Zootaxa 3973 (2): 251–270
www.mapress.com/zootaxa/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

http://dx.doi.org/10.11646/zootaxa.3973.2.3
http://zoobank.org/urn:lsid:zoobank.org:pub:F47630C2-B5D2-4F00-A147-2288D2073A1B

A fifth species of the genus *Euparkerella* (Griffths, 1959), the advertisement calls of *E. robusta* Izecksohn, 1988 and *E. tridactyla* Izecksohn, 1988, and a key for the *Euparkerella* species (Anura: Brachycephaloidea: Craugastoridae)

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Abstract

A new species of the anuran genus *Euparkerella* is described from a rainforest area in the state of Rio de Janeiro, southeastern Brazil. Morphologically, the species resembles *E. brasiliensis* and *E. cochranae,* but differs from them in acoustic features. Relative to its congeners, the new species is characterized by: (1) medium size; (2) slender body; (3) narrow head; (4) long Finger IV, Toes I and V; (5) tubercles of the hand and foot protuberant; (6) duration of advertisement call longer than three seconds; (7) pulse-section rate slower than two sections/second; and (8) exhibiting pulse clusters. The advertisement calls of *E. robusta* and *E. tridactyla* are described and a key based on morphological and acoustic characters is presented for species in the genus.

Key words: Atlantic Forest, bioacoustics, cryptic species, new species, taxonomy

Resumo

Uma nova espécie de anuro do gênero *Euparkerella* é descrita de uma área de floresta tropical no estado do Rio de Janeiro no sudeste do Brasil. Morfologicamente, a nova espécie se assemelha à *E. brasiliensis* e *E. cochranae*, mas difere das mesmas em características do canto de anúncio. Relativamente às demais espécies do gênero, a nova espécie é caracterizada por: (1) tamanho mediano; (2) corpo delgado; (3) cabeça estreita; (4) dedo IV e artelhos I e V longos; (5) tubérculos da mão e pé protuberantes; (6) duração do canto de anúncio maior que três segundos; (7) seções de pulsos emitidos em baixa taxa de repetição (menor do que duas secções/segundo); e (8) grupo com dois ou três pulsos em uma única seção de pulsos. Os cantos de anúncio de *E. robusta* e *E. tridactyla* são descritos e uma chave baseada em caracteres morfológicos e acústicos é apresentada para as espécies do gênero.

Palavras-chave: Mata Atlântica, bioacústica, espécie críptica, espécie nova, taxonomia

Introduction

The genus *Euparkerella* (Griffths, 1959) currently consists of four species that are endemic to the Atlantic Rainforest in southeastern Brazil (Izecksohn 1988; Frost 2015). The type species of the genus, *Euparkerella brasiliensis* (Parker, 1926), was described from Serra dos Órgãos, state of Rio de Janeiro. Subsequently, three other species were described—*E. cochranae* Izecksohn, 1988 from Guapimirim, the head office of Parque Nacional da Serra dos Órgãos in municipality of Guapimirim, state of Rio de Janeiro; *E. robusta* Izecksohn, 1988 from the

Accepted by J. Padial: 15 May 2015; published: 17 Jun. 2015

municipality of Mimoso do Sul, state of Espírito Santo; and *E. tridactyla* Izecksohn, 1988 from the municipality of Santa Teresa, state of Espírito Santo (Izecksohn 1988). Species of *Euparkerella* are terrestrial frogs characterized by their small and globular bodies with ventrolateral grooves, head narrower than body, masklike facial patterns, slender arms and short fingers, and narrow and pointed digital tips with small pads that lack circumferential grooves, and with plantar surfaces with large metatarsal tubercles (Izecksohn 1988). With respect to osteology, they are characterized by the absence of a dentigerous processes on vomers; nasals in contact with maxillae; frontoparietals fused with prootics; epicoracoids partially fused; Toe IV short, with two phalanges; and terminal phalanges with hooklike lateral process (Izecksohn 1988; Hedges *et al*. 2008).

Several specimens of *Euparkerella* that are morphologically polymorphic have been collected from the central region of state of Rio de Janeiro. These specimens can not be readily assigned to any recognized species on the basis of their morphology, although they are often tentatively identified as *Euparkerella brasiliensis* or *E. cochranae* in collections. Nonetheless Fusinatto *et al.* (2013) provided evidence that each of those nominal taxa are composites of genetic lineages that may represent unnamed cryptic species, and they recommended that the genus is reviewed with an integrative approach.

Acoustic signals are important for interspecific communication in frogs, especially advertisement calls, and their characteristics are often used as evidence of species divergence (*e.g.*, Canedo & Pombal 2007; Angulo & Reichle 2008; Carvalho & Giaretta 2013). The evidentiary potential of acoustic characters in the taxonomy of *Euparkerella* has already been explored—first by Izecksohn (1988) and later by Hepp & Carvalho-e-Silva (2011) in *E. brasiliensis* and *E. cochranae*. Nonetheless, populations of the morphologically polymorphic and taxonomically problematic taxa of *Euparkerella* have not yet been studied acoustically and the calls of several species remain unknown. One of the polymorphic populations mentioned above occurs in the municipality of Silva Jardim in the state of Rio de Janeiro. Morphologically, frogs from this population resemble *Euparkerella brasiliensis* and *E. cochranae*, but our bioacoustics analyses show that they have a unique advertisement call. Here, we examine the morphological and acoustic characters of individuals in this population and compare their features with those of other nominal species of *Euparkerella*. Our analyses suggest the existence of a new and morphologically cryptic species that is named and described herein. In addition, we describe for the first time the advertisement calls of *E. robusta* and *E. tridactyla.*

Material and methods

Morphological Assessment. Descriptive terminology of the snout profile follows Heyer *et al.* (1990), whereas terminology of other morphological structures such as the tubercles is adapted from Izecksohn (1988). We used a Leica MZ6 stereomicroscope equipped with a ocular micrometer for the measurements except snout–vent length (SVL), which was measured with calipers (0.01 mm precision) and the numerical result rounded to the first decimal unit to avoid pseudoprecision (Hayek *et al*. 2001). The morphometric variables are as follow: snout–vent length (**SVL**, tip of snout to cloacal opening); head length (**HL**, tip of snout to anterior arm insertion in body in dorsal aspect); head width (**HW**, greatest transverse width between maxillae); upper eyelid width (**UEW**, at midline of eyelid); interorbital distance (**IOD**, narrowest interorbital distance between inner edges of eyelids); eye diameter (**ED**, anterior corner to posterior corner of eye); eye–nostril distance (**END**, laterally from anterior corner of eye to posterior edge of nostril); nostril–snout distance (**NSD**, anterior margin of nostril to tip of snout in dorsal aspect); internostril distance (**IND**, between inner edges of nostrils); body width (**BW**, at midlength of body); upper arm length (**UAL**, axilla to elbow); forearm length (**FAR**, elbow to wrist joint in ventral view); hand length (**HAL**, proximal edge of outer metacarpal tubercle to tip of Finger III); Finger-I length (**FIL1**); Finger-II length (**FIL2**); Finger-III length (**FIL3**); Finger-IV length (**FIL4**); thigh length (**THL**, cloacal opening to knee); tibia length (**TIL**, knee to heel in dorsal view); tarsal length (**TAL**, heel to tarsus-metatarsal articulation in plantar view; foot length (**FL**, proximal edge of inner metatarsal tubercle to tip of Toe IV); Toe-I length (**TL1**); Toe-II length (**TL2**); Toe-III length (**TL3**); Toe-IV length (**TL4**); Toe-V length (**TL5**). Finger and toe lengths are measured from proximal edge of proximal subarticular tubercle to tip of the digit. All measurements are in millimeters. Drawings of the holotype were made using an Olympus SZ2-ILST with a camera lucida. Morphometric comparisons are based on measurements of male frogs, as follow: 21 *Euparkerella brasiliensis*, 20 *E. cochranae*, 17 *E. robusta*, 7 *E. tridactyla*, and 19 *Euparkerella* sp. from Silva Jardim (Appendix I).

Specimens from the following collections were examined: the Amphibian Collection of the Instituto de Biologia, Universidade Federal do Rio de Janeiro (ZUFRJ), Rio de Janeiro, Rio de Janeiro; the Eugenio Izecksohn Collection at the Universidade Federal Rural do Rio de Janeiro (EI), Seropédica, Rio de Janeiro; the Amphibian Collection of the Museu Nacional, Universidade Federal do Rio de Janeiro (MNRJ), Rio de Janeiro, Rio de Janeiro; and the Amphibian Collection of the Museu de Biologia Professor Mello Leitão (MBML), Santa Teresa, Espírito Santo (Appendix I). Photos were examined of type specimens deposited in the British Museum of Natural History Collection (BMNH), London, England (Appendix I). The geographic coordinates of the specimens of the type series and referred specimens derive from Google Earth (accessed on March 2010) based on the WGS84 datum.

Bioacoustic analysis. The analyzed recordings of *Euparkerella brasiliensis* and *E. cochranae* were the same ones used by Hepp & Carvalho-e-Silva (2011). All recordings of *E. robusta* were made at type locality. *Euparkerella tridactyla* was recorded in the municipality of Santa Maria de Jetibá, about 20 km southwest of the type locality of this species. The unidentified population from municipality of Silva Jardim (*Euparkerella* sp.) was recorded from November 2010 to September 2011, whereas *E. robusta* was recorded in October 2011 and *E. tridactyla* in November 2012. Vocalizations were recorded with Tascam DR-07 and DR-100 digital recorders, at a sample rate of 44.1 Hz and sample size of 16 bits, and microphones Sennheiser ME-66, ME-67 and MKH-70. Advertisement calls were analyzed with the software Raven Pro 1.4 from the Cornell Laboratory of Ornithology (Bioacoustics Research Program). Technical terms and definitions adopted follow those of Littlejohn (2001) and Hepp & Carvalho-e-Silva (2011). Pulse sections refer to the time sections with one or more pulses separated by long silence intervals (Fig. 1). In this definition, pulse section of *E. brasiliensis*, *E. cochranae*, *E. robusta*, and *E. tridactyla* has a single pulse and similarly a single pulse period. The following parameters were measured: Number of Pulses per Call (all pulses considered); Number of Pulse Sections per Call (number of sequences of pulses emitted); Pulse Duration; Pulse Periods (measured from the beginning of one pulse to the beginning of the next, thereby encompassing the pulse duration and the interpulse interval [Weber *et al.* 2005]); Pulse-Section Periods (the beginning of one pulse sequence to the beginning of the next); Call Duration (the beginning of the first pulse to the termination of the last); Pulse Rate (number of pulses divided by call duration); Pulse-Section Rate (number of sections divided by call duration); Dominant Frequency; and Fundamental Frequency. Numerical call parameters are given as a range followed by the mean ($\bar{x}$) ± standard deviation (SD), mode (Mo, when there is a mode value), and sample size (N) in parentheses. The temporal parameters were measured directly from the oscillogram and spectral parameters were measured directly from the audiospectrogram (using window function Hann, amplitude logarithmic, window size 512 samples, overlap 99%). We also counted the number of harmonically related frequencies observed in the audiospectrogram and power spectrum. Although these can vary with recording distance and quality, it is important to note their presence when possible (Angulo & Reichle 2008; Hepp *et al.* 2012). Recordings were obtained in the field, as well as from captive frogs collected at the sites at which field recordings were made; these voucher specimens allowed us to evaluate morphological features and correctly identify the species (Hepp & Carvalho-e-Silva 2011). Voucher specimens were deposited in ZUFRJ and MNRJ collections. The recordings were deposited in the acoustical collection of the Arquivo Sonoro Professor Elias Pacheco Coelho (ASEC), Laboratório de Bioacústica, Departamento de Zoologia, Instituto de Biologia, Universidade Federal do Rio de Janeiro (Appendix II).

Statistical analysis. A Principal Component Analysis (PCA) was performed for each dataset (advertisement call and adult morphometric measurements) to assess the degree of differentiation among adults of *Euparkerella brasiliensis, E. cochranae*, *E. robusta*, *E. tridactyla* and *Euparkerella* sp. All meristic data were logarithmically transformed prior to multivariate analysis. Principal components were extracted from the correlation matrix. We used R software version 3.1.2 to perform statistical analysis (R Core Team 2014). Correlated variables were identified in a first round of analysis and subsequently removed from the final analyses.

