






A new species of *Characidium* (Characiformes: Crenuchidae) from the Chapada dos Veadeiros, Goiás, Brazil

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A new species of *Characidium* is described from the tributaries of the rio Tocantinzinho, rio Tocantins basin, located in the southern portion of the Chapada dos Veadeiros, at about 1,200 meters of elevation, Goiás, Brazil. The new species can be diagnosed by an unusual combination of two apomorphic features present in distinct clades of *Characidium*, the presence of a scaleless isthmus in allied to with a single row of dentary teeth. Additionally, the new species has a unique color pattern of inconspicuous vertical bars disconnected from the dorsal midline, forming seven to nine square blotches along body sides, and the presence of a dark saddle-shaped mark at the dorsal-fin base. Osteologically, it can be diagnosed by having the first and second anal-fin proximal radials fused and contacting the third hemal spine, which is branched. The new species also has a peculiar, unusual variation of fin-ray counts among its congeners.

Keywords: Cerrado, *Characidium stigmatosum*, Endemism, Rio Tocantins basin, Taxonomy.

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Uma nova espécie de *Characidium* é descrita dos riachos tributários do rio Tocantins, bacia do rio Tocantins, localizados na vertente sul da Chapada dos Veadeiros, a aproximadamente 1.200 metros de altitude, Goiás, Brasil. A nova espécie pode ser diagnosticada pela combinação não usual de dois caracteres apomórficos presentes em clados distintos de *Characidium*, a presença do istmo sem escama em conjunto com uma única série de dentes no dentário. Adicionalmente, a nova espécie tem um padrão de coloração único de barras verticais desconectadas na região dorsal, formando sete a nove manchas quadradas ao longo do lado do corpo, e pela presença de uma mancha em forma de sela na base da nadadeira dorsal. Osteologicamente, ela pode ser diagnosticada por possuir o primeiro e segundo radiais da nadadeira anal fusionados e em contato com o terceiro espinho hemal, que é ramificado. A espécie nova também possui uma variação peculiar e pouco usual no número de raios das nadadeiras entre os congêneres.

Palavras-chave: Bacia do rio Tocantins, Cerrado, *Characidium stigmatosum*, Endemismo, Taxonomia.

INTRODUCTION

Characidium Reinhardt, 1867 currently includes 82 valid species of small-sized fishes typical from the Neotropical region between Northern Argentina and Panama (Armbruster *et al.*, 2021; Fricke *et al.*, 2021; Melo *et al.*, 2021). The number of known species has rapidly increased in the past two decades, with descriptions of almost 40% of the known diversity within the group, with new findings throughout South America (*e.g.*, Zarske, Géry, 2001; da Graça *et al.*, 2008; Zanata, Camelier, 2015; Agudelo-Zamora *et al.*, 2020). Until now, only three species of *Characidium* have been described from the rio Araguaia-Tocantins basin: *C. mirim* Netto-Ferreira, Birindelli & Buckup, 2013, a species with narrow distribution in the upper portion of the rio das Mortes and its tributaries; *C. stigmatosum* Melo & Buckup, 2002, endemic to rio das Almas and rio dos Bois at the northern realm of the Chapada dos Veadeiros; and *C. xanthopterum* Silveira, Langeani, da Graça, Pavanelli & Buckup, 2008, widely distributed in the upper Paraná and upper Tocantins basins (Melo, Buckup, 2002; Silveira *et al.*, 2008; Netto-Ferreira *et al.*, 2013).

Herein, we describe a new species of *Characidium* from the high elevation tributaries of the upper rio Tocantins, in the southern portion of the Chapada dos Veadeiros, Goiás, Brazil. In addition, we discuss the possible relationships of the new species with its congeners based on a comparative morphological analysis across the genus, provide additional information about the distribution of the genus *Characidium* in the Chapada dos Veadeiros, revise the coordinates of the type locality of *C. stigmatosum*, and give an updated list of endemic vertebrates that occur in that plateau.

MATERIAL AND METHODS

The 28 morphometric and 14 meristic characters were obtained from the left side of the individual under a stereomicroscope, according to the protocol described by Buckup (1993a) and modified by Melo, Oyakawa (2015), with a digital electronic caliper to 0.01 mm. All measurements are presented as proportions of standard length (SL), except for subunits of the head, which are presented as proportions of the head length (HL). Counts are given along the text with their frequency presented in parentheses and an asterisk indicating the values for the holotype. Cleared-and-stained specimens (cs) were used for counts of vertebrae, branchiostegal rays, osteological observations and to double check characteristics of dentition; the specimens were prepared according to Taylor, Van Dyke (1985). The anterior four vertebrae of the Weberian apparatus were counted as precaudal elements, and the fused PU1+U1 as a single caudal element. Gonads for sex identification were examined through an incision made on the left side of the specimens. Visual records were made by the senior authors with the aid of a snorkel and diving mask and photographed with an Olympus E-M5 digital camera in an underwater case. All photos and illustrations were made by MRMS otherwise stated. Institutional abbreviations follow Sabaj (2019).

RESULTS

Characidium kalunga, new species

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(Figs. 1–7, Tab. 1)

Holotype. MZUSP 125824, 40.5 mm SL, male, Brazil, Goiás, Alto Paraíso de Goiás, rio Almécegas at Cachoeira de Almécegas II, tributary of rio dos Couros, rio Tocantins basin, 14°11'11"S 47°36'15"W, 28 Nov 2012, J. L. Birindelli, F. C. Dagosta, M. V. Loeb & C. Santos.

Paratypes. All from Brazil, Goiás, Alto Paraíso de Goiás. MNRJ 52533, 4, 28.7–41.9 mm SL; MZUSP 114056, 60 (2 cs), 14.9–48.7 mm SL; ZUEC 17332, 3, 33.8–37.6 mm SL, collected with holotype. MZUSP 114058, 1, 36.6 mm SL, rio dos Couros at Cachoeira São Bento, tributary of rio Tocantins basin, 14°09'38"S 47°35'38"W, 28 Nov 2012, J. L. Birindelli, F. C. Dagosta, M. V. Loeb & C. Santos. UFRGS 9954, 2, 33.8–40.9 mm SL, rio das Cobras at road between Alto Paraíso de Goiás to the Chapada dos Veadeiros National Park, 14°09'39"S 47°37'55"W, 25 May 2008, T. P. Carvalho & F. C. Jerep. UFRGS 11257, 9, 22.8–39.9 mm SL, rio dos Couros, Portal da Chapada, near Fazenda São Bento, tributary of rio Tocantinzinho, 14°09'58"S 47°35'43"W, 10 Sep 2009, G. Frainer, F. R. Carvalho & V. A. Bertaco.



FIGURE 1 | *Characidium kalunga* in lateral (top), ventral (middle) and dorsal (bottom) views, holotype, MZUSP 125824, 40.5 mm SL, rio Almécegas at Cachoeira de Almécegas, Chapada dos Veadeiros, Alto Paraíso de Goiás, Brazil.

