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Gymnotus chimarrao, a new species of electric fish (Gymnotiformes: Gymnotidae) from Southern Brazil

Diego Cognato*, Mathilde M. Richer-de-Forges, James S. Albert** and William G. R. Crampton*****

Gymnotus chimarrao, new species, is described from Arroio Grande, an affluent of the Rio Taquari, in the Rio Jacuí basin, Rio Grande do Sul, Brazil. It is distinguished by features of external morphology, meristics, pigmentation, osteology and electric organ discharge (EOD). *Gymnotus chimarrao* differs from all congeners except some specimens of *G. ardilai* in that the oblique dark pigment bands are either extremely faint or hard to distinguish from the ground color. *Gymnotus chimarrao* also differs from all congeners south of the Amazon basin in a unique combination of measurements or observed morphological characters, such as body proportions and the number of cephalic laterosensory pores.

Gymnotus chimarrao, espécie nova, é descrita do Arroio Grande, afluente do rio Taquari na bacia do rio Jacuí, Rio Grande do Sul, Brasil. Ela pode ser distinguida com base em características de morfologia externa, dados merísticos, pigmentação, osteologia e descarga do órgão elétrico (DOE). *Gymnotus chimarrao* difere de todos os seus congêneres exceto alguns exemplares de *G. ardilai* por ter as bandas escuras orientadas obliquamente muita fracas e difíceis de distinguir da cor de fundo. *Gymnotus chimarrao* também difere de seus congêneres encontrados no sul da bacia Amazônica por uma combinação única de caracteres morfológicos que podem ser medidos ou observados, tais como proporções corporais e número de poros cefálicos.

Introduction

The species of the Neotropical electric fish genus *Gymnotus* are aggressive and nocturnal gymnotiform fishes distributed in shallow freshwater habitats from Southern Mexico to Argentina. Members of the genus are readily recognizable by the presence of a superior mouth with a prognathous lower jaw, and by oblique bands along the body (Albert et al., 2004). *Gymnotus* generate weak pulsed electric organ discharges (EODs) for electrolocation and communication (Caputi, 1999, 2005).

Gymnotus has undergone substantial taxonomic revision in recent years, with the number of described species increasing from nine in 1994

* Departamento de Zoologia, Laboratório de Ictiologia, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, 9500, 90540-000 Porto Alegre, RS, Brazil.
** Department of Biology, University of Louisiana at Lafayette, Lafayette, 70504-2451, USA.
*** Department of Biology, University of Central Florida, Orlando, 32816-2368, USA.
E-mail: crampton@mail.ucf.edu (corresponding author)

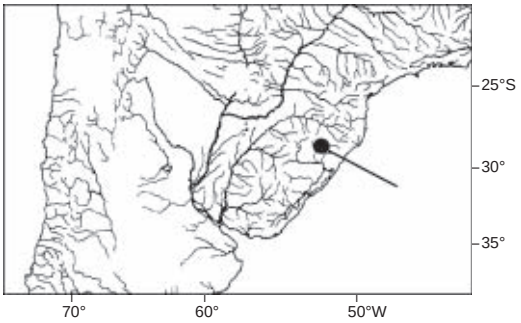

Fig. 1. Part of southern South America showing single known location of *Gymnotus chimarrao* in the Rio Jacuí basin of Rio Grande do Sul state, Brazil.

