

# A new species from subtropical Brazil and evidence of multiple pelvic fin losses in catfishes of the genus *Cambeva* (Siluriformes, Trichomycteridae)

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## Abstract

A third pelvic-less species of *Cambeva* from river basins draining the Geral mountain range in southern Brazil is described. It is distinguished from other congeners lacking pelvic fin and girdle, *C. pascuali* and *C. tropeiro*, by having six pectoral-fin rays, 20–23 dorsal procurent caudal-fin rays, 15–20 opercular and 25–30 interopercular odontodes and a different colour pattern consisting of flank dark brownish-grey with two irregular horizontal rows of small pale yellow grey marks. Whereas available molecular evidence indicates that *C. pascuali* is more closely related to *C. zonata*, a species with well-developed pelvic fin, and *C. tropeiro* is more closely related to *C. balios*, another species also with well-developed pelvic fin; osteological data strongly suggest that the new species herein described is more closely related to *C. diatropoporos* than to other congeners. Therefore, this study indicates that the pelvic fin and pelvic-fin support have been lost independently in each of these three species of *Cambeva*, which corresponds to 11% of all describe species. This result highly contrasts with the closely-related trichomycterine genera *Trichomycterus*, in which only one in 50 species lost pelvic fin and girdle (0.2%) and *Scleronema* with all the nine included species having well-developed pelvic fin. These data suggest a stronger tendency to losing pelvic fin in *Cambeva*, but factors favouring this evolutionary event are still unknown.

## Key Words

Mountain biodiversity, osteology, Rio Uruguai basin, Serra Geral, systematics

## Introduction

The presence or not of pelvic fin was considered an important morphological character for generic delimitation in teleost fishes by 19<sup>th</sup> century naturalists. Amongst the Trichomycterinae, one of the eight subfamilies of the Neotropical catfish Trichomycteridae, the two oldest genera were distinguished only on the basis of this character. *Trichomycterus* Valenciennes, 1832 was first diagnosed by its only included species, *Trichomycterus nigricans* Valenciennes, 1832, having pelvic fin (Valenciennes in Humboldt and Bonpland 1832), thus differing from the only other then-known trichomycterine *Eremophilus mutisii* Humboldt,

1805, in which pelvic fin is absent (Humboldt 1805). This classificatory scheme was followed without criticism for a long time. Over 100 years after, two other trichomycterids were placed in the genus *Eremophilus*, *E. candidus* Miranda-Ribeiro, 1949 and *E. camposi* Miranda-Ribeiro, 1957, just by lacking pelvic fin (Miranda-Ribeiro 1949, 1957). However, morphological and molecular studies have consistently shown that *E. candidus* is a member of the genus *Trichomycterus* (Barbosa and Costa 2003; Katz et al. 2018) and *E. camposi* belongs to the microcambevinae genus *Listrura* de Pinna, 1988 (de Pinna 1988; Costa et al. 2020a), therefore constituting independent evolutionary events of pelvic fin loss amongst trichomycterids.

Recent taxonomical studies on the Trichomycterinae, which is a species-rich clade with over 220 species occurring in most river basins between southern Central America and Patagonia in southern South America (Katz et al. 2018), have revealed few other species also lacking pelvic fin. Costa and Bockmann (1993) have shown that some specimens of *Ituglanis parahybae* (Eigenmann, 1918) lack pelvic fin. More recently, five pelvic-less trichomycterines have been recorded from the Argentinean Andes (Fernández and Liotta 2016), as well as two species lacking pelvic fin being described from south-eastern and southern Brazil (Ferrer and Malabarba 2011; Ochoa et al. 2017a). These Brazilian species are presently placed in *Cambeva* Katz, Barbosa, Mattos & Costa, 2018, a genus comprising 25 valid species endemic to south-eastern and southern Brazil (Katz et al. 2018; dos Reis et al. 2019), as well as a single species from north-eastern Argentina (Terán et al. 2017).