Diagnosis. *Characidium kalunga* can be distinguished from its cis-Andean congeners, except *C. alipioi* Travassos, 1955, *C. amaila* Lujan, Agudelo-Zamora, Taphorn, Booth & López-Fernández, 2013, *C. boavistae* Steindachner, 1915, *C. bolivianum* Pearson, 1924, *C. crandellii* Steindachner, 1915, *C. duplicatum* Ambruster, Lujan & Bloom, 2021, *C. cricareense* Malanski Sarmiento-Soares, Silva-Malanski, Lopes, Ingenito & Buckup, 2019, *C. declivirostre* Steindachner, 1915, *C. fasciatum* Reinhardt, 1867, *C. gomesi* Travassos, 1956, *C. grajahuense* Travassos, 1944, *C. hasemani* Steindachner, 1915, *C. helmeri* Zanata, Sarmiento-Soares & Martins-Pinheiro, 2015, *C. iaquira* Zanata, Ohara, Oyakawa & Dagosta, 2020, *C. japuhybensis* Travassos, 1949, *C. kamakan* Zanata & Camelier, 2015, *C. lauroi* Travassos, 1949, *C. macrolepidotum* (Peters, 1868), *C. oiticicai* Travassos, 1967, *C. pterostictum* Gomes, 1947, *C. purpuratum* Steindachner, 1882, *C. schubarti* Travassos, 1955, *C. tamata* Agudelo-Zamora, Tavera, Murillo & Ortega-Lara, 2020, *C. timbuiense* Travassos, 1946, *C. travassosi* Melo, Buckup & Oyakawa, 2016, *C. vidali* Travassos, 1967, and *C. wangyapoik* Ambruster, Lujan & Bloom, 2021, by lacking scales on the isthmus (*vs.* isthmus completely scaled), from *C. alipioi*, *C. amaila*, *C. boavistae*, *C. bolivianum*, *C. crandellii*, *C. cricareense*, *C. declivirostre*, *C. fasciatum*, *C. gomesi*, *C. grajahuense*, *C. hasemani*, *C. helmeri*, *C. iaquira*, *C. japuhybensis*, *C. kamakan*, *C. lauroi*, *C. macrolepidotum*, *C. oiticicai*, *C. pterostictum*, *C. purpuratum*, *C. schubarti*, *C. tamata*, *C. timbuiense*, *C. travassosi*, *C. vidali* by having a single row of dentary teeth (*vs.* dentary teeth in two rows, internal row with minute conical teeth), and from *C. duplicatum* and *C. wangyapoik* by having the scalelles are extending from

isthums to anterior margin of cleithra (*vs.* scalelles extending on isthmus, area between pectoral fins and part of belly to level of pelvic fins). It can be further distinguished from its congeners, except *C. heirmostigmata* da Graça & Pavanelli, 2008, *C. papachibe* Peixoto & Wosiacki, 2013, *C. satoi* Melo & Oyakawa, 2015, and *C. serrano* Buckup & Reis, 1997, by having vertical bars on body that are disconnected dorsally, and from those species by having the bars on body as deep as wide, forming blotches two to four scales wide (*vs.* blotches vertically elongated, and of one scale width in *C. heirmostigmata*, *C. papachibe*, and *C. serrano*, or blotches forming oval dots, V-shaped, W-shaped, or diamond-shaped marks along and ventral to the lateral line in *C. satoi*), and bars not obliquely oriented (*vs.* bars oblique in *C. heirmostigmata*, *C. papachibe*, and *C. serrano*), and from all congeners by the presence of a saddle mark at the base of the second to eighth dorsal-fin rays. Osteologically, *C. kalunga* is diagnosed by having the first and second anal-fin proximal radials fused and contacting the third hemal spine (*vs.* separated and intercalated with the hemal spines), and by the third hemal spine branched (*vs.* all hemal spines unbranched).

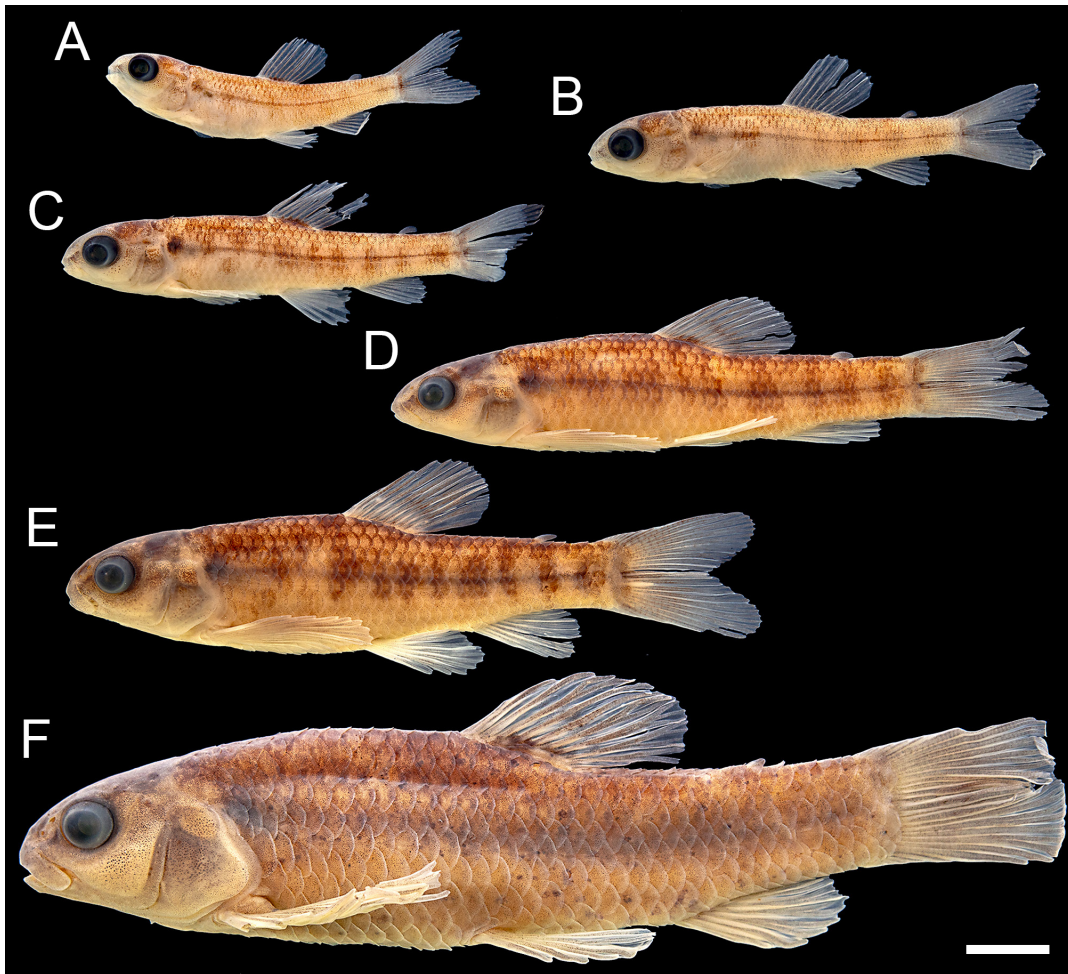


FIGURE 2 | Paratypes of *Characidium kalunga*, MZUSP 114054, **A**. 15.3 mm SL, **B**. 18.2 mm SL, **C**. 21.4 mm SL, **D**. 29.7 mm SP, **E**. 30.9 mm SL, and **F**. 48.7 mm SL. Scale bar = 5 mm, Chapada dos Veadeiros, Goiás, Brazil.

