

## ***Brachyhypopomus draco*, a new sexually dimorphic species of Neotropical electric fish from southern South America (Gymnotiformes: Hypopomidae)**

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*Brachyhypopomus draco*, new species, is described from central, southern and coastal regions of Rio Grande do Sul state, Brazil, and Uruguay. It is diagnosed from congeners by, among other characters, the shape of the distal portion of the caudal filament in mature males, which during the reproductive period forms a distinct paddle shape structure.

*Brachyhypopomus draco*, espécie nova, é descrita para as regiões central, sul e costeira do estado do Rio Grande do Sul, Brasil, e Uruguai. Ela é diagnosticada de seus congêneres, entre outros caracteres, pela porção final do filamento caudal de machos maduros, que adquire a forma de um remo durante o período reprodutivo, .

**Key words:** Electric Organ Discharge, EOD, Rio Uruguay, Laguna dos Patos, Rio Tramandaí.

### **Introduction**

The family Hypopomidae, proposed by Mago-Leccia (1978), is widespread in South American countries, except Chile, and distributed from the río de la Plata in Argentina (35°S) to northern Panama (8°N) (Albert, 2001). The genus *Brachyhypopomus* was described by Mago-Leccia (1994) to comprise six species that previously belonged to *Hypopomus* and that share the characters: short snout, absence of mesocoracoid bridge, short and crescent-shaped maxillary bone, and posterior nares closer to eyes than to snout tip. Later, Albert (2001) redefined the genus based on four synapomorphies: premaxilla gracile with a curved anterior margin and forming a distinct angle with the maxilla in lateral view, dentary gracile, body cavity with 16-17 precaudal vertebrae, single transitional vertebra. Albert (2001) maintained the same

six species cited by Mago-Leccia (1994) in the genus. Additionally he listed seven undescribed species and recognized five clades within *Brachyhypopomus* that were previously proposed by Sullivan (1997).

The six *Brachyhypopomus* species recognized as valid by Mago-Leccia (1994) and Albert (2001) are: *B. brevirostris* (Steindachner, 1868), which occurs in Eastern South America from the Orinoco to la Plata drainages; *B. occidentalis* (Regan, 1914), which occurs in Panama, and in several trans-Andean drainages of north eastern South America, including the Magdalena, Atrato, Catatumbo and Pacific slope rivers; *B. beebei* (Schultz, 1944), which is widespread through tropical areas east of Andes; *B. diazi* (Fernández-Yépez, 1972), which is restricted to the Caribbean littoral of Northwest Venezuela, from the río Tocuyo to río Alpagaton and also the northern Llanos in the Orinoco basin; *B. pinnicaudatus* (Hopkins,

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1991), which is widespread through cis-Andean South America, including the Guianas, the Orinoco and Amazon basins, and much of the rio Paraná-Paraguay-Uruguay drainage as far south as the río de la Plata; and *B. janeiroensis* (Costa & Campos-da-Paz, 1992), which is known only from the São João and Paraíba do Sul river basins in Rio de Janeiro state (Albert & Crampton, 2003).

Subsequently, Triques & Khamis (2003) described *B. jureiae*, which is known to occur in the Una do Prelado river system in southern Brazil, and also from Ribeira de Iguape drainage, near Iguape, São Paulo (Triques & Khamis, 2003; F. Lima & W. Crampton, pers. obs.). Loureiro & Silva (2006) described *B. bombilla*, which is distributed throughout the middle rio Uruguay tributaries and the laguna dos Patos and lagoa Mirim systems in eastern Uruguay.

In Rio Grande do Sul state, southern Brazil, there have been no previous studies of the species diversity of *Brachyhypopomus*, excepting the occasional mention of the genus in checklists and reviews. The oldest citation was by Ellis (1913), based on specimens identified as *Hypopomus brevirostris* (= *Brachyhypopomus brevirostris*) collected by Herman von Ihering in the laguna dos Patos drainage (Malabarba, 1989). *Brachyhypopomus pinnicaudatus*, *B. beebei* and an undescribed species have been quoted as widely distributed in cis-Andean South American basins by Sullivan (1997), including material from Rio Grande do Sul state. *Brachyhypopomus brevirostris* and *B. pinnicaudatus* have been cited to occur in the la Plata drainage (Campos-da-Paz, 1997; Albert & Crampton, 2003), and *B. beebei* from laguna dos Patos drainage (Campos-da-Paz, 1997).

Based upon extensive sampling in Rio Grande do Sul, our studies revealed the presence of three *Brachyhypopomus* species in this region: *B. bombilla*; a second species that has been largely identified as *B. pinnicaudatus* in the literature; and a third and new species that is widespread in the rio Uruguay, laguna dos Patos and rio Tramandaí drainages in southern Brazil and Uruguay. This latter species is described herein.

### Materials and Methods

Comparative data from *B. pinnicaudatus*, *B. bombilla* and *B. jureiae* were taken directly from the type specimens (see Comparative Material). Data from *B. brevirostris*, *B. occidentalis*, *B. beebei*, *B. diazi* and *B. janeiroensis* were compiled from original descriptions. Morphometric data were taken as point-to-point linear distances using digital calipers to the nearest 0.1 mm. Measurements were analyzed as percentage of length to the end of the anal fin (LEA), measured as the distance from tip of the snout to posterior end of anal fin base, or as percentage of head length (HL), measured from tip of snout to posterior margin of bony operculum. Total length was not used as a numerator in morphometric body