Amongst the 26 species of *Cambeva*, only *C. pascuali* (Ochoa, Silva, Costa e Silva, Oliveira & Datovo, 2017) and *C. tropeiro* (Ferrer & Malabarba, 2011) lack pelvic fin and girdle (Ferrer and Malabarba; 2011 Ochoa et al. 2017b), whereas, in all other 24 remaining species, these structures are well-developed, including an ossified pelvic girdle and a pelvic fin with five rays. We herein describe a third species of *Cambeva* lacking pelvic fin and girdle, exhibiting some morphological features indicating that it is not closely related to the other two congeners lacking pelvic fin.

## Material and methods

Morphometric and meristic data were taken following Costa (1992), with modifications proposed by Costa et al. (2020b); measurements are presented as percent of standard length (SL), except for those related to head morphology, which are expressed as percent of head length. Fin-ray counts include all elements; vertebra counts include all vertebrae except those participating in the Weberian apparatus; the compound caudal centrum was counted as a single element; counts of vertebrae and procurent fin rays were made only in cleared and stained specimens; counts of principal-fin rays were made in all available specimens, except juveniles about 25 mm SL or less; counts of jaw teeth were approximate, due to their irregular arrangement, great number and frequent loss, making impossible accurate counts. Specimens were cleared and stained for bone and cartilage (C&S in lists of specimens) following Taylor and Van Dyke (1985); osteological characters included in the description are those belonging to structures that have informative variability for positioning the new species amongst congeners, including the mesethmoidal region, suspensorium and opercular apparatus and the parurohyal. Terminology for bones followed Bockmann et al. (2004), except for: the ‘antorbital’ and the ‘tendon-bone supraorbital’ that are here called ‘lacrimal-antorbital’ and ‘fronto-lacrimal tendon bone’, respectively, following

Baskin (1973); ‘epibranchial 5 cartilage’, here replaced by ‘ceratobranchial 4 accessory element’ following Carvalho et al. (2013); ‘urohyal’, here substituted by ‘parurohyal’ following Arratia and Schultze (1990); ‘pleural rib’, here substituted by ‘rib’ following Britz and Bartsch (2003) that have shown to exist only a single rib type in teleosts. Osteological illustrations were made using a stereomicroscope Zeiss Stemi SV 6 with camera lucida. Cephalic laterosensory system terminology follows Arratia and Huaquin (1995), with modifications proposed by Bockmann et al. (2004). Specimens are deposited in the ichthyological collection of the Institute of Biology of the Federal University of Rio de Janeiro, Rio de Janeiro city and in the Centre of Agrarian and Environmental Sciences, Federal University of Maranhão, Campus Chapadinha (CICCAA). Comparative material is listed in Costa et al. (2020b), with the addition of *Cambeva diatropoporos* UFRJ 6913, 1 (C&S). Within the text, geographical names follow Portuguese terms used in the region, thus avoiding common errors or generalisations when tentatively translating them to English, besides making easier their identification in the field.

## Results

### *Cambeva flavopicta* sp. nov.

<http://zoobank.org/375CE4CA-F1ED-4E2D-B379-AF63A1F4E5D8>

Figs 1–2, Table 1

**Type material. Holotype.** UFRJ 12665, 69.2 mm SL; Brazil: Estado de Santa Catarina: Município de Campos Novos: Rio Inferno Grande, Rio Canoas drainage, upper Rio Uruguai basin, 27°21'29"S, 51°01'02"W, about 910 m a.s.l.; CRM Feltrin, 22 May 2019.

**Paratypes.** All from Brazil: Estado de Santa Catarina: Município de Campos Novos: Rio Canoas drainage, upper Rio Uruguai basin: UFRJ 12234, 61, 31.5–73.6 mm SL; UFRJ 12664, 5, 38.2–47.9 mm SL (C&S); CICCAA 04776, 10, 34.5–53.4 mm SL; UFRJ 12235, 8, 27.7–61.7 mm SL; collected with holotype. UFRJ 12662, 10, 35.8–62.2 mm SL; UFRJ 12663, 3 (C&S), 38.7–43.4 mm SL; 27°22'05"S, 51°00'34"W; CRM Feltrin, 12 January 2019.