Description. Morphometric data for holotype and paratypes summarized in Tab. 1. Largest specimen examined with 43.9 mm SL. Body fusiform. Dorsal profile moderately convex between tip of snout and dorsal-fin origin; gently arched along dorsal-fin base, nearly straight between dorsal fin and origin of first dorsal caudal-fin procurent ray; slightly convex along anal-fin base; nearly straight between anal fin and origin of first ventral caudal-fin procurent ray. Greatest depth of body at dorsal-fin origin.

Snout gently rounded in lateral view, its tip slightly below level of ventral margin of eye. Mouth small, subterminal. Snout-maxillary tip distance equal or slightly shorter than eye diameter; maxilla reaching level of anterior margin of orbit. Orbit circular, margin of orbit free. Nares distinctly separated by fleshy bridge; distance between nares shorter than distance between posterior naris to eye. Dermal flap along entire border of anterior naris, crescent-shaped and restricted to anterior margin of posterior naris.

Pectoral fin reaching vertical through dorsal-fin origin when adpressed to body; pectoral-fin rays iii,7 (1), iii,7,i (2), iii,8,i (6), iii,9,i* (5), iv,5,i (1), iv,6,i (1), iv,7,i (4), iv,7,ii (1), iv,8 (2), or iv,8,i (3). Pelvic fin barely reaching anal-fin origin; pelvic-fin rays i,6,i (1), i,7 (1), i,7,i (6), i,7,ii* (1), ii,5,i (2), ii,5,ii (3), ii,6,i (9), ii,7,i (1), iii,6 (1), or iii,7,i (1). Dorsal-fin rays ii,5,i (1), ii,8 (3), ii,9 (1), iii,7,i (2), iii,8 (10), iii,9 (3), or iv,8* (6), last dorsal-fin ray simple, not adnate (2 cs); dorsal-fin supranumerary element 1 (2 cs). Anal fin not reaching ventral caudal-fin procurent rays; distal margin of anal fin rounded; anal-fin rays ii,5,i (1), ii,6 (1), ii,7 (2), iii,4 (1), iii,5 (15), iii,6 (2), iii,7* (1), iv,4 (1) or iv,5 (2); last anal-fin ray adnate (2 cs); anal-fin supranumerary element 1 (2 cs). Principal caudal-fin rays i,7,8,i (1), i,7,8,ii (1), i,8,7,ii (1), i,8,8,ii (2), i,8,9,i (3), i,9,8,i (1), ii,2,i,5-4,i,5,i (1), ii,6,8,ii (1), ii,7,8,i (1), ii,7,8,ii (10), ii,7,9,i* (3), or ii,7,9,ii (1). Adipose fin absent (1), or present* (25).

Scales cycloid; parallel radii present only on posterior field of scales. Lateral line usually complete; scales along longitudinal row 35 (2), 36 (11), or 37* (13) scales. Perforated scales in lateral line 33 (1), 35 (1), 36 (11), or 37* (13). Scales series above lateral line 4 (5) or 5* (21). Scales below lateral line 4 (1) or 5* (25). Pre-dorsal scale series 12* (5), 13 (11), or 14 (10). Circumpeduncular scales 13 (1) or 14* (25). Scales between anus and anal-fin origin 2* (8), 3 (18), or 4 (1). Isthmus lacking scales to anterior margin of cleithrum.

Premaxillary teeth 5 (3), 6* (19), or 7 (3), all conical, arranged in single row, decreasing in size posteriorly (Fig. 3A). Maxillary teeth absent. Dentary teeth 8 (6), 9 (7), 10 (6), 11* (4) or 12 (2), all conical, arranged in single row, decreasing in size posteriorly (Fig. 3B). Ectopterygoid teeth 2 (2 cs), conical. Mesopterygoid edentulous (2 cs). Branchiostegal rays 4 (2 cs); 3 attached to anterior ceratohyal (2 cs) and 1 attached to posterior ceratohyal (2 cs). Total gill rakers 10 (1 cs) or 11 (1 cs); gill rakers on basibranchial 2 (1 cs) or 3 (1 cs); gill rakers on ceratobranchial 5 (1 cs) or 6 (1 cs); and gill rakers on epibranchial 4 (1 cs) or 5 (1 cs). Parietal branch of supraorbital laterosensory canal present (2 cs), not reaching parietal bone (1 cs) or reaching parietal bone (1 cs). Fontanel triangular, limited anteriorly by frontals, laterally by frontals and parietals, and posteriorly by supraoccipital (2 cs, Fig. 3C).

Precaudal vertebrae 21 (1 cs) or 20 (1 cs); total vertebrae 37 (2 cs). Supraneurals 5 (1 cs) or 6 (1 cs). Hypurals 6 (2 cs). Epurals 2 (1 cs) or 3 (1 cs). Upper caudal-fin procurent rays 8 (1 cs) or 9 (1 cs); lower caudal-fin procurent rays 7 (1 cs) or 8 (1 cs). Uroneural 1 (2). Postcleithrum 1 enlarged, oval, anterodorsally elongated, and connected dorsally