(Mago-Leccia, 1994) to 32 in 2004 (Albert et al., 2004; Crampton et al., 2005; Fernandes et al., 2005). Albert et al. (2004) provide a species-level tree for the genus based on morphological characters. This study recognizes three species-groups within the genus based on pigmentation, body proportions and counts. These are the *G. cylindricus*, *G. pantherinus* and *G. carapo* species-groups. Members of the *G. carapo* species-group, including the species described here, can be distinguished from species in the *G. pantherinus* and *G. cylindricus* species-groups by the possession of a clear or pale patch near the caudal end of the anal fin, and the presence of two laterosensory canal pores in the preopercular-mandibular series of the dorsoposterior portion of the preopercle (Albert et al., 2004). Of the 32 valid species of *Gymnotus*, 18 (56 %) are known from the Amazon basin, of which 13 are endemic (Crampton et al., 2005). Twenty species of *Gymnotus* (63 %) occur in drainages of the Amazon, Orinoco or coastal drainages of the Guyanas. South of the Amazon basin, only six species of *Gymnotus* have been described. Two species, *G. pantherinus* and *G. pantanal*, belong to the *G. pantherinus* species-group. *Gymnotus pantanal* is known from the upper Rio Paraná in the Pantanal wetlands of the Brazilian state of Mato Grosso and from the Río Paraguay in Paraguay. Populations with indistinguishable morphology to *G. pantanal* are also known from the Rio Guaporé drainage of the Amazon basin (Fernandes et al., 2005). *Gymnotus pantherinus* is restricted to coastal drainages of Brazil between Rio de Janeiro and northern Rio Grande do Sul (Campos-da-Paz, 1997; pers. comm.). The remaining four species (*G. bahianus*, *G. paraguensis*, *G. inaequilabiatus*, *G. sylvius*) belong to the *G. carapo* species-group. *Gymnotus bahianus* is endemic to coastal drainages of Brazil's north eastern state of Bahia. *Gymnotus paraguensis* is known from the Rio Paraguai in Brazil (Rio Nueva, Mato Grosso) and Paraguay (Río Itapua). *Gymnotus inaequilabiatus* is known from the southern portions of the Paraná-Paraguai basin and some coastal drainages of Uruguay and southeastern Brazil (Albert & Crampton, 2003). *Gymnotus sylvius* is known from coastal drainages of São Paulo state and the Rio Paraná basin (Albert et al., 1999; Albert & Crampton, 2003).

Many records of *Gymnotus,* from the Paraná-Paraguai-Uruguai drainages and from the coastal drainages of Brazil south of the mouth of the Amazon, are often indiscriminately listed in ecological studies and museum databases as *G. carapo*. However, Albert & Crampton's (2003) redescription of *G. carapo* restricted this species to the Amazon and Orinoco basins, coastal drainages of the Guyanas, and to the Parnaíba and Itapicuru basins of northeast Brazil. While some collections of *Gymnotus* can now be easily assigned to one of the four members of the *G. carapo* species-group listed above, several additional undescribed taxa resembling *G. carapo* are known from the Paraná-Paraguai-Uruguai drainages, and from coastal drainages of South East and Central Brazil (Crampton & Albert, 2006). We describe a new species of *Gymnotus* from the southernmost Brazilian state of Rio Grande do Sul.

Materials and methods

Specimens were captured at Arroio Grande in the Rio Taquari drainage (Rio Jacuí basin), near the town of Arroio do Meio, Rio Grande do Sul, Brazil (Fig. 1). All specimens were located with a device for detecting EODs, and then captured with a dip net. Measurements and counts follow Albert & Crampton (2003). All measurements were taken with digital calipers to the nearest 0.1 mm. Counts of precaudal vertebrae were taken from radiographs. Osteological data were taken from specimens cleared and stained following the technique described by Dingerkus & Uhler (1977). Size of specimens reported as total length (TL) in mm from tip of chin to tip of tail. Morphometric measurements reported as percentages of TL were not taken from specimens with caudal filaments that exhibited signs of regeneration following earlier damage. Institutional

