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## CALL DIVERSITY OF *LEPTODACTYLUS NATALENSIS* LUTZ, 1930 (ANURA; LEPTODACTYLIDAE)

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### ABSTRACT

*The extensive vocal repertoire of Leptodactylus natalensis is described. The field observations were made at three forest fragments of the Tropical Atlantic Domain, in Northeast (State of Alagoas) and Southeast (State of Espírito Santo) regions of Brazil. The vocal repertoire of L. natalensis was constituted by ten notes emitted alone or in different combinations. The several vocalizations were organized in three distinct groups according to the social context in the moment of emission. L. natalensis presents extensive diversity of acoustic signals supported by variations in duration of each note, as well as in the number and sequence of emission of different notes.*

KEYWORDS: Anura, Leptodactylidae, call diversity, *Leptodactylus natalensis*.

### INTRODUCTION

Lutz (1930) described *Leptodactylus natalensis* from the State of Rio Grande do Norte, Northeast Brazil. The species, member of the *L. podicipinus-wagneri* complex of the *L. melanonotus* group (*sensu* Heyer, 1994), is associated with the northern and central portions of the Atlantic Forest Morphoclimatic Domain from its most northern extent in the State of Rio Grande do Norte to the State of Rio de Janeiro (Heyer & Heyer, 2006). Aspects of reproductive behavior were first reported by Lutz (1930) in the description of the species, whereas Heyer (1994) presented habitat data from localities where some individuals were collected. Oliveira & Lício Júnior (2000) described the tadpole and suggested parental care behavior based on the observation

of a female inside the nest. Izecksohn & Carvalho-e-Silva (2001) gave some information about habitat and vocal behavior, and Prado & Pombal (2005) analyzed resource partitioning in a population including *L. natalensis*. Santos & Amorim (2005) observed females caring for clutches inside foam nests in depressions excavated by males. More wide-ranging information appears in Heyer & Carvalho (2000) where they described two kinds of calls, the seasonality, daily activity, and characteristics of the calling site. Finally, Heyer & Heyer (2006) presented new illustrations of the wave form and audiospectrogram of the advertisement call.

New data about the vocal repertoire of *L. natalensis* are presented herein based on observations of individuals from three forest fragments of the Tropical Atlantic domain (*sensu* Ab'Sáber, 1977).

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## MATERIAL AND METHODS

## RESULTS

Observations were made at three localities in the edge and inside of Atlantic Forest fragments: a permanent swamp bordering the dam reservoir of Reserva Biológica de Duas Bocas – RBDB (20°16'51"S, 40°28'37"W; 200 m elevation), Municipality of Cariacica, State of Espírito Santo, Southeast Brazil, on 16 June 2002; a permanent pond at Varrela farm (09°41'07"S, 36°03'20"W), located between the Municipalities of Pilar and São Miguel dos Campos, State of Alagoas, Northeast Brazil, on 18 August 2004; and a sugar cane plantation trench (temporary body water; 09°30'S, 35°50'W) along a forest in the Municipality of Rio Largo, State of Alagoas, on 8 February 2005. Calls from RBDB were recorded for a total of 74 seconds, with an Aiwa TP-VS 480 cassette recorder and Le Son MK-60 microphone, at an air temperature of 20°C, between 18:00 and 18:15 h. Calls from Varrela farm were recorded for a duration of 179 seconds, with a Tascam DA-P1 tape recorder and Senheiser M66 microphone, at an approximate air temperature of 22°C, at 21:00 h. Calls from Rio Largo were recorded during 34 seconds with a Panasonic RQ-L30 with internal microphone, at an air temperature of 25°C, approximately 21:30 h. Recordings were analyzed in a PC-Pentium with the software Avisoft-Sonograph Light 1, version 2.7. The vocalizations were digitized at a sampling frequency of 8 kHz and 16 bit resolution. For acoustic characterization and sonogram construction the following parameters were used: fft-length = 128, frame = 100%, window = flat top, and overlap = 93,75%. Power spectrum graphics were built up using Sound Ruler Program version 0.9.4.1.