relationships because of the high number of specimens with a damaged and/or regenerated caudal filament. Regenerated parts of the body were not measured and their meristic data were not recorded. The other measurements used were: caudal filament length, measured from the end of anal fin base to the tip of caudal filament; snout to anal-fin origin, from tip of snout to origin of anal-fin base; depth of caudal filament, measured at the posterior end of anal-fin base; longest anal-fin ray, from base to tip of the longest ray; pectoral-fin length, from the dorsal border of the fin base where it contacts the cleithrum to tip of the longest ray; body depth, measured at anal-fin origin; snout length, from tip of snout to anterior margin of orbit; gape width, between lateral margins of mouth gape; orbital diameter, between anterior and posterior margins of the orbit; interorbital distance, shortest distance between margins of orbits; posterior nare to eye, from posterior margin of posterior nare to anterior margin of orbit; branchial aperture, from posterodorsal to anteroventral extent of branchial fold; head width at operculum, largest width measured at bony operculum; head width at eyes, head width measured at center of eyes. Pectoral and anal-fin ray counts were taken directly from ethanol preserved specimens under a stereomicroscope. Vertebrae were counted from radiographed specimens including the four vertebrae of the Weberian Apparatus. Apparently, Albert (2001) did not include the vertebrae of the Weberian Apparatus in the precaudal counts; therefore, four vertebrae were added to Albert's (2001) counts for comparison. Osteological data were taken from cleared-and-stained (cs) specimens following Taylor & Van Dyke (1985). Sex and the stage of sexual maturity were determined by dissection, following Cognato & Fialho (2006).

Fish specimens belong to the collections of Academy of Natural Sciences of Philadelphia, Philadelphia (ANSP), California Academy of Sciences, San Francisco (CAS), Universidade Federal de Minas Gerais, Belo Horizonte (DZUFMG), Museu de Ciências e Tecnologia, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre (MCP), Museu Nacional, Rio de Janeiro (MNRJ), Museu de Zoologia, Universidade de São Paulo, São Paulo (MZUSP), Departamento de Zoologia, Universidade Federal do Rio Grande do Sul, Porto Alegre (UFRGS), University of Michigan Museum of Zoology, Ann Arbor (UMMZ), National Museum of Natural History, Washington D.C. (USNM), Facultad de Ciencias Naturales, Montevideo (ZVC-P).

Electric Organ Discharge (EOD) recordings were taken from fishes obtained from rio Uruguay, rio Tramandaí and laguna dos Patos drainages. Specimens were held in water from the capture locality at 27°C +/- 0.5 °C for at least 12 hours before the recording. All recordings were made in an aquarium maintained at 27°C +/- 0.1 °C, containing water from the capture locality (or nearby). Each specimen was allowed 10 minutes to acclimate before recording. Signals were picked up from silver/silver-chloride electrodes placed posterior and

anterior to the fish and with a ground contact in the center. Individual fish were placed within a nylon-mesh sock. The electrodes were connected to a custom-built AC-coupled differential amplifier with a frequency response of  $\pm 3$  dB from 0.2 Hz–110 kHz (Wells & Crampton, 2006). EODs were digitized using an Edirol UA5 A-D converter at a sampling rate of 96 kHz and resolution of 24 bits. Recordings of resting repetition rate were taken during daylight hours between 1000 and 1400 from fish held in nylon-mesh socks under subdued lighting. Recordings of nocturnal activity were taken from 1–3 hrs after sunset from single specimens held in 10 l buckets containing water from the source locality, and water hyacinths. An electrode was placed in the center of this tank and the fish was allowed unrestricted movement before and during the recording. All signal analyses were conducted using custom-written MATLAB or Java software designed by W. Crampton. EOD durations were calculated with the beginning and end of the EOD taken at a 1% threshold of the amplitude of the dominant positive phase (P1) following normalization to the P1 amplitude. EODs recorded from specimens with more than 10% damage to the caudal filament were not included for waveform analyses.

Calculations of EOD repetition rate were taken by measuring all successive inter-pulse intervals over one minute recordings. The EOD rate for each fish was characterized by three parameters. 1. The mean pulse rate in Hz calculated as the reciprocal of the mean of all IPIs (in seconds). 2. The standard deviation (SD) around the mean pulse rate in Hz. This measure of variance indicates the stability of the EOD repetition rate. 3. The coefficient of variance (CV) calculated as a percentage ( $\text{mean}/\text{SD} \times 100$ ). Because the CV is weighted by the mean, it is used for standardized comparisons of the relative stability of the pulse rate over a wide range of rates. The mean and SD of these three measures were then calculated among all recorded adult or post-larval specimens, and are presented here to summarize diurnal and nocturnal EOD activity.

## Results

### *Brachyhypopomus draco*, new species

Figs. 1, 2

**Holotype.** MCP 41540, 1 (male, 137.3 mm LEA), Brazil, Rio Grande do Sul, Parque Estadual de Itapuã, lagoa Verde (30°22'52.4"S, 51°01'25"W), 12 Jan 2004, D. Cognato, L. R. Malabarba, C. E. Machado & R. Q. Carvalho.

**Paratypes.** All from Brazil, Rio Grande do Sul. **Laguna dos Patos drainage:** MCP 41539, 1 (male, 147.1 mm LEA), collected with the holotype. UFRGS 8888, 1 (male, 126.4 mm LEA), same locality of the holotype, 18 Jan 2006, J. Giora, A. P. Dufech & J. Ferrer. MNRJ 30916, 2 (1 male, 151.8 mm LEA, 1 female, 128.4 mm LEA), same locality of the holotype, 9 Feb 2004, D. Cognato, M. Azevedo, A. Schaan & C. Hiroshi. MCP 41538, 2 (1 male, 88.4 mm