Six morphometric variables were analyzed in the final PCA: Snout–Vent Lenght (SVL) Head Width (HW) Eye–Nostril Distance (END) Internostril Distance (IND) Forearm Length (FAR) Finger-III Length (FIL3). Sample sizes (number of specimens) are as follow: *Euparkerella brasiliensis,* 21; *E. cochranae,* 20; *E. robusta,* 17; *E. tridactyla,* 07; and *Euparkerella* sp., 19.

Six variables of advertisement calls were analyzed in the final PCA: Dominant Frequency (DF), Number of Pulses (NP), Call Duration (CD), Pulse-Section Period (SP), Pulse-Section Rate (SR) and Pulse Duration (PD). Sample sizes (number of calls) are as follow: *Euparkerella brasiliensis,* 10 calls (five specimens); *E. cochranae,* eight calls (six specimens); *E. robusta,* 17 calls (four specimens); *E. tridactyla,* 12 calls (one specimen); and *Euparkerella* sp., 13 calls (five specimens).

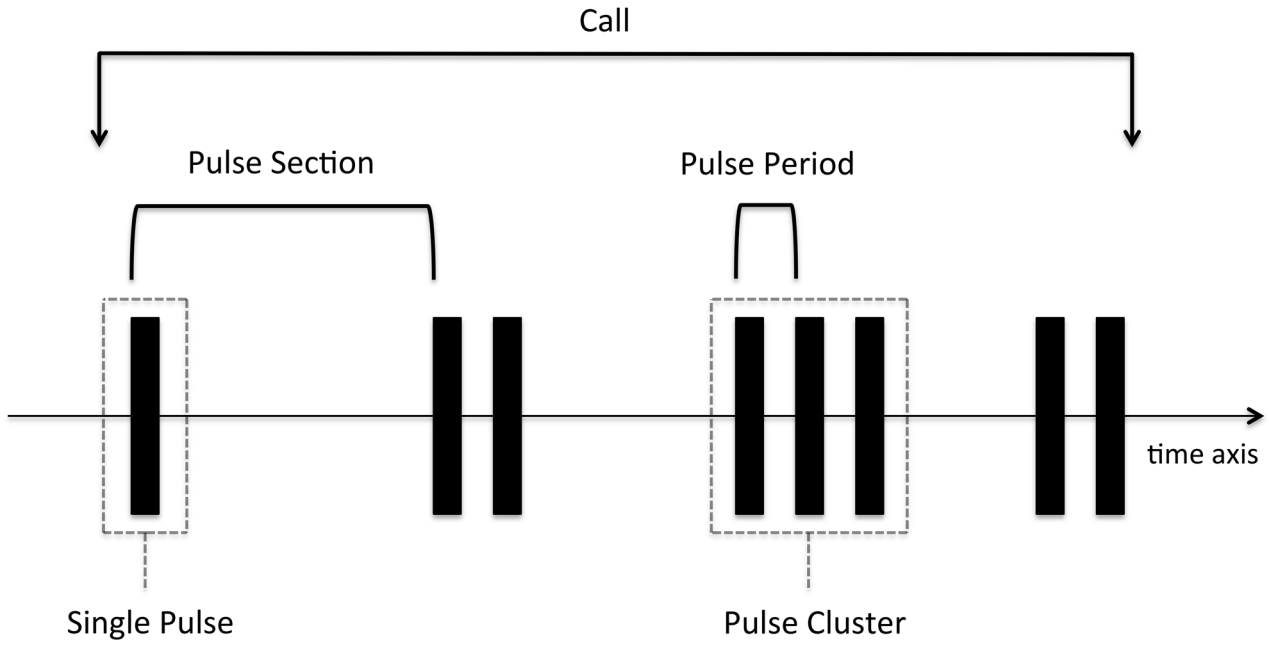

FIGURE 1. Graphical illustration of terms used in the structural and temporal description of advertisement calls.

Results

Traditional qualitative morphological characters were highly polymorphic and although some specimens of the new species differ from all other *Euparkerella* in possessing a unique subarticular tubercle partially fused with the digital pad on Finger IV, this character was intraspecifically highly variable. The extremes of the variation of this character, *i.e.*, subarticular tubercle completely separated and subarticular tubercle absent, are similar to those observed in *E. brasiliensis* and *E. cochranae*.

Two components were extracted from the PCA of morphometric variables that account for 92.4% of the total variation (Table 1). The most explanatory variables are Snout–Vent Length (SVL) and Forearm Length (FAR) for PC I, and internostril distance (IND) and Toe-III Length (FIL3) for PC II (Table 1). Figure 2 does not show a clear discrimination of species from the state of Rio de Janeiro (*Euparkerella brasiliensis*, *E. cochranae* and *E. cryptica* **sp. nov.**); however, *E. tridactyla* is shown as significantly distinct and *E. robusta* is slightly separated from the rest of species (*E. brasiliensis*, *E. cochranae,* and *E. cryptica* **sp. nov.**).

Two components were extracted from the PCA of acoustic variables that account for 75.4% of the total variation (Table 2). The most explanatory variables are Pulse-Section Periods (SP) and Pulse-Section Rate (SR) for PC I, and Call Duration (CD) and Pulse Duration (PD) for PC II (Table 2). Figure 3 shows a clear separation of nominal species according to variables of their advertisement calls and furthermore shows, unequivocally, the new species as distinct.

TABLE 1. Character loadings for Principal Components (PC) I and II. The analysis was based on six morphometric variables measured from 84 adults of the five species of the genus *Euparkerella*. Bold numbers indicate highest loadings.

Variable	PC I	PC II
Snout–Vent Lenght (SVL)	**-0.4381893**	0.1227340
Head Width (HW)	-0.4177114	0.3409510
Eye–Nostril Distance (END)	-0.4102344	-0.3177506
Internostril Distance (IND)	-0.3740647	**-0.6513607**
Forearm Length (FAR)	**-0.4192648**	-0.1072629
Finger-III Length (FIL3)	-0.3866623	**0.5761487**

TABLE 2. Character loadings for Principal Components (PC) I and II. The analysis was based on six acoustics variables measured from 60 advertisement calls of adult males of the five species of the genus *Euparkerella*. Bold numbers indicate highest loadings.

Variable	PC I	PC II
Dominant Frequency (DF)	0.2450698	0.049051144
Call Duration (CD)	0.3692179	**-0.584464114**
Number of Pulses per Call (NP)	-0.3726526	-0.509619788
Pulse-Section Periods (SP)	**0.5293802**	-0.287090115
Pulse Duration (PD)	-0.2998306	**0.560220704**
Pulse-Section Rate (SR)	**-0.5427773**	0.003922369

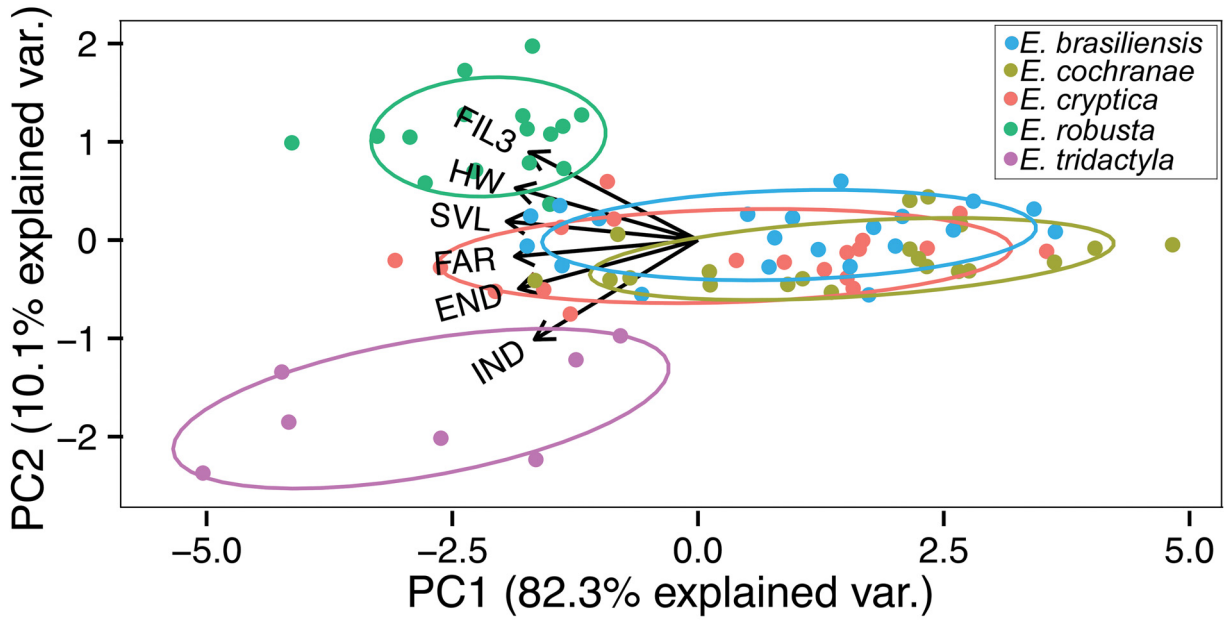

FIGURE 2. Distribution of 84 specimens of five species of *Euparkerella* (males and females) along the first and second axes of a Principal Component Analysis (PCA) generated from six morphometric variables.

***Euparkerella cryptica* sp. nov.**
(Figures 4 and 5)

Holotype. ZUFRJ 13281, adult male, collected in a rainforest fragment (22°29'1.53"S, 42°15'11.82"W; ca. 70 m above sea level) at Sítio Igarapê, municipality of Silva Jardim, state of Rio de Janeiro, Brazil, on 19 May 2011 by F. Hepp, S.P. de Carvalho-e-Silva, J. Kirchmeyer, M. Folly, and D. de Goes. The area is near the Reserva Biológica Poço das Antas.

Paratopotypes. ZUFRJ 12645, 12648–12649, MNRJ 85756–85757 collected on 11 November 2010 by F. Hepp, S.P. de Carvalho-e-Silva, J. Kirchmeyer, P. Bragança, A.M.P.T. de Carvalho-e-Silva and D. de Goes; ZUFRJ 12683 collected on 24 November 2010 by F.F. Hepp, S.P. de Carvalho-e-Silva, J. Kirchmeyer; ZUFRJ 12849–12855 collected on 15 April 2011 by F. Hepp, S.P. de Carvalho-e-Silva, J. Kirchmeyer, M. Folly, and D. de Goes; ZUFRJ 13449 collected on 2011 by F. Hepp, S.P. de Carvalho-e-Silva, J. Kirchmeyer, and D. de Goes; ZUFRJ 13524–13527 collected in 2011 by F. Hepp, S.P. de Carvalho-e-Silva, J. Kirchmeyer, and D. de Goes; ZUFRJ 13282, 13283, 13285, 13286 collected on 26 August 2011 by F. Hepp, S.P. de Carvalho-e-Silva, J. Kirchmeyer and D. de Goes.

Etymology. The species epithet "cryptica" is used as an adjective in feminine. The Latin word *crypticus* means "covered" or "concealed," and it is used in reference to the morphological similarity of some individuals of this species to *Euparkerella brasiliensis* or *E. cochranae*.