Ten different notes of *L. natalensis* calls uttered alone or in different combinations, were recognized at the three localities. Considering the social context of emission and the structure of the notes, the vocalizations can be organized into three distinct groups: (1) group A (Fig. 1), composed by the notes A1, recorded at Varrela farm, and A2, recorded at Rio Largo and RBDB; (2) group B (Fig. 2), composed by the notes B1 and B2, recorded at Varrela farm and RBDB; B3 and B4, recorded at Varrela farm; and B5, recorded at Rio Largo and RBDB; and (3) group C (Fig. 3), composed by the notes C1, C2 and C3, recorded at Varrela farm only (see Table 1 for descriptive resume).

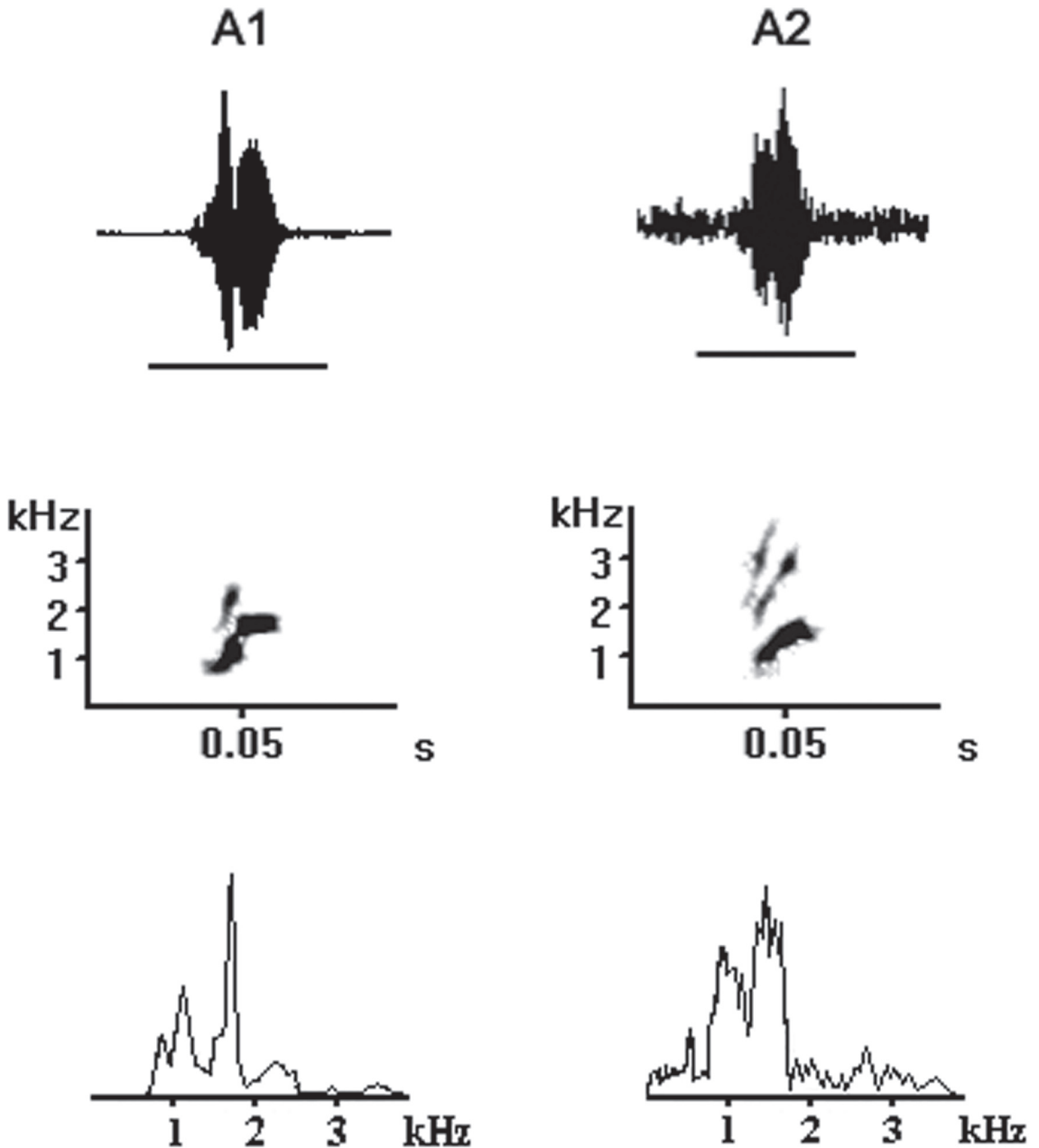
The notes of the group A were the most common notes emitted by males [ $3.8 \pm 0.8$  notes/s at Varrela farm (range = 2-5 notes/s; n = 45 s);  $1.9 \pm 1.2$  notes/s at Rio Largo (range = 0-3 notes/s; n = 17 s)] in a mean interval of  $0.24 \pm 0.05$  s (range = 0.18-0.40 s; n = 31) at Varrela farm and  $0.94 \pm 1.89$  s (range = 0.27-7.73 s; n = 15) at Rio Largo. Note A1 recorded at Varrela farm has a sharply rising frequency in its first half and a smooth and slowly rising frequency in its second half. Note A2 recorded at Rio Largo has a rising frequency modulation for most of the call and a brief descent at the finish. Note type A2 was recorded at RBDB only two times and uttered together with notes B2 and B5. Two prominent peaks of frequency are evident in notes A1 and A2 (see the power spectrum in Fig. 2), with the dominant frequency always in the second peak. Notes A1 (n = 32) have the first peak at 1125 Hz and the second at 1695 Hz on average. The A2 notes have the first peak at 1354 Hz and the second at 1519 Hz, on average.

