

Morphological and Acoustical Variation, Geographic Distribution, and Conservation Status of the Spinythumb Frog *Crossodactylus bokermanni* Caramaschi and Sazima, 1985 (Anura, Hylodidae)

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ABSTRACT.—*Crossodactylus bokermanni* is a spinythumb frog known only from the type locality and categorized as Endangered or Vulnerable in different red lists. The examination of many unidentified specimens collected in the range of the Serra do Espinhaço, State of Minas Gerais, Brazil, revealed that *C. bokermanni* has a wider distributional range than previously reported. Nontopotypic specimens could not be referred to *C. bokermanni* earlier because of the confused taxonomy of the genus. A detailed comparative diagnosis is presented, and morphological and acoustical variations are characterized to accurately determine the species limits of *C. bokermanni*. Previous studies presenting evidence for the decline of the topotypic populations of *C. bokermanni* are not supported by the available literature, museum collections, and recently collected field data. The conservation status of this species needs to be revised based on the new information regarding the geographic distribution of the species.

The genus *Crossodactylus* Duméril and Bibron, 1841 currently comprises 11 diurnal species associated with streams on mountain areas in the Atlantic forest or in the rocky altitudinal fields known as “campos rupestres,” from the State of Alagoas, Northeastern Brazil, south to Misiones, Argentina (Nascimento et al., 2005a). Data on taxonomy, natural history, and geographic distribution of species of *Crossodactylus* are scarce. Five species are currently known only from their type localities (*Crossodactylus bokermanni* Caramaschi and Sazima, 1985, *Crossodactylus cyclospinus* Nascimento, Cruz and Feio, 2005, *Crossodactylus dantei* Carcerelli and Caramaschi, 1992, *Crossodactylus grandis* B. Lutz, 1951, and *Crossodactylus lutzorum* Carcerelli and Caramaschi, 1992; Frost, 2007). Heyer et al. (1990) stated that the systematics of the genus is confused, making difficult the association between some names and populations. Izecksohn and Carvalho-e-Silva (2001) emphasized the necessity of a taxonomic review, whereas Haddad et al. (2003) recognized *Crossodactylus* as the least taxonomically resolved genus among the Hylodinae Günther, 1858 (now Hylodidae, following Grant et al., 2006). Hence, the endemicity of these forms may be unrelated to special requirements or habitat restrictions, but to the poorly resolved taxonomy of this group as

demonstrated by the large amount of unidentified specimens of *Crossodactylus* currently deposited in anuran collections.

Crossodactylus bokermanni was described from Serra do Cipó, Municipality of Jaboticatubas, State of Minas Gerais, Brazil, and allocated to the species group of *Crossodactylus gaudichaudii* Duméril and Bibron, 1841 (Caramaschi and Sazima, 1985). “Serra do Cipó” is a regional name for one of the southernmost portions of the Serra do Espinhaço, a mountainous complex ranging from central Minas Gerais, southeastern Brazil, to northern Bahia, northeastern Brazil. The species is known to occur in permanent streams with sandy or rocky bottom and bordered by shrubs and grasses that occur in the rocky mountain fields known as “campos rupestres” (Caramaschi and Sazima, 1985; Eterovick and Sazima, 2004; for a brief description and discussion about the Brazilian “campos rupestres,” see Heyer, 1999).

Since the species description, no populations of *C. bokermanni* have been recognized outside the range of Serra do Cipó. Its “restricted endemism” was one of the criteria used to include the species on the red list of the State of Minas Gerais (Machado et al., 1998) and by the Global Amphibian Assessment (GAA; Young et al., 2004; Baillie et al., 2004). *Crossodactylus bokermanni* was included in the GAA list after a “consistency check” performed by its coordinators, which changed the categorization of “Data Deficient” (DD) species given by the

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herpetologists that attended the GAA workshop in Brazil (for further discussion see Pimenta et al., 2005 and Stuart et al., 2005). Recently Eterovick et al. (2005) asserted that topotypic populations of *C. bokermanni* are declining, and Stuart et al. (2005) used that data to state that the species possibly meets their definition of "rapidly declining species."

The composition and distribution of the anuran fauna in Brazilian mountainous areas is still poorly known, even for places with easy access. Recent fieldwork within the meridional portion of Serra do Espinhaço (i.e., the portion in the State of Minas Gerais), including the type locality of *C. bokermanni* and surrounding areas, and the analysis of unidentified specimens of the *C. gaudichaudii* group deposited in herpetological collections revealed the occurrence of previously unreported populations of *C. bokermanni*. The original description of this species does not contain a detailed diagnosis or comparisons with the species of *Crossodactylus* then known; hence, the lack of this information probably hindered the earlier identification of nontopotypic specimens deposited at various museums. Herein, we describe the morphological variation of adult specimens and present a detailed comparative diagnosis for *C. bokermanni* to accurately determine its species limits. We also describe the variation in the advertisement call and present new data on habitat, behavior, and geographic distribution. Additionally, we discuss the conservation status of *C. bokermanni* with the available data and show that there is no evidence neither supporting the recent categorization of this species as threatened nor indicating that the topotypic populations are declining.

MATERIALS AND METHODS

We used external morphological characters to compare 55 unidentified specimens from 14 different localities along the range of the Serra do Espinhaço with 12 types (the holotype and 11 paratypes) of *C. bokermanni*, 15 topotypic specimens of *C. bokermanni*, with all other species presently assigned to the *C. gaudichaudii* species group (sensu Caramaschi and Sazima, 1985), and with *Crossodactylus trachystomus* (Reinhardt and Lütken, 1861), the other species of the genus with a restricted distribution to the Serra do Espinhaço (see Appendix 1). Morphological variation was characterized by the analysis of 63 adult nontopotypic and topotypic specimens, and measurements were taken on 67 adult specimens (51 males and 16 females). Abbreviations used for measurements are SVL (snout-vent length), HL (head length), HW (head width), TBL (tibia length), THL (thigh

length), FL (foot + tarsus length, measured from the tip of toe IV to the end of tarsus), TD (tympanum diameter), ED (eye diameter), END (eye-nostril distance), NSD (nostril-snout distance), IND (internarial distance), and IOD (interorbital distance). All measurements are in millimeters and, except for FL, following Duellman (1970). SVL, HL, HW, THL, TBL, and FL were measured with a digital caliper, whereas other measurements were made with an ocular grid on a stereo dissecting microscope. The occurrence of sexual dimorphism in body dimensions was tested with a *t*-test for independence of samples by groups, after a Levene's test for homogeneity of variances. Relative snout length was determined by (END + NSD) / HL. Relative tympanum size is the ratio of TD : ED; tympanum was considered small when TD was less than 50% of ED and large when TD was more than 50% of ED. Relative leg length was determined by (THL + TBL + FL) / SVL. Snout shape standards follow Heyer et al. (1990).