LEA, 1 female, 91.7 mm LEA), same locality of the holotype, 30 Jun 2004, D. Cognato & A. Schaan. MNRJ 30917, 1 (male, 150.2 mm LEA), MZUSP 94429, 1 (male, 139.1 mm LEA), same locality of the holotype, 9 Sep 2004, D. Cognato, M. Schossler & A. Schaan. MCP 41537, 1 (female, 108.4 mm LEA), same locality of the holotype, 10 Oct 2003, D. Cognato & A. Schaan. MNRJ 30918, 1 (male, 138.2 mm LEA), same locality of the holotype, 11 Nov 2003, D. Cognato, J. Giora, J. Anza & A. P. Dufech. UFRGS 732, 1 (female, 78.0 mm LEA), Viamão, arroio Alexandrina (30°6'S, 50°57'W), 7 Sep 1980, L. R. Malabarba. UFRGS 820, 1 (male, 93.7 mm LEA), Guaíba, açude near BR290 highway (30°07'S, 51°20'W), 4 Nov 1979, L. R. Malabarba, C. F. M. Souto & P. A. Buckup. UFRGS 822, 1 (male, 92.5 mm LEA), Guaíba, açude in BR290 highway, near junction with BR116 highway (30°03'S, 51°21'W), 18 Jan 1980, P. A. Buckup & C. Souto. UFRGS 6526, 1 (male, 102.2 mm LEA), UFRGS 6525, 1 (male, 100.6 mm LEA), Eldorado do Sul, artificial canal near BR290 highway (30°2'55"S, 51°23'34"W), 10 Dec 2003, W. Crampton & L. R. Malabarba. UFRGS 4317, 1 (male, 50.0 mm LEA), Viamão, arroio Itapuã (30°15'S, 51°02'W), 1 Mar 1988, F. Becker & L. R. Malabarba. **Rio Tramandaí drainage:** UFRGS 6486, 1 (male, 85.3 mm LEA), UFRGS 6488, 1 (male, 98.1 mm LEA), UFRGS 6489, 1 (male, 100.8 mm LEA), UFRGS 6490, 1 (female, 95.5 mm LEA), UFRGS 6491, 1 (male, 80.9 mm LEA), Capão da Canoa, creek parallel to Estrada do Mar road (29°43'9"S, 50°56'0"W), 20 Nov 2003, L. R. Malabarba, J. Giora, J. Anza & D. Cognato. MNRJ 30915, 2 (1 male, 69.9 mm LEA, 1 female, 85.2 mm LEA), Cidreira, lagoa Fortaleza (30°8'58"S, 50°14'30"W), 11 Jul 2003, L. R. Malabarba. UFRGS 6671, 3 (2 males, 85.7–107.0 mm LEA, 1 female, 96.3 mm LEA), Terra de Areia, creek into rio Três Forquilhas, along the road RS486 (29°33'22"S, 50°4'19"W), 20 Nov 2003, L. R. Malabarba, J. Giora, J. Anza & D. Cognato. **Rio Uruguay drainage:** UFRGS 6748, 1 (male, 90.8 mm LEA), Rosário do Sul, Sanga do Jacaré, BR290 (30°12'4"S, 55°3'17"W), 18 Jun 2004, D. Cognato, W. Crampton, J. Giora & D. Rocha. MZUSP 94428, 8 (2 males, 95.6–126.7 mm LEA, 6 females, 51.9–103.94 mm LEA), UFRGS 6753, 1 (male, 88.3 mm LEA), Rosário do Sul, stream tributary of arroio Gueromana, BR290 (30°1'00"S, 55°23'18"W), 19 Jun 2004, D. Cognato, W. Crampton, J. Giora & D. Rocha. UFRGS 6785, 4 (2 males, 79.3–105.1 mm LEA, 2 females, 84.5–85.3 mm LEA), UFRGS 6494, 1 (male, 92.5 mm LEA), UFRGS 6497, 1 (male, 90.1 mm LEA), Rosário do Sul, sanga do Jacaré, BR290 (30°12'42"S, 55°3'17"W), 26 Nov 2003, L. R. Malabarba, J. Giora, D. Cognato, G. Neves & J. Ferrer. UFRGS 6789, 4 (2 males, 106.5–126.3 mm LEA, 2 females, 71.5–80.0 mm LEA), Rosário do Sul, stream tributary of arroio Gueromana, BR290 (30°1'0"S, 55°23'18"W), 26 Nov 2003, L. R. Malabarba, J. Giora, D. Cognato, G. Neves & J. Ferrer. UFRGS 6507, 1 (male, 92.9 mm LEA), UFRGS 6509, 1 (male, 92.5 mm LEA), UFRGS 6511, 1 (male, 98.3 mm LEA), São Gabriel, stream tributary of arroio Piraí, BR290 (30°18'56"S, 54°24'22"W), 26 Nov 2003, L. R. Malabarba, J. Giora, D. Cognato, G. Neves & J. Ferrer.

**Non-type material.** The following specimens were used to record the distribution of the new species, but are not used in the species description and are not part of the type series. However, they do not differ in morphometric or meristic characteristics from the type specimens. **Brazil, Rio Grande do Sul:** MCP 20215, 5, and MCP 20217, 3, Eldorado do Sul; MCP 20711, 1, Osório; UFRGS 7686,



**Fig. 1.** Holotype (MCP 41540, male, 137.3 mm LEA, above) and paratype (MCP 41537, female, 108.4 mm LEA, below) of *Brachyhypopomus draco*, from Parque Estadual de Itapuã, Rio Grande do Sul, Brazil.

30, Viamão, and UFRGS 7707, 3, Viamão; UFRGS 8475, 4, Pantano Grande - Rio Pardo; UFRGS 8938, 1, rio Tramandaí; UFRGS 6780, 11, São Gabriel; UFRGS 6750, 14, Rosário do Sul - Alegrete; UFRGS 8263, 28, Charqueadas. **Paraguay:** USNM 181483, 5, Pueblo Ybytymí, Departamento Paraguairí; ANSP 170412, 1, Departamento Misiones; ANSP 175180, 1, Departamento Misiones. **Uruguay:** ZVC-P 2727, 1, Departamento Artigas, lagoa Redonda.