**TABLE 1:** Acoustic parameters of the notes emitted by males of *Leptodactylus natalensis* at three localities in the Atlantic Forest domain, Brazil. VF: Varrela farm (State of Alagoas); RL: Rio Largo (State of Alagoas); RBDB: Reserva Biológica de Duas Bocas (State of Espírito Santo). Values are presented as mean  $\pm$  standard deviation. H: harmonic structure in call; NH: non-harmonic structure in call; A: ascendant frequency modulation; D: descendant frequency modulation.

Note	N	Locality	Acoustic parameters					
			Note duration (ms)	Note duration range (ms)	Dominant frequency (Hz)	Dominant frequency range (Hz)	Physical structure	Frequency modulation
A1	32	VF	30 $\pm$ 1	29 – 33	1695 $\pm$ 14	1687-1718	NH	A
A2	16	RL / RBDB	24 $\pm$ 2	21 – 27	1519 $\pm$ 46	1437-1593	NH	A and D
B1	26	VF / RBDB	12 $\pm$ 3	7 – 17	1787 $\pm$ 203	1500-2093	H	–
B2	42	VF / RBDB	16 $\pm$ 3	13 – 28	1040 $\pm$ 52	937-1125	H	–
B3	11	VF	19 $\pm$ 4	16 – 28	1042 $\pm$ 64	968-1156	H	A
B4	13	VF	74 $\pm$ 18	44 – 93	942 $\pm$ 40	906-1031	H	A
B5	9	RL / RBDB	47 $\pm$ 13	27 – 69	1932 $\pm$ 212	1687-2312	H	A
C1	11	VF	12 $\pm$ 2	10 – 17	1062 $\pm$ 31	1000-1093	H	–
C2	6	VF	17 $\pm$ 1	15 – 17	1062	–	H	A
C3	16	VF	25 $\pm$ 3	19 – 31	1810 $\pm$ 131	1687-2062	NH	A and D