Museum acronyms follow Leviton et al. (1985) with the corrections and additions by Frost (2007), except for MCNAM (Amphibian Collection, Museu de Ciências Naturais da Pontifícia Universidade Católica de Minas Gerais, Belo Horizonte, MG, Brazil), MZUFV (Museu de Zoologia João Moojen de Oliveira, Universidade Federal de Viçosa, MG, Brazil), DZ-UFGM (Herpetological Collection, Departamento de Zoologia, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil), and R (formerly ZMUC; Zoological Museum, University of Copenhagen, Denmark).

Advertisement calls were obtained at the type locality (29 calls from three males), at the Reserva Particular do Patrimônio Natural (RPPN) Santuário do Caraça, Municipality of Catas Altas, State of Minas Gerais (34 calls from 11 males), and at the Serra do Bico de Pedra, Municipality of Ouro Preto, State of Minas Gerais (23 calls from four males). Recordings were made with a BOSS digital recorder or a SONY DAT TCD-D8 digital tape recorder coupled to a Seinnheiser ME66/K6 directional microphone set, or with a Panasonic RQ-L31 cassette tape recorder coupled to a Leson SM-48 cardioid microphone. Vocalizations were digitized using the software Avisoft SASLab Light version 4.39 at a sampling frequency of 22050 Hz and 16 bits resolution; sonograms were produced using FFT with 256 points, 100% frame, Blackman Window, and 93.75% overlap.

RESULTS

The analysis of the nontopotypic specimens showed high morphological similarity among themselves and with topotypic *C. bokermanni*.

TABLE 1. Means, standard deviations (SD), and ranges of some measurements (in millimeters of topotypic and nontotypic specimens of *Crossodactylus bokermanni* from the meridional portion of Serra do Espinhaço, State of Minas Gerais, Brazil.

	Males (N = 51)			Females (N = 16)		
	Mean	SD	Range	Mean	SD	Range
SVL	22.1	1.15	18.7–25.1	24.2	1.60	20.5–27.5
HL	8.2	0.48	7.0–9.4	8.5	0.59	7.3–9.5
HW	7.4	0.36	6.7–8.4	7.8	0.38	6.9–8.6
TBL	11.2	0.79	9.1–13.1	12.0	0.57	11.1–12.9
THL	10.8	0.68	9.1–12.4	11.5	0.73	10.3–12.6
FL	17.3	1.18	15.0–20.0	18.7	1.12	16.8–20.5
TD	1.5	0.23	1.1–2.0	1.6	0.22	1.1–2.0
ED	3.0	0.23	2.6–3.5	3.1	0.26	2.7–3.5
END	1.7	0.21	1.3–2.3	1.9	0.21	1.6–2.3
NSD	1.0	0.23	0.5–1.4	1.0	0.25	0.5–1.4
IND	2.8	0.19	2.3–3.1	2.9	0.21	2.3–3.1
IOD	2.7	0.29	1.7–3.3	2.7	0.29	2.2–3.1

However, some variation is worth noting although it is spread over all populations analyzed, and it did not allow the separation of the nontotypic specimens from *C. bokermanni*.

Diagnosis.—*Crossodactylus bokermanni* is characterized by (1) slender body; (2) rounded snout; (3) rounded, nondilated toe tips; (4) absence of dorsolateral folds; (5) presence of a white or cream stripe from the snout to the shoulder and another narrow stripe of same color on the flank; and (6) throat and belly reticulated.

Comparison with Other Species.—*Crossodactylus bokermanni* differs from *Crossodactylus aeneus* Müller, 1924, *C. dantei*, and *C. gaudichaudii* by its slender body (body robust in these species). *Crossodactylus bokermanni* further differs from *C. aeneus*, *Crossodactylus caramaschii* Bastos and Pombal, 1995, *C. dantei*, *C. gaudichaudii*, and *C. lutzorum* by its rounded snout in dorsal view (nearly pentagon-shaped in these species). *Crossodactylus bokermanni* differs from *C. dantei* and *C. lutzorum* by its weakly expanded vocal sacs (not expanded in *C. dantei* and *C. lutzorum*). *Crossodactylus bokermanni* differs from *C. aeneus*, *C. caramaschii*, *C. cyclospinus*, *C. gaudichaudii*, *C. lutzorum*, and *C. trachystomus* by its rounded toe tips (truncated in these species) and from these species and *C. dantei* because of its nondilated finger tips (dilated in these species). The lack of dorsolateral folds differentiates *C. bokermanni* from *C. aeneus*, *C. caramaschii*, *C. gaudichaudii*, and *C. trachystomus* (folds developed in *C. aeneus*, *C. gaudichaudii*, and *C. trachystomus*; weakly marked in *C. caramaschii*). A conspicuous gland located between the tympanum and the shoulder is observed in *C. bokermanni* and in most of the species analyzed; it is poorly developed in *C. caramaschii* and *C.*

lutzorum. *Crossodactylus bokermanni* differs from *C. aeneus*, *C. dantei*, *C. gaudichaudii*, and *C. lutzorum* because of the presence of a white or cream stripe from the snout to the shoulder and another stripe on the flank (an undefined, light, marbled/dotted area from snout to shoulder, and no stripe on the flanks of these species). *Crossodactylus bokermanni* differs from *C. dantei*, *C. lutzorum*, *C. aeneus*, *C. cyclospinus*, *C. caramaschii*, and *C. gaudichaudii* because of its reticulated belly (with brown scattered blotches and short stripes in *C. cyclospinus*; immaculate in the other species).