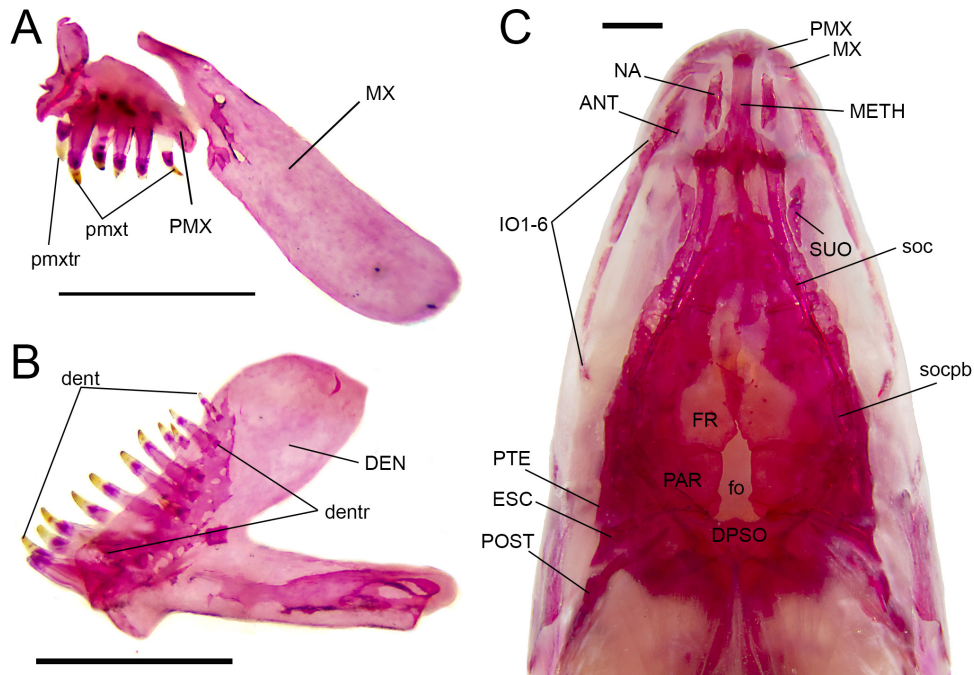


FIGURE 3 | Osteological characteristics of head in *Characidium kalunga*, MZUSP 114054, paratype. **A.** Right upper jaw in medial view; **B.** Right dentary in medial view; **C.** Skull in dorsal view. Abbreviations: ANT, antorbital; DEN, dentary; dent, dentary teeth; dentr, replacement dentary teeth; DPSO, dorsal process of the supraoccipital; ESC, extrascapular; FR, frontal; fo, fontanel; IO 1–6, infraorbitals 1 to 6; METH, mesethmoid; MX, maxilla; NA, nasal; PAR, parietal; PMX, premaxilla; pmxt, premaxillary teeth; pmxtr, replacement premaxillary teeth; PTE, pterotic; POST, posttemporal; SUO, supraorbital; soc, supraorbital canal; and socpb, parietal branch of the supraorbital canal. Scale bar = 1 mm.

to ventral tip of supracleithrum; postcleithrum 2 triangular, anterodorsally elongated, connected dorsally to posterior cleithral process; postcleithrum 3 slender and elongated, rib like, connected dorsally to postcleithrum 1 (2 cs, Fig. 4A). Dorsal-fin pterygiophores 9 (1 cs) or 10 (1 cs), all disconnected, intercalating between neural spines from twelfth to eighteenth vertebrae (1 cs) or eleventh to eighteenth vertebrae (1 cs). Anal-fin pterygiophores 7 (2 cs), first and second proximal radials fused medially and contacting hemal spine of third caudal vertebra, remaining pterygiophores disconnected and inserting on musculature intercalating between hemal spines of third and fourth, fourth and fifth, and fifth and sixth caudal vertebrae (Fig. 4B).

Humeral hiatus of *obliquus superioris* and *obliquus inferioris* muscles well developed, filled with fatty tissue and not visible externally by transparency. Humeral hiatus oval-shaped, with two chambers divided by pleural rib of fifth vertebra, anterior chamber covered by connective tissue membrane; limited dorsally by *lateralis superficialis*, posteroventrally by *obliquus inferioris* and posterodorsally, ventrally and anteriorly by *obliquus superioris*. Lateral line nerve passing along dorsal margin of humeral hiatus and continuing along midlateral horizontal septum (Fig. 5).

Coloration in alcohol. General ground color tan yellow, dark brown dorsally and pale beige ventrally. Dorsal part of head snout and skull dark brown; lateral and ventral part of snout, distal portion of upper jaw, lower jaw, cheek, ventral part of opercle, and

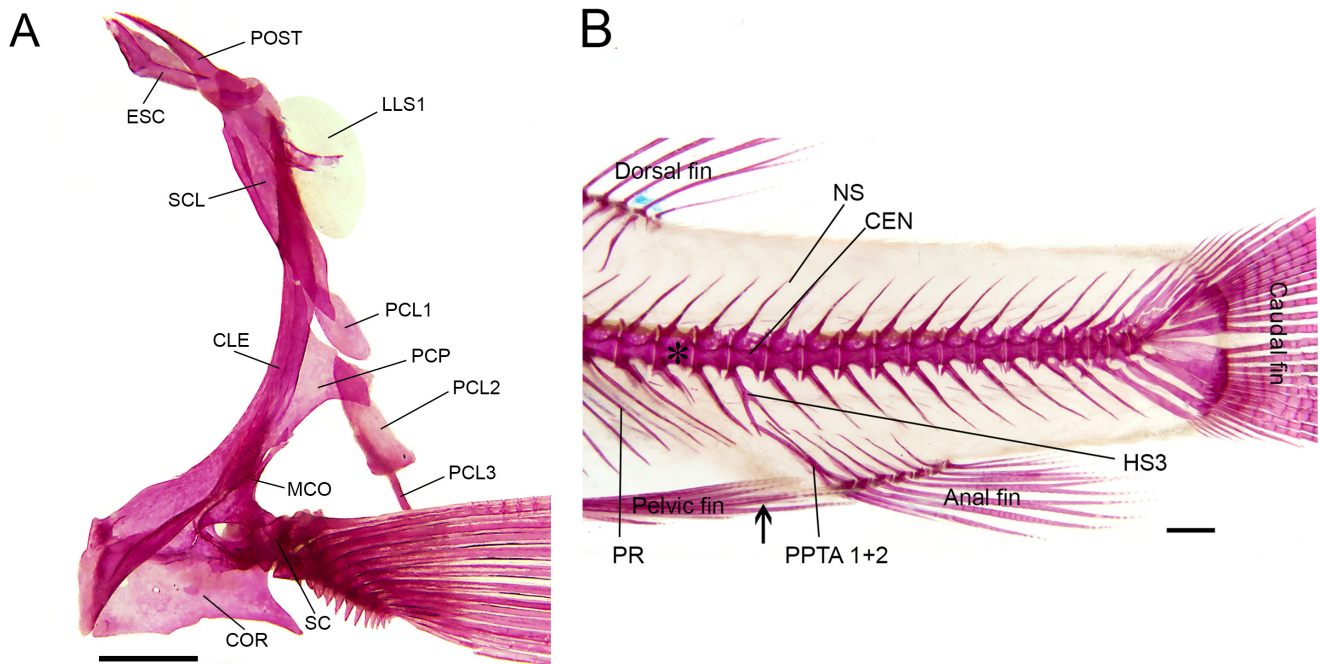


FIGURE 4 | Osteological characteristics of fins in *Characidium kalunga*, MZUSP 114054, paratype. **A.** Left pectoral girdle in lateral view; **B.** Caudal peduncle in lateral view – left intermuscular bones removed. Abbreviations: arrow, position of anus; asterisk, first caudal vertebra; CEN, centrum; CLE, cleithrum; COR, coracoid; ESC, extrascapular; LLS1, first lateral-line scale; HS3, third haemal spine; MCO, mesocoracoid; NS, neural spine; PCP, posterior cleithral process; PR, pleural rib; PRA 1+2, fused anal-fin proximal radials 1 and 2; PTC1, postcleithrum 1; PTC2, postcleithrum 2; PTC3, postcleithrum 3; POST, posttemporal; SC, scapula; SCL, supracleithrum. Scale bar = 1 mm.