The B notes present harmonic structure and were commonly uttered together in a diversity of combinations that indicates a high complexity of vocal communication in the species. Note B1 has the dominant frequency situated on second harmonic, while for note B2 the dominant frequency is its first harmonic (= fundamental frequency). Note B3 is similar to B2, with respect to dominant frequency, but differs from it by have a longer mean duration and

stronger rising frequencies in its second half. B4 is the longest note in the group B recorded at Varrela farm, with a rising frequency modulation and dominant frequency equal to the first harmonic. Finally, note B5 is also long with rising frequency modulation recorded at RBDB and Rio Largo. Note B5 differs from note B4 because the first presents a mean dominant frequency on the second harmonic and has shorter duration. At Varrela farm twelve combinations of B

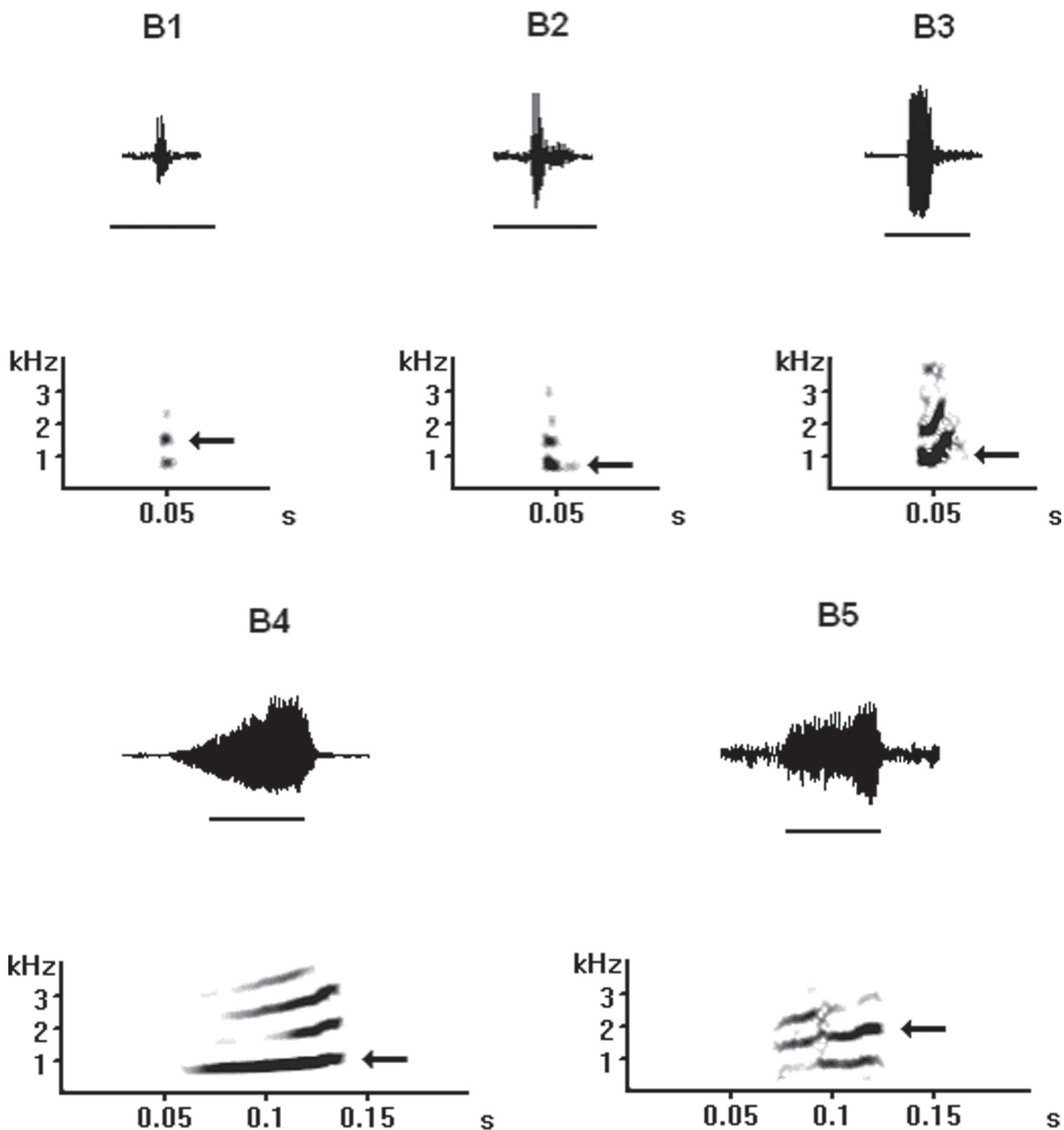


**FIGURE 1:** Waveforms, sonograms and power spectrum of two notes from group A uttered by males of *Leptodactylus natalensis*: note A1, recorded at Varrela farm, State of Alagoas; and note A2, recorded at Rio Largo, State of Alagoas, and Reserva Biológica de Duas Bocas, State of Espírito Santo. Scales = 0.05 s.

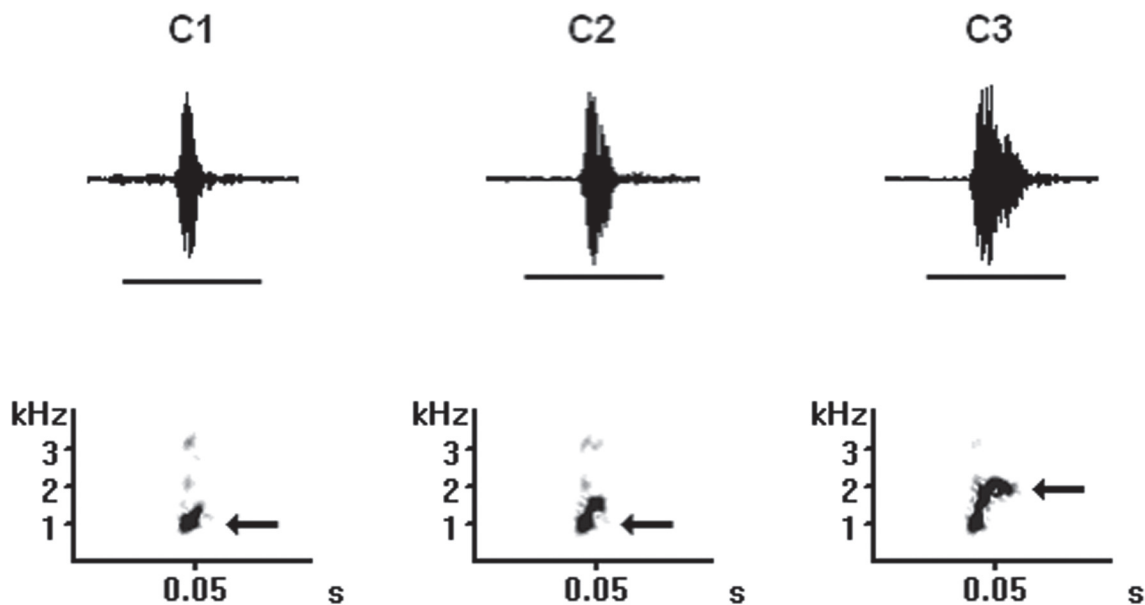