Morphological Variation.—Females of *C. bokermanni* are significantly larger than males ($t_{1,65} = 5.94$, $P < 0.05$) and have longer and wider heads ($t_{1,65} = 2.86$, $P < 0.05$; $t_{1,65} = 3.78$, $P < 0.05$), larger eye and tympanum diameters ($t_{1,65} = 0.62$, $P < 0.05$; $t_{1,65} = 2.01$, $P < 0.05$), and longer eye–nostril distance ($t_{1,65} = 3.70$, $P < 0.05$). Morphometric variation is shown in Table 1. Toe and tarsal fringes are broadly developed in males and very reduced in females and forearms are thicker in males than in females. Supratympanic folds are indistinct in six specimens (9.5%), reaching the region above the gland between the tympanum and the shoulder in seven specimens (11.1%), and reaching the shoulder in 50 specimens (79.4%). Minuscule keratinized spines on the upper lip are absent in eight specimens (12.7%); poorly developed, white or brown in 39 specimens (61.9%); or developed, black, appearing over the entire length of upper lip in 16 specimens (25.4%). Poorly developed thumb spines are observed in 43 specimens (68.3%), whereas thumb spines are well developed in 20 specimens (31.7%). Spines also vary in number and arrangement: two specimens (3.2%) present two spines on the right hand and three on the left hand; two

TABLE 2. Finger length variation of *Crossodactylus bokermanni*.

Finger length	Number of specimens
I~II~IV<III	09 (14.3%)
I~II<IV<III	02 (3.2%)
I<IV<II<III	01 (1.6%)
II<I~IV<III	03 (4.8%)
II~IV<I<III	15 (23.8%)
II<IV<I<III	16 (25.4%)
IV<I~II<III	04 (6.3%)
IV<II<I<III	13 (20.6%)

specimens (3.2%) present four spines on both hands, with a row of three posterior spines and a smaller anterior one; five specimens (7.9%) present four spines on the right hand, arranged as a square, and three on the left hand; and 54 specimens (85.7%) present two or three spines in both hands. Additional minute black spines are observed on the inner margins of fingers II and III of one specimen (MNRJ 42928), on supernumerary tubercles of two specimens (MNRJ 40641 and MZUFV 6593), and on the carpal tubercle of one specimen (MZUFV 6593). Variation in finger lengths is shown in Table 2. The outer fringe of toe V ends at the level of the anterior margin of the tubercle in one specimen (1.6%), in the middle of the basal tubercle in eight specimens (12.8%), at the level of the posterior margin of the tubercle in 15 specimens (24%), or after the tubercle at a distance nearly equal to its diameter in 39 specimens (62.4%). A faint, narrow vertebral line is observed from the snout to midbody in two specimens (3.2%), from the snout to the sacral region in four

specimens (6.4%), from the snout to the vent, but interrupted at midbody, in 17 specimens (27.2%), from the snout to the vent, but fragmented, in eight specimens (12.8%), from the snout to the vent, not interrupted, in 23 specimens (36.8%), or absent in nine specimens (14.4%). Arms with two (54 specimens, 85.7%) or three (five specimens, 7.9%) ill-defined transverse bars, or with blotched arms, with no bars (four specimens, 6.4%). Legs with three (six specimens, 9.5%), four (47 specimens, 74.6%), or five bars (eight specimens, 12.7%), or with blotched legs, with no bars (two specimens, 3.2%). Ten specimens (15.9%) present cream, immaculate bellies, but it seems to be an artifact of preservation because in recently preserved specimens bellies and throats are reticulated with light-brown and grey over a white background. The longitudinal line on the gular region is light-brown in 49 specimens (77.8%) and absent in 14 specimens (22.2%).

Variation in Advertisement Calls.—The advertisement call of *C. bokermanni* is long (although its duration is highly variable), consisting of many notes with harmonic structure (Fig. 1). Call duration ranges from 1.4–10.1 sec and the number of notes per call, from 13–121. Note dominant frequency ranges from 1,802–4,826 Hz and may be situated in the second (23.9%, $N = 299$ notes), third (75.9%, $N = 951$ notes), or, more rarely, in both second and third harmonics (0.2%, $N = 3$ notes); its location can also vary among notes within the same call. It was not possible to identify the fundamental frequency on sonograms because of the high background noise from the fast flowing waters

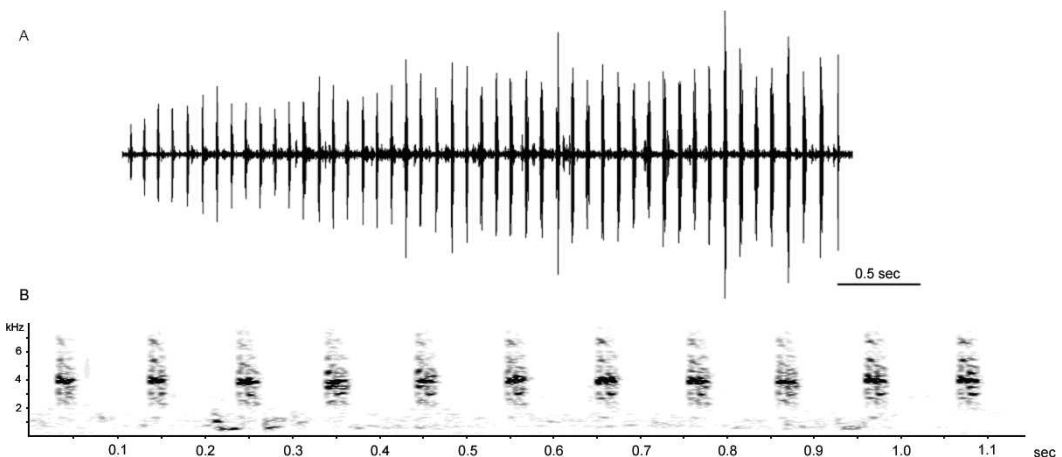


FIG. 1. Waveform (A) and audiospectrogram of a portion of the advertisement call (B) of *Crossodactylus bokermanni* recorded on 16 February 2006, 4:10 p.m., at Parque Nacional da Serra do Cipó, Municipality of Santana do Riacho, State of Minas Gerais, Brazil. Air temperature 23.9°C, water temperature 21.2°C. No voucher specimen.

of the streams. Means, standard deviations, ranges, and number of calls, notes, and intervals used in the acoustic analysis are shown in Table 3.

