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Redescription of *Gymnotus coatesi* (Gymnotiformes, Gymnotidae), a Rare Species of Electric Fish from the Lowland Amazon Basin, with Descriptions of Osteology, Electric Signals and Ecology

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***Gymnotus coatesi*, a small and rare species of Neotropical electric fish, was originally described by LaMonte from material collected in Pará, Brazil, in 1934. The senior author discovered populations of this species in the vicinity of Tefé, Amazonas, Brazil, and near Iquitos and Jenaro Herrera in the lowland Upper Amazon of Peru. We provide a formal redescription of this species and describe external morphology, osteology, ecology, and electric signals, with emphasis on the Tefé population. *Gymnotus coatesi* can be distinguished from all congeners by a unique banding pattern and by a unique combination of morphometric and meristic characters. *Gymnotus coatesi* is known from localities along the main stem of the Amazon River from near the confluence of the Río Marañon with the Río Ucayali (Loreto, Peru) to the Rio Tocantins (Pará, Brazil) but is poorly represented in museum collections. In the Tefé region, *G. coatesi* inhabits the seasonally flooded lower courses of terra firme rain-forest streams. In the Peruvian Amazon, it also occurs in the upper, non-flooded, reaches of rainforest streams.**

***Gymnotus coatesi* é uma espécie rara e de pequeno porte de peixe elétrico neotropical, descrita originalmente por LaMonte em 1934, com base em material proveniente do Estado do Pará, Brasil. O primeiro autor descobriu populações desta espécie perto de Tefé, Amazonas, Brasil, e perto de Iquitos e Jenaro Herrera na Amazônia Peruana. Fornecemos uma redescrição formal da espécie e descrevemos a morfologia externa, osteologia, ecologia e sinais elétricos da mesma com ênfase na população de Tefé. *Gymnotus coatesi* diferencia-se inequívocamente das outras espécies do gênero por um padrão de pigmentação único e por uma combinação única de características morfométricas e merísticas. *Gymnotus coatesi* distribui-se ao longo do trecho principal do Rio Amazonas entre localidades perto da confluência do Río Marañon com o Río Ucayali (Loreto, Perú) e o Rio Tocantins (Pará, Brasil). Contudo, é representada por poucos exemplares em coleções zoológicas. Na região de Tefé *G. coatesi* ocorre exclusivamente nos trechos baixos e sazonalmente alagáveis de igarapés (riachos) de terra firme. Na Amazônia Peruana esta espécie ocorre também nos trechos altos e não alagáveis de riachos de terra firme.**

THE Banded Knife-Fish genus *Gymnotus* is a diverse and widespread group of weakly electric Neotropical fishes. Twenty-seven species of *Gymnotus* are currently recognized as valid (Albert and Crampton, 2003; Crampton and Albert, 2003; Crampton et al., 2003), and the number is rising quickly with the exploration of new regions and habitats of the Neotropics. Several species of *Gymnotus* described previous to Mago-Leccia's (1994) review of gymnotiform fishes are known only from short and relatively uninformative descriptions with brief diagnostic notes. Such incomplete descriptions routinely complicate the correct and prompt identification of these species in surveys and collections.

Recently, three species of *Gymnotus* have been redescribed: *Gymnotus cylindricus* from Middle America (Campos-da-Paz, 1996); the widespread and often misidentified type-species, *Gymnotus carapo* (Albert and Crampton, 2003), and *Gymnotus coropinae*, a small stream-dwelling species previously placed in the synonymy of *Gymnotus anguillaris* (Crampton and Albert, 2003). Here we redescribe *Gymnotus coatesi*, a poorly known and rare species originally described from the Amazon Basin by LaMonte (1935). Before Mago-Leccia's (1994) description of *Gymnotus pedanopterus* and *Gymnotus stenoleucus*, and the subsequent description of several other Amazonian species (Albert and Crampton 2001, 2003), many small, slender-bodied *Gymnotus* in museum holdings from the Amazon were labeled *G. coatesi*.

This redescription was prompted by the discovery of a population of *G. coatesi* in the vicinity of the town of Tefé, Brazil, near the confluence of the Rio Solimões (Amazon) with the Rio Japurá. This region contains an exception-

ally diverse fauna of electric fishes (e.g., Crampton, 1998a,b; Crampton et al., 2004) and the most diverse sympatric assemblage of *Gymnotus* known, with 11 species documented from within 50 km of Tefé (Albert and Crampton, 2001, 2003; Crampton and Albert, 2003).

Gymnotus coatesi was originally described by LaMonte (1935) from ''tropical fish tanks in charge of Mr. C. W. Coates at the New York Aquarium.'' The collector is cited as Carl Griem, and the locality simply as ''Amazon River, Brazil.'' In the same year, Brind (1935) published an article in an aquarium magazine on a ''Tiger Knife Fish,'' which he described as *Rhamphichthys cingulatus*. Campos-da-Paz (2000) compared the color descriptions and images presented in the two papers, concluded that LaMonte and Brind were referring to the same species from the same aquarium shipment, and designated *R. cingulatus* as a junior synonym of *G. coatesi*. Brind's article reveals more details about the precise collecting site and prompted Campos-da-Paz (2000) to assign a more precise type locality near Santarém, Pará.