notes were found (see Table 2 for descriptive resumé of acoustical parameters), but notes B1, B2 and B4 were emitted alone for, respectively, three, four and seventeen times. Vocalization of one male was recorded at RBDB where calls consisted of group B notes or in combinations of group B notes with note A2. Notes B1 and B5 were emitted alone only during a short period of time of the total recording made at RBDB, where combinations forming nine different calls were found at this locality (see Table 3 for de-

scriptive resumé of acoustical parameters). Considering all combinations of notes from group B found in this study, only the combination B2-B2-B1 occurred both at Varrela farm and RBDB.

During 30 s, one male uttered 26 notes from group C (7 C1, 9 C2, and 10 C3, not necessarily in this order) in irregular intervals of time, close to another male that uttered 97 A1 notes at regular intervals of time. In contrast to the notes from group B, notes from group C are not harmonically structured



**FIGURE 2:** Waveforms and sonograms of five notes from group B emitted by males of *Leptodactylus natalensis*: notes B1 and B2 recorded at Varrela farm, State of Alagoas, and Reserva Biológica de Duas Bocas, State of Espírito Santo; notes B3 and B4, recorded at Varrela farm, State of Alagoas; and note B5, recorded at Rio Largo, State of Alagoas, and Reserva Biológica de Duas Bocas, State of Espírito Santo. Arrows indicate the dominant frequency. Scales = 0.05 s.