Variation among acoustic parameters was found in three different populations. Ranges of the intercall interval, internote interval, and note duration were highly variable, but ranges overlap among samples from the three localities. Table 3 summarizes comparative data on advertisement calls from these three populations. In all populations, the first note is less intense and shorter than the other notes. It has half of the mean duration and lower mean dominant frequency when compared to the other notes (Table 4).

Geographic Distribution.—The type locality of *C. bokermanni* was originally published as “km 114 of the road between Vespasiano and Conceição do Mato Dentro, Municipality of Jaboticatubas, Serra do Cipó, State of Minas Gerais, Brazil” (Caramaschi and Sazima, 1985). This locality is currently included in the Municipality of Santana do Riacho, at km 107 of road MG-010 (19°17’S, 43°35’W; 1,210 m elevation) and is part of the buffer area for Parque Nacional da Serra do Cipó (Serra do Cipó National Park), a legally protected area under administration of the Brazilian Government with 31,733 ha comprising several habitats (IBAMA, 2004). Since its description, no populations of *C. bokermanni* have been recognized outside Serra do Cipó. Recent surveys close to the type locality and in other localities within the range of Serra do Espinhaço in the State of Minas Gerais, together with the examination of museum specimens, revealed the occurrence of several previously unknown populations reported here. Some of these populations are in protected areas under administration of private land owners or under different levels of governmental authority (Reserva Particular do Patrimônio Natural Santuário do Caraça, Municipality of Catas Altas; Parque Municipal Ribeirão do Campo, Municipality of Conceição do Mato Dentro; Parque Estadual do Pico do Itambé, Municipality of Santo Antônio do Itambé; Parque Estadual do Biribiri and Parque Nacional das Sempre-Vivas, Municipality of Diamantina; and Parque Estadual do Rio Preto, Municipality of São Gonçalo do Rio Preto). The species range is extended approximately 400 km north and approximately 130 km south; the municipalities of Serranópolis de Minas and Ouro Preto correspond to the northern and southern limits of its known distribution, respectively. The species range now comprises the whole meridional portion of Serra do Espinhaço, from central to northern Minas

TABLE 3. Means, standard deviations (SD), and ranges of acoustic parameters of the advertisement calls of *Crossodactylus bokermanni* from Serra do Cipó, RPPN Santuário do Caraça, and Ouro Preto, Minas Gerais, Brazil. Data are presented as mean ± SD, range (N).

	Serra do Cipó			RPPN Santuário do Caraça			Ouro Preto			Calls of all localities		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Notes per call	35	± 12.7	13–61(29)	68	± 23.5	25–104 (34)	76	± 20.76	28–121 (23)	58.8	± 26.2	13–121 (86)
Call duration (sec)	3.90	± 1.27	1.4–7.16 (29)	7.40	± 3.42	2.24–12.69 (33)	6.26	± 1.71	2.22–10.07 (23)	4.95	± 1.9	1.4–10.1 (52)
Intercall interval (sec)	43.95	± 24.48	5.87–117.29 (19)	38.52	± 10.24	25.05–55.94 (09)	36.35	± 19.40	4.83–78.17 (14)	40.73	± 22.5	4.83–117.29 (33)
Note duration (sec)	0.016	± 0.006	0.001–0.032 (785)	0.012	± 0.003	0.001–0.033 (1005)	0.015	± 0.004	0.002–0.024 (688)	0.014	± 0.005	0.001–0.033 (2478)
Internote intervals (sec)	0.10	± 0.022	0.072–0.265 (756)	0.10	± 0.014	0.069–0.214 (971)	0.07	± 0.005	0.056–0.098 (665)	0.092	± 0.021	0.056–0.265 (2392)
Note dominant frequency (Hz)	3890	± 336.6	2,692–4,656 (289)	3973	± 537.9	1,802–4,826 (920)	3677	± 563.2	2,686–4,498 (326)	3894	± 525	1,802–4,826 (1535)

TABLE 4. Comparison among the acoustic parameters of the first note and other notes of the advertisement calls of *Crossodactylus bokermanni*. Data are presented as mean \pm standard deviation, range (N).

Acoustics parameters	First note	Other notes
Note duration (sec)	0.007 \pm 0.004, 0.001–0.016 (86)	0.015 \pm 0.005, 0.002–0.080 (2392)
Note dominant frequency (Hz)	3489 \pm 712.4, 1802–4574 (53)	3909 \pm 511.4, 1999–4826 (1482)

Gerais, almost reaching the border with the State of Bahia (Fig. 2).

Habitat and Habits.—Individuals from topotypic populations of *C. bokermanni* are active during the day associated with permanent streams having a sandy or rocky bottom at “campos rupestres.” Bordering vegetation consists of shrubs and grasses. Topotypic males were observed calling exposed on stones near the margins of the streams. During periods of heavy rains, when water level increased drastically, adults were observed on marginal ponds, probably avoiding the fast water torrents. Males were not calling from these ponds.