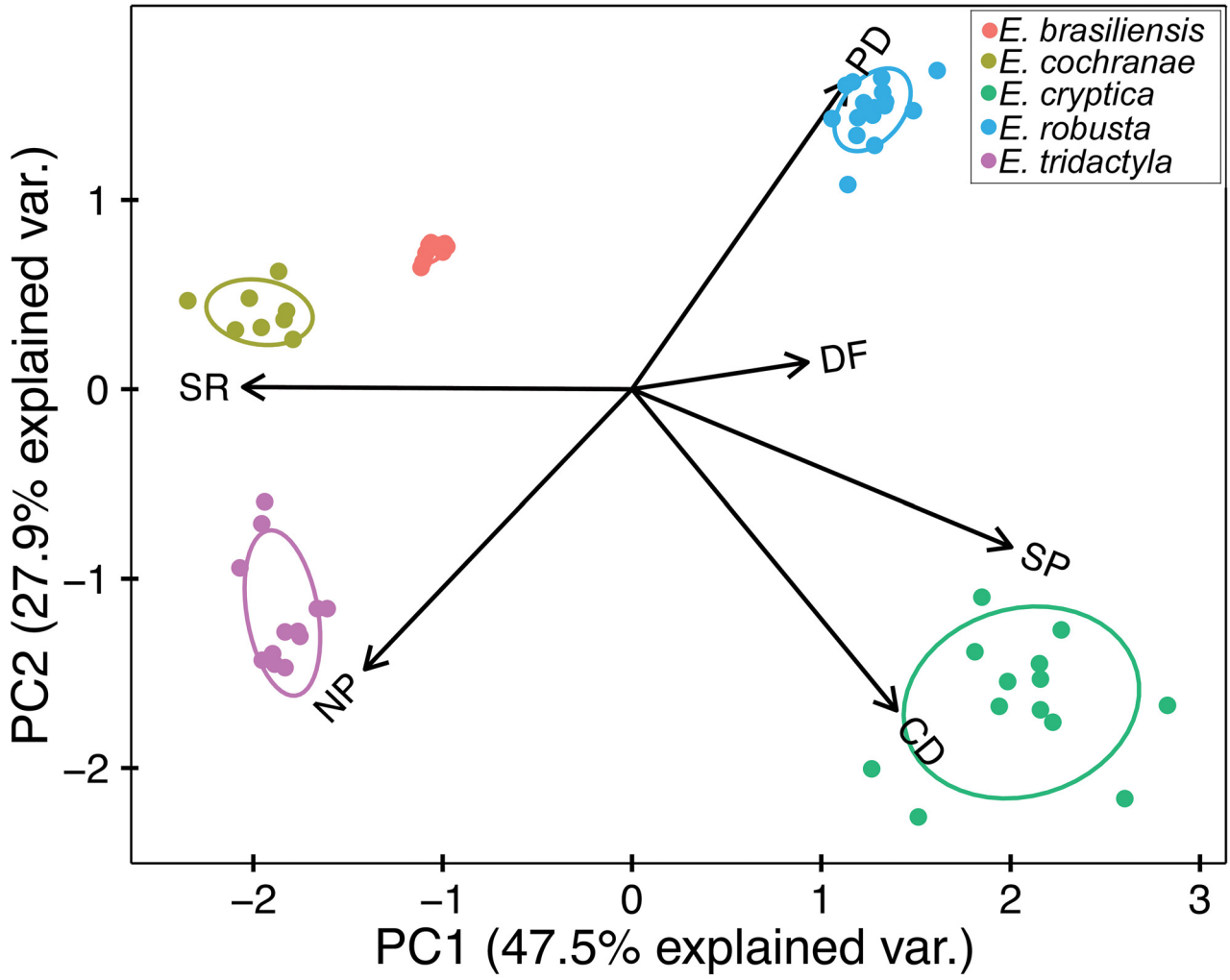

FIGURE 3. Distribution of 60 calls of five species of *Euparkerella* (males) along the first and second axes of a Principal Component Analysis (PCA) generated from six acoustical variables. Note the five distinct clusters corresponding to five recognized species.

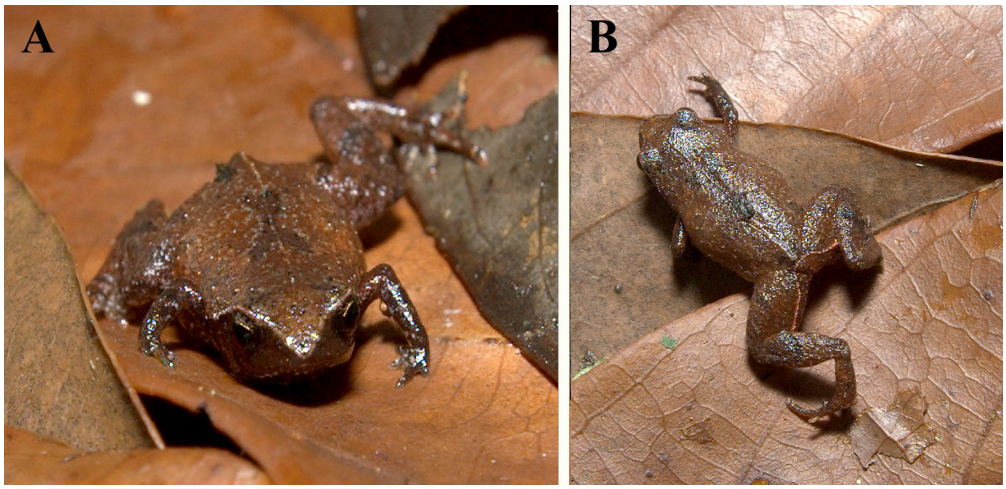

FIGURE 4. *Euparkerella cryptica* **sp. nov.** from Silva Jardim, RJ, Brazil, holotype (ZUFRJ 13281, adult male, SVL 14.30 mm), in life. Frontal (A) and (B) dorsal views.

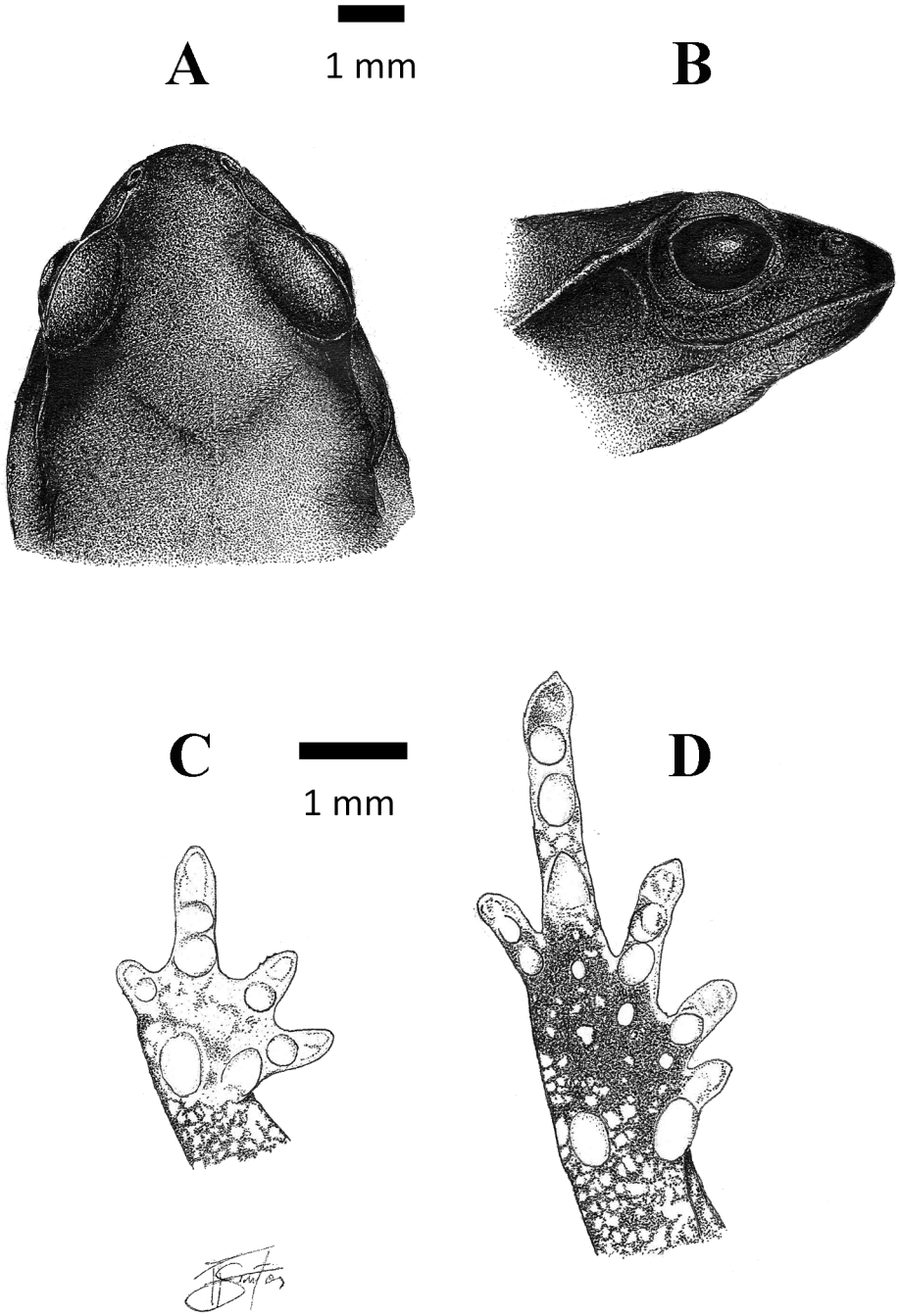

FIGURE 5. *Euparkerella cryptica* **sp. nov.** from Silva Jardim, RJ, Brazil, holotype (ZUFRJ 13281). Dorsal (A) and lateral (B) views of the head. Ventral views of the right hand (C) and foot (D).

Diagnosis. A species of *Euparkerella*, according to its globular body, head narrower than body, lateral surfaces of the head darker than dorsal surface, forming a masklike facial pattern, a pair of ventrolateral grooves along body, slender arms, short fingers and toes, terminal digits pointed with small pads with no circumferential grooves, large inner and outer metatarsal tubercles, and no tarsal tubercles. *Euparkerella cryptica* **sp. nov.** is diagnosed as follows: (1) medium size (adults SVL: $\bar{x}$ = 15.7 ± 2.1; 12.5–19.5 mm); (2) slender body (BW: $\bar{x}$ = 7.4 ± 1.0; 5.7–9.0 mm); (3) narrow head (HW: $\bar{x}$ = 6.6 ± 0.8; 5.5–8.0 mm); (4) long Finger IV, Toes I and V; (5) all plantar tubercles protuberant; (6) duration of advertisement call longer than 3 s ($\bar{x}$ = 4.7; Mo = 5.0; 3.4–6.2 s); (7) Pulse-Section Rate slower than two sections/s ($\bar{x}$ = 1.5; Mo = 1.8; 1.2–1.9 sections/s); and (8) exhibiting pulse clusters made up two or three pulses grouped in a single pulse section.

Comparisons with the other species. *Euparkerella cryptica* **sp. nov.** is smaller than *E. robusta* and *E. tridactyla* (SVL: $\bar{x}$ = 15.7 ± 2.1; 12.5–19.5 mm in *E. cryptica vs.* $\bar{x}$ = 18.5 ± 1.0; 17.2–21.5 mm and = 18.3 ± 1.8; 16.0–20.7 mm in *E. robusta* and *E. tridactyla*, respectively). The new species differs from *E. robusta* by its slender body (BW: $\bar{x}$ = 7.4 ± 1.0; 5.7–9.0 mm in *E. cryptica vs.* $\bar{x}$ = 10.3 ± 1.2; 9.0–13.5 mm in *E. robusta*) and its narrower head (HW: $\bar{x}$ = 6.6 ± 0.8; 5.5–8.0 mm in *E. cryptica vs.* $\bar{x}$ = 8.3 ± 0.6; 7.4–10.0 mm in *E. robusta*). *Euparkerella cryptica* **sp. nov.** differs from *E. tridactyla* in having long completely developed Finger IV, and Toes I and V (*vs.* vestigial Finger IV, and Toes I and V in *E. tridactyla*; Table 3); tubercles of the hand and foot protuberant (*vs.* not protuberant, large and flat in *E. tridactyla*). Acoustically, *E. cryptica* differs from all other species of *Euparkerella* in having a longer call (3.4–6.2 s in *E. cryptica vs.* 0.4–2.2 s in the other 4 species; Table 4); presence of pulse clusters (*vs.* absence in the other species); and slower repetition rate (1.2–1.9 pulse sections/s in *E. cryptica vs.* 3–45 pulse sections/s in the other species).

TABLE 3. Body measurements of the five species of *Euparkerella*. Ranges, in parentheses, follow the mean ± standard deviation (SD). All measurements are in mm.