**Diagnosis.** *Brachyhypopomus draco* can be distinguished from all described congeners by the extreme broadening of the distal portion of the caudal filament in males during the reproductive period to form a distinct paddle shaped structure (vs. moderately broadened distally in *B. pinnicaudatus* and *B. brevirostris* into paddle-shaped structures, and versus broadened along most of the length of the caudal filament in *B. occidentalis*, *B. diazi*, *B. beebei*, and *B. janeiroensis*). *Brachyhypopomus draco* can be further diagnosed from other species of the genus by the following characters: caudal filament length 17.3-35.2% of LEA (vs. 36.5-50.0% in *B. jureiae*; 33.0-50.0% in *B. janeiroensis*, and 13.3-20.0% in *B. bombilla*); pectoral fin ray length 4.1-5.8% of LEA (vs. 6.7-7.9% in *B. pinnicaudatus*); body depth 8.8-12.2% of LEA (vs. 12.1-16.2% in *B. pinnicaudatus*); snout length 20.7-30.0% of HL (vs. 31.7-32.2% in *B. jureiae*); gape width 9.5-16.5% of HL (vs. 17.8-23.1% in *B. pinnicaudatus*); interorbital distance 22.7-35% of HL (vs. 14.9-20.5% in *B. bombilla*); branchial aperture 16.5-26% of HL (vs. 24.9-31.0% in *B. pinnicaudatus*); head width at operculum 48.4-65% of HL (vs. 60.0-73.0% in *B. pinnicaudatus*); head width at eyes 31.3-45.6% of HL (vs. 24.7-31.7% in *B. bombilla*); number of anal fin rays 155-198 (vs. 188-211 in *B. jureiae*; 251-295 in *B. brevirostris*; 214-228 in *B. beebei*, and 200-240 in *B. occidentalis*); upper jaw equal to lower jaw (vs. upper jaw slightly longer than lower jaw in *B. bombilla*, *B. occidentalis*, *B. diazi*, *B. brevirostris* and *B. jureiae*).

**Description.** Morphometric and meristic data are presented in Table 1. Head conical, nearly triangular in lateral view, snout short, eyes small, mouth terminal with upper jaw equal to lower jaw, no teeth in both jaws. Body slender, slightly laterally compressed. Dorsal profile straight from snout to supraoccipital, slightly convex posteriorly to caudal filament. Ventral profile gently convex from lower jaw to anal-fin origin, slightly convex to nearly straight along anal-fin base. Highest body depth located posterior to anal-fin origin. Body depth increasing smoothly from head to body region near the 30th anal-fin ray, clearly gradually decreasing from that point to caudal filament. Caudal filament moderately short, slender and laterally compressed in females, juveniles and males in non-reproductive period; caudal filament paddle-shaped in sexually mature males (see sexual dimorphism, below). Cycloid scales covering uniformly the body, except head and fins. Scales smaller on all anterior quarter portion of body; posterior scales at dorsal and medial body regions two to four times larger in diameter than anterior ones; smallest scales covering region of anal-fin pterygiophores. First anterior perforated scale of lateral line above pectoral fin origin and lateral line extending to caudal filament tip, hardly discernible. Branchial aperture small and slightly anterior to pectoral fin origin. Anus with the presence of urogenital papilla in males and females, although less developed in juveniles. Pectoral fins rounded with pigmented rays and perpendicular insertion; pectoral-fin rays i-ii + 13-15 (15-17 total pectoral-fin rays,  $n = 47$ , median = 16). Anal fin relatively long with vii-xii + 148-186 rays (155-198 total anal-fin rays,  $n = 41$ , mean = 181.3) which are pigmented. Anal-fin origin located posterior to posterior edge of pectoral fin. Precaudal vertebrae 21-23 (20-22 anterior, 1-2 transitional;  $n = 6$ ).

**Coloration in life.** General body color brownish varying from dark brown to yellowish brown, dark brown near dorsal mid-

**Table 1.** Morphometric data for *Brachyhypopomus draco*.

| Character                                 | Holotype | n  | Minimum | Maximum | Mean | 95% confidence limit |       | SD    |
|---|----------|----|---------|---------|------|----------------------|-------|-------|
|   |          |    |         |         |      | L1                   | L2    |       |
| Length to the end of anal fin (mm)        | 137.3    | 44 | 50      | 151.9   | 96.9 |                      |       | 24.55 |
| Percents of length to the end of anal fin |          |    |         |         |      |                      |       |       |
| Head length                               | 10.1     | 44 | 9.4     | 14.2    | 11.4 | 11.08                | 11.69 | 1.00  |
| Caudal filament length                    | 29.1     | 34 | 17.3    | 35.2    | 25.1 | 23.32                | 26.86 | 5.15  |
| Snout to anal fin origin                  | 18.3     | 44 | 17.9    | 23.0    | 20.3 | 19.93                | 20.70 | 1.27  |
| Depth of caudal filament                  | 2.7      | 44 | 1.4     | 3.1     | 2.1  | 2.01                 | 2.24  | 0.38  |
| Longest anal fin ray                      | 3.7      | 43 | 2.9     | 4.4     | 3.6  | 3.52                 | 3.73  | 0.34  |
| Longest pectoral fin ray                  | 4.1      | 41 | 4.1     | 5.8     | 5.0  | 4.85                 | 5.16  | 0.50  |
| Body depth                                | 9.4      | 44 | 8.8     | 12.2    | 10.8 | 10.52                | 11.08 | 0.92  |
| Percents of head length                   |          |    |         |         |      |                      |       |       |
| Snout length                              | 26.5     | 50 | 20.7    | 30.0    | 25.6 | 25.12                | 26.08 | 1.68  |
| Gape width                                | 14.5     | 50 | 9.5     | 16.5    | 13.7 | 13.32                | 14.14 | 1.45  |
| Orbital diameter                          | 9.5      | 50 | 9.4     | 14.4    | 12.3 | 11.90                | 12.64 | 1.30  |
| Interorbital distance                     | 23.4     | 50 | 22.7    | 35.0    | 28.4 | 27.60                | 29.25 | 2.91  |
| Posterior nare to eye                     | 3.4      | 49 | 2.9     | 5.4     | 4.2  | 4.04                 | 4.34  | 0.52  |
| Branchial aperture                        | 23.3     | 50 | 16.5    | 26.0    | 19.9 | 19.31                | 20.44 | 1.99  |
| Head width at operculum                   | 54.1     | 50 | 48.4    | 65.0    | 57.0 | 55.96                | 57.96 | 3.50  |
| Head width at eyes                        | 37.2     | 50 | 31.3    | 45.6    | 39.9 | 39.09                | 40.63 | 2.71  |