Crossodactylus bokermanni has been considered a species endemic to the Cerrado biome,

because it was known only from the western slope of Serra do Cipó; however, populations from Barão de Cocais, Caeté, Catas Altas, Conceição do Mato Dentro, Congonhas do Campo, and Ouro Preto occur in transitional or typical patches of semideciduous Atlantic forest in the eastern slope of Serra do Espinhaço. Specimens from these localities were observed in narrow streams inside primary or secondary gallery forests, with sandy bottom covered with leaf litter and small stones, 0.20–0.60 m deep. In these habitats, males normally call from sandy margins, close to relatively fast waters, but some were also observed on floating leaves or, more rarely, on emergent rocks in the middle of the streams. When disturbed, they

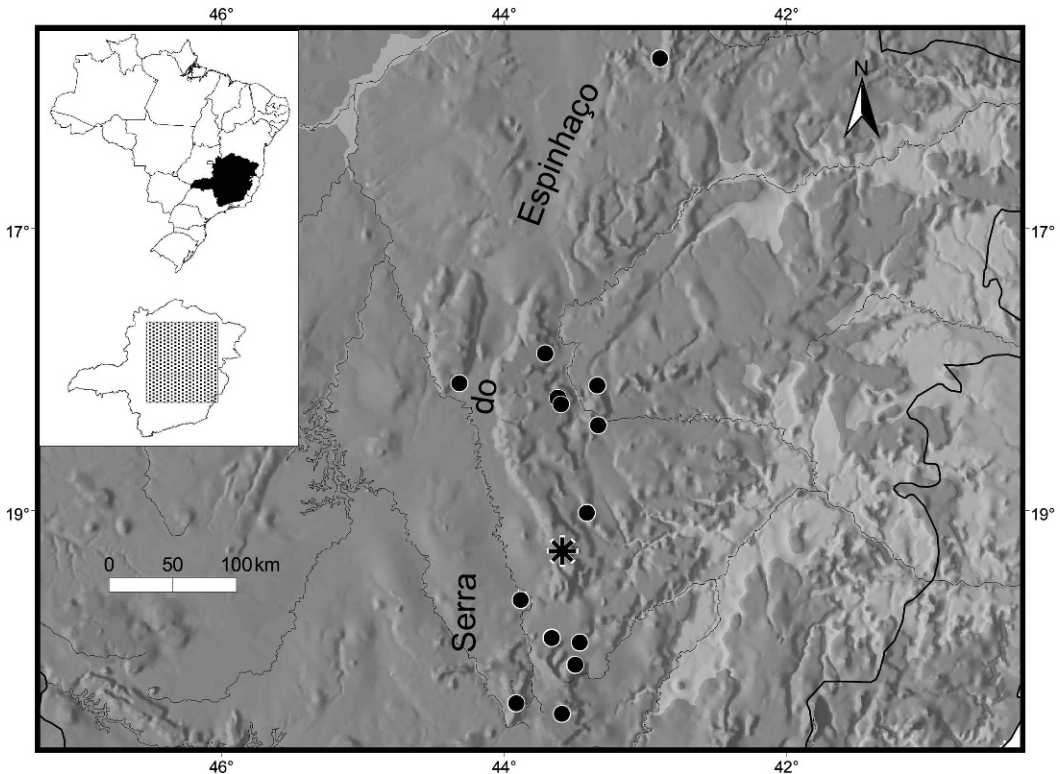


FIG. 2. Geographic distribution of *Crossodactylus bokermanni* in the meridional portion of Serra do Espinhaço, State of Minas Gerais, Brazil (dots). The frame in the upper left shows the location of the State of Minas Gerais in Brazil (above) and the approximate area covered by the map (below). Asterisk = type locality. Grayscale variations refer to altitudinal variations, from lower (light gray) to higher (dark gray) elevations.

TABLE 5. Comparison among SVL, relative snout length (END + NSD/HL), relative tympanum size (TD / ED), and relative leg length (TBL + THL + FL/SVL) of species of the *Crossodactylus gaudichaudii* group and *Crossodactylus trachystomus*. Data are presented as mean ± standard deviation, range (N).

	SVL		Relative snout length	Relative tympanum size	Relative leg length
	Males	Females			
<i>C. aeneus</i>	24.7 ± 1.39, 22.1–28.9 (25)	27.9 ± 1.77, 25.6–31.7 (8)	0.36 ± 0.05, 0.27–0.45 (33)	0.55 ± 0.10, 0.36–0.79 (33)	1.7 ± 0.07, 1.6–1.9 (33)
<i>C. bokermanni</i>	22.1 ± 1.15, 18.7–25.1 (51)	24.2 ± 1.60, 20.5–27.5 (16)	0.33 ± 0.05, 0.24–0.43 (70)	0.50 ± 0.08, 0.36–0.65 (70)	1.8 ± 0.10, 1.6–2.0 (70)
<i>C. caramaschii</i>	23.5 ± 0.61, 22.5–24.5 (11)	25.5 ± 1.81, 23.6–27.2 (3)	0.33 ± 0.04, 0.21–0.41 (14)	0.54 ± 0.07, 0.42–0.63 (14)	1.8 ± 0.07, 1.7–1.9 (14)
<i>C. cyclospinus</i>	23.7 ± 0.60, 22.8–24.5 (9)	29.0 (1)	0.32 ± 0.03, 0.28–0.39 (10)	0.64 ± 0.05, 0.57–0.75 (10)	1.8 ± 0.09, 1.6–1.9 (10)
<i>C. dantei</i>	24.6 ± 2.86, 19.5–28.2 (15)	25.6 ± 3.71, 19.3–30.0 (12)	0.34 ± 0.04, 0.25–0.41 (27)	0.45 ± 0.08, 0.30–0.62 (27)	1.8 ± 0.09, 1.7–1.9 (27)
<i>C. gaudichaudii</i>	26.3 ± 2.75, 23.5–30.4 (21)	28.2 ± 1.75, 22.9–35.1 (41)	0.32 ± 0.06, 0.17–0.43 (62)	0.59 ± 0.15, 0.38–0.75 (62)	1.7 ± 0.08, 1.5–1.9 (62)
<i>C. lutzorum</i>	22.8 ± 1.24, 20.7–25.0 (9)	25.2 ± 0.88, 24.4–26.4 (4)	0.32 ± 0.04, 0.25–0.40 (13)	0.44 ± 0.07, 0.32–0.57 (13)	1.7 ± 0.05, 1.6–1.8 (13)
<i>C. schmidti</i>	23.3 ± 1.37, 21.4–25.0 (7)	27.7 ± 2.05, 23.8–29.8 (7)	0.29 ± 0.02, 0.26–0.33 (14)	0.54 ± 0.07, 0.42–0.64 (14)	1.7 ± 0.10, 1.5–1.8 (14)
<i>C. trachystomus</i>	22.9 ± 2.62, 20.0–25.1 (3)	25.2 ± 0.85, 24.2–25.8 (3)	0.28 ± 0.03, 0.25–0.32 (6)	0.55 ± 0.07, 0.50–0.69 (6)	1.7 ± 0.06, 1.7–1.8 (6)

hide in small burrows nearby or jump into the water.