Measurements	*E. brasiliensis* (N = 21)	*E. cochranae* (N = 20)	*E. cryptica* **sp. nov.** (N = 19)	*E. robusta* (N = 17)	*E. tridactyla* (N = 7)
SVL	14.9 ± 1.7 (12.1–18.6)	14.6 ± 1.8 (11.5–17.7)	15.7 ± 2.1 (12.5–19.5)	18.5 ± 1.0 (17.2–21.5)	18.3 ± 1.8 (16.0–20.7)
HL	6.6 ± 0.8 (5.4–8.0)	6.4 ± 0.8 (4.8–7.6)	6.7 ± 0.8 (5.5–8.2)	8.0 ± 0.4 (7.1–8.5)	7.8 ± 0.7 (6.9–8.9)
HW	6.6 ± 0.7 (5.1–7.9)	6.1 ± 0.8 (4.9–7.6)	6.6 ± 0.8 (5.5–8.0)	8.3 ± 0.7 (7.4–10.0)	7.6 ± 0.6 (6.8–8.3)
IOD	5.3 ± 0.5 (4.4–6.4)	5.2 ± 0.5 (4.3–5.9)	5.4 ± 0.6 (4.5–6.4)	6.0 ± 0.3 (5.6–6.6)	6.4 ± 0.5 (5.9–7.2)
UEW	1.3 ± 0.2 (1.0–1.6)	1.3 ± 0.1 (10–1.6)	1.3 ± 0.2 (1.0–1.7)	1.4 ± 0.1 (1.2–1.6)	1.4 ± 0.1 (1.2–1.5)
ED	1.7 ± 0.1 (1.5–2.1)	1.7 ± 0.2 (1.4–2.0)	1.7 ± 0.2 (1.5–2.0)	1.9 ± 0.1 (1.7–2.3)	2.1 ± 0.2 (1.8–2.3)
END	1.0 ± 0.1 (0.8–1.2)	1.0 ± 0.1 (0.8–1.2)	1.0 ± 0.1 (0.8–1.2)	1.1 ± 0.1 (1.0–1.2)	1.3 ± 0.1 (1.1–1.5)
NSD	1.0 ± 0.1 (0.8–1.2)	1.0 ± 0.1 (0.8–1.2)	1.1 ± 0.1 (0.9–1.4)	1.1 ± 0.1 (1.0–1.2)	1.3 ± 0.1 (1.2–1.5)
IND	1.8 ± 0.2 (1.5–2.1)	1.8 ± 0.2 (1.5–2.1)	1.9 ± 0.2 (1.5–2.3)	1.9 ± 0.1 (1.7–2.1)	2.4 ± 0.2 (2.2–2.6)
BW	7.8 ± 1.2 (6.0–10.1)	7.7 ± 1.3 (4.9–9.8)	7.4 ± 1.0 (5.7–9.0)	10.3 ± 1.2 (9.0–13.5)	8.2 ± 1.4 (6.0–10.0)
UAL	3.2 ± 0.4 (2.3–3.8)	3.1 ± 0.5 (2.3–3.8)	3.4 ± 0.4 (2.7–4.0)	3.7 ± 0.4 (3.0–4.4)	4.2 ± 0.3 (3.8–4.6)
FAR	3.2 ± 0.4 (2.4–4.0)	3.2 ± 0.4 (2.5–3.9)	3.4 ± 0.3 (2.9–3.8)	3.8 ± 0.2 (3.3–4.1)	4.1 ± 0.3 (3.7–4.6)
HAL	2.7 ± 0.3 (2.1–3.2)	2.5 ± 0.3 (2.0–3.0)	2.7 ± 0.3 (2.0–3.3)	3.3 ± 0.1 (3.1–3.5)	2.9 ± 0.3 (2.5–3.3)
FIL1	0.7 ± 0.1 (0.5–0.9)	0.6 ± 0.1 (0.5–0.8)	0.7 ± 0.1 (0.5–0.9)	0.8 ± 0.05 (0.8–0.9)	0.7 ± 0.1 (0.6–0.8)
FIL2	0.9 ± 0.1 (0.7–1.1)	0.8 ± 0.1 (0.6–1.0)	0.8 ± 0.1 (0.58–1.08)	1.0 ± 0.1 (0.9–1.1)	0.8 ± 0.1 (0.7–1.0)
FIL3	1.4 ± 0.2 (1.1–1.7)	1.3 ± 0.1 (1.0–1.5)	1.4 ± 0.2 (1.0–1.7)	1.7 ± 0.1 (1.6–1.9)	1.4 ± 0.1 (1.3–1.6)
FIL4	0.6 ± 0.1 (0.5–0.8)	0.4 ± 0.1 (0.3–0.6)	0.6 ± 0.1 (0.4–0.8)	0.6 ± 0.1 (0.5–0.8)	0.4 ± 0.1 (0.3–0.6)

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TABLE 3. (Continued)

Measurements	*E. brasiliensis* (N = 21)	*E. cochranae* (N = 20)	*E. cryptica* **sp. nov.** (N = 19)	*E. robusta* (N = 17)	*E. tridactyla* (N = 7)
THL	7.0 ± 0.8 (5.3–8.5)	6.7 ± 0.6 (5.3–7.9)	7.3 ± 0.7 (6.0–8.9)	8.3 ± 0.7 (7.7–10.9)	8.1 ± 0.6 (7.5–9.1)
TIL	6.4 ± 7.8 (4.6–8.0)	6.2 ± 0.5 (4.8–6.9)	6.6 ± 0.6 (5.5–7.8)	7.1 ± 0.5 (6.5–8.9)	7.2 ± 0.4 (6.5–7.7)
TAL	3.8 ± 0.4 (2.9–4.7)	3.8 ± 0.3 (3.2–4.4)	4.0 ± 0.4 (3.2–4.8)	4.0 ± 0.3 (3.5–4.5)	4.7 ± 0.3 (4.3–5.1)
FL	5.3 ± 0.6 (4.2–6.2)	5.1 ± 0.5 (4.1–6.1)	5.7 ± 0.6 (4.7–7.0)	6.0 ± 0.3 (5.1–6.6)	5.6 ± 0.4 (5.0–6.2)
TL1	0.6 ± 0.1 (0.5–0.9)	0.6 ± 0.1 (0.4–0.8)	0.6 ± 0.1 (0.5–0.7)	0.7 ± 0.1 (0.5–0.8)	0.5 ± 0.1 (0.4–0.6)
TL2	1.0 ± 0.1 (0.8–1.3)	0.9 ± 0.1 (0.7–1.3)	1.0 ± 0.1 (0.8–1.1)	1.1 ± 0.1 (1.0–1.2)	0.8 ± 0.1 (0.8–1.0)
TL3	1.5 ± 0.2 (1.2–1.9)	1.4 ± 0.2 (1.1–1.9)	1.6 ± 0.2 (1.2–2.0)	1.6 ± 0.1 (1.5–1.8)	1.4 ± 0.1 (1.3–1.5)
TL4	2.6 ± 0.3 (2.1–3.1)	2.5 ± 0.3 (2.0–3.1)	2.8 ± 0.5 (1.9–4.0)	2.9 ± 0.5 (1.0–3.3)	2.8 ± 0.3 (2.4–3.2)
TL5	1.1 ± 0.2 (0.9–1.5)	0.9 ± 0.1 (0.6–1.1)	1.2 ± 0.2 (0.9–1.6)	1.2 ± 0.1 (0.9–1.4)	0.5 ± 0.1 (0.5–0.7)

Description of holotype. Slender robust. Head slightly longer than wide (HW/HL = 0.9); HL 43% of the SVL. Snout rounded, slightly protuberant in ventral view. Interorbital distance slightly greater than 1.5× upper eyelid width (IOD/UEW = 1.7). Eye diameter slightly greater than 1.5× eye–nostril distance (ED/END = 1.7). Tympanic membrane indistinct externally. Supratympanic fold pronounced and glandular. Vomerine teeth absent. A single, small toothlike process at anterior margin of lower jaw that fits in a single, small socket between premaxillae. Tongue long, free posteriorly, unnotched. Skin almost smooth, slightly granulated on lateral and dorsolateral surfaces. A median dorsal glandular fold. A pair of deep ventrolateral grooves along body. An area with large granules on ventral surface of thighs, corresponding to less than half of the ventral thigh surface. A slight midventral groove.

Arms slender; forearm long, slender; fingers short; finger lengths: IV < I ≅ II < III. Number of subarticular tubercles of Fingers I, II, III, and IV—1, 1, 2, and 1, respectively. Subarticular tubercles present on all fingers. Subarticular tubercle partially overlapping digital pad of Finger IV (Fig. 6A). Palmar subarticular tubercles large and protuberant. Finger tips conical (especially on Finger III). Three large, rounded accessory tubercles on hand; tubercles aligned with Fingers II, II and IV. Carpal tubercles large, elliptical or rounded; outer carpal tubercle slightly larger than the inner one. Legs robust. Toe lengths: I < II ≅ V < III < IV; tip of Toe V reaching top of proximal tubercle of Toe IV. Numbers of subarticular tubercles of Toes I, II, III, IV, and V – 1, 1, 2, 3, and 2, respectively. Tips of longer toes conical, especially that of Toe IV. Subarticular tubercles large, elliptical or rounded. Many small, elliptical or rounded accessory tubercles on foot aligned with Toes II, III, IV, and V. Metatarsal tubercles large, elliptical and of similar size. Tarsi without tubercles.

Measurements of holotype (mm). SVL 14.3; HL 6.2; HW 5.9; IOD 2.2; UEW 1.3; ED 1.8; END 1.0; NSD 1.0; IND 1.7; BW 1.7; UAL 3.2; FAR 3.1; HAL 2.6; FIL1 0.6; FIL2 0.7; FIL3 1.3; FIL4 0.5; THL 6.4; TIL 6.2; TAL 3.9; FL 5.2; TL1 0.6; TL2 0.9; TL3 1.4; TL4 2.5; TL5 1.1.

Color of holotype in life. Dorsum brown, with a dark Y-shaped mark. Two pairs of dark straight marks on the dorsolateral region, all marks with anterior end slanted to the body midline. One pair is in the anterior and the other in the posterior region of dorsum near inguinal and axillary regions, respectively. Upper eyelid slightly darker than dorsum. Posterior upper surface of head with inverted triangular mark, slightly darker than dorsum. Lateral surfaces of head slightly darker than dorsum, resulting in a mask-like pattern. Upper edge of mask formed by two narrow bands, one dark and one light; the upper one is twice the width of the ventral. No longitudinal median light stripe on dorsum. A pair of transversal narrow light stripes on the posterior surface of each thigh; stripes ending at

the posterior end of the urostyle. Two symmetrical dark blotches on posterior part of dorsum (coccyx region, one on each side); dark transverse bars on thighs and shanks. Venter and throat purplish-brown. Throat darker than abdomen, with small, dispersed light marks. Narrow pale brown or beige fragmented stripe traversing abdomen and throat longitudinally along ventral groove. Peri-cloacal region pigmented. Pupil elliptical, horizontal; iris with numerous gold dots on black background.