line and clearing ventrally. A highly variable number of dark brown bands, well delineated or not, nearly perpendicular or oblique to longitudinal body axis, running posterodorsally from base of anal-fin rays to nearby lateral line and occurring from head to tip of caudal filament. Anal and pectoral-fin rays speckled brown, with hyaline inter-radial membranes. Adults and juveniles exhibit the same coloration pattern.

**Secondary sexual dimorphism.** During reproductive period, established through monthly variation analysis of male and

female gonads in a *B. draco* population, males undergo hypertrophy of the distal portion of caudal filament (Fig. 2). This has been observed between August and December in a population studied from the type-locality (A. Schaan, J. Giora and C. Fialho, in preparation). Extremely vertical broadening and lateral compression give the caudal filament a paddle-like shape. After the reproductive period, this structure regresses until the caudal filament resembles those of females and juveniles. In addition, adult males are significantly larger than females.



**Fig. 2.** *Brachyhypopomus draco* (holotype, MCP 41540, male, 137.3 mm LEA). Detailed images of head, above, and tail, below.

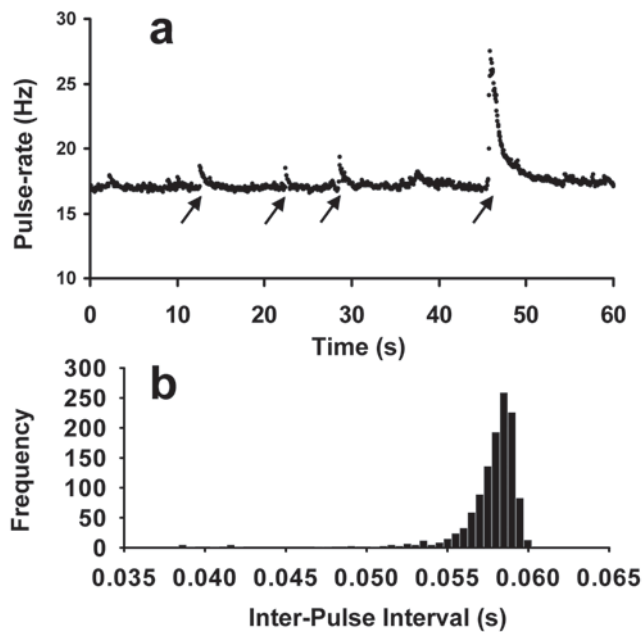
**Electric organ discharge.** *Brachyhypopomus draco* generates a continuous train of pulse-type EODs. Adult specimens (with developing or fully developed gonads) (72.6-105 mm LEA) exhibited the following EOD parameters. The mean EOD repetition rate (per individual) during the day ranged from 15.7-24.6 Hz (mean among all specimens, 19.6 Hz, SD 2.5, n = 11 individuals fishes), with a standard deviation (SD) of 0.4-1.2 Hz (mean 0.7, SD 0.3, n = 11), and coefficient of variance of 1.8-7.0 % (mean 3.9 %, SD 1.88, n = 11). The lowest and highest absolute pulse rates recorded from all diurnal recordings were 13.7 and 29.2 Hz respectively. During the hours of peak foraging activity, 1-3 hours after sunset, the mean EOD repetition rate (per individual) ranged from 34.2-45.8 Hz (mean among all specimens 38.6 Hz, SD 5.2, n = 6) with a standard deviation of 2.8-10.8 Hz (mean 2.9, SD 1.1, n = 6) and a coefficient of variation of 8.3-27.3 % (mean 20.7 %, n = 6). The lowest and highest absolute pulse rates recorded from all nocturnal recordings were 8.4 and 80.2 Hz respectively.

In sum, adult specimens of *B. draco* exhibited a distinct increase in pulse rate from the resting day-time state (mean 19.6 Hz) to the nocturnal active state (mean 38.6 Hz). The coefficient of variation of pulse rate during nocturnal activity (mean 20.7 %) was considerably higher than during the day (mean 3.9%) reflecting the greater variability in pulse rate

during foraging. Disturbances such as minor vibrations provoked novelty responses, sudden increases in the resting pulse rate from the baseline rate (Fig. 3). The approximately stable resting diurnal EOD punctuated by novelty responses results in a right-skewed distribution of inter-pulse intervals in a histogram (Fig. 3). Some specimens of *B. draco* displayed spontaneous complete cessations of the EOD for periods of up to 1 minute. Normal EOD activity was resumed after these interruptions.

The EODs waveforms of adult specimens of *B. draco* comprised two components of alternating polarity (P1 and P2) *sensu* Crampton & Albert (2006), and varied in duration from 1.172–1.992 ms (mean 1.578, SD 0.147,  $n = 23$ ) (Fig. 4). The Peak Power Frequency (PPF) (see Fig. 4) of these EODs varied from 0.6958–0.8942 kHz (mean 0.7707, SD 0.0534,  $n = 23$ ).