DISCUSSION

Diagnosis and Morphological Variation.—*Crossodactylus bokermanni* was distinguished by Caramaschi and Sazima (1985) from the other species then allocated in the *C. gaudichaudii* species group (*C. aeneus* and *C. gaudichaudii*) by the smaller size, fairly defined *canthus rostralis*, longer legs, narrower head, and smaller tympanum. From *C. trachystomus*, it was distinguished by the slender body, longer legs, longer snout, narrower head, and smaller tympanum (Caramaschi and Sazima, 1985). We note that some of these characters are not adequate to separate *C. bokermanni* from the other species of the *C. gaudichaudii* group and from *C. trachystomus*. Although *C. bokermanni* is generally smaller, the range of SVL overlaps with those of all species (Table 5). The slender build is a character shared with many species of the *C. gaudichaudii* species group and also with *C. trachystomus*. When leg length is compared to SVL, snout length is compared to head length, and tympanum diameter is compared to eye diameter, all of these ratios overlap (Table 5).

Caramaschi and Sazima (1985) mentioned that secondary sexual characters are barely evident among species of *Crossodactylus*, but Duméril and Bibron (1841) had already noticed that toe and tarsal fringes are more developed in *C. gaudichaudii* males than in females.

Recently, this dimorphic character was reported to occur in *C. cyclospinus* (Nascimento et al., 2005a). Our analyses showed this to be a common dimorphism for all species of the *C. gaudichaudii* species group and in *C. trachystomus*, also occurring in some species of the sister genus *Hylodes* Fitzinger, 1826 (Pavan et al., 2001; Canedo and Pombal, 2007). Our analysis also showed that the gland between the tympanum and the shoulder, previously reported as absent in *C. caramaschii* and *C. lutzorum* (Carcerelli and Caramaschi, 1992; Bastos and Pombal, 1995; Nascimento et al., 2005a), is actually present in both species but reduced to a short slight ridge. The variation observed in the presence, development, and distribution of spines on thumb and upper lip is not related to specimens' size or condition of preservation. We have examined small specimens with developed spines on thumb and lip, as well as large ones with poorly developed spines. Preservation caused only color fading or detachment of the horny layer of the thumb's spine in a few specimens, but the size of spines denotes their degree of development.

Recently, Canelas and Bertoluci (2007) recognized a *Crossodactylus* occurring at RPPN Santuário do Caraça as *C. trachystomus*. We analyzed the specimens collected in their study (DZ-UFMG 1158–63) and also 13 specimens from this locality and two others from the neighboring municipalities of Barão de Cocais and Caeté and concluded that they are all conspecific to *C. bokermanni*. Our conclusions

are supported by the comparisons made among these specimens, the types and topotypes of *C. bokermanni*, and the type of *C. trachystomus* (see Appendix 1).

Variation in Advertisement Calls and Comparisons with Calls of Other Species.—Acoustic parameters in *C. bokermanni* presented interpopulation differences: shorter call duration, fewer notes per call, and shorter note duration were observed in the population from Serra do Cipó, whereas shorter internote interval was observed in the population from Ouro Preto (Table 3). Intraspecific variation in advertisement calls has been reported by many authors and may be related to geographic and genetic isolation (Heyer and Reid, 2003), morphological variation in larynx and ear (McClelland et al., 1998), behavior (Kime et al., 2004), body size (Castellano et al., 2002), temperature (Giacoma et al., 1997; Guimarães and Bastos, 2003), and habitat structure (Ellinger and Hödl, 2003). Even different reproductive seasons may exhibit greater intra- than interpopulation variation (Smith and Hunter, 2005). Normally, social context is the most easily observable variable to interpret the occurrence of variation within populations (e.g., Bastos and Haddad, 1995; Abrunhosa and Wogel, 2004). For example, in an agonistic interaction observed at RPPN Santuário do Caraça, it was possible to verify that aggressive calls emitted by a resident male (MNRJ 38475) toward an invader (MNRJ 38476) were preceded by much longer advertisement calls (unfortunately, no good quality recordings were obtained for these calls).

Advertisement calls of *Crossodactylus* are reported only for *C. caramaschii*, *C. cyclospinus*, and *C. gaudichaudii* (Weygoldt and Carvalho-e-Silva, 1992; Bastos and Pombal, 1995; Nascimento et al., 2005a); all of these species are currently allocated to the *C. gaudichaudii* species group (sensu Caramaschi and Sazima, 1985). Descriptions are generally based in one or a few specimens, making the comparison of acoustic parameters and their variation a difficult task. Call parameters, such as call duration and number of notes per call, greatly overlap among *C. bokermanni*, *C. caramaschii*, *C. cyclospinus*, and *C. gaudichaudii* (range of call duration 1.4–10.1 sec in *C. bokermanni*, combined range of call duration 2.0–6.25 sec in the other species; range of notes per call 13–121 in *C. bokermanni*, combined range of notes per call 25–130 in the other species). The note duration in *C. bokermanni* (0.001–0.033 sec) is shorter than in *C. cyclospinus* and *C. gaudichaudii* (0.003–0.04 sec and 0.04–0.05 sec respectively; data not available for *C. caramaschii*), but the internote interval is longer in *C. bokermanni* (0.056–0.265 sec) than in *C. cyclospinus* and *C. gaudichaudii* (0.029–

0.065 sec and 0.04–0.05 sec, respectively; data not available for *C. caramaschii*). Dominant frequency in *C. bokermanni* may be situated in the second, third, or second and third harmonics (the dominant frequency can also change its location within one call), whereas in *C. cyclospinus*, it has been reported in the second or third harmonics and in *C. caramaschii* in the third harmonic only. The first note of the advertisement call of *C. bokermanni* is less intense and has a lower dominant frequency, a characteristic probably present but not yet described for other species of *Crossodactylus*. The lower dominant frequency of the first note was also reported in *Hylodes amnicola* Pombal, Feio, and Haddad, 2002 (Pombal et al., 2002) and other anuran species (e.g. Bastos and Haddad, 2002; Castellano et al., 2002) and was considered a common effect associated with the beginning of the call (Giacoma et al., 1997).