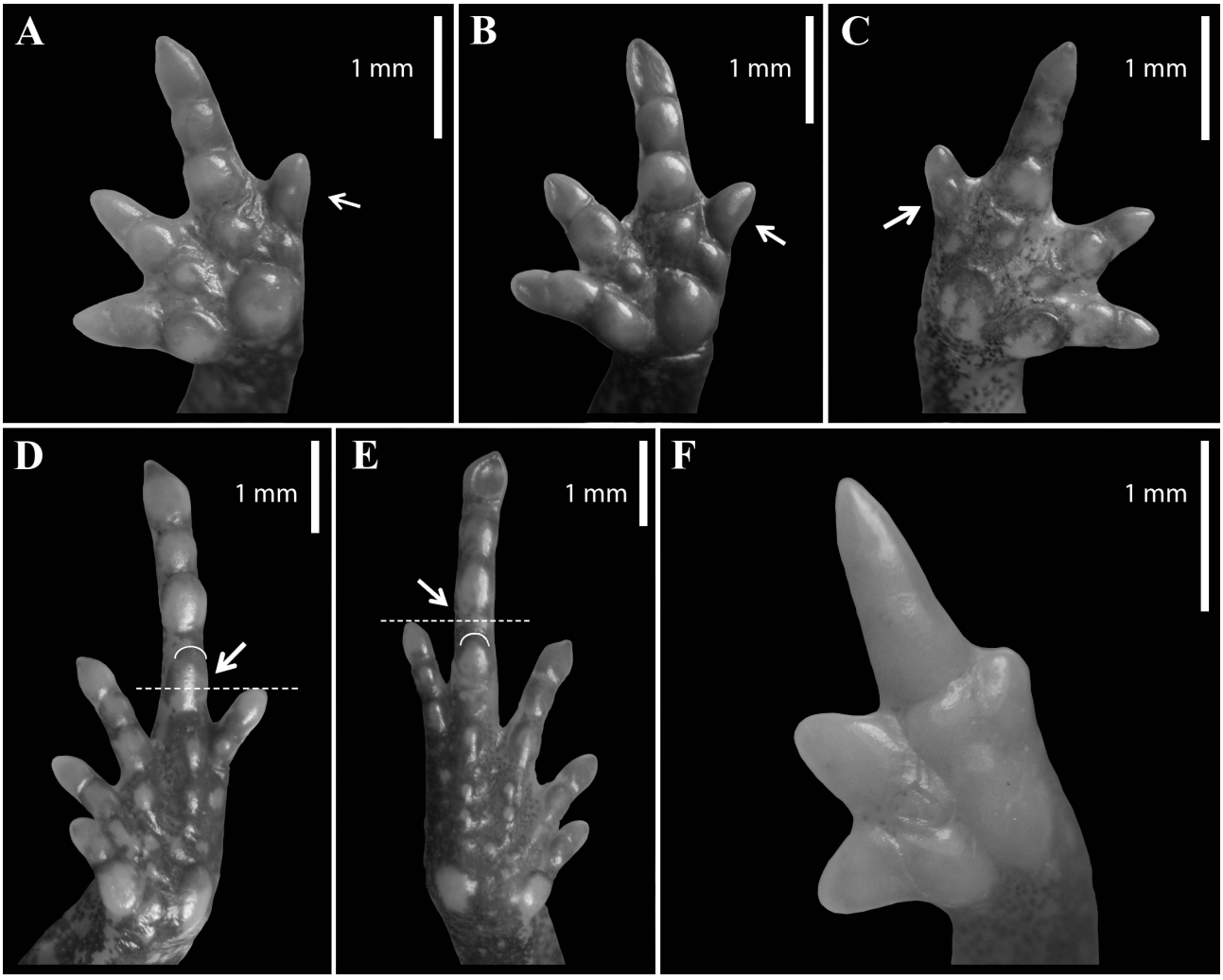

FIGURE 6. (A–E) *Euparkerella cryptica* **sp. nov.** from Silva Jardim, RJ, Brazil. (A) Ventral view of the left hand, holotype (ZUFRJ 13281). The arrow indicates the presence of digital pad and partially overlapped subarticular tubercle. (B) Ventral view of the left hand (MNRJ 85756). The arrow indicates the presence of a single digital pad. (C) Ventral view right hand (ZUFRJ 12851). The arrow indicates the presence of a digital pad and a subarticular tubercle. (D) Ventral view of the left foot (ZUFRJ 12645). The arrow and dashed line indicate the tip of the Toe V reaching near the middle of proximal subarticular tubercle of the Toe IV. (E) Ventral view of the right foot (ZUFRJ 12852). The arrow and dashed line indicate the tip of the Toe V extending beyond the proximal subarticular tubercle of the Toe IV. (F) *Euparkerella tridactyla* from Santa Teresa, ES, Brazil. Ventral view of the left hand (ZUFRJ 1928). Hand greatly reduced, with triangular fingers; Finger IV vestigial; digital tubercles and pads weakly developed and planar.

Color of holotype in preservative. Coloration similar to that in life, but darker and pattern less evident. Dorsum and flanks dark brown. Venter brown, vermiculated or marbled with pale brown or beige. Ventral surfaces of thighs lacking unpigmented patches.

Variation of morphology among paratopotypes. *Euparkerella cryptica* **sp. nov.** is highly polymorphic. Frequently, individuals vary bilaterally (*e.g.*, different features observed on right and left hands or feet). Head as long as wide (HW/HL: $\bar{x}$ = 1.0 ± 0.0). Mean head length is 43% (SD = 2%) of snout–vent length. Snout in dorsal aspect varies from rounded to subovoid, slightly acuminated to protuberant in lateral profile. In ventral view, mandible prognathous or not. Interorbital distance usually slightly longer than 1.5× width of upper eyelid (IOD/

UEW: $\bar{x}$ = 1.7 ± 0.2). Eye diameter slightly greater than 1.5× eye–nostril distance (ED/END: = 1.7 ± 0.1). Tympanic membrane indistinct. Supratympanic fold may be less pronounced than observed in holotype. In most specimens (75%), skin granulate (especially darker specimens); some individuals with nearly smooth skin, with granules on body sides only. Middorsal glandular fold frequently pronounced and elevated, but sometimes present as a depression. Ventral thigh area with large granules about 25–50% of the ventral thigh surface. Slight medial ventral groove on thighs present or absent. Inguinal, ventrolateral, axillary, and cephalic glands (near anterior insertion of the arm in body) variably present, lumped and highlighted, or sparse and less prominent. More highly pigmented specimens with less obvious glands.

Finger lengths: I ≅ IV < II < III, or IV < I < II < III, or IV < I ≅ II < III. Five paratypes (ZUFRJ 12645–12648, 12854) lacking subarticular tubercle on Finger IV, only the digital pad (Fig. 6B) at least on one hand. Specimen MNRJ 85756 with subarticular tubercle clearly isolated from digital pad on Finger IV only on one hand (Fig. 6C). Frequently (in the holotype and 8 paratypes), subarticular tubercle partially overlapping digital pad on Finger IV (Fig. 6A). Outer carpal tubercle commonly rounded and inner elliptical (45%) or both elliptical (45%); sometimes both rounded (only on one hand, specimen ZUFRJ 13449). Outer and inner carpal tubercles similar in size in MNRJ 85756. Toe lengths: I < II < V < III < IV or I < II ≅ V < III < IV or I < V < II < III < IV. Frequently (55%), top of Toe V not reaching distal limit of proximal tubercle of Toe IV (Fig. 6D); sometimes (25%) reaching or extending beyond tubercle (10%; Fig. 6E). Number of subarticular tubercles of Toes I, II, III, IV, and V – 0, 1, 2, 3, and 1, respectively, in ZUFRJ 12645 and 13449 (only one foot). Variation of morphometric data in Table 3.

Variation in color among paratopotypes. In preservative, much of the dorsum and flanks of some paratypes is grayish brown, brown, or light brown. There is a dark M-shaped mark on the dorsum; the central angle of the M is connected posteriorly to a triangle or arrow. A pair of inverted V-shaped marks may be present, one on each side of the dorsum. The inner end of each mark is connected to one upper angle of the M, configuring a pattern resembling two, partially overlapped, M-shaped marks. Frequently, the dorsal pattern is incomplete, with a larger V or Y-shaped mark located dorsomedially. Five paratypes (ZUFRJ 12645, 12854–55, 13449 and 13526) have a pair of light brown, circular blotches in scapular region. The upper eyelids may present the same color as the dorsum. The posterodorsal part of the head may lack a dark mark. The dark and light bands of the dorsolateral edge of mask can have the same width. A longitudinal median light stripe may be present posterior to the dorsal fold, not pronounced, starting from the posterior end of the urostyle (connected to the light stripes of the thighs) and ending at the level of the interorbital region. The two light stripes on the posterior surface of the thighs may be fragmented and connected to the dorsal light stripe at end of the urostyle. The dark marks on the posterior part of the trunk may be absent or well developed and connected to the other M-shaped mark of the dorsum. The venter may be more or less vermiculated, or marbled with pale brown or beige. The ventral stripe may traverse the whole or only the posterior half of the abdomen. The peri-cloacal region may have a slightly depigmented or clear patch.

Advertisement call. Thirteen calls of five individuals of *Euparkerella cryptica* **sp. nov.** were analyzed in detail. The advertisement call (Fig. 7A–C) consists of a single note comprising five to twelve sections of pulses ($\bar{x}$ = 7.4 ± 1.9; N = 13), in which one, two, or three pulses are present. Seventy of 96 pulse sections (73%) have two pulses; 25 (26%) have a single pulse, and one (<1%) has three pulses. Only one call lacked a pulse cluster (*i.e.*, pulse sections with more than one pulse). The intervals between pulse sections are regular, as are the intervals between the pulses within the sections. All pulses show the attack shorter than the decay. There are 9–19 ($\bar{x}$ = 13 ± 3; Mo = 11; N = 13) pulses per call. The amplitude varies irregularly throughout the call, except for the first section, which always has the lowest amplitude. However, second pulses tend to have lower (ca. 50%) amplitude than the first ones within each section. Call Duration ranges from 3.393–6.184 s ($\bar{x}$ = 4.472 ± 0.697; Mo = 5.015; N = 13). Although the pulses have a wide frequency band, between 2000 and 21000 Hz, a harmonic series is notable (frequency bands more energetic in spectrogram), with up to seven harmonics. The Fundamental Frequency ranges from 2756.2–3703.7 Hz ($\bar{x}$ = 3067.6 ± 236.3; Mo = 3000.0; N = 13). The Dominant Frequency corresponds to the Fundamental Frequency in 12 of the 13 calls, ranging from 2756.2–3617.6 Hz ($\bar{x}$ = 3193.5 ± 535.7; Mo = 3000.0; N = 13); in another call, the Dominant Frequency corresponds to the second harmonic with a value of 4823.4 Hz. The Pulse-Section Periods decrease throughout the call, and range from 0.656–1.246 s ($\bar{x}$ = 0.978 ± 0.206; N = 13) for the first period and 0.464–0.721 s ($\bar{x}$ = 0.618 ± 0.069; N = 13) for the last period. The Pulse Periods within the sections range from 0.057–0.101 s ($\bar{x}$ = 0.078 ± 0.013; Mo = 0.062; N = 71). The Pulse-Section Rate ranges from 1.232–1.940 pulse sections per second ($\bar{x}$ = 1.545 ± 0.227; Mo = 1.795; N = 13). Pulse

TABLE 4. Numerical values of call parameters for five species of *Euparkerella*. Mean ± standard deviation is followed by mode in parentheses, followed by range. * mode not available; — not applicable. Note that in all calls the dominant frequency corresponds with the fundamental frequency.

	Dominant Frequency (Hz)	Call Duration (s)	Total Number of Pulses	Number of Cryptic Pulses	Number of Pulse Sections	Number of Pulses Group	Number of Pulses per Group
E. brasiliensis	2793.8 ± 59.3 (2812.5) 2625.0−2812.5 N = 10	0.543 ± 0.037 (*) 0.506−0.630 N = 10	9.2 ± 0.4 (9) 9−10 N = 10	1.2 ± 0.4 (1) 1−2 N = 10	9.2 ± 0.4 (9) 9−10 N = 10	0 N = 10	—
E. cochranae	3259.6 ± 91.0 (3187.5) 3187.5−3375.5 N = 9	0.509 ± 0.093 (*) 0.375−0.633 N = 10	17.5 ± 1.8 (18) 14−20 N = 10	1.4 ± 0.8 (2) 0−2 N = 7	17.5 ± 1.8 (18) 14−20 N = 10	0 N = 10	—
E. cryptica **sp. nov.**	3193.5 ± 535.7 (3000.0) 2756.2−4823.4 N = 13	4.742 ± 0.697 (5.015) 3.393−6.184 N = 13	13.0 ± 3.0 (11) 9−19 N = 13	1.3 ± 0.8 (2) 0−2 N = 13	7.4 ± 1.9 (7) 5−12 N = 13	5.5 ± 2.3 (6) 0−9 N = 13	2.0 ± 0.0 (2) 2−3 N = 71
E. robusta	3033.1 ± 95.3 (3000.0) 2906.2−3187.5 N = 17	1.700 ± 0.200 (*) 1.300−2.200 N = 17	5.8 ± 0.8 (6) 5−8 N = 17	0 N = 17	5.8 ± 0.8 (6) 5−8 N = 17	0 N = 17	—
E. tridactyla	2648.5 ± 53.5 (2670.1) 2584.0−2756.2 N = 12	1.468 ± 0.141 (*) 1.240−1.711 N = 12	30.3 ± 2.5 (28) 27−34 N = 12	1.4 ± 2.5 (1) 1−2 N =12	30.3 ± 2.5 (28) 27−34 N = 12	0 N = 12	—