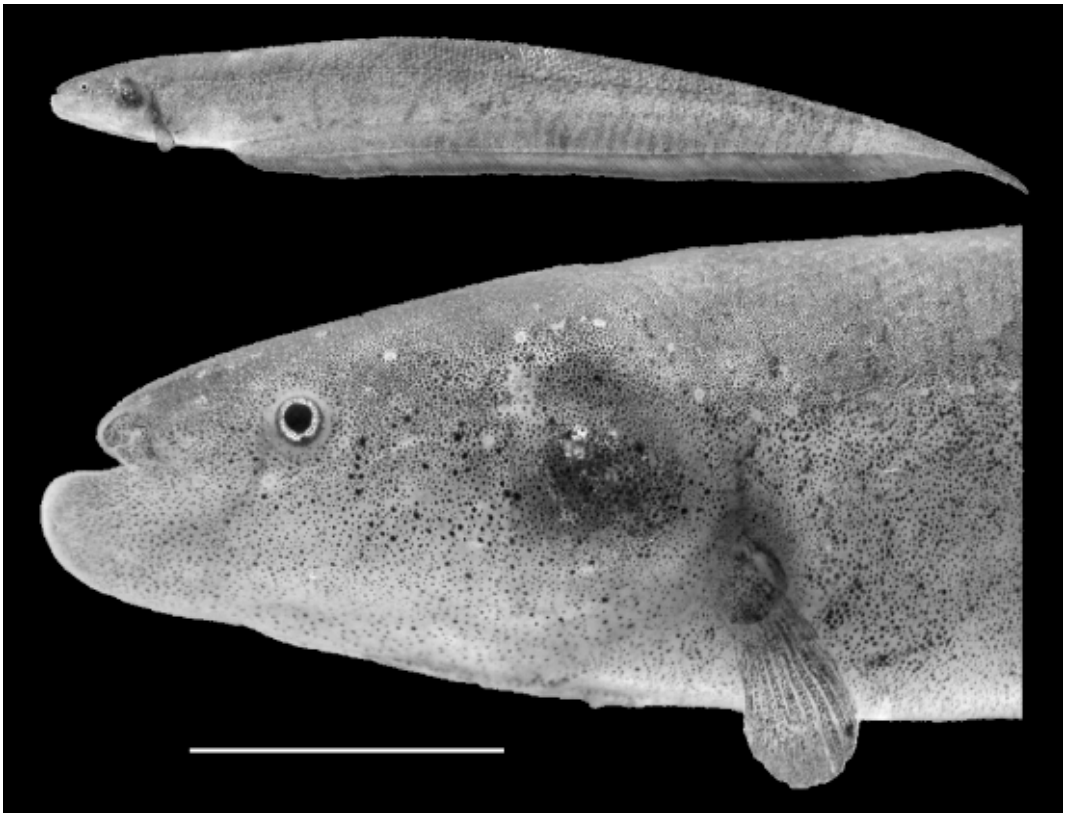

Fig. 2. *Gymnotus chimarrao*, holotype, UFRGS 6774, 118.4 mm TL; Brazil: Rio Grande do Sul: Rio Jacuí basin. Scale bar 10 mm.

abbreviations follow Leviton et al. (1985).

Electric Organ Discharge (EOD) recording methods follow Crampton et al. (2005). Each fish was held in an aquarium filled with water from the capture locality and held at 27 ± 0.2 °C for at least 12 hours before the recording. All recordings were taken at 27 ± 0.1 °C. Signals were picked up from silver/silver-chloride electrodes placed posterior and anterior to the fish and with a ground contact in the center. The electrodes were connected to a custom-built AC-coupled differential amplifier with a frequency response of ±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. All signal analyses were conducted using custom-written MATLAB software designed by W. Crampton. EOD durations were calculated with the beginning and end of the EOD taken at a 2 % threshold of the amplitude of the dominant positive phase (P1) following normalization to the P1 amplitude. Calculations of EOD repetition rate are taken by measuring all successive inter-pulse intervals over one minute recordings.

Gymnotus chimarrao, new species
(Fig. 2)

Holotype. UFRGS 6774, immature male, 118.4 mm; Brazil: Rio Grande do Sul State: Arroio do Meio, Arroio Grande, Taquari Drainage, 29°21'09"S 51°57'28"W, altitude 54 m above mean sea level; D. Cognato, J. Giora, D. Rocha & M. Majolo, 17 March 2004.

Paratypes. UFRGS 6770, immature female, 191 mm; UFRGS 6771, immature male, 237 mm; UFRGS 6772, immature female, 177 mm; UFRGS

6773, immature male, 206 mm; UFRGS 6775, immature male, cleared and stained, 193 mm; UFRGS 6776, immature male, 124 mm; collected with holotype.