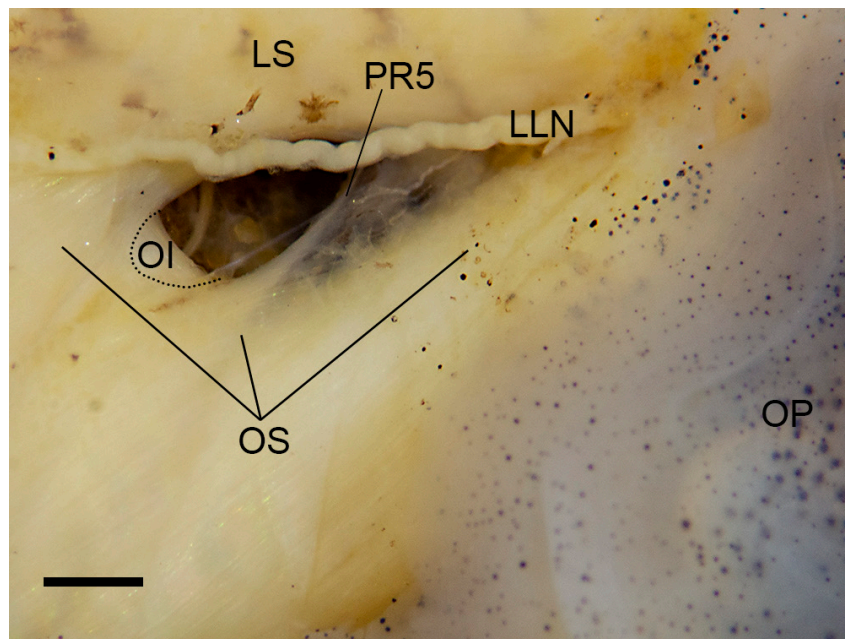


FIGURE 5 | Humeral hiatus in *Characidium kalunga*, MZUSP 114054, 42.0 mm SL, paratype. Abbreviations: LLN, lateral-line nerve; LS, *lateralis superficialis*; OI, *obliquus inferioris*; OS, *obliquus superioris*; PR5, pleural rib of fifth vertebra. Scale bar = 1 mm.

TABLE 1 | Morphometric data for *Characidium kalunga*. Values for the holotype (MZUSP 125824) and 25 paratypes (MZUSP 114056, 114058). Abbreviations: N, number of specimens; SD, Standard deviation.

Characters	Holotype	N	Range	Mean	SD
Total length (mm)	49.8	24	54.2–44.5	48.7	–
Standard length (mm)	40.5	26	43.9–35.8	39.5	–
Percentage of standard length					
Head length	27.8	26	25.1–28.8	26.8	1.0
Prepectoral distance	25.9	26	23.5–27.5	25.4	1.0
Pectoral-fin height	19.5	26	16.9–22.2	19.4	1.2
Predorsal distance	52.2	26	50.4–55.6	52.8	1.2
Dorsal-fin height	15.7	26	13.4–18.1	15.4	1.3
Dorsal-fin base	13.8	26	11.8–14.2	13.1	0.7
Prepelvic distance	53.5	26	51.7–56.6	54.1	1.2
Pelvic-fin height	12.5	26	9.5–14.3	11.6	1.0
Preanal distance	74.7	26	71.8–78.8	76.1	1.6
Anal-apex distance	93.7	26	91.0–99.1	95.4	2.0
Anus to anal fin distance	3.8	26	3.2–6.2	4.4	0.7
Anal-fin height	12.3	26	11.5–16.1	13.5	1.0
Anal-fin base	9.5	26	6.7–9.5	8.0	0.7
Adipose-fin height	4.5	25	0.0–5.1	3.5	0.9
Peduncle length	18.5	26	16.6–20.1	18.3	1.1
Body width	11.3	26	11.0–14.0	12.1	0.8
Body depth at dorsal-fin origin	22.0	26	20.3–24.7	22.3	1.3
Body depth at anal-fin origin	15.3	26	13.1–17.4	16.1	0.9
Body depth at caudal peduncle	12.1	26	8.9–12.7	11.9	0.8
Percentage of head length					
Snout length	25.2	26	21.7–28.7	25.4	1.7
Snout – maxillary tip	28.7	26	24.7–31.0	28.8	1.5
Anterior naris – orbit	10.6	26	8.0–12.4	10.3	1.1
Posterior naris – orbit	4.4	26	3.3–6.3	4.5	0.7
Cheek	10.0	26	7.3–12.5	10.1	1.3
Orbital diameter	24.3	26	23.5–27.6	26.2	1.2
Interorbital distance	13.1	26	11.5–18.5	14.2	1.9

branchiostegal membranes lighter, with scarcely spaced melanophores. Scales on dorsal portion of body with melanophores more concentrated on distal margin, providing reticulated aspect on dorsal portion of body. Sides of body gradually lighter from dorsal to ventral surface, with ventral parts of belly and caudal peduncle light beige.

Preorbital stripe thin, extending obliquely between proximal third of upper jaw and anterior margin of eye. Postorbital stripe thicker than preorbital and longitudinal stripes, extending horizontally between posterior margin of eye and dorsal margin of opercle. Longitudinal stripe having less than one scale width, extending horizontally between dorsal margin of opercle to posterior portion of caudal peduncle, but not reaching base of caudal-fin rays. Humeral blotch oval located immediately posterior to upper corner of opercle, with three scales depth and two scales wide. Basicaudal spot inconspicuous and not easily discernible, positioned at middle caudal-fin rays.

Bars on body seven to nine, present in most specimens examined. Bars on dorsum irregularly distributed and disconnected from lateral portion, often fused and forming irregular longitudinal dorsal lines between head and dorsal fin. Lateral portion of bars disconnected from dorsal portion and not connected in ventral midline, forming large square blotches on sides of body but, in larger specimens, inconspicuous and not easily discernible (Fig. 2F).

Pectoral and pelvic fins mostly hyaline, with melanophores concentrated on dorsal margin of fin rays. Anal fin hyaline. Dorsal-fin mostly hyaline except for one middle, longitudinal dusk and inconspicuous stripe, and one discernible saddle-like mark on base of fourth to eighth dorsal-fin rays. Caudal fin mostly hyaline, or with irregularly distributed melanophores on proximal two thirds. Adipose-fin hyaline, with scarce melanophores.



FIGURE 6 | Underwater photography of *Characidium kalunga* in the rio Preto, at the Parque Nacional da Chapada dos Veadeiros, Goiás, Brazil (not collected).