We redescribe *G. coatesi* using features of external morphology, meristics, squamation, pigmentation, osteology, electric organ morphology and the electric organ discharge. We emphasize material from the Tefé region, from where ecological information, osteological data, and electric signals are available and also describe the geographical range of this species.

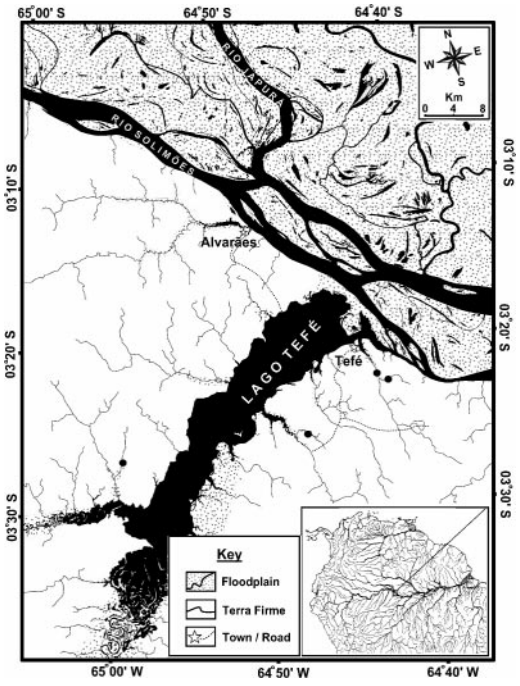

Fig. 1. Map of Tefé area, Brazil, showing collecting localities (black circles) of *Gymnotus coatesi*. Some symbols represent more than one collection record. All systems south of the Rio Solimões are nutrient-poor blackwater habitats of the Tertiary terra firme. All systems to the north are nutrient-rich Quaternary floodplain habitats. Base map traced from 1999 1:150,000 Landsat TM5 images. Extent of annual flooding plotted from June 1995 NASDA JERS-1 image.

Materials and Methods

Specimens and their electric organ discharges (EODs) were captured as part of a long-term multihabitat sampling program undertaken by the senior author near the town of Tefé, Brazil, between 1993 and 2002 (Fig. 1). Sampling was undertaken with dip-nets (0.3–0.4 m diameter, 2–4 mm mesh) and a portable electric-fish detector (Crampton et al., 2003). Additional material was examined from museum collections, for which abbreviations presented here follow Leviton et al. (1985) with the addition of MUSM (Museo de Historia Natural de la Universidad Nacional Mayor de San Marcos, Lima).

Morphometric data were measured using protocols described by Albert and Crampton (2001, 2003). Meristic and scale counts follow Albert and Crampton (2003). Osteological data were taken from specimens cleared and stained and dissected following Albert and Crampton (2003). Dissection methods, osteological nomenclature, and the preparation of osteological and cephalic sensory canal pore illustrations follow Albert and Crampton (2003). EOD recording techniques follow Crampton (1998a), and Campton et al. (2003a), but recordings were taken in water from source at ambient stream temperatures of 24–26 C.

The differential diagnosis is limited to salient characters that do not necessitate clearing and staining. *Gymnotus coatesi* is diagnosed here only from congeners of the *Gymnotus carapo* and *Gymnotus pantherinus* species groups (sensu Albert and Crampton, 2003) endemic to the Amazon and Orinoco Basins and to the Guyana Shield (geographical areas sensu Albert, 2001). Species in the *G. cylindricus* species-group are confined to Middle America where *G. coatesi* does not occur. Comparative morphometric and meristic data for the differential diagnosis are presented in Albert and Crampton (2003), Crampton and Albert (2003) and Crampton et al. (2003).

Gymnotus coatesi LaMonte
Figures 2–6

Gymnotus coatesi. LaMonte (1935):1–3, fig. 1. (photograph of live holotype) [type locality:

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Fig. 2. Photographs of *Gymnotus coatesi* from near Tefé, Brazil: (A) adult (MCP 34474); (B) juvenile (MCP 34472). Scale bar = 10 mm. Note diagnostic increase in pale band width from anal-fin base to dorsal midline in adult.

Amazon River, Brazil, 1934] Mago-Leccia (1994), p. 55, fig. 82 (photograph of head of preserved holotype) [review]. Albert and Campos-da-Paz (1998): 424 [review]. Albert (2001): 124 [review]. Campos-da-Paz (2000): 1114–1117, fig. 1 (drawing reproduced from Brind, 1935, fig. no numeration), fig. 2 (photograph of live Holotype reproduced from LaMonte, 1935, fig. 1) [amends type locality to Brazil, Pará, Rio Moju, approx. 02°25′S, 54°10′W, lists *Rhamphichthys cingulatus* as junior synonym]. Albert and Crampton (2001) 261–263 [comparative morphometric and meristic data, citation in diagnostic comments]. Albert and Crampton (2003):11–19 [comparative morphometric and meristic data]. Crampton and Albert (2003): 8 [citation in diagnostic comments].–Crampton et al. (2003): 2 [citation in list of valid *Gymnotus*]. Campos-da-Paz (2003):484 [citation in catalog of valid species].