Diagnosis. *Gymnotus chimarrao* differs unambiguously from all 32 congeners except for some specimens (over 300 mm) of *G. ardilai* (from the Río Magdalena drainage in northwest South America) in possessing a pigmentation pattern in which the oblique dark-pigmented bands are faint, and difficult to distinguish from the ground color (Fig. 2). *Gymnotus chimarrao* differs from *G. ardilai* in possessing a shallower body depth (7.4-9.1 % TL [mean 8.2] vs. 11.4-13.2 [12.3]). In addition to the pigmentation differences described above, *G. chimarrao* differs from all species in the *G. pantherinus* species-group (and is placed in the *G. carapo* species-group) by the presence of two (vs. one) laterosensory canal pores in the preopercular-mandibular series of the dorsoposterior portion of the preopercle. Moreover, *G. chimarrao* differs from all species in the *G. carapo* species-group that occur south of the Amazon basin except *G. inaequilabiatus* in possessing a much shallower body depth (7.4-9.1 % TL [mean 8.2, n = 6] vs. 8.9-11.6 [mean 11.1, n = 21] in *G. bahianus*, 9.8-10.3 [mean 10.1, n = 4] in *G. paraguensis*, and 10.3-13.1 [mean 11.7, n = 3] in *G. sylvius*). *Gymnotus chimarrao* further differs from *G. inaequilabiatus* in possessing a substantially narrower head (53.1-59.3 % HL [mean 57.5, n = 6] vs. 65.3-72.0 [mean 67.8, n = 12]).

Table 1. Morphometric and meristic data for *Gymnotus chimarrao*. Total length and head length expressed in mm. Head length, body depth, body width, and anal-fin length as percentage of total length. Other measurements reported as percentage of head length. AVG = mean for morphometric data; median for meristic.

	min	max	N	mean
Total length (mm)	125	237	6	–
Head length (mm)	14.4	24.2	7	–
Percent of total length				
Head length	9.2	11.6	6	10.6
Body depth	7.4	9.1	6	8.2
Body width	4.8	6.6	6	5.7
Anal-fin length	80.6	82.6	6	81.7
Percent of head length				
Preorbital length	27.0	35.2	7	30.3
Postorbital length	55.7	61.6	7	59.1
Interorbital length	34.6	41.5	7	39.2
Head depth	59.1	65.5	7	62.7
Head width	53.1	59.3	7	57.5
Branchial opening	33.1	43.6	7	37.7
Pectoral fin length	34.5	47.3	7	40.5
Preanal length	82.7	87.1	4	84.6
Ratio body width/body depth	0.64	0.75	6	0.65
Meristics				
Bands	24	26	3	25
Scales above lateral line	6	7	7	6
Pored lateral line scales	82	94	3	88
Anal fin pterygiophore scales	8	9	7	8
Pectoral-fin rays	13	15	7	14
Anal-fin rays	180	213	4	196
Precaudal vertebrae	29	32	3	30

Description. Body shape and pigmentation illustrated in Fig. 2. Morphometric and meristic data presented in Table 1. Largest known specimen 237 mm. Size at maturity not known. Sexual dimorphism not known to occur (all specimens sexually immature). Lateral head profile conical, its dorsal portion flattened towards tip of snout. Mouth position superior, lower jaw longer than upper, rictus decurved. Mouth width large, extending beyond posterior naris. Eye position lateral, lower margin of eye slightly ventral to rictus. Anterior narial pore included within gape in large narial fold. Scales cycloid, ovoid, present on entire post-cranial portion of body from nape to tip of caudal appendage. Scales from lateral line to dorsal midline arranged in 6-7 rows. Scales over anal-fin pterygiophores at midbody arranged in 8-9 obliquely oriented rows.

Superficial skull bones (laterosensory canal bones, oral jaws, suspensorium) illustrated in Figure 3. Circumorbital laterosensory bones tubular, forming an ovoid series around eye in lateral view in which infraorbital canal contacts supraorbital canal at approximately a right or weakly acute angle. Premaxilla with 4-5 arrowhead-shaped teeth anteriorly, additional 7-8 conical teeth posteriorly arranged in single row along oral margin. Maxillary orientation vertical. Maxilla rod-shaped with straight dorsal and ventral margins, and narrow distal portion. Maxilla-palatine articulation located near anterior tip of endopterygoid (= mesopterygoid). Maxilla length equal to about width of 7-9 dentary teeth. Dentary with 2-4 arrowhead-shaped teeth anteriorly, additional 10-13 conical teeth posteriorly in a single row along oral margin. Dentary ventral posterior process shorter than dorsoposterior process; dorsoposterior process narrow distally.