Coloration in life. General pigmentation like that of preserved specimens. Live specimens with ground color brownish, and square blotches on flanks more easily discernible (Fig. 6).

Ontogenetic variation of pigmentation. In smaller specimens (<19 mm SL), the body is pale beige and the blotches are poorly marked and barely indistinguishable (Figs. 2A–B); in larger specimens (>20.0 mm SL), the ground color becomes yellowish and the blotches well defined (Figs. 2C–E); and the largest specimen examined (48.3 mm SL) lacks bars, has the overall body pattern dusky, including the areas on cheeks and fins and the blotches are merged into the background and indistinguishable (Fig. 2F). The humeral and basicaudal spots and the saddle mark at base of dorsal fin are visible in all specimens examined but are inconspicuous in the largest specimen. The pseudotympanum is visible by skin transparency in smaller were observed in the available specimens.

Geographical distribution. *Characidium kalunga* is known only from the streams draining the southern portion of the Chapada dos Veadeiros, tributaries of the upper rio Tocantins basin. It was collected in the rio dos Couros and rio Almécegas, but field observations and photographic records also include the rio Preto, upstream from the Salto de 120 Metros waterfall (Fig. 7).

Ecological notes. *Characidium kalunga* is a bottom dweller species, known from localities with elevation of about 1,200 meters. It inhabits rivers with fast flowing, cold, black water with rocky bottom, characterized by the presence of many rapids, canyons, and relatively large waterfalls, alternating with pools with sandy bottom. Those rivers are often impacted by sudden water flow increase caused by precipitation runoff in the

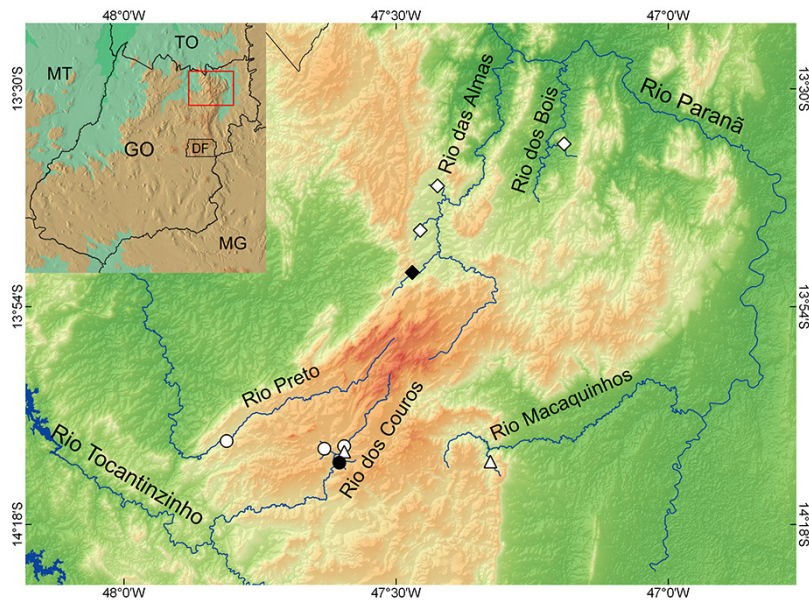


FIGURE 7 | Map of the Chapada dos Veadeiros indicating the known distribution of *Characidium*: circles represent *Characidium kalunga*, triangles, *C. xanthopteron*, and diamonds, *C. stigmatum*. Black symbols indicate the type locality and white symbols other records.



FIGURE 8 | Habitats of *Characidium kalunga* at the Chapada dos Veadeiros: **A.** Type locality, cachoeira das Almécegas II, at rio Almécegas, tributary of rio dos Couros; **B.** Rio Preto, at Parque Nacional da Chapada dos Veadeiros.

watershed. The Cerrado vegetation is restricted to the margins, with no aquatic plants present in the river channel (Fig. 8).

Etymology. The specific name honors the Comunidade Quilombola Kalunga, a resilient community of Afro-Brazilians that lives in the Chapada dos Veadeiros area, helping to protect its natural resources. Kalunga also means a sacred place in the African Bantu language. A noun in apposition.

Conservation status. *Characidium kalunga* has a narrow distribution, with an area of occupancy smaller than 500 km². It occurs within the limits of a protected area, the Parque Nacional da Chapada dos Veadeiros. Impacts such as continuing populational decline or extreme fluctuations of the extent of occurrence, area of occupancy, quality of habitat, number of locations or subpopulations, or number of mature individuals were not observed. Therefore, in accordance with the IUCN Red List Categories and Criteria (IUCN Standards and Petitions Subcommittee, 2019), *C. kalunga* is categorized as Least Concern (LC).

DISCUSSION

Interspecific relationships and comparisons. The genus *Characidium* was erected by Reinhardt (1867) to include *C. fasciatum*, the type species by original designation. Buckup (1993b) reevaluated the genus in a phylogenetic sense, proposing the only interspecific phylogenetic hypothesis to date. More recently, a few contributions to test the delimitation between species and populations of *Characidium* based on cytochrome oxidase I (COI) mitochondrial gene were published, but the dendrograms produced include clades with low support, indicating that the difficulties on the systematics and taxonomic practices faced by traditional morphological approaches may also apply at the molecular level in the genus (e.g., Serrano *et al.*, 2018; Malanski *et al.*, 2019; Agudelo-Zamora *et al.*, 2020).

According to Buckup (1993b), the monophyly of *Characidium* is supported by a single synapomorphy, the presence of a basicaudal spot near to the base of the caudal-fin rays, which is present, but inconspicuous in *C. kalunga*. Buckup (1993b) was apparently more focused on the generic relationships among the crenuchid genera and, therefore, did not investigate much further the specific interrelationships within *Characidium*. That analysis included relatively few representatives and characters relevant to the resolution of the internal nodes, resulting on a basal polytomy formed by *C. zebra* Eigenmann, 1909, *C. hasemani*, clade C1 (including clades C2 and C3), clade C4, and clade C5 (including clades C6 and C7).