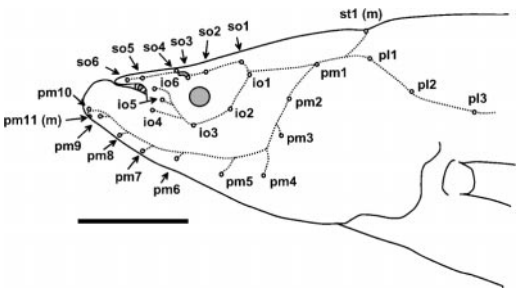

Fig. 3. Head of adult specimen of *Gymnotus coatesi*, MCP 34474, illustrating organization of cephalic sensory canals and pores. Centerline of canals (ossified and unossified) indicated by dashed lines. Pores indicated by small circles. Eye and anterior and posterior nares shaded gray. Abbreviations: so, supraorbital; io, infraorbital; pl, posterior lateral-line; pm, preopercular-mandibular; st, supratemporal; m, medial. Scale bar = 5 mm.

Rhamphichthys cingulatus. Brind (1935):8–10, fig. (drawing, no numeration) [nr. Santarém, Pará, Brazil]: designated junior synonym of *G. coatesi* by Campos-da-Paz (2000)].

Holotype.—AMNH 12624, 180 mm, Brazil, Pará, south bank affluent of Rio Amazonas nr. Santarém, approx. 02°25′S, 54°10′W, collected by C. Griem, 1934.

Nontype material.—AMNH 12975, 2, 191–210 mm, Brazil, Pará, Rio Tocantins, coll. C. Griem, 1934 (original AMNH label reads ''Tocantins, Brazil, 1934,'' and specimen is accompanied by a handwritten label ''*Gymnotus coatesi* N.Y Aq. Tocantins, Brazil, 1934,'' B. Brown pers. comm.). FMNH 32788, 1, 186 mm, Amazon River, 1934, donated by John G. Shedd Aquarium

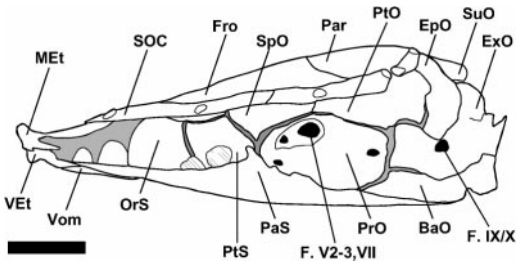

Fig. 4. Diagrammatic representation in left lateral view of neurocranium of *Gymnotus coatesi*, MCP 34473. Shading: White, bone; Gray, cartilage; Black, foramenae for nerves and blood vessels; Hatched, absence of bone. Abbreviations: MEt, mesethmoid; SOC, supraorbital laterosensory canal; Fro, frontal; SpO, sphenotic; Par, parietal; PtO, pterotic; EpO, epioccipital; SuO, supraoccipital; ExO, exoccipital; VEt, ventral ethmoid; Vom, vomer; OrS, orbitosphenoid; PtS, pterosphenoid; PaS, parasphenoid; PrO, prootic; BaO, basioccipital; F, foramenae for cranial nerves. Scale bar = 1 mm.

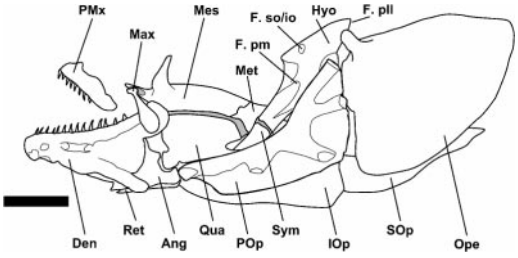

Fig. 5. Diagrammatic representation in left lateral view of suspensorium and jaws of *Gymnotus coatesi*, MCP 34473. Gray indicates cartilage. Abbreviations: PMx, premaxilla; Max, maxilla; Mes, mesopterygoid; Met, metapterygoid; Hyo, hyomandibula; Den, dentary; Ret, retroarticular; Ang, anguloarticular; Qua, quadrate; POp, preopercle; Sym, symplectic; IOp, interopercle; SOp, subopercle; Ope, opercle; F, foramenae for trigeminal nerve branches (pm, preopercular-mandibular; so, supraorbital; io, infraorbital; pll, posterior lateral line). F. pll is located on medial surface of hyomandibula. Scale bar = 1 mm.