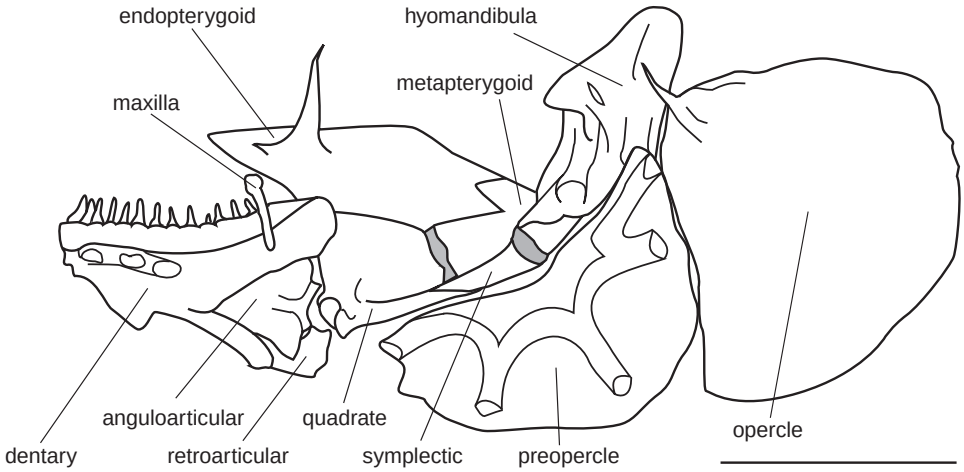

Fig. 3. *Gymnotus chimarrao*, UFRGS 6775, 193 mm TL; lateral view of suspensorium. Grey shading: cartilage. Scale bar 5 mm.

Dentary ventral margin with large lamella, greater than width of ventral posterior process. Dentary without hook-shaped process near mental symphysis. Anguloarticular ventrolateral lamellae expanded, extending over retroarticular. Anguloarticular posterodorsal process long, extending beyond ventral margin of dentary. Retroarticular posterior margin square. Endopterygoid ascending process straight and robust, its base greater than its length, reaching more than half distance to neurocranium and with simple apical tip. Metapterygoid superior (dermal) portion small, ossified to less than anterior margin of ventral (endochondral) portion. Hyomandibula with two separate foraminae on dorsolateral surface for passage of supraorbital and infraorbital trigeminal nerve rami. Hyomandibula with foramen at posterodorsal margin for passage of posterior lateral line nerve. Preopercle with two dorsoposterior laterosensory pores, anterior notch, and broad median shelf extending more than half the width of symplectic. Opercle dorsal margin convex, posterior margin rounded, smooth, entire. Interopercle with anterior ascending process. Subopercle dorsal margin concave.

Neurocranium illustrated in Figure 4. Mesethmoid anterior margin concave with paired anterolateral processes. Mesethmoid neck narrow, about twice width of its anterolateral processes. Cranial fontanels closed in juveniles and adults. Frontal anterior margin straight, continuous with margins of adjacent roofing bones. Frontal postorbital process broad, more than two times width of supraorbital canal. Frontal broad, its width at posterior articulation of infraorbital series subequal to that of parietal. Lateral ethmoid absent. Vomer short, extending less than half distance to parasphenoid lateral process. Parasphenoid broad, its length less than 2.2 times its width. Parasphenoid posterior processes gracile, elongate, its posterior margin with deep convexity on midline. Parietal shape rectangular, its length less than its width. Pterosphenoid antero-ventral portion broad. Prootic foramenae for Vp and V2-3+VII separate. Gill rakers not ossified and not contacting gill bar. All basibranchials unossified. First basibranchial broad and triangular.

Pectoral girdle illustrated in Figure 5. Pectoral fin short to moderate in breadth and length, with four large cartilaginous radials, single large anterior unbranched ray, and 13-15 (mode 14) branched rays. Mesocoracoid proximal portion thin, its distal portion not ossified. Cleithrum broad, its ventral margin curved. Cleithrum anterior limb long, about twice length of ascending limb, and with an anterior notch. Cleithrum dorsoposterior facet small. Dorsal lateral line rami (DLR) absent in adults. Rib 5 robust along entire extent, less than three times width of rib 6. Hemal spines present. Displaced hemal spines absent. Length anal-fin pterygiophores slightly longer than hemal spines at midbody.