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TABLE 4. (Continue)

	Pulse Period (s)	Pulse-Section Period (s)	Pulse Duration (s)	Pulse-Group Duration (s)	Pulse-Section Repetition Rate (section/s)	Pulse Repetition Rate (pulse/s)	Number of Visible Harmonics
E. brasiliensis	0.065 ± 0.005 (0.066) 0.053−0.084 N = 82	0.065 ± 0.005 (0.066) 0.053−0.084 N = 82	0.007 ± 0.002 (0.008) 0.002−0.010 N = 92	----	17 ± 0.7 (*) 15.9−17.8 N = 10	17 ± 0.7 (*) 15.9−17.8 N = 10	5.9 ± 0.6 (6) 5−7 N = 10
E. cochranae	0.030 ± 0.004 (0.028) 0.021−0.041 N = 129	0.030 ± 0.004 (0.028) 0.021−0.041 N = 129	0.005 ± 0.001 (0.005) 0.002−0.008 N = 135	----	35 ± 4.3 (*) 30.2−45.1 N = 10	35 ± 4.3 (*) 30.2−45.1 N = 10	6.3 ± 1.1 (7) 4−7 N = 7
E. cryptica **sp. nov.**	0.078 ± 0.013 (0.062) 0.057−0.101 N = 71	0.730 ± 0.183 (0.581) 0.464−1246.000 N = 83	0.007 ± 0.001 (0.007) 0.003−0.011 N = 168	0.088 ± 0.013 (0.088) 0.068−0.143 N = 71	1.5 ± 0.2 (1.8) 1.2−1.9 N = 13	23.2 ± 3.1 (22.7) 18.5−29.4 N = 71	7 ± 0 (7) 7 N = 4
E. robusta	0.329 ± 0.042 (0.293) 0.261−0.498 N = 82	0.329 ± 0.042 (0.293) 0.261−0.498 N = 82	0.077 ± 0.011 (0.073) 0.043−0.116 N = 99	----	3.5 ± 0.2 (*) 3.0−3.9 N=17	3.5 ± 0.2 (*) 3.0−3.9 N=17	6.5 ± 0.8 (7) 5−8 N=17
E. tridactyla	0.050 ± 0.004 (0.052) 0.039−0.063 N = 352	0.050 ± 0.004 (0.052) 0.039−0.063 N = 352	0.007 ± 0.001 (0.008) 0.001−0.010 N = 364	----	20.7 ± 1.0 (*) 19.1−22.7 N= 12	20.7 ± 1.0 (*) 19.1−22.7 N= 12	6.6 ± 1.0 (6) 5−8 N=12

Duration ranges from 0.003–0.011 s ($\bar{x}$ = 0.007 ± 0.001; Mo = 0.007; N = 168). The Pulse Rate within pulse sections ranges from 18.5–29.4 pulses per second ($\bar{x}$ = 23.1 ± 3.0; Mo = 22.7; N = 71). Frequently, the first pulse section is cryptic and barely noticed because of its low amplitude.

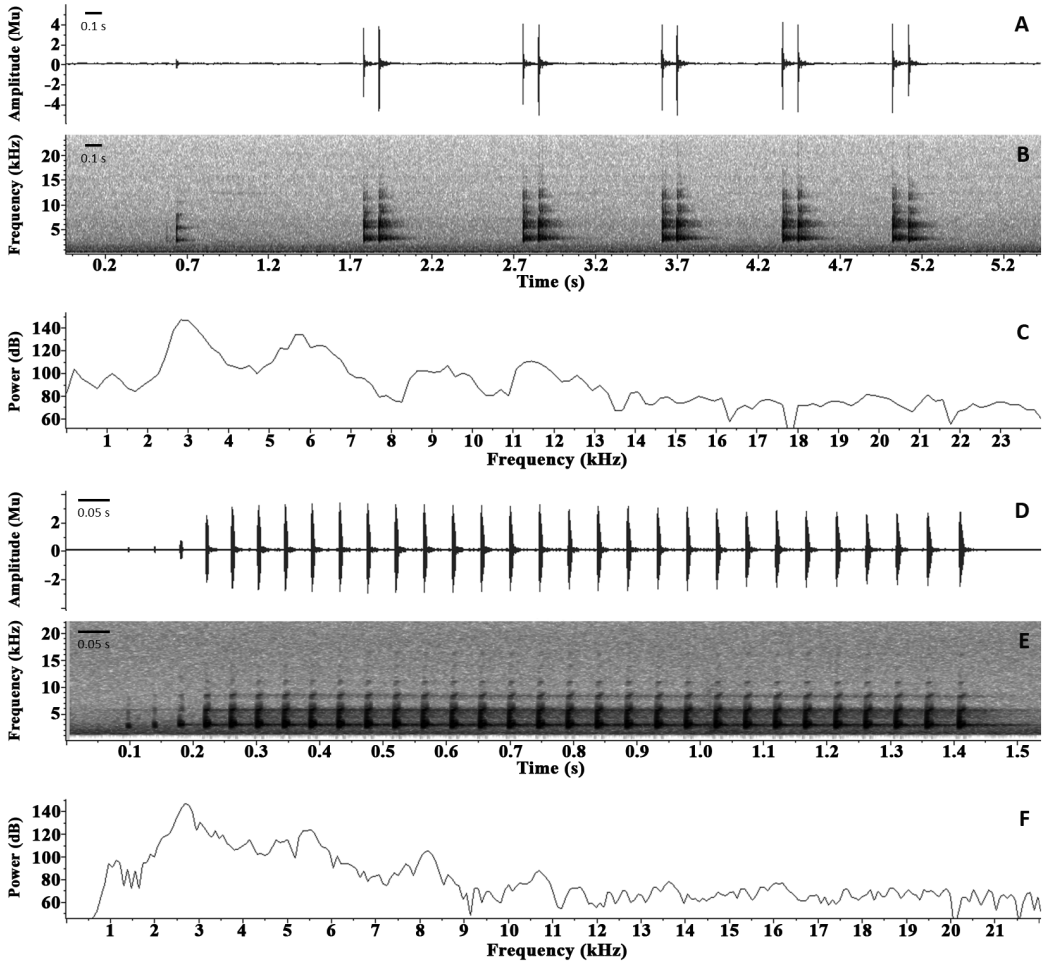

FIGURE 7. (A–C) *Euparkerella cryptica* **sp. nov.** from Silva Jardim, RJ, Brazil. (A) Oscillogram, (B) audiospectrogram (C) and power spectrum of an advertisement call (ASEC 17678). Note the long duration and the presence of pulse clusters. (D–F) *Euparkerella tridactyla* from Santa Maria de Jetibá, ES, Brazil. (D) Oscillogram, (E) audiospectrogram (F) and power spectrum of an advertisement call (ASEC 17704). Note the long duration and high number of pulses. Audiospectrograms and power spectrums with window function Hann, amplitude logarithmic, window size 256 (B, C) and 512 (E, F) samples, overlap 99%.

Distribution and natural history. *Euparkerella cryptica* **sp. nov.** is known only from the type locality (Fig. 8). Specimens were collected mainly at night. Advertisement calls were emitted more frequently just after sunset and just before sunrise. Most specimens were found covered in leaf litter on the ground, frequently at the bottom of small ravines. Although some males were observed exposed on top of the leaves or on the bare ground at the side of ravines, most males called in short choruses, hidden and dispersed across the forest (this behavior is similar in *Euparkerella brasiliensis* and *E. cochranae* [Hepp & Carvalho-e-Silva 2011]). Frequently, specimens exhibited thanatotic behavior after jumping, remaining motionless in relaxed positions until they were captured. In captivity, frogs moved slowly in the terrarium, rarely jumping. They frequently hid inside rolled leaves. The slow motion of *E. cryptica* **sp. nov.** resembles that of the other species of *Euparkerella*.

Euparkerella robusta

Advertisement call (figure 9). Seventeen calls from four individuals were analyzed in detail. The advertisement

call consists of a single note comprising 5–8 long pulses ($\bar{x}$ = 5.8 ± 0.8; Mo = 6.0; N = 17) repeated periodically (Fig. 9A, B). In all pulses, the attack is approximately of the same length as the decay. Pulse amplitudes are similar throughout the call; however, a second peak of amplitude occurs at the end of a pulse (Fig. 9C). In some calls, the amplitude and frequency are periodically modulated at the end of the pulses (Fig. 9D, E *vs.* no final modulation in Fig. 9A, B). In modulated calls, the first pulse usually has the strongest upward sweep in frequency modulation, reaching the initial band before a second downward phase. Call Duration ranges from 1.290–2.224 s ($\bar{x}$ = 1.659 ± 0.237; N = 17). There are as many as eight visible harmonics in the call. The Dominant Frequency corresponds to the fundamental one and ranges from 2906.2–3187.5 Hz ($\bar{x}$ = 3033.1 ± 95.3; Mo = 3000.0; N = 17). The Pulse Periods decrease slightly throughout the call, and range from 0.261–0.498 s ($\bar{x}$ = 0.367 ± 0.065; N = 17) for the first period and 0.289–0.355 s ($\bar{x}$ = 0.310 ± 0.019; Mo = 0.289; N = 17) for the last period. The Pulse Rate ranges from 3.0–3.9 pulses per second ($\bar{x}$ = 3.5 ± 0.2; N = 17). The Pulse Durations are long, ranging from 0.043–0.116 s ($\bar{x}$ = 0.077 ± 0.011; Mo = 0.073; N = 99). There is no cryptic pulse.

Comparisons with the other species. Acoustically, *Euparkerella robusta* differs from *E. brasiliensis* and *E. cochranae* by having fewer pulses (5–8 in *E. robusta vs.* 9–20 in *E. brasiliensis* and *E. cochranae*); longer Pulse Durations (43–116 ms in *E. robusta vs.* 2–10 ms in *E. brasiliensis* and *E. cochranae*); longer Call Duration (1.3–2.2 s in *E. robusta vs.* 0.4–0.6 in *E. brasiliensis* and *E. cochranae*); and slower Pulse Rate (3–4 pulses/s in *E. robusta vs.* 16–45 pulses/s in *E. brasiliensis* and *E. cochranae*). It differs from *E. cryptica* in having a shorter call duration (1.3–2.2 s in *E. robusta vs.* 3.4–6.2 s in *E. cryptica*); absence of pulse clusters (*vs.* presence in *E. cryptica*); longer pulses (43–116 ms in *E. robusta vs.* 3–11 ms in *E. cryptica*); and faster repetition rate (3.0–3.9 pulses/s in *E. robusta vs.* 1.2–1.9 pulse sections/s in *E. cryptica*). It differs from *E. tridactyla* by presenting fewer pulses (5–8 in *E. robusta vs.* 27–34 in *E. tridactyla*); longer Pulse Durations (43–116 ms in *E. robusta vs.* 1–10 ms in *E. tridactyla*); and slower pulse rate (3 or 4 pulses/s in *E. robusta vs.* 19–23 pulses/s in *E. tridactyla*).