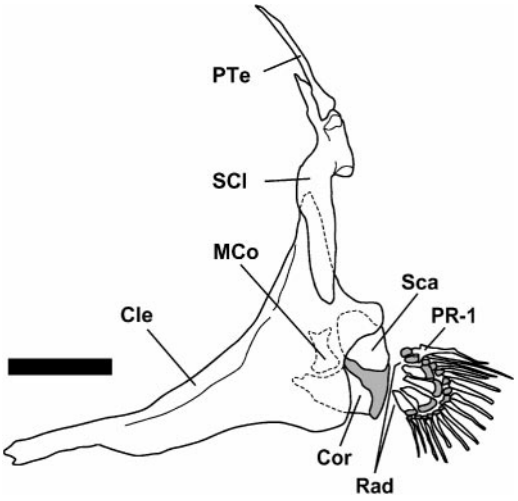

Fig. 6. Diagrammatic representation in left lateral view of pectoral girdle of *Gymnotus coatesi*, MCP 34473. Gray indicates cartilage. Abbreviations: PTe, posttemporal; SCl, supracleithrum; MCo, mesocoracoid; Cle, cleithrum; Sca, scapula; PR-1, first pectoral ray; Cor, coracoid; Rad, distal radials. Scale bar = 1 mm. Dotted lines show bone outlines behind cleithrum and supracleithrum.

(locality and year suggest that this specimen forms part of the series collected by C. Griem, in Pará, Brazil, see Remarks on the type locality below). MCP 34471, 1, WGRC 01.250200, 81 mm; Brazil, Amazonas, Rio Tefé, Lago Tefé, Igarapé do Xidarini, stream southeast of city of Tefé, Municipality of Tefé, 03°22′S, 64°40′W, coll. W. Crampton, 25 February 2000. MCP 34472, 1, WGRC 02.250200, 83 mm, collected with MCP 34471. MCP 34473, 1, WGRC 03.250200, 100 mm, cleared and stained, collected with MCP 34471. MCP 34474, 1, WGRC NR01.100400, 166 mm; locality and collector as MCP 34471, 10 Apr. 2000. MCP 34475, 1, WGRC NR02.100400, 74 mm, collected with MCP 34474. MCP 34838, 2, WGRC 04–05.070104, 98–144 mm; Peru, Loreto, Río Nanay, stream approximately 26 km south of city of Iquitos, Municipality Maynas, 03°56.63′S, 73°23.90′W, coll. W. Crampton, H. Ortega, R. Reis, F. Lima, 7 January 2004. MCP 34839, 3, WGRC 09–11.090104, 47–72 mm; Peru, Loreto, Río Ucayali, stream approximately 2 km north of Instituto de Investigaciones de la Amazonía Peruana (IIAP) field station (2.7 km east of town of Jenaro Herrera), Municipality of Sapuena, 04°52′S, 73°38′W, coll. W. Crampton, H. Ortega, R. Reis, F. Lima, 9 January 2004. MCP 34840, 1, WGRC 01.201200, 192; locality and collector as MCP 34471, 20 December 2000. MCP 34841, 5, WGRC 05–09.261200, 141–196 mm; locality and collector as MCP 34471, 26 December 2000. MUSM 20681, 2, WGRC 08–09.070104, 126–190 mm; collected with MCP 34838. MUSM 20682, 8, WGRC 01–08.090104, 36–133 mm; Peru, Loreto, Río Ucayali, stream approximately 2.5 km north of IIAP field station, 04°52.70′S, 73°38.85′W, coll. W. Crampton, H. Ortega, R. Reis, F. Lima, 9 January 2004. MUSM 20683, 1, WGRC 03.120104, 121 mm; Peru, Loreto, Río Ucayali, stream approximately 3 km south of town of Jenaro Herrera, 04°55.63′S, 73°39.23′W, coll. W. Crampton, H. Ortega, R. Reis, F. Lima, 12 January 2004. UF 137570, 2, WGRC 06–07.070104, 145–167 mm; collected with MCP 34838. UF 137571, 1, WGRC 16.090104, 32 mm; collected with MCP 34838. UF 137572, 2, WGRC 04–05.120104, 135–186 mm; Peru, Loreto, Río Ucayali, forest stream, tributary of Quebrada Parnayari, approximately 2 km south of town of Jenaro Herrera, 04°55.10′S, 73°39.20′W, coll. W. Crampton, H. Ortega, R. Reis, F. Lima, 12 January 04. USNM 103827, 1, 126 mm, South America, coll. National Zoological Park, D.C. (''aquarium fish'').

Diagnosis.—*Gymnotus coatesi*, like all species in the *G. pantherinus* species group, can be distinguished from species in the *G. carapo* species-group by the absence of a clear or pale patch near the caudal end of the anal fin and by the presence of one (vs two) laterosensory canal pores in the preopercular-mandibular series at the dorsoposterior portion of the preopercle. *Gymnotus coatesi* is unique among all species in the *G. pantherinus* species-group endemic to the Amazon and Orinoco Basins and the Guyana

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TABLE 1. MORPHOMETRIC DATA FOR HOLOTYPE AND NONTYPE SPECIMENS OF *Gymnotus coatesi*. Abbreviations: TL, total length; HL, head length; PR, preorbital length; MW, mouth width; PO, postorbital length; IO, interorbital distance; HD, head depth; HW, head width; PA, preanal distance; P1, pectoral-fin length; AF, anal fin base length; BD, body depth; BW, body width. TL and HL in millimeters. Percentage measurements in HL or, if marked with an asterisk, in TL. BW/BD expressed as ratio. N-values for nontype specimens (in parentheses) vary because measurements were excluded from specimens with damage or unusual preservation artifacts.