**Diagnosis.** *Cambeva flavopicta* is distinguished from all other congeners, except *C. pascuali* and *C. tropeiro*, by the absence of pelvic fin and pelvic girdle (vs. pelvic fin and girdle present and well-developed). It is distinguished from both *C. pascuali* and *C. tropeiro* by having 6 pectoral-fin rays (vs. 5 in *C. pascuali* and 7 in *C. tropeiro*), more dorsal procurent caudal-fin rays (20–23 vs. 17–18 in *C. pascuali* and 14–15 in *C. tropeiro*), more opercular odontodes (15–20 vs. 10–12 in *C. pascuali* and 12–14 in *C. tropeiro*), more interopercular odontodes (25–30 vs. 11–12 in *C. pascuali* and 18–24 in *C. tropeiro*) and colour pattern consisting of flank dark brownish-grey with two irregular horizontal rows of small pale yellow grey marks (vs. flank pale yellow with dark brown stripes or horizontal rows of spots in *C. pascuali* and flank yellowish-brown with dark brown spots irregularly arranged



**Figure 1.** *Cambeva flavopicta* sp. nov., UFRJ 12665, holotype, 69.2 mm SL: **A.** Left lateral view; **B.** Dorsal view; **C.** Ventral view.

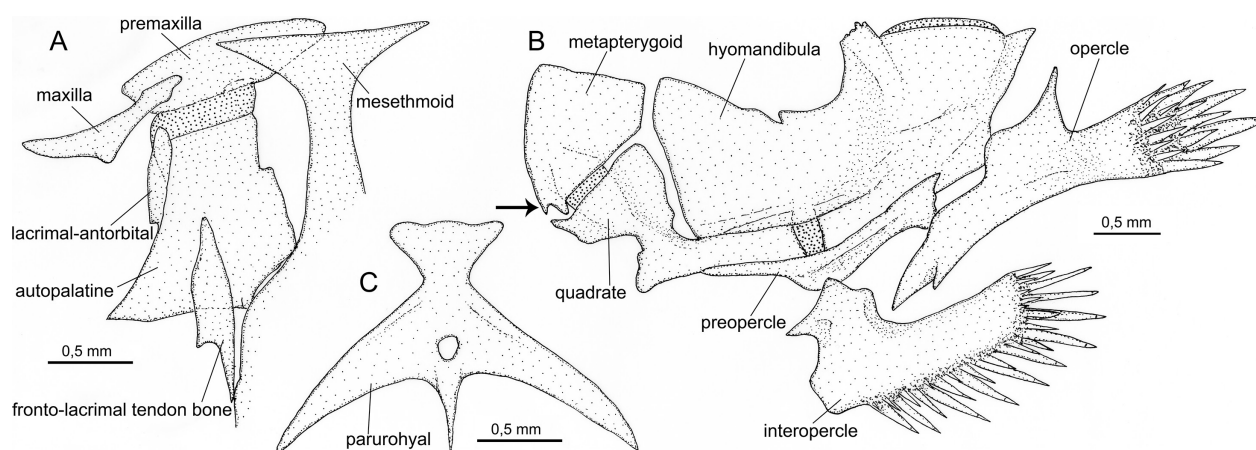
in *C. tropeiro*). *Cambeva flavopicta* also differs from *C. pascuali* by the presence of the anterior section of the infra-orbital canal (vs. absence), more vertebrae (38–39 vs. 37) and more branchiostegal rays (9 vs. 7); and from *C. tropeiro* by having more ventral procurent caudal-fin rays (16–17 vs. 10–11), the first pectoral-fin ray terminating in a short filament (vs. without a filament) and caudal fin rounded (vs. subtruncate).

**Description.** Morphometric data are presented in Table 1. Body moderately slender, subcylindrical and slightly depressed anteriorly, compressed posteriorly. Greatest body depth at midway between opercle and anal-fin origin. Dorsal profile of head and trunk slightly convex, approximately straight on caudal peduncle; ventral profile straight to slightly convex between lower jaw and end of anal-fin base, straight on caudal peduncle. Skin papillae minute. Anus and urogenital papilla in vertical through anterior portion of dorsal-fin base. Head trapezoidal in dorsal view. Anterior profile of snout convex in dorsal view. Eye small, dorsally positioned in head. Posterior nostril located slightly nearer anterior nostril than orbital rim. Tip of maxillary barbel reaching area between