We did not encounter evidence for obvious sexual differences in the EOD waveforms of *B. draco*, despite evidence for this phenomenon in other species of *Brachyhypopomus* (e.g. *B. occidentalis*, Hagedorn, 1985, Shumway & Zelick,



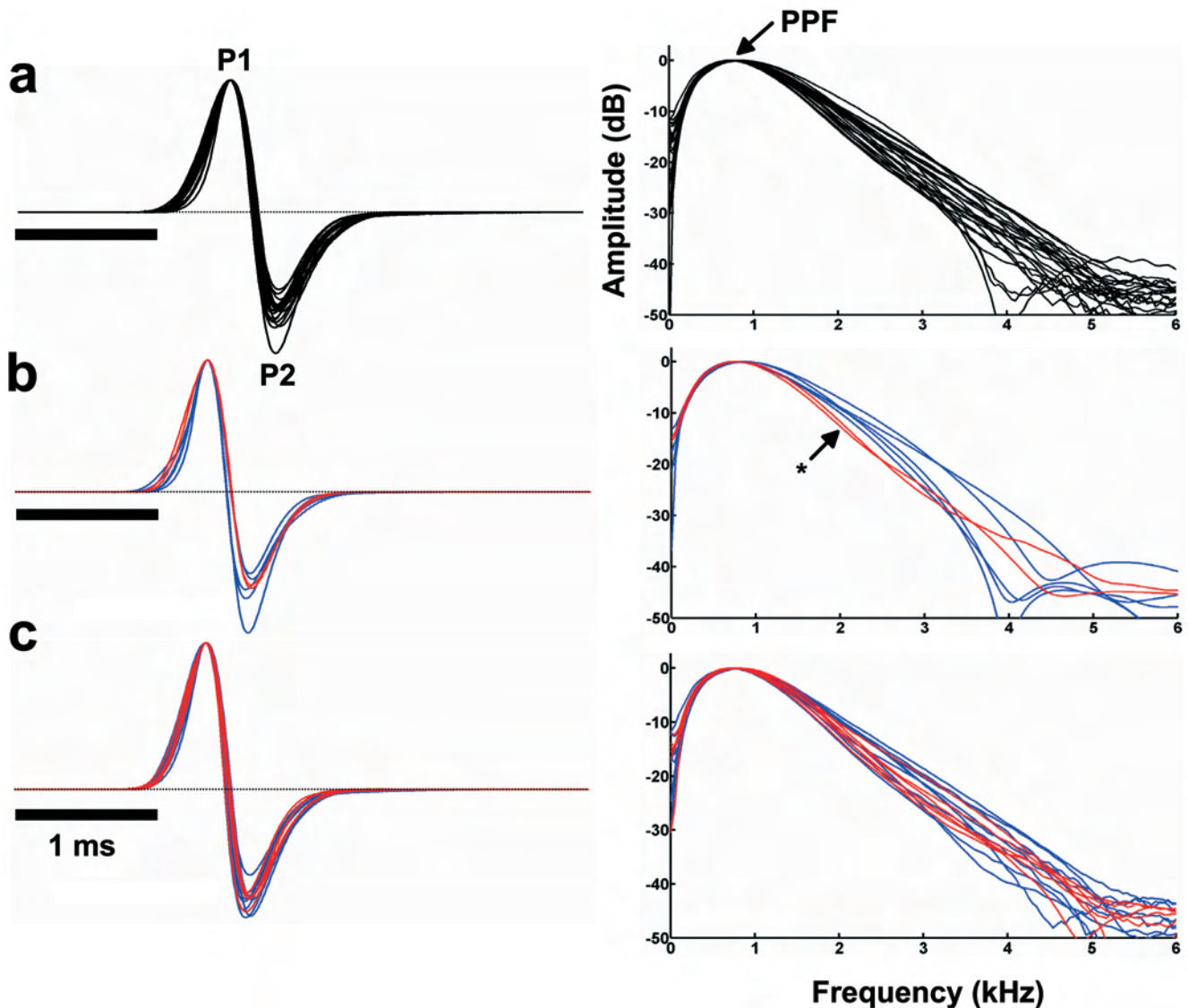
**Fig. 3.** **a.** Resting diurnal Electric Organ Discharge (EOD) repetition rate of a single specimen of *Brachyhypopomus draco* (UFRGS 6487). Repetition rate in Hz (pulses per second) is plotted for a 60 s recording. Each point represents the distance from an EOD to the preceding one (Inter-Pulse Interval, IPI). Note the intermittent upward modulations of repetition rate (arrows) in response to disturbances such as minute vibrations. These ‘novelty responses’ are a normal part of EOD activity in the wild. **b.** Histogram of 1218 IPIs for the 60 s recording, exhibiting a typical right-skewed distribution due to the novelty responses. Repetition rate (Hz) is the reciprocal of Inter-pulse interval (e.g.  $1/20 \text{ Hz} = 0.05 \text{ s}$ ).