Single hypaxial electric organ, extending along entire ventral margin of body. Two to three (mode 3) tubes (or rows) of electroplates at anterior and posterior ends of anal fin.

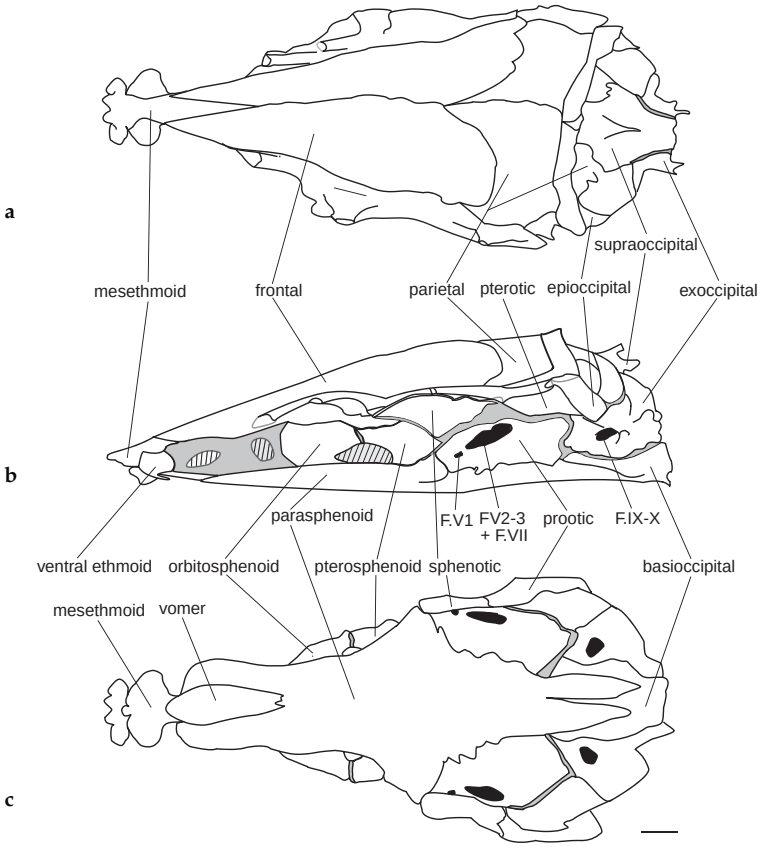

Fig. 4. *Gymnotus chimarrao*, UFRGS 6775, 193 mm TL; neurocranium. **a,** dorsal view; **b,** lateral view; **c,** ventral view. Uniform grey shading: cartilage. Hatching: apertures. Uniform black shading: foraminae (F), named by cranial nerve. Scale bar 1 mm.

Color in alcohol. Ground color brownish dorsal to lateral line, with vertical bands hardly visible or absent in all specimens. Ground color olive green or green-yellow ventral to lateral line, with darker vertical bands very faint or absent. Vertical bands in anterior portion of body mostly oblique and narrow, becoming wider and perpendicular to long axis posteriorly. Ground color of head dark grey, inferior portion clearer than superior portion. Anal-fin rays and pectoral-fin rays dark brown, with pale hyaline membranes. Posterior one fifth of anal fin completely hyaline (rays and membrane).

Electric Organ Discharge. *Gymnotus chimarrao* generates EODs as discrete three-phase pulses of 1.248-1.981 msec duration (mean 1.747, n=7) (Fig. 6). First negative phase (P0) comprises two components that may correspond to the phases 'V1' and 'V2' in studies of *G. "carapo"* from Uruguay (review in Caputi, 1999). First positive phase (P1) and second negative phase (P2) correspond to phases V3 and V4 respectively from Caputi (1999). Peak Power Frequency (PPF) of the Fourier Transform of EODs 1.110-1.255 kHz at 27 °C (mean 1.208, n=7). Mean resting day time EOD repetition rate for 1 minute recordings 19.2-27.2 Hz at 27 °C (mean 25.07, n=7). Standard deviation pulse rate for 1 minute recordings 0.352-0.951 Hz (mean 0.6011, n=7); coefficient of variation ((standard deviation/mean) × 100) for 1 minute recordings 1.481-3.503 Hz (mean 2.358, n=7).