The Decline of Crossodactylus bokermanni.—Eterovick et al. (2005) reported that *C. bokermanni* is currently declining at the type locality, based on a comparison between data gathered on four sites during the early 1970s and late 1990s. *Crossodactylus bokermanni* used to occur at three of these four sites; two of them are temporary streams. The highest number of adult specimens recorded on a single site was estimated to be 22, all in the 1970s, with an effort of 496 person hours; no specimens were observed on any site between 1996 and 2000. A few adults (a category they used to express the occurrence of three individuals) were found in 2001 at another site not studied in the 1970s, a permanent stream called Riacho Água Escura. In the present study, the senior author and collaborators recently visited the Riacho Água Escura on three different occasions: two days on January 2005, two days on September 2005, and one day on February 2006. A 50-m section of this stream was searched for the presence of *C. bokermanni*. Thirty-two adults were recorded in this small section only, with an effort of 86 person hours.

Two reasons might explain the discrepancy in the number of observed adults at one site within the type locality. First, there are differences in sampling methods, since we aimed specifically to observe *C. bokermanni*, whereas the previous studies cited in Eterovick et al. (2005) focused on overall inventories and community analysis. Second, some of the sites investigated by Eterovick et al. (2005) may not be suitable for breeding activity of *C. bokermanni*. Although tadpoles were observed in temporary streams in the 1970s, these are probably not suitable habitats for long-term breeding populations of *C. bokermanni*, since Caramaschi and Sazima (1985) and Eterovick and Sazima (2004) stated

that it breeds in permanent streams. Two of the three sites where the species used to occur in the 1970s are temporary streams, a factor that may affect larval development of stream-breeding species. Hence, population fluctuations are expected to occur because the environmental instability of the habitat.

Furthermore, the methodologies used in the studies carried out in the 1970s and in the 1990s were not designed to assess the occurrence of fluctuations of specific populations, taking into account their ecological and behavioral characteristics. First, field activities in the 1970s were conducted sporadically; second, a thorough count of specimens was not conducted during those studies (Eterovick et al., 2005). Abundance of specimens in that period was expressed in field notes as "present," "a few," or "a lot" and converted by Eterovick et al. (2005) to numerical estimations of one, three, and five individuals, respectively. We conclude that the comparisons between the studies carried out in the 1970s and in the 1990s (Eterovick et al., 2005) are not adequate to detect declines.

It is worth mentioning that all the sites investigated for the presence of anurans in the Parque Nacional da Serra do Cipó are very close to the park facilities or to the road cited in the original description of *C. bokermanni* (now called MG-010), which borders some marginal areas of the park (Nascimento et al., 2005b). It provides easy access to some of these areas, but interior areas are difficult to reach and have never been sampled. Eterovick et al. (2005) also stated that all populations from areas surrounding the Parque Nacional da Serra do Cipó seem to have disappeared. That may be correct for the areas directly affected by the impacts caused when road MG-010 was paved. However, specimens MCNAM 3218 and MCNAM 8017-18, from the Municipality of Conceição do Mato Dentro, near the type locality but outside the park, were collected in 2003 and 2006, respectively (see Appendix 1). These specimens were found only about 40 km north from the Riacho Água Escura, the northernmost locality where *C. bokermanni* had been recorded at Serra do Cipó.

Despite the determination of Brazilian specialists that *C. bokermanni* was DD (for discussion, see Pimenta et al., 2005), the GAA considered the species as "Endangered" (EN) because of an estimated extent of occurrence < 5,000 km², occurrence at no more than five locations, and an observed, inferred, or projected continuing decline in the area or quality of habitat (Baillie et al., 2004; Young et al., 2004). Based on the data presented by Eterovick et al. (2005), Stuart et al. (2005) suggested that *C. bokermanni* could meet their definition of a rapidly declining species. When specialists recommended the categoriza-

tion of *C. bokermanni* as DD, they were aware of the scarce amount of data currently available on the taxonomy and composition of anuran faunas for large Brazilian regions and adopted an evidentiary attitude (in the sense of Stuart et al., 2005). That is, only species with convincing evidence of population declines were considered as threatened; species lacking data on taxonomy, distribution, and natural history were considered as DD (Pimenta et al., 2005). This approach is justified because the continuing improvement of taxonomic and geographic data shows that range expansions for species previously known from a single locality are very common in Brazil (for several examples, see Pimenta et al., 2005; see also the first record for *C. cyclospinus* outside the type locality in Appendix 1). In fact, this has been recently demonstrated for four other species from Serra do Cipó (Leite et al., 2006). The case of *C. bokermanni* is another example of how some of the underlying data provided by Brazilian specialists was misinterpreted, causing the unnecessary recategorization of DD species into threatened species.

Based on the information gathered by the present study and on the arguments presented above, we conclude that there is no evidence available to categorize *C. bokermanni* as a declining species or as a rapidly declining species. The apparent decline of topotypic populations of *C. bokermanni* was related to the lack of collections in poorly sampled regions and taxonomic knowledge. Our data was recently used to support the removal of *C. bokermanni* from the red list of the State of Minas Gerais (Fundação Biodiversitas, unpubl. data), and we strongly recommend the categorization of *C. bokermanni* as "Not threatened" in the GAA consistent list, taking into account that many of the populations recently found occur in legally protected areas.