1988; *B. pinnicaudatus* Stoddard *et al.*, 2003; *B. brevirostris*, Kawasaki & Heiligenberg, 1989, Crampton, 1996). Where a sexual difference exists, this is manifest as an elongation of the second negative waveform phase, P2 and a corresponding reduction in the PPF of the EOD. We observed no consistent EOD waveform shape differences. Likewise, we observed no significant difference between the PPF of five sexually mature males (0.7504–0.8942 kHz, mean 0.8178, SD 0.0675) and 2 sexually mature females (0.7385–0.7949 kHz, mean 0.7667, SD 0.0399) (2-sample T-test,  $df = 5$ ,  $n = 7$ ,  $P = 0.38$ ). The observation of a lower PPF in mature females than males contrasts with cases of sexual EOD differences in *Brachyhypopomus*, where sexually mature males invariably display lower PPFs. Nonetheless, we did note that the Spectral Power Densities of the two sexually mature females exhibited a more rapid decline from the PPF than in the five sexually mature males (Fig. 4). Males and females with developing gonads also exhibited no obvious difference in waveform shape, and no significant difference in the PPF (males: 0.6958–0.8362 Hz, mean 0.7518, SD 0.0460,  $n = 10$ ; females: 0.7111–0.8194 kHz, mean 0.7642, SD 0.0422,  $n = 6$ ) (2-sample T-test,  $df = 14$ ,  $n = 16$ ,  $P = 0.59$ ). All recorded specimens had been held in social isolation for several days before they were recorded. This is known to minimize the hormonally-induced modulation of the P2 phase in sexually mature males (Stoddard *et al.*, 2003). Further investigation is required to explore whether EOD differences emerge in males that are exposed to normal social stimuli (*i.e.* the presence of sexually mature conspecifics).

All recordings presented here were made during the southern summer (December) when ambient water temperature is typically in the range 24 – 30° C. During the winter, water temperatures in Rio Grande do Sul decline to as low as 10° C. We noted that these seasonal temperature changes have a significant impact on the waveform duration and shape of the EODs of *B. draco*. The PPF of the EOD declines substantially, and the P2 phase becomes diminished in relative amplitude. We will present detailed observations on this phenomenon elsewhere. Loureiro & Silva (2006) discuss the effect of temperature on the EODs of *B. bombilla*.

**Distribution.** *Brachyhypopomus draco* is widely known from central, southern and coastal regions of Rio Grande do Sul state, Brazil, and Uruguay. It is known from three drainages: laguna dos Patos, rio Uruguay and rio Tramandaí, and was also found at two localities in Paraguay (ANSP 170412; ANSP 175180; USNM 181483).

**Habitat.** *Brachyhypopomus draco* inhabits river edges, slow-moving creeks, lagoons and flooded areas with muddy or sandy bottom and abundant emergent or floating vegetation. The species was particularly abundant in the type locality, a lagoon (30°22'52.4"S, 51°01'25"W) inside a state preserved

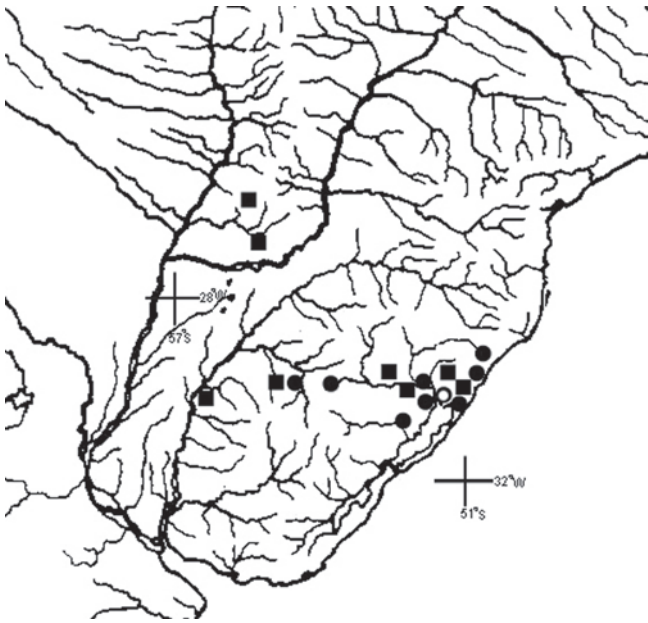


**Fig. 4.** Electric Organ Discharge (EOD) waveform (left) and Spectral Power Density (right) of adult specimens of *Brachyhypopomus draco* from Rio Grande do Sul state, Brazil. **a:** All 23 recorded specimens with developing or fully developed gonads (86–135 mm). **b:** 7 adult specimens with fully mature gonads; 5 male (blue) 2 female (red). **c:** 16 adult specimens with developing gonads; 10 males (blue), 6 females (red). EODs plotted with head positivity upwards, normalized to the amplitude of the dominant positive phase (P1), and aligned at the P1 peak. Scale bar = 1 ms. Spectral Power Densities (SPDs) were computed from a 65, 536-point Fast Fourier Transform and the Peak Power Frequency (PPF) scaled to 0 dB. Upper and lower ranges of the PPF are marked with arrows. Note the more rapid decline of the SPDs of the two sexually mature females versus males (labeled with asterisk in c) but no obvious sexual difference in EOD waveform shape or PPF.

area, Parque Estadual de Itapuã in Rio Grande do Sul, Brazil. The lagoon is approximately 4 hectares in area and reaches 1 meter in depth. It has a muddy bottom, abundant macrophytes and vegetal material in various stages of decomposition, and is surrounded by psammophilous forest with strong vegetational influence from Atlantic forest formations (Fig. 6). At the type locality, *B. draco* was found occurring together with an undescribed *Gymnotus* (Crampton *et al.*, in prep.). At other collecting sites throughout Rio Grande do Sul state the spe-

cies was collected along with the gymnotiforms *Eigenmannia trilineata*, *B. bombilla* and another undescribed *Brachyhypopomus* species (see Comparative Material).

**Etymology.** Name “draco”, from the Greek “drakon” meaning dragon, in reference to the shape of distal portion of caudal filament in mature males, similar to that illustrated in these imaginary creatures.



**Fig. 5.** Map of Southern Brazil, Uruguay, Argentina and Paraguay with the distribution of *Brachyhypopomus draco*. Squares represent non-type specimens. Empty circle represents the type locality.

### Discussion

The new species is referred to the genus *Brachyhypopomus*, since it conforms to diagnoses of the genus proposed by Mago-Leccia (1994) and Albert (2001). The new species lacks a mesocoracoid bridge, presents a short snout, a short and crescent-shaped maxillary bone, and posterior nares closer to eyes than to snout tip, as proposed in Mago-Leccia's (1994) diagnosis.