**Table 1.** Morphometric data of *Cambeva flavopicta*.

Measurements	Holotype	Paratypes (n = 10)
Standard length (mm)	69.2	41.2–73.6
<b>Percent of standard length</b>		
Body depth	12.9	13.2–17.0
Caudal peduncle depth	11.9	12.1–13.6
Body width	10.4	9.8–11.3
Caudal peduncle width	4.0	2.4–3.5
Pre-dorsal length	64.5	62.9–66.7
Dorsal-fin base length	12.6	10.5–12.4
Anal-fin base length	9.4	8.5–10.3
Caudal-fin length	15.7	14.2–18.4
Pectoral-fin length	11.4	10.4–12.7
Head length	19.0	18.9–22.6
<b>Percent of head length</b>		
Head depth	48.5	45.5–56.0
Head width	86.6	77.2–86.5
Snout length	44.7	39.1–42.8
Interorbital length	25.7	21.1–26.1
Preorbital length	13.1	9.4–11.3
Eye diameter	9.6	9.2–12.7

interopercular patch of odontodes and pectoral-fin base; rictal barbel reaching posterior part of interopercular patch of odontodes; tip of nasal barbel reaching area just



**Figure 2.** Osteological structures of *Cambeva flavopicta* sp. nov., UFRJ 12664, paratype, 47.9 mm SL: **A.** Mesethmoidal region and adjacent structures, left and middle portions, dorsal view; **B.** Left suspensorium and opercular series, lateral view; **C.** Parurohyal, ventral view. Arrow indicates the ventral process on the metapterygoid. Larger stippling represents cartilaginous areas.

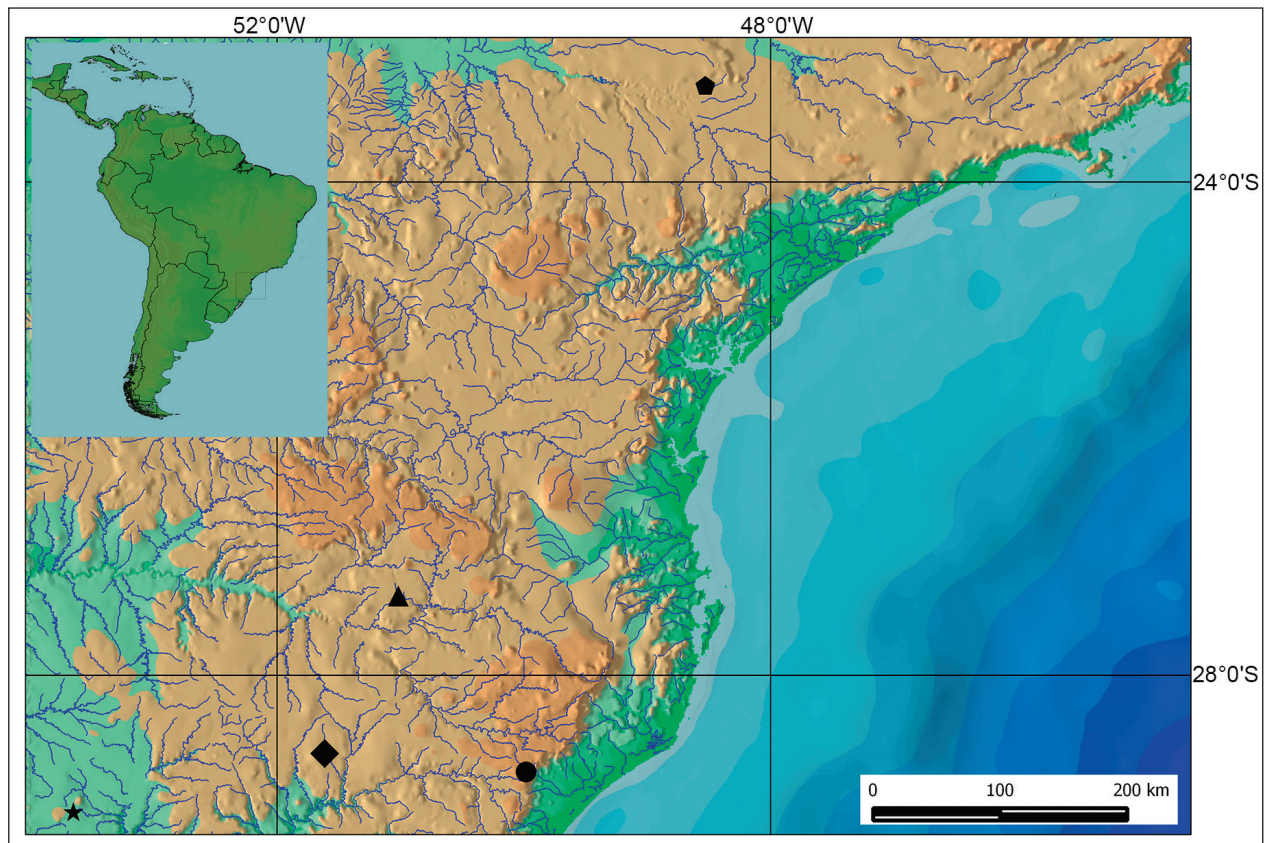
anterior to opercular patch of odontodes. Mouth subterminal. Jaw teeth slightly pointed, few external-most teeth incisiform in larger specimens (above about 65 mm SL); premaxillary teeth about 45, slightly curved, arranged in 3 irregular rows; dentary teeth about 40–45, curved inside mouth, arranged in 3 irregular rows, more concentrated near dentary symphysis. Branchial membrane attached to isthmus only at its anterior point. Branchiostegal rays 9.