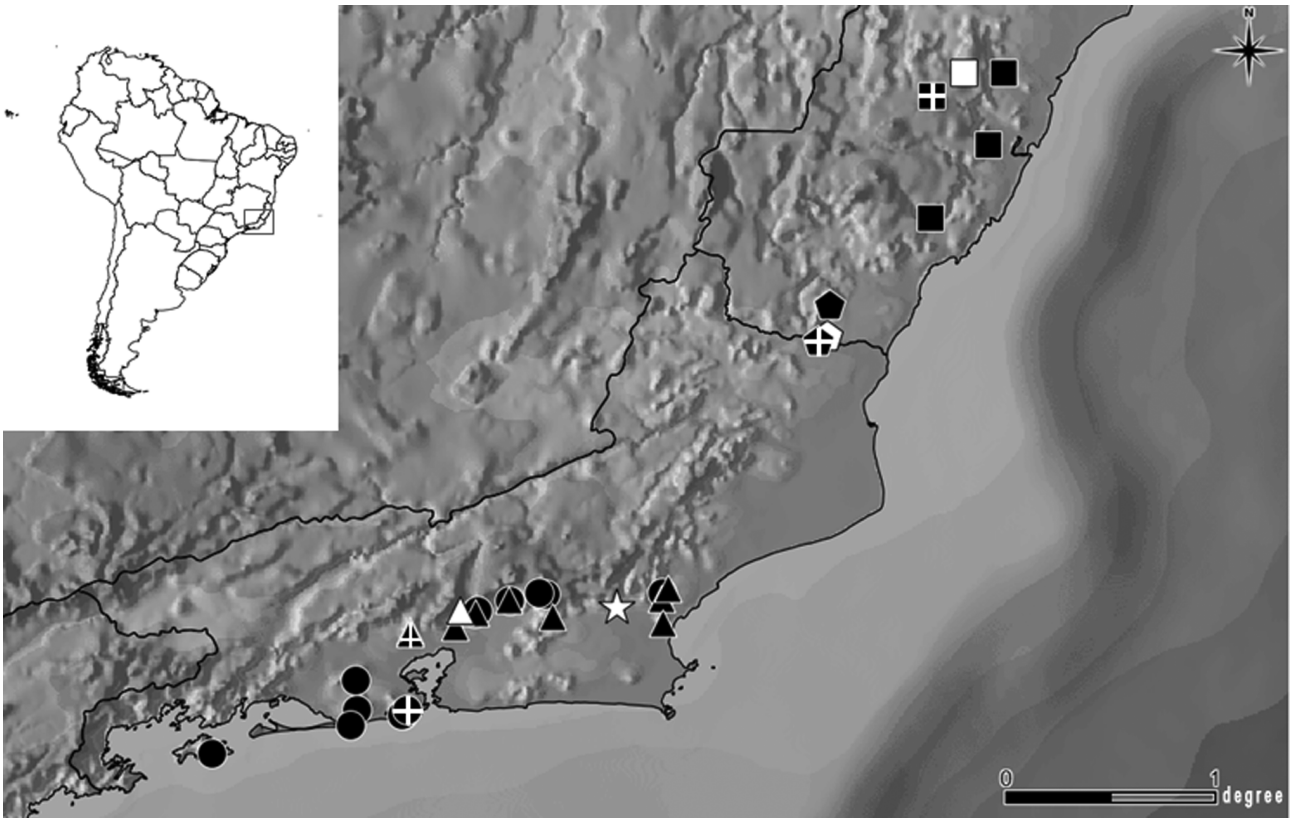

FIGURE 8. Distribution of the species of *Euparkerella*. *Euparkerella brasiliensis* (circle); *E. cryptica* **sp. nov.** (white star); *E. cochranae* (triangle); *E. robusta* (pentagon); *E. tridactyla* (square). White symbols represent type localities; black symbols indicate the provenances of the specimens examined from zoological collections; symbols marked with a cross indicate the provenances of the acoustically recorded specimens. The type locality of *E. brasiliensis* is not precisely known (Izecksohn 1988) and therefore, not shown.

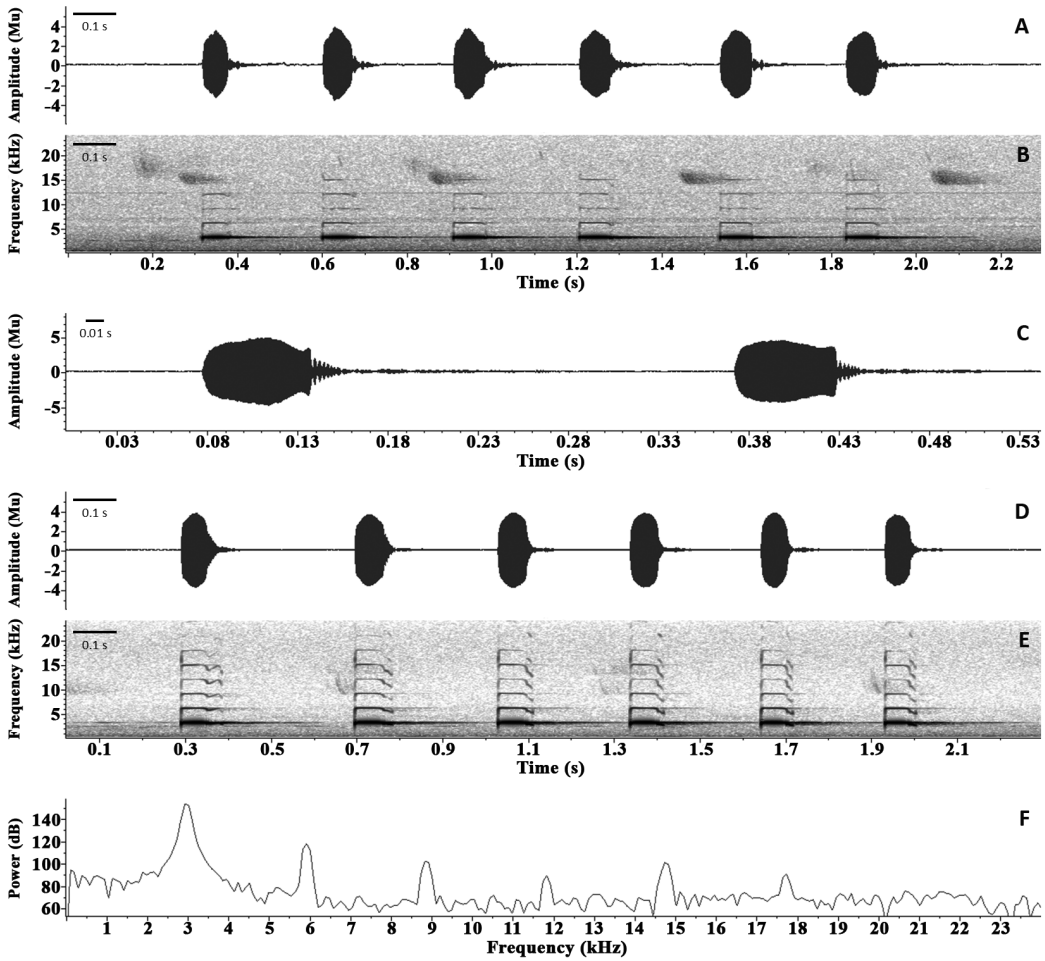

FIGURE 9. *Euparkerella robusta* from Mimoso do Sul, ES, Brazil. (A) Oscillogram and (B) audiospectrogram of an advertisement call (ASEC 17693) without frequency modulation. (C) Oscillogram of two pulses of an advertisement call (ASEC 17687) which presents the second amplitude peak and de periodic amplitude modulation at the end of the pulses. (D) Oscillogram, (E) audiospectrogram and (F) power spectrum of an advertisement call (ASEC 17684) which illustrates frequency modulation at the end of the pulses. Note the low number of pulses and their long duration. Audiospectrograms and power spectrums with Window function Hann, amplitude logarithmic, window size 512 samples, overlap 99%.

Euparkerella tridactyla

Advertisement call (figure 7D–F). Twelve calls of one individual were analyzed. The advertisement call (Fig. 7D, F) consists of a single note comprising 27–34 short pulses ($\bar{x}$ = 30.3 ± 2.5; Mo = 28; N = 12) repeated periodically. All pulses present the attack shorter than the decay. There are one or two cryptic pulses (*sensu* Hepp & Carvalho-e-Silva 2011) at the beginning of the call. In one call (ASEC 17696), one pulse with an intermediate amplitude (between cryptic and normal pulses) occurs at the end of the call. The call amplitude rises abruptly through cryptic pulses to the large-amplitude first pulse and decays smoothly until the last pulse (except for call ASEC 17696, which has a stronger amplitude difference between the penultimate and last pulse, as described above). Call Duration ranges from 1.240–1.711 s ($\bar{x}$ = 1.468 ± 0.141; N = 12). The call has as many as eight visible harmonics. The Dominant and Fundamental Frequencies are the same and range from 2584.0–2756.2 Hz ($\bar{x}$ = 2648.6 ± 53.5; Mo = 2670.1; N = 12). The Pulse Periods increase slightly throughout the call, except for the first period that is slightly longer than the second. The first period ranges from 0.039–0.048 s ($\bar{x}$ = 0.044 ± 0.002; Mo = 0.044; N = 12), the second from 0.040–0.048 s ($\bar{x}$ = 0.043 ± 0.002; Mo = 0.042; N = 12), and the last from 0.051–0.063 s ($\bar{x}$ = 0.056 ± 0.003; Mo = 0.055; N = 12). The Pulse Rate ranges from 19.11 to 22.74 pulses per second ($\bar{x}$ = 20.71 ±

1.05; N = 12). The Pulses Durations are long, ranging from 0.001–0.010 s ($\bar{x}$ = 0.007 ± 0.001; Mo = 0.008; N = 12).

Comparisons with the other species. Acoustically, *Euparkerella tridactyla* differs from *E. brasiliensis* and *E. cochranae* by having a greater number of pulses (27–34 in *E. tridactyla vs.* 9–20 in *E. brasiliensis* and *E. cochranae*); longer Call Duration (1.2–1.7 s in *E. tridactyla vs.* 0.4–0.6 s in *E. brasiliensis* and *E. cochranae*); and intermediate Pulse Rate (19–23 pulses/s in *E. tridactyla vs.* 16–18 pulses/s in *E. brasiliensis* and 30–45 pulses/s in *E. cochranae*). It differs from *E. cryptica* in having more pulses (27–34 in *E. tridactyla vs.* 9–19 in *E. cryptica*); shorter Call Duration (1.2–1.7 s in *E. tridactyla vs.* 3.4–6.2 s in *E. cryptica*); faster Pulse Rate (19–23 pulses/s in *E. tridactyla vs.* 1–2 pulse sections/s in *E. cryptica*); and in lacking pulse clusters (*vs.* presence in *E. cryptica*). It differs from *E. robusta* in having more pulses (27–34 in *E. tridactyla vs.* 5–8 in *E. robusta*); shorter pulses (1–10 ms in *E. tridactyla vs.* 43–116 ms in *E. robusta*); and a faster Pulse Rate (19–23 pulses/s in *E. tridactyla vs.* 3–4 pulses/s in *E. robusta*).

Key for the identification of the species of *Euparkerella* based on acoustic and morphological characters

1 a) Advertisement call with more than 25 pulses; hand greatly reduced, with triangular fingers (Fig. 6F); Finger IV, Toes I and V vestigial; digital tubercles and pads weakly developed and planar . . . . . *E. tridactyla*

b) Advertisement call with fewer than 25 pulses; hand developed with cylindrical fingers, tubercles and pads developed and prominent, round to oval (*e.g.*, in Fig. 6B–C). 2

2 a) Advertisement call less than 1 s long 3

b) Advertisement call longer than 1 s 4

3 a) Advertisement call with 10 or fewer pulses; the pulse periods longer than 50 ms; repetition rate about 17 pulses/s; dominant frequency slightly below 3 kHz; subarticular tubercle of Finger IV present . . . . . *E. brasiliensis*

b) Advertisement call with 14 or more pulses; pulse periods shorter than 50 ms, repetition rate of about 35 pulses/s; dominant frequency slightly above 3 kHz; subarticular tubercle of Finger IV absent; top of Toe V not reaching distal limit of the proximal tubercle of Toe IV . . . . . *E. cochranae*

4 a) Advertisement call less than 3 s, with up to 8 pulses; pulses longer than 40 ms; pulse rate about 3.5 pulses/s; robust body and large size (SVL ~18.5 mm). . . . . *E. robusta*

b) Advertisement call longer than 3 s; two or three pulses often grouped; pulses less than 15 ms long, pulse sections rate about 1.5 sections/s; slender body and medium size (SVL ~15.7 mm) . . . . . *E. cryptica*

Discussion

Euparkerella cryptica **sp. nov.** is morphologically similar to *E. brasiliensis* and *E. cochranae*. According to Izecksohn (1988) *Euparkerella brasiliensis* is recognizable by the presence of a subarticular tubercle separated from the digital pad of Finger IV and by the tip of Toe V surpassing the top of the proximal tubercle of Toe IV. Still, according to Izecksohn (1988), *E. cochranae* is recognizable by a single digital pad (without subarticular tubercle) on Finger IV and by the tip of Toe V not reaching the distal limit of the proximal tubercle of Toe IV. *Euparkerella cryptica* **sp. nov.** has all these characteristics, which are variable, and specimens of this species have possibly been constantly confounded with either *E. brasiliensis* or *E. cochranae* due to the lack of acoustic data associated with collected specimens.