Albert (2001) considered the characters used by Mago-Leccia (1994) ambiguous in his analysis, and proposed four other characters to diagnose the genus. *Brachyhypopomus draco* possesses two of these: the premaxilla gracile with a curved anterior margin and forming a distinct angle with the maxilla in lateral view, and the dentary gracile. The two other characters used by Albert (2001) were the presence of a single transitional vertebra and body cavity with 16-17 precaudal vertebrae (20-21, with the addition of C1-C4).

We observed 21-23 precaudal vertebrae in *B. draco* (20-22 anterior, 1-2 transitional;  $n=6$ ). The number of transitional vertebrae exhibited variability, with three of six specimens bearing one transitional vertebra; two bearing one transitional vertebra, and one vertebra associated to a rib (but not completely developed, and not attached to the vertebra); and one bearing two transitional vertebrae. Variability in the number of precaudal and transitional vertebrae has also been observed in *B. bombilla* (Loureiro & Silva, 2006).



**Fig. 6.** Typical habitat of *Brachyhypopomus draco*; marshland in the Parque Estadual de Itapuã, Rio Grande do Sul, Brazil.

From a study of both morphological and molecular sequence data, Sullivan (1997) diagnosed five species groups within *Brachyhypopomus*, discussed later by Albert (2001): the *B. brevirostris* group, consisting of *B. brevirostris* and one undescribed species; the *B. beebei* group, including *B. beebei*, *B. pinnicaudatus*, *B. janeiroensis*, and two undescribed species, and the *B. occidentalis* group, including *B. occidentalis* and *B. diazi*. Within the *B. beebei* species group, two subgroups were established: one clade consisting of two undescribed species, and another consisting of *B. beebei* and *B. pinnicaudatus*. *Brachyhypopomus draco* can be included in the *B. beebei* species group, sharing all the group characteristics: lower jaw equal to upper jaw; ventral ethmoid reduced; fourth supraorbital lateral line pore close to vertical through posterior nares; and supraorbital lateral line canal not attached to frontal rostral to the orbit. Nevertheless, *B. draco* cannot be included in any of the *B. beebei* subgroups because it does not share any of their characteristics.

Although *B. draco* is more closely related to *B. beebei*, *B. pinnicaudatus*, and *B. janeiroensis*, included in the *B. beebei* group, it can be easily distinguished from these species. In addition to the presence of the paddle-shaped tail in mature males and the morphometric and meristic characters presented in diagnosis, the coloration pattern of *B. draco* also differs from these *Brachyhypopomus* species. According to the diagnoses presented by Sullivan (1997), *B. beebei* has a narrow depigmented stripe running along the posterior half of upper dorsum, *B. pinnicaudatus* has a nearly solid dark brown pigment over the dorsum broken by fine unpigmented reticulations, and *B. janeiroensis* lacks lateral bands along sides of the body in mature individuals. All these color patterns diverge from *B. draco* that presents a dark brown dorsal surface with a variable number of darker bands, nearly perpen-



dicular or oblique to the longitudinal body axis. Moreover, the clade consisted of *B. beebei* and *B. pinnicaudatus* is diagnosed by the presence of a tiny hook-like ossification medial to first branchiostegal ray (Sullivan, 1997; Albert, 2001), which is absent in *B. draco*.

The undescribed species referred herein as occurring in Rio Grande do Sul can also be diagnosed from *B. draco* by the lack of a paddle-shaped distal portion of caudal filament in mature males, and by the coloration pattern, showing dorsal surface of the body with chocolate-brown stains that form a reticulated drawing contrasting with a yellow background. Furthermore, *B. draco* has the anal-fin origin located posterior to posterior edge of the pectoral fin (*versus* anal-fin origin located at the same line of posterior edge of the pectoral fin in the undescribed species).

**Comparative material.** *Brachyhypopomus bombilla*: ZVC-P 6287, Holotype, Uruguay, Rocha Departamento, rio Cuatro Palmas; ZVC-P 5688, 1, Paratype, Uruguay, rio Quebracho; ZVC-P 5686, 10, 3cs, Uruguay, Rocha Departamento, rio San Luiz; ZVC-P 5685, 1, Uruguay, Tacuarembó Departamento, rio Batovi; UFRGS 9282, 15, UFRGS 9273, 18, UFRGS 9284, 17, UFRGS 6741, 1, UFRGS 6742, 1, UFRGS 6745, 1, UFRGS 6496, 1, UFRGS 6495, 1, Brazil, Rio Grande do Sul, Rosário do Sul; *Brachyhypopomus jureiae*: DZUFMG 011, 2, Paratype, Brazil, São Paulo, rio do Descavado, Juréia Ecological Station; *Brachyhypopomus pinnicaudatus*: ANSP 163463, Holotype, 1, French Guiana; ANSP 163464, Paratype, 1, French Guiana; USNM 301966, Paratype, 1, French Guiana; USNM 301967, Paratype, 1, French Guiana; USNM 301968, 1, French Guiana; UMMZ 216032, Paratype, 3, French Guiana; *Brachyhypopomus* sp.: UFRGS 6520, 1, UFRGS 6524, 1, UFRGS 8932, 1, Brazil, Rio Grande do Sul, Viamão, Parque Estadual de Itapuã, lagoa Negra; UFRGS 2219, 2, Brazil, Rio Grande do Sul, Santo Antônio da Patrulha; UFRGS 3844, 2, Brazil, Rio Grande do Sul, Capão da Canoa, lagoa dos Quadros; UFRGS 6499, 1, UFRGS 6503, 1, UFRGS 6504, 1, UFRGS 6505, 1, Brazil, Rio Grande do Sul, São Gabriel.

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