short-term movements and microhabitat use, we attached a spool-and-line tracking device (Wilson, 1994) to 19 frogs (11 males and eight females) greater than 124.4 mm SVL (Fig. 1A). This device was constructed using quilting cocoons (Spoltex Ltd.) containing 300 m of cotton thread (4.7 g, 4 cm long, 1.2 cm wide; Fig. 1B). A case for each cocoon was made by wrapping it in a food-wrap plastic (e.g., Saran Wrap®) and then winding a short length of 2 cm wide adhesive tape around it. A hole in the protective covering allowed the line to run free. The spool was attached in the inguinal region of the frog with an elastic band belt (1 cm wide). The final mass of the device was approximately 8 g, never more than 5% of the individual's body mass. After attachment of the spool-and-line device, frogs were released at the site of capture. We followed the trail of thread twice daily: at night (from 2000–2300 h) and during the day (from 0800–1100 h). After three days of monitoring, the device was removed to prevent skin abrasion (Dole, 1965b).

The distance moved by the animals was determined by measuring the distance and the angle from the capture/recapture sites. For each individual, we measured the distance between sequential capture/recapture sites (DSS: measured from the thread pulled from the spool), distance moved from initial site (DMIS: a linear distance between capture/recapture sites), and total distance moved (TDM; by calculating the sum of DSS). For the DSS estimation, we monitored the individuals just after sunrise (0800 h ± 30 min) and just after sunset (2000 h ± 30 min). The mean mobility of frogs was estimated by dividing those distances by the time between observations. We recorded the following data for every encounter with adult *L. labyrinthicus*: period of the day (day or night), air temperature and relative humidity (rh). We also described the position of the animal during each observation (e.g., exposed, under vegetation, or inside burrows) and the substrate moisture level (dry, moist, flooded). We were careful to not disturb focal animals during observation periods.

We used the Mann-Whitney U-test to compare differences in DSS, DMIS, and TDM between males and females. The relationship between body size (SVL), air temperature, rh, and mean DSS was inferred using Multiple Linear Regression. We used the paired sample t-test (one-tailed) to compare differences between DMIS and TDM. We used the Kruskall-Wallis ANOVA to compare substrate moisture levels among active and resting frogs. A Mann-Whitney U-test was used to compare the retreat site exposure (sheltered or exposed) among active and resting frogs. We considered each recapture site as an independent sample because they were separated by approximately 12 h. In all cases significant differences were considered when $P < 0.05$ (Zar, 1999).

RESULTS

Tracking data were obtained from 10 males and seven females (two frogs lost their tracking devices). The movements of both sexes were erratic: They did not moved linearly between capture/recapture sites. There were no differences between sexes when comparing DSS ($U = 26$; $P = 0.6$; $N = 16$), DMIS ($U = 31$; $P = 0.7$;

TABLE 1. Distances moved (between sequential sites: DSS; from the initial site: DMIS and total distance moved: TDM) by adult males and females of *Leptodactylus labyrinthicus* at the Ecological Station of Itirapina, State of São Paulo, southeastern Brazil. Values are presented as number of individuals.

Distance moved	DSS		DMIS		TDM	
	Females ($N = 7$)	Males ($N = 9$)	Females ($N = 7$)	Males ($N = 10$)	Females ($N = 7$)	Males ($N = 9$)
< 2 m	1	1	2	2	1	1
2–10 m	2	5	1	5	1	5
11–30 m	1	0	1	1	2	0
31–60 m	1	2	1	1	1	1
> 60 m	2	1	2	1	2	2

TABLE 2. Mobility of adult males and females of *Leptodactylus labyrinthicus* estimated between sequential sites (DSS), distance moved from initial site (DMIS), and over the total distance moved (TDM). Values presented in meters as mean $\pm$ SD (range; N).

	DSS	DMIS	TDM
Mobility (m/day)			
Males	28.4 $\pm$ 47.6 (0.2–150.0; 9)	24.4 $\pm$ 45.9 (0.2–150.0; 10)	30.9 $\pm$ 48.6 (0.2–150.0; 9)
Females	48.7 $\pm$ 61.1 (1.2–138.7; 7)	48.5 $\pm$ 61.4 (0.1–138.7; 7)	50.2 $\pm$ 60.0 (1.6–138.7; 7)

$N = 17$) and TDM ($U = 25$; $P = 0.5$; $N = 16$; Table 1). Between the sexes, there was no difference in average mobility during DMIS ($U = 67.5$; $P = 0.69$; $N = 10$), TDM ($U = 66.0$; $P = 0.53$; $N = 9$), and DSS ($U = 60$; $P = 0.42$; $N = 12$; Table 2); although, females showed a trend to be more mobile and move greater distances than males (Tables 1, 2).