Several specimens examined from localities near the municipality of Silva Jardim (*e.g.*, municipalities of Cachoeira de Macacu, Silva Jardim, Casimiro de Abreu, Guapimirim, and Rio das Ostras) are partially incongruent with any diagnosis of the previously recognized species (*sensu* Izecksohn 1988). As well as in *Euparkerella cryptica* **sp. nov.**, these problematic specimens show a mosaic of morphological features that cover the variation of *Euparkerella brasiliensis* and *E. cochranae*. These populations correspond to some of the divergent genetic lineages discovered by Fusinatto *et al*. (2013) for *E. brasiliensis* (Unit 5), *E. cochranae* (Units 3 and 4) and *Euparkerella* sp. (Unit 8). Considering the geographic proximity of populations of *Euparkerella cryptica* **sp. nov.** and *Euparkerella* sp. (Unit 8) by Fusinatto *et al.* (2013), both populations may be conspecific. Our study of the morphology of Unit 8 specimens supports this assumption, although we cannot confidently confirm the identity of that population in the absence of bioacoustic evidence. Some of these populations may belong to *E. cryptica* **sp. nov.** or represent additional unnamed species. Further analyses of bioacoustic evidence for genetic lineages discovered by Fusinatto *et al.* (2013) will help clarify the taxonomic status of multiple populations.

Species of *Euparkerella* exhibit subtle morphological differences (Fusinatto *et al.* 2013), and commonly have high levels of intraspecific polymorphism, as observed for other Neotropical groups of frogs (*e.g.*, Padial *et al.* 2009). For continuous morphological characters, we can visualize the extent of this polymorphism in the overlapping pattern resulting from the PCA analysis (Fig. 1), especially among species from Rio de Janeiro. The highest loadings for the PCA are Snout–Vent Length for PC I, and Internasal Distance and Finger-III Length for PC II (Table 1). In fact, *E. robusta* and *E. tridactyla* differ from the group of species from Rio de Janeiro by their larger body sizes. Izecksohn (1988) noticed the smallest nasal bones in *E. robusta*, this condition possibly is reflected in the explanation of Internasal Distance found in the PCA. Furthermore *E. tridactyla* is distinguished from *E. robusta* in the possession of shorter fingers (Table 3).

The PCA of the advertisement call parameters of *Euparkerella* (Fig. 3) illustrates a clear distinction among the calls of members of *Euparkerella*, even those with very similar morphology. This pattern of morphological similarity associated with a marked acoustic divergence has been observed in several other amphibian taxa (*e.g.*, Angulo & Reichle 2008; Padial *et al.* 2008; Padial & De La Riva 2009; Lima *et al*., 2014; Peloso *et al*., 2014). The advertisement calls of *Euparkerella cryptica* **sp. nov.**, *E. robusta,* and *E. tridactyla* resemble the calls of *E. brasiliensis* and *E. cochranae* in many aspects, such as: the presence of periodic pulse sequences; the dominant and fundamental frequencies of ca. 3000 Hz; and the presence of ca. seven harmonics (Hepp & Carvalho-e-Silva 2011). The call of *E. cryptica* **sp. nov.** has, nonetheless, the longest duration, the slowest repetition rate (considering the pulse-sections rate), and it is the only one to have pulse clusters. The call of *E. robusta* is also notably distinguished by its long pulses, which are perceived as whistles rather than as short snaps. In contrast, the call of *E. tridactyla* has the greatest number of pulses and intermediate call duration.

As first suggested by Hepp & Carvalho-e-Silva (2011), the divergence between the species analyzed here is greater when observing temporal and structural characters than when observing spectral characters. Indeed, temporal and structural characters may be the most informative acoustic characters for the taxonomy of species in this genus, as they show marked differences that are purportedly associated with reproductive isolation and genetic divergence. The values of dominant and fundamental frequencies and the distribution patterns of the harmonics are similar between the species. Hepp & Carvalho-e-Silva (2011) also suggested that the small differences between the dominant frequencies of *E. brasiliensis* and *E. cochranae* could be explained by differences in body size (SVL: $\bar{x}$ = 15.0 mm and 14.6 mm, respectively). Although *E. robusta* and *E. tridactyla* are the largest species in the genus (both SVL: $\bar{x}$ = 18.5 mm), *E. tridactyla* has a lower dominant frequency (ca. 2600 Hz), whereas the call of *E. robusta* has an intermediate dominant frequency (ca. 3000 Hz), even higher than the call of *E. brasiliensis* (ca. 2800 Hz [Hepp & Carvalho-e-Silva 2010]). Apparently, the inverse relationship between dominant frequency and body size is less evident in interspecific comparisons than in intraspecific ones (Gringas *et al*. 2012). This pattern could be explained by a stronger intraspecific correlation between body size and vocal apparatus. Therefore, despite the greater size of *E. robusta*, we expect that the vocal apparatus is proportionally smaller. Further anatomical research will be necessary to test this hypothesis.

Acknowledgments

We thank Juliana Kirchmeyer, Pedro Bragança and Daniel de Goes helped us conduct fieldwork on the de Goes family property. Dr. João Gasparini provided fieldwork information. Dr. Mark Wilkinson and Dr. Gabriela Bittencourt for the photos of type specimens from British Museum. Tainá Ferreira dos Santos executed the line drawings. Dr. José P. Pombal Jr., Pedro Pinna, and Ms. Marcia Gomes dos Reis provided access to their collections. Dr. Ivan Nunes and Ms. Pedro Pinna provided critical comments on early drafts of the manuscript, which was reviewed for English usage by Dr. Anne T. H. Baldisseri. Dr. Pedro Peloso, Dr. José Padial, and Dr. Linda Trueb for the careful revision and the many suggestions made throughout the text. We are grateful to all of these individuals. Financial support was provided to F.H. by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq). Permits (#26256-2, 12164) for the collection of frogs were issued by the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis – IBAMA.

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APPENDIX I. Additional specimens examined from Southeastern of Brazil. * Specimens measured.

Euparkerella brasiliensis: state of RIO DE JANEIRO: Organ Montains, no municipality (photos examined BMNH 1902.11.25.9–10 (paralectotypes), 1902.11.25.8 (lectotype)); municipality of *Angra dos Reis:* Ilha Grande: Dois Rios (MNRJ 57551); municipality of *Cachoeiras de Macacu*: Boca do Mato (MNRJ 49300), Parque Estadual Três Picos (MNRJ 55504, 56927–56929), Guapiaçu (MNRJ 57787–57790), Reserva Ecológica de Guapiaçu (ZUFRJ 8936; MNRJ 38212 – 38220, 56947–56951, 57735, 68702, 68703); municipality of *Guapimirim*: Centro de Primatologia (MNRJ 40596, 40598), Estação Ecológica Paraíso (MNRJ 48243); municipality of *Rio das Ostras*: Reserva Biológica União (MNRJ 39522); municipality of *Rio de Janeiro*: Grumari (MNRJ: 59067, 59068), Parque Nacional da Tijuca (ZUFRJ 535, 536, 1514, 9543– 9546, 9579*, 9580*, 9586*, 10715–10718*, 11729, 12800–12802*), Parque Natural Municipal Serra do Mendanha, Bangu (MNRJ 49180–49186, 50220, 52995, 53822, 55667–55670, 55685, 57007, 58153, 58154, 59850, 59851, 66379), Pedra da Gávea (MNRJ 19343), São Conrado (ZUFRJ 1273, 2433* – 2438*, 2446*, 2466, 8471*), Parque Natural Municipal de Grumari (MNRJ 71531).

Euparkerella cochranae: state of RIO DE JANEIRO: municipality of *Cachoeiras de Macacu*: Reserva Biológica de Guapiaçu (MNRJ 37317, 37318); *Casimiro de Abreu*: (MNRJ 73509), Morro de São João (MNRJ 44625), Reserva Biológica União (MNRJ 49494); municipality of *Duque de Caxias*: Parque Natural Municipal Duque de Caxias (MNRJ 53184, 72082–72088), Parque Natural Municipal da Taquara (MNRJ 60259, 65594); municipality of *Guapimirim*: (ZUFRJ 3400, 4996, 6096), Barreiras Sítio da Ana (MNRJ 51357, 51358), Caneca Fina (ZUFRJ 704, 705), Centro de Primatologia (MNRJ 241 40593 – 40595, 40597, 40599); municipality of *Macaé*: Reserva Biológica União (MNRJ 48759–48761); municipality of *Magé*: (ZUFRJ 7528), Campo Escoteiro Geraldo Hugo Nunes (ZUFRJ 2290*–2293*(paratypes), 2589 (paratype), 2590 (paratype), 2731 (paratype), 2880, 2881, 7528, 10459, 10460*, 10804, 10805*–10807*, 11075*–11077*, 11092*–11095*, 11238*, 11239, 11240*, 11241*, 11242*, 11516, 11517*, 11518*, 12240; MNRJ 71172); municipality of *Silva Jardim*: (MNRJ 73435, 73442, 71693 – 71695), Reserva Biológica de Poço das Antas (ZUFRJ 9337), Serra dos Gaviões (MNRJ 53509 – 53519); Reserva Biológica União (MNRJ 48746 – 48748, 48751).

Euparkerella cryptica: state of RIO DE JANEIRO: municipality of *Silva Jardim* - Sítio Igarapê (ZUFRJ 12645*–12649*, 12679*–12683*, 12849*, 12850*–12855*, 13281*–13283, 13285, 13286, 13449, 13524, 13525, 13526*, 13527).

Euparkerella robusta: state of ESPÍRITO SANTO: municipality of *Atílio Vivácqua*: Serra de Torres (MNRJ 60992*–60994*); municipality of *Mimoso do Sul*: Sítio do Sr. Fernando (ZUFRJ 13379*–13385*, MNRJ 60995*–61010*, 66515, 66516), Sítio do Sr. Joaquim (EI 7284).

Euparkerella tridactyla: state of ESPÍRITO SANTO: municipality of *Alfredo Chaves* (MBML 6720); municipality of *Cariacica* (MBML 5386 – 5388); municipality of *Fundão* (MBML 853); municipality of *Santa Maria de Jetibá* (ZUFRJ 13901; MBML 5699); municipality of *Santa Teresa* (ZUFRJ 1349*, 1350*, 1928*–1929*, EI 7254*–7256* (paratypes), 7273*–7275*; MBML 7565).

Euparkerella sp.: state of RIO DE JANEIRO: municipality of *Cachoeiras de Macacu*: Reserva Ecológica de Guapiaçu (ZUFRJ 10358, 10359; MNRJ 53757); municipality of *Guapimirim* (ZUFRJ 6761); municipality of *Casimiro de Abreu*: Reserva Biológica União (MNRJ 39529).

APPENDIX II. Recordings Examined from Southeastern of Brazil.

Euparkerella brasiliensis: state of RIO DE JANEIRO**:** municipality of *Rio de Janeiro*: Floresta da Tijuca (ASEC 14833–14834 [ZUFRJ 9579], 14835–14840, 14841–14842 [ZUFRJ 9586]).

Euparkerella cochranae: state of RIO DE JANEIRO**:** municipality of *Magé*: Campo Escoteiro Geraldo Hugo Nunes (ASEC 14843–14848, 14849 and 14852 [ZUFRJ 11095], 14850–14851 [ZUFRJ 11093]).

Euparkerella cryptica: state of RIO DE JANEIRO**:** municipality of *Silva Jardim*, Sítio Igarapê: ASEC 17670 – 17678 (ZUFRJ 13449), 17679 – 17682 (ZUFRJ 12645, 12648 – 12649, MNRJ 85756 – 85757).

Euparkerella robusta: state of ESPÍRITO SANTO**:** municipality of *Mimosos do Sul* (ASEC 17683–17689 [ZUFRJ 13379], 17690–17691 [ZUFRJ 13383], 17692 [ZUFRJ 13381], 17693 [ZUFRJ 13384]).

Euparkerella tridactyla: state of ESPÍRITO SANTO**:** municipality of *Santa Maria de Jequitibá* (ASEC 17694–17705 [ZUFRJ 13901]).