	Holotype	Nontypes	Mean	± SD
TL	180	74–210 (7)	—	—
HL	16.2	8.8–16.7 (7)	—	—
HL %*	9.0	8.0–11.9 (6)	10.2	1.54
PR %	32.7	25.4–36.5 (7)	31.4	3.47
MW %	33.0	31.2–38.2 (7)	33.8	2.50
PO %	64.2	58.5–66.6 (7)	62.0	2.98
IO %	34.6	32.9–39.3 (7)	36.0	1.90
BD %*	6.6	5.6–7.5 (6)	6.8	0.63
BW %*	4.7	3.8–5.9 (6)	5.1	0.74
BW/BD	0.71	0.65–0.86 (7)	0.74	0.08
HD %	58.0	43.7–58.1 (7)	54.0	5.11
HW %	58.0	49.5–62.5 (7)	56.2	5.62
PA %	76.5	76.2–83.7 (7)	79.9	2.90
PI %	damaged	29.2–50.0 (6)	43.3	7.74
AF %*	80.6	67.3–83.3 (6)	78.4	5.08

TABLE 2. MERISTIC DATA FOR HOLOTYPE AND NONTYPE SPECIMENS OF *Gymnotus coatesi*. BND, dark bands; AFR, anal-fin rays; P1R, pectoral-fin rays; SAL, scales above lateral line; APS, anal-fin pterygiophore scales; CEP, caudal electroplate rows; PCV, precaudal vertebrae; PLR, pored lateral-line scales to first ramus; PLL, total pored lateral-line scales; VLR, lateral-line ventral rami (left or right). N-values (in parentheses) vary because counts were excluded from specimens with damage or unusual preservation artifacts.

	Holotype	Nontypes	Median/ Mode*
BND	16	16–20 (6)	17
AFR	232	214–245 (6)	222
P1R	15	14–15 (7)	5*
SAL	7	6–8 (7)	6*
APS	7	6–7 (7)	7*
CEP	2	2 (7)	2*
PCV	41	41–44 (7)	43*
PLR	57	55–65 (7)	62
PLL	100	85–105 (6)	100
VLR	13	8–23 (6)	16

Shield in possessing a color pattern in which pale bands (on dark brown ground color) progressively widen, from one-quarter to one-half width of dark bands, between lateral line and dorsal midline on anterior half of body, in which pale bands are oriented obliquely in a anterior-ventral to posterior-dorsal direction on anterior half of body, and in which pale bands are white or pale yellow below lateral line and tan above lateral line with tan color more intense in middle of each band, sometimes forming a dark patch and sometimes rendering the pale band Y-shaped. *Gymnotus coatesi* can also be distinguished from species in the *G. pantherinus* species-group endemic to the Amazon and Orinoco Basins and the Guyana Shield in possessing the following unique combination of characters: 1, precaudal vertebrae 41–44 versus 31–39 in *G. anguillaris*, *G. jonasi*, *G. melanopleura*, *G. onca*, and *G. pedanopterus*, and versus 47–51 in *G. cataniapo*; 2, pectoral-fin rays 14–15 versus 11–13 in *G. jonasi* and *G. onca* and versus 16–18 in *G. anguillaris*; 3, dark bands 16–20 versus none in *G. onca* (spotted), and versus 23–35 in *G. cataniapo*; 4, anal-fin rays 214–245 versus 135–180 in *G. anguillaris* and *G. onca*; 5, scales over anal-fin pterygiophores 6–7 versus 9–10 in *G. javari*; 6, caudal electroplate rows invariably two versus invariably three in *G. anguillaris*, *G. cataniapo*, *G. javari*, *G. jonasi*, *G. melanopleura*, *G. pedanopterus*, and *G. stenoleucus*; 7, pored lateral-line scales to first ventral ramus of lateral line 55–65 versus 31–46 in *G. jonasi*, *G. melanopleura*, and *G. onca*; 8, total pored lateral-line scales 85–105 versus 73–80 in *G. jonasi* and *G. onca*, and versus 114–120 in *G. cataniapo*; 9, mouth width 31.2–38.2% HL versus 41.4–55.1 in *G. anguillaris* and *G. cataniapo*; 10, interorbital distance 32.9–39.3% HL versus 41.2–56.3 in *G. anguillaris* and *G. cataniapo*; 11, body depth 5.6–7.5% TL versus 8.0–9.4 in *G. cataniapo*; 12, head depth 43.7–58.1% HL versus 59.6–67.7 in *G. anguillaris* and *G. cataniapo*; 13, preanal distance 76.2–83.7% HL versus 50.6–63.1 in *G. pedanopterus*, and versus 83.9–122.3 in *G. anguillaris* and *G. cataniapo*; 14, pectoral-fin length 29.2–50.0% HL versus 51.9–56.9 in *G. jonasi*.