Ecology. Known from a small stream (1.5 m width) running through gallery forest in low hills (altitude 54 m above mean sea level). Substrate of stream mud and sand. All specimens captured

from marginal grasses rooted to the bottom of the stream in areas sheltered from the stream flow (negligible current). Water was stained dark. Conductivity at capture site 107 $\mu S \cdot cm^{-1}$, temperature 24.1 °C.

Distribution. Known only from Arroio Grande in the Rio Taquari Drainage, Arroio do Meio, Rio Grande do Sul, Brazil (Fig. 1).

Etymology. Named for *chimarrão*, the traditional mate tea *(Ilex paraguariensis)* of Rio Grande do Sul State, Brazil, and neighboring countries. Live specimens of *G. chimarrao* exhibit olive green ground coloration reminiscent of the color of the dried tea leaves. A noun in apposition.

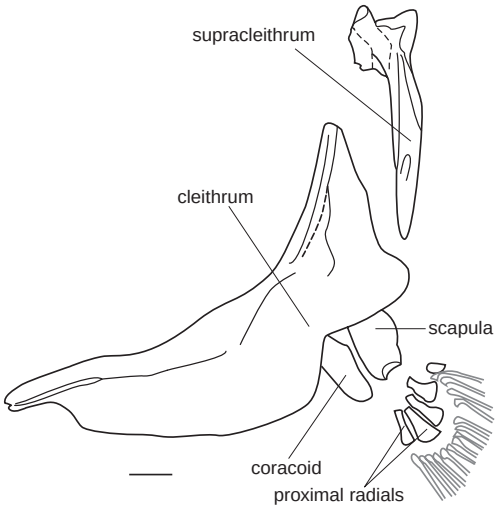

Fig. 5. *Gymnotus chimarrao*, UFRGS 6775, 193 mm TL; lateral view of pectoral girdle. Dashed line of supracleithrum represents canal bone of posterior lateral line. Dashed line on cleithrum represents depth of supracleithrum facet (not visible from lateral view). Scale bar 1 mm.

Comparative material. Here we list only species that occur to the south of the Amazon basin. Further materials examined used for the diagnoses are listed in Albert & Crampton (2003), Crampton et al. (2005), Maldonado-Ocampo & Albert (2004), and Fernandes et al. (2005).

Gymnotus bahianus: Brazil: MCP 18110, 2, 2 C&S, 90-92 mm TL; Minas Gerais, Rio Jequitinhonha, Padre Paraiso. – MCZ 9386, 7, 89-219 mm TL; Rio de Janeiro, fazenda Santa Cruz. – MCZ 9373, 15, 117-210 mm TL; Rio de Janeiro, Rio Itabapoana at Itabapoana.

G. cf. *inaequilabiatus*: Brazil: MCP 6956, 1, 602 mm TL; Rio Grande do Sul, Rio Uruguai Santana Velha, Uruguaiana. – MZUSP 46001, 1, 998 mm TL; São Paulo, Porto Primavera, Paraná. – MZUSP 51268, 1, 270 mm TL; São Paulo, Rio Capivara, affluent do Rio Paranapanema, South East Atlantic.

G. pantanal: Brazil: MZUSP 67874, holotype, 196 mm TL; Mato Grosso do Sul State, Rio Miranda. – MZUSP 67876, 2 paratypes, 189-264 mm TL; Mato Grosso do Sul State, Rio Paraguai. – MZUSP 67876, 1, 251 mm TL; Mato Grosso do Sul State, Rio Paraguai. – MZUSP 67875, 1, 192 mm TL; Mato Grosso do Sul State, Rio Paraguai. Paraguay: UMMZ 206080, 21, 82-260 mm TL; Arroyo in Parque Nacional Ybycui, Río Paraguay. – UF 38173, 1, 192 mm TL; Dept Cochabamba, Province Chaparé, Río Espiritu, Chaparé-Mamoré drainage, brook at village Tunari, elevation 350 m. – NRM 42397, 1, 171 mm TL; Río Paraguay. – NRM 42830, 1, 240 mm TL; Río Paraná.