**FIGURE 3:** Waveforms and sonograms of three notes from group C emitted by males of *Leptodactylus natalensis* at Varrela farm, State of Alagoas, Brazil: notes C1, C2 and C3. Arrows indicate the dominant frequency. Scales = 0.05 s.

**TABLE 2:** Acoustic parameters of twelve calls emitted by males of *Leptodactylus natalensis*, formed by combinations of notes B1, B2, B3 and B4, at Varrela farm, State of Alagoas, Brazil. (\* combination found at Reserva Biológica de Duas Bocas).

Combinations	N	Call duration (ms)	Interval between notes (ms)			
			First interval	Second interval	Third interval	Fourth interval
B2-B2	1	110	50	–	–	–
B2-B3	1	220	150	–	–	–
B3-B3	1	130	70	–	–	–
B2-B1-B2	2	320 ± 20	80 ± 30	170 ± 10	–	–
B2-B2-B1*	1	220	60	110	–	–
B2-B2-B3	1	290	60	150	–	–
B2-B2-B4	1	350	100	140	–	–
B1-B1-B2-B2	1	510	90	140	230	–
B1-B2-B2-B4	3	480 ± 80	100 ± 10	140 ± 50	130 ± 40	–
B2-B1-B1-B2	1	380	60	110	140	–
B2-B2-B2-B2	1	360	80	120	130	–
B1-B1-B2-B1-B4	1	540	100	120	100	110

**TABLE 3:** Acoustic parameters of nine calls emitted by males of *Leptodactylus natalensis*, formed by combinations of the notes B1, B2, B5 and A2, at Reserva Biológica de Duas Bocas, State of Espírito Santo, Brazil. (\* combination found at Varrela farm).

Combinations	N	Call duration (ms)	Interval between notes (ms)		
			First interval	Second interval	Third interval
B2-B5	1	130	90	–	–
B1-B1-B1	1	230	120	70	–
B2-B1-B1	1	170	80	50	–
B2-B2-B1*	1	250	130	80	–
B2-B1-B5	3	280 ± 20	120 ± 10	90 ± 3	–
B1-B1-B1-B5	1	360	120	70	90
B2-B1-B1-B5	1	340	100	70	80
A2-B2-B1	1	290	130	90	–
A2-B2-B2-B5	1	310	80	60	80

and were not uttered in combinations among themselves or with notes from other groups. Notes C1 and C2 have rising frequency modulation, but the first has a smaller frequency range and mean duration. Note C3 presents an accentuated ascendant frequency modulation in its first half and descendant in its final half. Structurally, note C3 resembles the A notes, but acoustically they are very different.

## DISCUSSION

Considering the call repertoire, the single notes A1 and A2 are advertisement calls of *L. natalensis*, as they were the most common, and were emitted in regular intervals of time. Heyer & Carvalho (2000) described the advertisement call of *L. natalensis* as a single note emitted frequently when actively calling, coinciding most closely to note A1 of this study. The advertisement call described by Heyer & Carvalho (2000) differs from notes A1 and A2 by the longer call duration (60-70 ms) and the lower dominant frequency of the second peak (1020-1040 Hz). This study found two prominent peaks of frequency in the A notes, but only the second was considered dominant by its always strongest energy. In contrast, Heyer & Carvalho (2000) registered some variation in the loudness of the two peaks, with the first or second peak having the strongest energy. The advertisement calls of *L. natalensis* described by Heyer & Carvalho (2000) and herein, present modulated frequency, differing by the extremely fast rise times observed in Heyer & Carvalho (2000), the strong ascendance only in the first half of note A1, and the slight descent in the finish part of the note A2.