Description.—Body shape and pigment patterns illustrated for adult and juvenile specimens from near Tefé, Brazil, in Figure 2. LaMonte (1935:fig. 1, p. 1) presents a photograph of the live holotype specimen. Mago-Leccia (1994:fig. 82, p. 180) presents a photograph of the head of the preserved holotype specimen. Morphometric and meristic data presented in Tables 1 and 2. Size up to 210 mm. Size at maturity unknown. Sexual dimorphism not known to exist.

Cephalic sensory canal pore configurations il-

lustrated in Figure 3. Gape size in mature specimens moderate, extending half distance from tip of snout to posterior nares. Mouth position superior, lower jaw extends beyond upper, rictus slightly decurved. Chin fleshy and bulbous with thick pad of electroreceptor organs and support tissues overlying tip of snout and oral jaws. Anterior narial pore entirely included within gape in large narial fold. Anterior nares small, one-third diameter of eye. Circumorbital series ovoid. Ethmoid region between anterior nares narrow, its anterior margin truncate. Eye without free orbital margin, position lateral, lower margin of eye slightly below horizontal with rictus.

Neurocranium illustrated in Figure 4. Cranial fontanels closed. Frontal anterior margin straight in dorsal view. Lateral ethmoid absent. Vomer short, less than half distance to parasphenoid in ventral view. Parasphenoid with robust posterior process, posterior margin convex and shallow. Parietal rectangular in dorsal view, length less than width. Pterosphenoid with robust anteroventral process, extending ventral to lateral margin of parasphenoid.

Jaws and suspensorium illustrated in Figure 5. Premaxilla rectangular in ventral view with 18–20 needle-shaped teeth (n = 1, range for left and right sides). Eight to nine teeth in single row along outer edge and remaining teeth irregularly arranged. Dentary with 18–20 recurved needle-shaped teeth disposed in single row along outer edge and seven needle-shaped teeth in inner row confined to anterior one third of tooth bearing portion of bone (n = 1, range for left and right sides). Inner-row teeth smaller, less slender, and more distantly spaced posteriorly. Dentary dorsoposterior process narrow distally. Dentary ventral margin with small lamella (less than depth of posterior process of dentary). Dentary with anterior hook. Opercle dorsal margin convex, posterior margin smooth and entire. Preopercle with anterior notch, median shelf small (less than half width of symplectic). Mesopterygoid with curved, robust ascending process; longer than width of base; tapering to simple rounded tip. Metapterygoid superior portion ossified less anteriorly than inferior portion. Subopercle with concave dorsal margin. Retroarticular with square posterior margin. Anguloarticular with expanded ventrolateral lamella, extending over retroarticular. Anguloarticular process short, extending to ventral margin of dentary. Hyomandibula foramenae for supraoccipital (SO) and infraorbital (IO) trigeminal nerve branches united, foramen of preopercular-mandibular nerve located at dorsoposterior margin.

Pectoral girdle illustrated in Figure 6. Mesocoracoid with broad proximal portion. Postcleithrae thin, sickle shaped. Cleithrum narrow, its ventral margin straight; anterior limb long, more than 1.8 times length of ascending limb. Cleithrum without anterior notch. Cleithrum with small dorsoposterior facet. Medial pectoral radials absent. Adductor mandibula intermuscular bones absent. Basibranchials unossified. Gill rakers not contacting gill bar.

Rib 5 broad, more than 3 times width of rib 6 at its midlength, with a large medial triangular shelf. Hemal spines present. Displaced hemal spines absent. First 8–10 anal-fin rays unbranched, all rays posteriorly with single branch. Body scaled. Scales cycloid, ovoid, present on entire post-cranial portion of body from nape to tip of caudal appendage. In holotype, lateral-line scales approximately 0.9 mm high by 1.1 mm long at nape, 1.4 mm high by 1.9 mm long at midbody and 0.9 mm high by 1.5 mm long at one head length anterior to end of caudal appendage. Variable number (8–23) of asymmetrically arranged lateral-line rami extending posteroventrally at posterior end of lateral line. Dorsal lateral line rami absent in all specimens. Anal-fin pterygiophores at posterior end of body cavity shorter than first hemal spine at posterior end of body cavity. Caudal appendage short, less than half pectoral-fin length in undamaged and unregenerated specimens. Single hypaxial electric organ, extending along entire ventral margin of body. Invariably two rows of electroplates at one head length from distal end of caudal appendage.