Characidium kalunga shares a putative synapomorphy with the species placed in clade C1, the absence of scales on the isthmus. Noteworthy, Buckup (1993b) considered this to be a multistate character, and described three states: state 0, scaled isthmus (e.g., outgroup and *C. zebra*); state 1, only the isthmus lacking scales (e.g., *C. lauroi*); state 2, scaleless area on isthmus and area between the pectoral fins (e.g., *C. gomesi*); state 3, scaleless area extending along the belly to the level of the pelvic fins (e.g., *C. crandellii*). In *C. kalunga*, the scaleless area is restricted to a small, triangular area restricted to the isthmus and lined posteriorly to the level of the cleithra, therefore, as described in state 1. The two additional synapomorphies assigned for clade C1 are absent in *C. kalunga*, the reduction or absence of the postcleithrum 1 (*vs.* well developed in *C. kalunga*, Fig. 5A), and the fontanel reduced and limited anteriorly by the parietals (*vs.* fontanel extending anteriorly to the frontals, Fig. 4C). Besides, *C. kalunga* also lacks any of the two synapomorphies supporting clade C2 and the five synapomorphies that support clade C3. Finally, the scaleless isthmus is not a unique synapomorphy to that clade, and has at least three independent origins in the subfamily, being also present in distantly related crenuchids such as *Ammocryptocharax lateralis* (Eigenmann, 1909), *A. vintonae* (Eigenmann, 1909), *Melanocharacidium depressum* Buckup, 1993, and *M. pectorale* Buckup, 1993 (Buckup, 1993a), and variable in *C. lanei* Travassos, 1967, which may have the isthmus fully scaled or with a small, unscaled area (MRSM pers. obs.), indicating that the condition in *C. kalunga* could be an additional independent origin, considering the lack of additional characters suggesting its close relationships with representatives of clade C1 of Buckup (1993b).

The clade C4 was more recently revised with the inclusion of additional species and reevaluation of morphological characters (Netto-Ferreira *et al.*, 2013; Mendonça, Netto-Ferreira, 2015). *Characidium kalunga* also shares one of the three synapomorphies

that support the monophyly of clade C4, the absence of the dentary-teeth medial row (Fig. 5B). However, unlike the representatives of that clade, *C. kalunga* has the parietal branch of the supraorbital laterosensory canal, despite of being short (*vs.* parietal branch absent) and has seven to nine bars on body (*vs.* 12 or more bars). Like the characters discussed above, those three synapomorphies are not unique to that group being even variable within the species of clade C4, as discussed by Melo, Espíndola (2016).

The overall pigmentation pattern of *C. kalunga* resembles that of *C. heirmostigmata*, *C. papachibe*, *C. satoi*, and *C. serrano* because the lateral portion of the vertical bars are disconnected from their dorsal portions and form a series of midlateral blotches on the flanks (Buckup, Reis, 1997; da Graça, Pavanelli, 2008; Peixoto, Wosiacki, 2013). Despite showing a superficial resemblance, in *C. heirmostigmata*, *C. papachibe* and *C. serrano* the bars form oblique bands along the body, centered at level of the lateral line and in *C. satoi*, oval dots, V-shaped, W-shaped, or diamond-shaped marks along and ventral to lateral line. In addition, *C. serrano* has more bars (10–14 *vs.* 8–9), which allows unambiguous distinction from *C. kalunga*. In addition, *C. kalunga* further differs from those species in the number of circumpeduncular scales (14 *vs.* 10 in *C. papachibe* and 12 in *C. heirmostigmata* and *C. serrano*).

The variation of fin-ray counts in *Characidium kalunga* is unusual and never recorded in any congener. In *Characidium*, fin-ray counts usually do not have significant interspecific variation and show a typical modal distribution. As *C. kalunga* has a relatively limited geographic distribution and such variations are random among the specimens, we were unable to identify any pattern related to geographical variation or sexual dimorphism, for example, and suppose that such variation may be the result of long-time inbreeding in small populations.

In summary, the phylogenetic position of *C. kalunga* among its congeners could not be hypothesized by us based on the available data. The discovery of a new species having synapomorphies from different well-supported clades stress the understanding that the genus *Characidium* urges for a phylogenetic revision, including more extensive taxa sampling, reevaluation of morphological characters and reinterpretation of homologies, in combination to molecular data.

The Chapada dos Veadeiros species richness and endemism. The Chapada dos Veadeiros is an ancient plateau located in the northern portion of the Planalto Central Goiano, formed by the collision between the Congo and São Francisco cratons during the assembly of Gondwana, which has altitudes varying from 1,000 to 1,600 (mean 1,200) meters above sea level (de Carvalho Júnior *et al.*, 2015). The atmospheric temperature is mild all over the year, with means of 21°–25° C during summer (June to September) and 18°–22° C in the other months, but often reaching below 10° C in the winter. The vegetation is a typical high-altitude rocky grassland of the Cerrado (Eiten, 1972). The Chapada dos Veadeiros works as a watershed for the headwaters of rio Maranhão draining to the northwest; the rio Tocantinzinho, to the central and southern areas; and the rio Paranã to the east and northeast, all tributaries of the upper rio Tocantins (Brasil, 1982).

Besides *C. kalunga*, there are two additional congeners occurring in the Chapada dos Veadeiros, namely *C. stigmatosum* and *C. xanthopterum* (Figs. 9A–B). *Characidium stigmatosum* was described from the tributaries of rio das Almas (Melo, Buckup, 2002).