DMIS was significantly shorter (mean = 1.3 times shorter; SD = 1.27; $N = 21$) than the TDM ($t = 1.72$; $P < 0.001$; $N = 21$). There was no correlation between mean DSS and SVL ($t = 0.11$; $P = 0.91$; $N = 14$), air temperature ($t = 0.16$; $P = 0.88$; $N = 14$) or relative humidity ($t = 0.49$; $P = 0.63$; $N = 14$). At night, during approximately 79% of the observations, individuals were above herbaceous vegetation ($N_{total} = 29$). During the day, three of four individuals moved beneath this vegetation.

Most individuals (89.4%) were active when observed at night ($N_{total} = 47$). During the day, most individuals (81.5%) were found in diurnal retreats ($N_{total} = 27$). Retreats were on the ground, under dense or sparse herbaceous vegetation (81.8%), and in burrows constructed by a large rodent (*Clyomis bishop*) and several species of armadillo (*Cabassous unicinctus*, *Euphractus septencinctus*, *Dasypus* spp.) (18.2%). Retreat sites were either close to, or far from bodies of water, such as rivers and ponds. The remaining five individuals found during the day were exposed above wet ($N = 4$) or dry ($N = 1$) litter. There were significant differences in microhabitat use between active ($H = 8.65$; $P = 0.01$; $N = 72$) and inactive individuals ($H = 8.67$; $P = 0.01$; $N = 66$). Active individuals preferred flooded/humid substrates and inactive individuals preferred humid/dry substrate (Fig. 2). Animals preferred exposed sites when active ($U = 137.5$; $P < 0.01$; $N = 25$) and inactive ($U = 94.5$; $P < 0.01$; $N = 21$), but this tendency was greater in active individuals (Fig. 2).

DISCUSSION

According to Duellman and Trueb (1994:265) "movements of individuals can be monitored more accurately when the animals have been tagged with radioactive isotopes, because then continuous monitoring of individuals provides an hour-by-hour or day-by-day schedule of movements, whereas most capture/recapture studies do not provide such accuracy." Alternatively, we used a low-cost, highly efficient capture/recapture method, with almost 100% of predictability of relocations, which provided us precise routes moved by the frogs and enabling us to monitor them hour-by-hour and day-by-day. Furthermore, we observed that linear measurements of the distances between capture/recapture sites represent underestimated values when comparing to measurements of the line pulled from the spool. The methodology used here has also been used to track large anurans (Lemckert and Brassil, 2000), turtles (Wilson, 1994), and small mammals (Vieira and Cunha, 2002). Furthermore, in contrast to earlier trailing devices (e.g., Dole, 1965b), it appears to cause little or no interference with the activity of large bodied anurans (Lemckert and Brassil, 2000; Griffin and Case, 2001).

The trend of males to move shorter distances than females, which has also been observed in other leptodactylids (Ovaska, 1992), supports the notions that male *L. labyrinthicus* are conspicuously territorial during the breeding season (Silva et al., 2005). Some individuals moved distances (DMIS) greater than 100 m per day; this ability, associated with a natural habitat preference (i.e., open habitats; Heyer and Maxon, 1982), may help frogs colonize adjacent disturbed areas, such as degraded forests or agricultural fields, which are common landscapes in southeastern Brazil. The absence of a correlation between distance moved and SVL may result from the low variation in body size
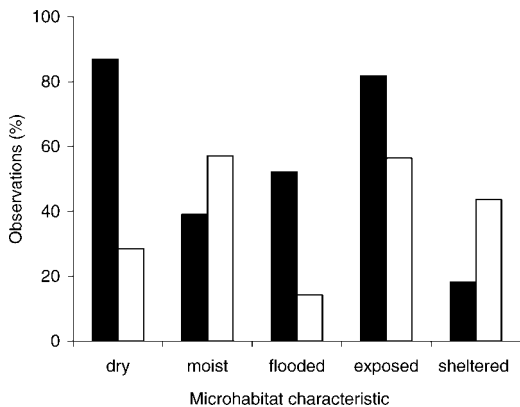

FIG. 2. Substrate moisture ($N = 44$) and microhabitat exposure ($N = 61$) of active (dark bars) and inactive (white bars) adult individuals of *Leptodactylus labyrinthicus* at the Itirapina Ecological Station, State of São Paulo, southeastern Brazil.

among the individuals selected for the study. Future studies, employing the same methodology, are needed to compare the movement patterns of frogs comprising different life history stages. (see Lemckert and Brassil, 2000).

The observed difference in movement patterns during the day (protected) and night (exposed) and the use of diurnal retreat sites may reflect adaptations designed to reduce desiccation (Denton and Beebee, 1992; Schwarzkopf and Alford, 1996). Furthermore, avoidance of visually oriented predators may also be related to the temporal variation in the movement patterns and exposure of the individuals (references in Hodgkison and Hero, 2001). The use of burrows constructed by other animals has been reported in other anuran species (e.g., Mullally, 1953; Denton and Beebee, 1993; Bossert et al., 2003) and is likely to reflect opportunism of the anurans, rather than any interespecific ecological association.

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