Color in life.—Adults (100–210 mm): ground color dark chestnut brown, banded with 17–19 (n = 3) pale bands with straight and regular margins on lateral surface from nape to distal end of caudal appendage. All pale bands white or pale yellow below lateral line and tan above lateral line with tan color more intense in middle of each band. Pale band margins highly contrasted with intervening dark bands. Pale bands one-quarter of the width of dark bands below lateral line on anterior half of body. Pale bands progressively wider from one-quarter to one-half of the width of dark bands from lateral line to dorsal midline on anterior half of body. Three to five dark bands in middle region of body divided ventrally by small white or pale yellow pigment patch over ventral margin of anal-fin pterygiophores. Pale bands of equal width below and above lateral line in posterior one-third of body, one-third of width of dark bands. No dark bands divided ventrally on posterior one-third of body. Pale bands on anterior two-

thirds of body oriented obliquely in anterior-inferior to posterior-superior orientation. Pale bands on posterior one-third of body oriented vertically. Band appearance regular in shape both on and among individuals. Two pale bands meet on ventral midline between the anus and anal-fin origin. Two pale bands lie posterior to last anal-fin ray. Head dark brown, as ground color of body, grading to a slightly lighter brown ventrally, with numerous minute chromatophore speckled over branchiostegal membranes and ventral surface of head. Irregular white or pale yellow pigment patch sometimes present below and in front of one or both eyes, approximately two times eye diameter in width and one eye width in depth. Pectoral-fin rays brown, interradial membranes hyaline. Anal-fin membrane grading from charcoal gray on posterior two-thirds of its length to hyaline on anterior one-third of its length, no unpigmented or dark patch at the caudal end. Holotype and other specimens from 1934 series are faded but retain the diagnostic banding pattern.

Electric organ discharges (EODs).—EOD waveform with a total duration of 1.12–1.17 ms (mean 1.14, $n = 3$) with beginnings and ends taken at a 1% threshold of peak-to-peak amplitude of the EOD. EOD comprises four phases with low-voltage pre- and postpotentials preceding (P0) and following (P3) a dominant, approximately symmetrical biphasic component (P1, P2; Fig. 7A). The Peak Power Frequency (PPF) of the Fourier Transform of EODs ranges from 2.02–2.16 kHz (mean 2.08, $n = 3$; Fig. 7B). The EOD repetition rate is relatively low and less variable during the day when *G. coatesi* lodges itself into submerged roots or leaf litter (approximately 32–37 Hz). The EOD repetition rate is higher and more variable at night, when *G. coatesi* is active (approximately 34–60 Hz). A sudden mechanical stimulus, such as a prod with a glass rod, elicits a rapid and transient increase in resting EOD repetition rate to up to around 140 Hz.

Habitat and ecology.—Ecological notes on *G. coatesi* were compiled from studies in the Tefé region. Here, this species is rare and is encountered only in the lower, seasonally inundated, reaches of small streams (*igarapés*) flowing out of terra firme rain forests into blackwater rivers and mouthbay lakes (Fig. 1). Igarapés in the lowland Amazon are stained a tea-color to varying degrees of intensity by tannic and folic acids leached from forest litter. Temperatures are low (23–26 C), conductivity low (5–25 μScm^{-1}), pH low (3–5 units), transparency high (1.0–2.0 m

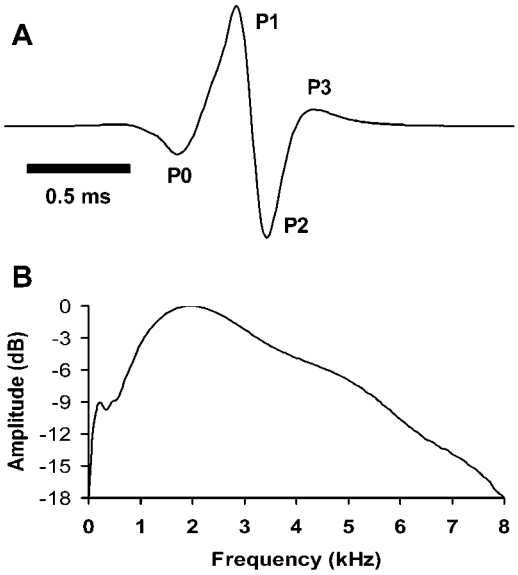

Fig. 7. EOD waveform (A) and Fourier Power Spectrum (B) of *Gymnotus coatesi*. MCP 34473. The EOD is plotted with head-positivity upwards and its component phases labeled P-1 through P3. The Power Spectrum was computed from a 2048 point Fast-Fourier-Transform and the Peak-Power-Frequency scaled to 0 dB.

with Sechi disk despite the high concentration of tannins), suspended sediment loads very low, and oxygen levels relatively high (greater than 40% saturation). For much of the year, the lower reaches of igarapés are similar in physicochemical conditions to their upper reaches. However, during the flood season, blackwater rivers flood the lower reaches of the streams with warmer water (26–30 C). When this happens flow rates decline, but water chemistry is not substantially altered. *Gymnotus coatesi* was not encountered at high water in localities at which it was present during low water. However this may be because sampling becomes more difficult as water depth increases.