Many species of *Leptodactylus* have frequency modulated calls that result in broadcasting their voices over a range of frequencies, but only *L. melanonotus*, *L. podicipinus* and *L. natalensis* within the *L. melanonotus* group share the condition of two most prominent peaks of loudness, as pointed by Heyer & Carvalho (2000). These authors hypothesized that the separated dominant frequencies correspond to different tuning curves in males and females related to their different tympanum size. Broadcasting of higher and lower dominant frequencies, as seen in *L. natalensis*, is one solution to matching different receptor sensitivities to the advertisement call.

Heyer & Carvalho (2000) recognized a chirp call another one with 1 or 2 notes, louder, longer and much more variable than the advertisement call. The B notes are equivalent to the chirp call but present variation in the dominant frequency and more com-

plex combinations among them, forming calls with 1 to 5 notes uttered in different sequences. The B4 note has the greatest similarity with the chirp call (*sensu* Heyer & Carvalho, 2000) considering the dominant frequency in the first harmonic and the note duration. The slight fall at the end of the fundamental frequency suggested for some chirp calls appears in some B5 notes. The longest B notes of each call are almost always the last uttered, as observed also in the chirp calls with two notes. The exceptions are some combinations found at Varrela farm and RBDB, where B1 was the last note, uttered after B2. The function of the B notes is unknown. Other members of the *L. melanonotus* group have these kinds of calls, which usually initiate calling bouts, but as observed by Heyer & Carvalho (2000) for the chirp calls of *L. natalensis*, at Varrela farm and RBDB the B notes were uttered after there was a slowing down in the rate of advertisement calls.

The C notes were uttered by a male calling very close to other one giving advertisement calls, as an antiphonal vocalization without stereotyped pattern of time. No interactive displays of both individuals were observed and the function of these notes remains also unknown. At Varrela farm, where many males were calling close together, eight different notes, including those from group C, were recorded. At RBDB and Rio Largo, males were calling separated for great distances, and the C notes were not uttered. In the same manner, no C correspondent note appears in the recordings used by Heyer & Carvalho (2000) for the description of the advertisement and chirp calls of *L. natalensis*, probably because males are vocalizing not so close to each other as at Varrela farm, as was verified through acoustic inspections of the original recordings. Thus, as observed for various species (e.g. Sullivan & Wagner, 1988; Bastos & Haddad, 2002; Abrunhosa & Wogel, 2004), the social context may influence the call repertoire of *L. natalensis*.

Other studies have also shown complex calls of anurans (e.g. Narins *et al.*, 2000; Feng *et al.*, 2002; Brandão & Heyer, 2005; Toledo & Haddad, 2005). The intraspecific and/or individual variations are mainly in dominant frequency and duration of each note, number and sequence order of pulses or notes, but a high call diversity as observed in *L. natalensis* is not common. Probably the significance of this great repertoire involves behavioral, morphological and historical factors, whose associations should be investigated in future studies. Notes with different dominant frequencies uttered by the same male, as presented herein and by Heyer & Carvalho (2000) and the study of Feng *et al.* (2002), suggest that indi-



viduals have control over the amount of energy used in the sound broadcasting. With the greater utilization of call parameters as systematic tools applicable to anurans, research has shown that call parameters, like other characters, can be subject to intraspecific or even individual variation.

## RESUMO

*O extenso repertório vocal de Leptodactylus natalensis é descrito. Observações de campo foram feitas em três fragmentos florestais no Domínio Tropical Atlântico, localizados nas regiões Nordeste (Estado de Alagoas) e Sudeste (Estado do Espírito Santo) do Brasil. O repertório vocal de L. natalensis foi constituído de dez notas emitidas em unicidade ou em diferentes combinações. As diferentes vocalizações foram organizadas em três grupos distintos de acordo com o contexto social no momento da emissão. L. natalensis apresenta extensa diversidade de sinais acústicos sustentada pela variação na duração de cada nota, assim como no número e seqüência de emissão das diferentes notas.*

PALAVRAS-CHAVE: Anura, Leptodactylidae, diversidade de canto, *Leptodactylus natalensis*.

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