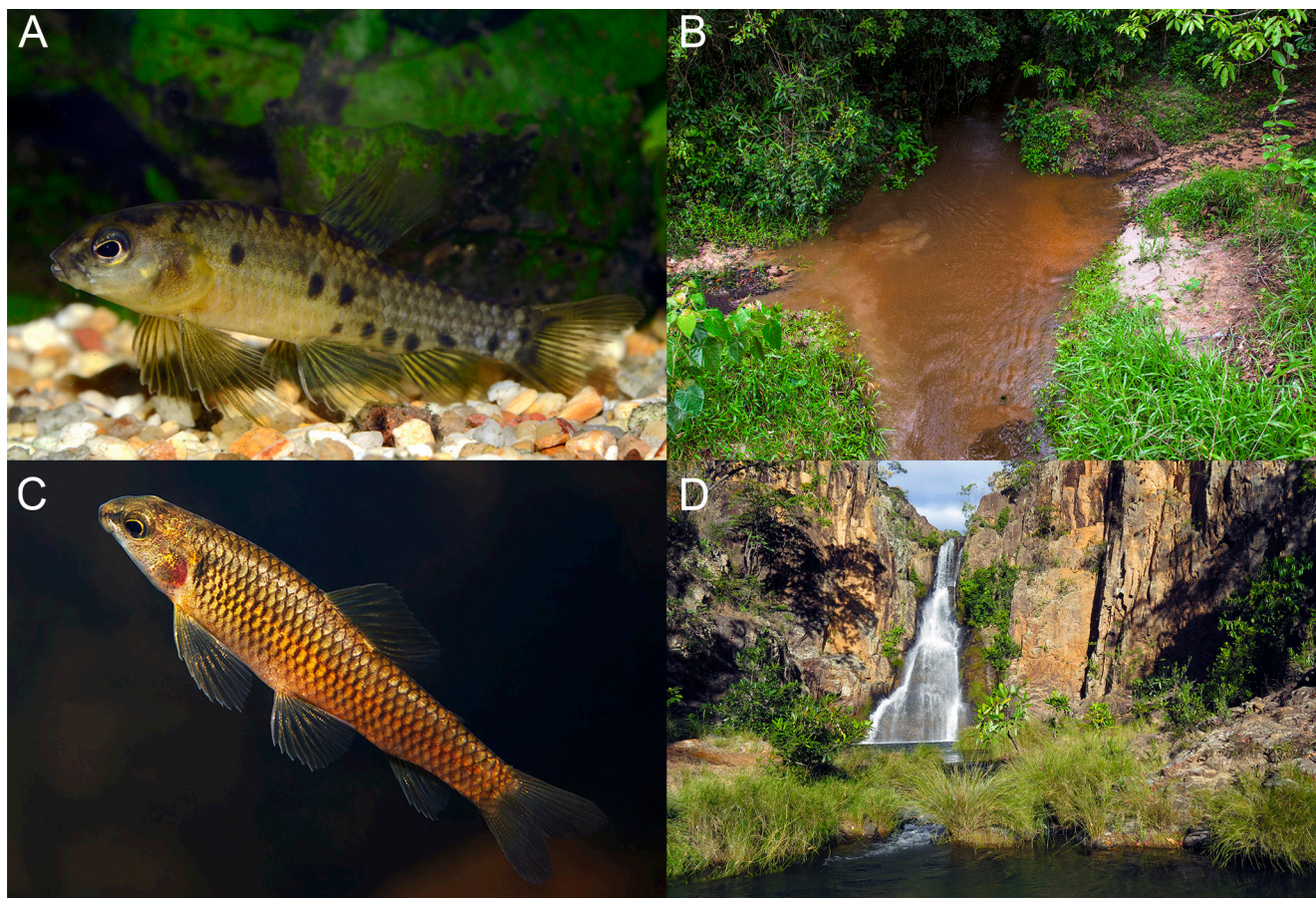


FIGURE 9 | Additional species and habitats of *Characidium* in the Chapada dos Veadeiros, Goiás, Brazil: **A.** *Characidium stigmatosum*, live specimen in aquarium (collected with MZUSP 113939, photo by Fernando Dagosta) collected at **B.** stream tributary of rio das Almas, Cavalcante (photo by Osvaldo Oyakawa); **C.** *Characidium xanthopterum* live specimen (photo by MRSM) at **D.** Cachoeira dos Macaquinhos, rio dos Macacos (not collected).

The coordinates of the type locality, a small stream tributary of córrego Ave Maria, were originally inferred as 13°47'S 47°30'W based on paper maps with 1:1.000.000 scale, but should be corrected to a more precise location: 13°45'34"S 47°27'20"W. The distribution of *C. stigmatosum* is restricted to the northern portion of the Chapada dos Veadeiros, in the rio das Almas and rio dos Bois drainages, both tributaries of the Rio Paranã.

We also report for the first time the occurrence of *C. xanthopterum* in the Chapada dos Veadeiros. This species is widely distributed in the Planalto Central Goiano, occurring in both the upper rio Paraná basin and upper rio Tocantins basins, in the States of Goiás and Tocantins, and in the Distrito Federal (Silveira *et al.*, 2008). In the Chapada dos Veadeiros, it was collected in sympatry with *C. kalunga* at Cachoeira de Almécegas (UFRGS 11257) and photographed at Cachoeira do Macaquinho, a tributary of rio Macacão in the eastern border of the Chapada dos Veadeiros, rio Paranã basin (Fig. 9B).

In addition, the Chapada dos Veadeiros hosts eight endemic species of fishes, three of which are restricted to the tributaries of the upper rio Tocantinzinho [the characids

Astyanax goyanensis (Miranda-Ribeiro, 1944) and *Astyanax courensis* Bertaco, Carvalho & Jerep, 2010, and the loricariid *Corumbataia anosteos* (Carvalho, Lehmann & Reis, 2008)], and seven, to the tributaries of rio Paranã [the characids *Hasemania kalunga* Bertaco & Carvalho, 2010, and *Hemigrammus tocantinsi* Carvalho, Bertaco & Jerep, 2010, *Moenkhausia dasalmas* Bertaco, Jerep & Carvalho, 2011; the parodontid *Apareiodon cavalcante* Pavanelli & Britski, 2003; and the loricariids *Corumbataia canoeiro* (Roxo, Silva, Ochoa & Zawadzki, 2017) and *Corumbataia veadeiros* Carvalho, 2008)] (Miranda-Ribeiro, 1944; Pavanelli, Britski, 2003; Carvalho, 2008; Carvalho *et al.*, 2008, 2010; Bertaco, Carvalho, 2010; Bertaco *et al.*, 2010; Roxo *et al.*, 2017; Thimotheo *et al.*, 2020). Additional vertebrates with narrow distribution at the Chapada dos Veadeiros and vicinity (Serra do Trombador) include four anurans [the hylids *Boana phaeopleura* (Caramashi & Cruz, 2000) and *Scinax rupestris* Araujo-Vieira, Brandão & Faria, 2015; the leptodactylid *Leptodactylus tapiti* Sazima & Bokermann, 1978; and the odontophrynid *Proceratophrys rotundipalpebra* Martins & Giaretta, 2013] and a rodent [the cricetid *Oligoryzomys moojeni* (Weksler & Bonvicino, 2005)] (Sazima, Bokermann 1978; Caramaschi, Cruz, 2000; Weksler, Bonvicino, 2005; Nogueira *et al.*, 2011; Santoro, Brandão, 2014; Araujo-Vieira *et al.*, 2015).

In conclusion, the discovery of a new species of fish with narrow distribution emphasizes the unique species richness and endemism present on the highlands of the Chapada dos Veadeiros, which should be treated as a hotspot for vertebrates in Central Brazil and, therefore, a priority area for the conservation of the Cerrado biodiversity (Cavalcanti, Joly, 2002; Nogueira *et al.*, 2010, 2011; França, Braz, 2013; Lima, Franco, 2014).

Comparative material examined. Goiás, Brazil: *Characidium stigmatosum*: UFRGS 9925, 39, 18.3–38.5 mm SL; UFRGS 11195, 26, 18.4–38.9 mm SL; MZUSP 40804, 33.7 mm SL, holotype; MNRJ 21974, 4, 27.7–38.3 mm SL, paratypes; MZUSP 70221, 15, 16.7–38.7 mm SL, paratypes; USMN 36832, 2, 31.7–31.9 mm SL, paratypes; MZUSP 40797, 2, 25.6–39.9 mm SL, paratypes; MZUSP 40810, 11, 22.0–39.5 mm SL, paratypes; MZUSP 40813, 6, 23.2–37.5 mm SL, paratypes; MCP 21715, 15, 19.6–37.5 mm SL, paratypes; MZUSP 113839, 1, 40.1 mm SL; MZUSP 113939, 61, 18.7–41.1 mm SL. *Characidium xanthopteron*: UFRGS 11226, 16, 26.2–36.4 mm SL; UFRGS 11299, 4, 24.6–36.6 mm SL; MZUSP 53404, 32, 30.7–40.6 mm SL, MZUSP 53422, 3, 38.8–45.2 mm SL.

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Neotropical Ichthyology

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