Gymnotus coatesi shelters during the day in curtains of dense rootmats that festoon stream banks. During the night, *G. coatesi* forages in and around these rootmats and preys on aquatic invertebrates of primarily autochthonous origin. Aquatic vegetation is rare in the streams of the Tefé region. Chironomid larvae and the nymphs or larvae of other aquatic insects and crustaceans make up most of the diet of *G. coatesi*. Sexually mature specimens of *G. coatesi* in breeding condition were not encountered. Nonetheless, this species probably breeds during the period of greatest rainfall (December through April in the Tefé region) along with

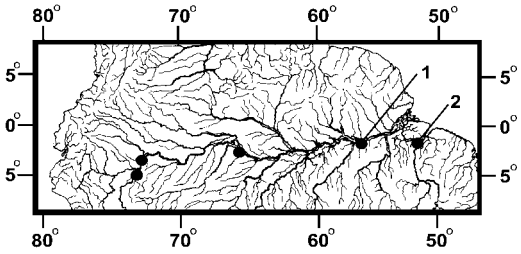

Fig. 8. Map of northern South America showing collection records for *Gymnotus coatesi*. 1 and 2 represent alternative type localities (see text). Some symbols represent more than one collection site (see Fig. 1 for details of Tefé region). Base map by M. Weitzman.

other species of stream dwelling gymnotiforms. In the Tefé region, *G. coatesi* is found in syntopy with three other species of *Gymnotus*: *G. coropinae*, *Gymnotus* sp. nov. CUR, and *G. arapaima*.

At localities near the towns of Iquitos and Jenaro Herrera in the Peruvian Amazon *G. coatesi* is an abundant species in low-conductivity blackwater terra firme rain-forest streams well above the area exposed to seasonal flooding by major rivers. Here *G. coatesi* shelters in submerged leaf litter and in hanging roots along stream margins and occurs in syntopy with *G. carapo* and *Gymnotus* sp. nov. CUR. The ecological habits of *G. coatesi* in other areas of its geographical range are unknown although Brind (1935) reports that the type specimen was captured in dense masses of water plants.

Distribution.—*Gymnotus coatesi* is known from localities along the main stem of the Amazon River from near the confluence of the Río Marañon with the Río Ucayali (Loreto, Peru) to the Rio Tocantins (Pará, Brazil; Fig. 8).

Remarks on the type locality and collection records.—The locality of the holotype and other specimens collected during Carl Griem's 1934 expedition to the Amazon is confused. Brind (1935:10) wrote of the 16 or so specimens of the ''Tiger Knife Fish'' exported to New York by Walter and Carl Griem: ''They were all found in dense masses of water plants in one of the side streams which connect with the main stream of the Amazon River on its southern bank, about three hundred miles from Pará at the mouth of the river.'' Brind also noted that ''The nearest town to the spot where the Tiger Knife Fish was caught is Santarém, at least fifty miles upstream on the Amazon.'' Campos-da-Paz (2000:1115) concluded that the holotype locality ''is somewhere near to, or in, the Rio Moju (Pará, Brazil: approximately 02°25′S, 54°10′W), the largest river in the area described by Brind (1935).'' These coordinates lie just to the east of Santarém.

Brind's description of Carl Griem's collecting expedition is taken, in places almost word for word, from Henry Walter Bates' account of travels near Cametá on the lower Rio Tocantins some 70 years earlier (Bates, 1863:91–92). The plagiarism raises doubts about the accuracy of the rest of the article. Furthermore, the locality of ''Rio Tocantins'' for AMNH 12975 (which was collected by Griem in 1934) suggests an alternative type locality near Belém, Pará. It seems unlikely that Griem would have found two separate populations of *G. coatesi*, which is a rare species, in such disparate locations (i.e., Rio Tocantins near Belém, and Amazon tributary near Santarém; see Fig. 8). Also, Brind's article reports that all the ''tiger knife-fish'' specimens that were exported to the United States were collected together. Nonetheless, the museum record ''Rio Tocantins'' for AMNH 12975 is also questionable. Unless further information comes to light the type locality near Santarém and/or the collecting record for the lower Tocantins should be regarded as uncertain and the type locality defined more generally, as Pará, Brazil.

As part of an ongoing systematic revision, around 3200 museum specimens of *Gymnotus* were examined. This material is mostly listed in Albert (2001), Albert and Crampton (2001, 2003), Crampton and Albert (2003), and Crampton et al. (2003). This search included careful examination of the prodigious Amazon collections of INPA, MUSM and MZUSP, in addition to major collections outside South America. Remarkably, the only specimens of *G. coatesi* located during this search were those probably captured together on the Griem expedition along with the holotype (AMNH 12975, FMNH 32788), and one specimen from ''South America'' lacking locality information (USNM 103827). Likewise, *G. coatesi* is not mentioned in ecological accounts of fish inventories of the Amazon basin. The only exception, to our knowledge, is Ortega and Vari's (1986) citation of *G. coatesi* from the Peruvian Amazon.

Etymology.—Named for Christopher W. Coates, Curator of tropical fishes at the New York Aquarium during the 1930s. Moller (1995:34–36) provides a biographical sketch of C. W. Coates.

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