G. pantherinus: Brazil: MCP 20666, 6, 106-171 mm TL; Minas, Padre Paraiso, Arrio afluente do Rio Jequitinhonha em São Joaninho, near Santo Antonio. – USNM 297939, 6, 49-116 mm TL; Paraná, Rio do Praia, near

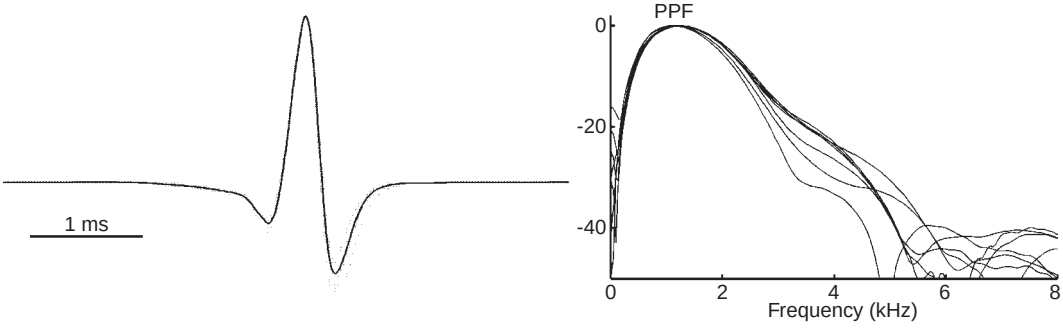

Fig. 6. Electric Organ Discharge (EOD) waveform (left) and Power Spectral Density (PSD) (right) for seven specimens of *Gymnotus chimarrao* (UFRGS 6770-6776). EODs plotted (gray) with head-positivity upwards, normalized to amplitude of dominant positive phase (P1), and aligned at P1 peak. Averaged EOD plotted black. PSDs computed from a 32,768-point Fast Fourier Transform and Power Frequency (PPF) scaled to 0 dB.

Guaratuba. – MCP 18108, 1, 170 mm TL; Rio de Janeiro, Rio Macae 5 km W Lumiar. – USNM 297933, 6, 21-242 mm TL; São Paulo, blackwater stream at km 56, NW Cananeia. – LGP 932, 1, 1 C&S, 136 mm TL; São Paulo, near Itanhaem, affluent of Rio Preto. – MZUSP 51670, 1, 160 mm TL; São Paulo, Santa Fe, affluent Paraibo do Sul, Jacareí.

G. paraguensis: Brazil: FMNH 108546, 1, 164 mm TL; Mato Grosso do Sul, Aquiduana, Rio Nueva in Brejo do Santo Sofia. – MUSM 16975, 2, 78-114 mm TL; Mato Grosso do Sul, Corre 60 São Joao. – MUSM 17114, 1, 82 mm TL; Mato Grosso do Sul, Rio Vermelho. Paraguay: NRM 42380, 1, 240 mm TL; Canindeyu, Río Paraná, Río Paraná at Saltos del Guaira. – UMMZ 206155, holotype, 222 mm TL; Paraná, Arroyo Tembley, near San Rafael. – UMMZ 240700, 1 paratype, 193 mm TL; Paraná, Arroyo Tembley, near San Rafael.

G. sylvius: Brazil: LIUSP P2468, 1, 209 mm TL; São Paulo, Chapecó. – LIUSP P2454, 1, 271 mm TL; São Paulo, Chapecó. – LIUSP P2346, 1, 1 C&S, 160 mm TL; São Paulo, Jacareí. – LIUSP P2338, 1, 1 C&S, 180 mm TL; São Paulo, Jacareí. – LIUSP P2333, 1, 219 mm TL; São Paulo, Jacareí. – LIUSP P2336, 1, 175 mm TL; São Paulo, Jacareí. – LGP 925.1, holotype, 259 mm TL; São Paulo, Miracatu, Ribeira de Iguape. – LGP 925.2, 2 paratypes, 251-307 mm TL; São Paulo, Miracatu, Ribeira de Iguape. – UMMZ 234347, 2 paratypes, 255-271 mm TL; São Paulo, Miracatu, Ribeira de Iguape. – LGP 931, 1, 157 mm TL; São Paulo, São Simão, Rio Tamandua, Pardo.

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