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- Crossodactylus bokermanni* (89): Brazil: km 114 of MG-010 road, Municipality of Santana do Riacho, MG (JJ 6044, holotype; 6045–55, paratypes); Fazenda Canabrava, Serra do Cabral, Augusto de Lima, MG (MCNAM 541); Serra do Intendente, Tabuleiro, Parque Municipal Ribeirão do Campo, Conceição do Mato Dentro, MG (MCNAM 3218); Parque Estadual do Rio Preto, São Gonçalo do Rio Preto, MG (MCNAM 3733–34; 3769); Parque Estadual do Pico do Itambé, Santo Antônio do Itambé, MG (MCNAM 5082–84); RPPN Santuário do Caraça, Catas Altas, MG (MCNAM 3359–60; 3362–63; 3516–17; MNRJ 38316; MNRJ 38473–77; DZ–UFMG 1158–63); Parque Estadual de Biribiri, Diamantina, MG (MCNAM 5085–87); Conceição do Mato Dentro, MG (MCNAM 8017–18); Parque Nacional das Sempre-Vivas, Diamantina, MG (MCNAM 8206); Alto do Palácio, Parque Nacional da Serra do Cipó, Santana do Riacho, MG (MNRJ 38465–70; 39982–87); Riacho Sentinela, Diamantina, MG (MNRJ 40138); Serra do Bico de Pedra, km 156 of the Estrada Real, Ouro Preto, MG (MNRJ 40395–99; 40637–41; MZUFV 6592–93); Congonhas do Campo, MG (MNRJ 42926–29); Serranópolis de Minas, MG (MNRJ 42930–35); Serra do Cipó, MG (MZUSP 314); Caeté, MG (MZUSP 23865); Lagoa Santa, MG (MZUSP 30770); Palácio, Serra do Cipó, Santana do Riacho, MG (MZUSP 57281; 110627); Serra da Pedra Redonda, Barão de Cocais, MG (MZUSP 58623); Chapéu do Sol, Serra do Cipó, Santana do Riacho, MG (USNM 218124).
- Crossodactylus caramaschii* (15): Brazil: S.E.A.R.A., Pariqueira-Açu, SP (CFBH 340, paratype); Fazenda São Luís, Ribeirão Branco, SP (CFBH 1850, paratype); Caverna do Diabo, Eldorado, SP (DZSJRP 5344; 5346; 5349; 5761; MNRJ 16671; 18675, paratype; 31421; MZUSP 30628, paratype); Gruta dos Caboclos, Apiaí, SP (MZUSP 21894–96, paratypes); Iporanga, SP (USNM 318232); São João da Graciosa, Morretes, PR (USNM 318234). *Crossodactylus cyclospinus* (18): Brazil: Fazenda Duas Barras, Santa Maria do Salto, MG (MCNAM 4813, paratype; MNRJ 34500, paratype; 34501, holotype; 34502–04, paratypes; 35404–07, paratypes; MZUFV 5609, paratype); Fazenda Curral Velho, Cristália, MG (MNRJ 40220–26).
- Crossodactylus dantei* (48): Brazil: Murici, AL (MNRJ 4769, holotype; 4770–811, paratypes; Fazenda Bananeira, Estação Ecológica de Murici, Murici, AL (MNRJ 39443–46; 40400).
- Crossodactylus gaudichaudii* (98): Brazil: Alto da Boa Vista/Gávea, Rio de Janeiro, RJ (MNRJ 1212–13); Floresta da Tijuca, Rio de Janeiro, RJ (MNRJ 13694–95; 33394–97; 33399; 34771–75; 31868–69; 38958–59; 39540–41); Parque Estadual da Pedra Branca, Rio de Janeiro, RJ (MNRJ 27654–55); Parque Lage, Rio de Janeiro, RJ (MNRJ 35957–60); Barra de Guaratiba, Rio de Janeiro, RJ (MNRJ 36526); Reserva Biológica União, Rio das Ostras, RJ (MNRJ 39536–39); Represa Rio Grande, Rio de Janeiro, RJ (MZUSP 49676–736); Rio de Janeiro, RJ (USNM 52602; 97442; 132997–998; 164104–105).
- Crossodactylus lutzorum* (11): Brazil: Fazenda Água Branca, Valença, BA (MNRJ 4753, holotype; 4756–4765, paratypes).
- Crossodactylus schmidti* (20): Argentina: Parque Provincial Salto Encantado, Depto. Cainguas, Misiones (MNRJ 38742–48); Depto. Guarani, Misiones (MNRJ 38749); Misiones (MZUSP 108946);

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APPENDIX 1

Specimens Examined

Crossodactylus aeneus (31): Brazil: Guapimirim, RJ (MNRJ 30982; 35120; 35985–86; 35944–49); Parque Nacional Serra dos Órgãos, Guapimirim, RJ (MNRJ 35955–56; 35987–88; 37309–13; 39368–70; 39372–73; 39535); Cachoeira de Macacu, RJ (MNRJ 36477); Teresópolis, RJ (USNM 97693–95; 97698–99; 97728).

San Vicente, Misiones (MZUSP 129278-79); Brazil: Porto Camargo, PR (MZUSP 15857-58; 15860-63); Caviúna, PR (USNM 125511); Paraguay: El Tirol, Encarnación, Depto. Itapúa (USNM 253380; USNM 253382).

Crossodactylus trachystomus (07): Brazil: Parque das Mangabeiras, Belo Horizonte, MG (MZUSP 59906); Caixa de Areia, Belo Horizonte, MG (MZUSP 110833); Lagoa Santa, MG (R 11126, formerly ZMUC 128, holotype), Estrada Morro Velho-Belo Horizonte, Belo Horizonte, MG (USNM 98017-18); Country Club, Belo Horizonte, MG (USNM 97891); Estrada Morro Velho-Lagoa Grande, Belo Horizonte, MG (USNM 98014).