Dorsal and anal fins subtriangular; total dorsal-fin rays 11–12 (ii–iii + II–III + 6–7), total anal-fin rays 9 (ii + II + 5); anal-fin origin in vertical between middle and posterior half of dorsal-fin base, approximately between base of 3<sup>rd</sup> and 5<sup>th</sup> branched dorsal-fin ray. Dorsal-fin origin in vertical through centrum of 20<sup>th</sup> or 21<sup>st</sup> vertebra; anal-fin origin in vertical through centrum of 23<sup>rd</sup> or 24<sup>th</sup> vertebra. Pectoral fin subtriangular in dorsal view, posterior margin slightly convex, first pectoral-fin ray terminating in minute filament, about 10% or less of pectoral fin length without filament; total pectoral-fin rays 6 (I + 5). Pelvic fin and girdle absent. Posterior margin of caudal fin convex, upper and lower margins straight; total principal caudal-fin rays 13 (I + 11 + I), total dorsal procurent rays 20–23 (ixx–xxii + I–II), total ventral procurent rays 16–17 (xv–xvi + I). Vertebrae 38–39. Ribs 13 or 14. Two dorsal hypural plates, corresponding to hypurals 4 + 5 and 3, respectively; single ventral hypural plate corresponding to hypurals 1 and 2 and parhypural.

**Latero-sensory system (Fig. 1).** Supraorbital sensory canal continuous, connected to posterior section of infra-orbital canal posteriorly. Supraorbital sensory canal with 3 pores: s1, adjacent to medial margin of anterior nostril; s3, adjacent and just posterior to medial margin of posterior nostril; and s6, in transverse line through posterior half of orbit; pore s6 slightly nearer orbit than its paired homologous pore. Infra-orbital sensory canal arranged in 2 segments, each with two pores; anterior segment with pore i1, in transverse line through anterior nostril, and pore i3, in transverse line just anterior to posterior nostril; posterior segment with pore i10, adjacent to ventral margin of orbit, and pore i11, posterior to orbit. Postorbital canal with 2

pores: po1, in vertical line above posterior portion of interopercular patch of odontodes, and po2, in vertical line above posterior portion of opercular patch of odontodes. Lateral line of body short, with 2 pores, posterior-most pore in vertical just posterior to pectoral-fin base.

**Osteology (Fig. 2).** Mesethmoid robust, its anterior margin nearly straight; mesethmoid cornu subtriangular in dorsal view, basal portion wide, abruptly narrowing distally, extremity pointed. Lacrimal-antorbital thin, drop-shaped; fronto-lacrimal tendon bone slender and with lateral process, sometimes membranous expansion, its length about one and half times or twice lacrimal-antorbital length. Premaxilla sub-rectangular in dorsal view, long, longer than distance between extremities of mesethmoid cornua. Maxilla boomerang-shaped, slender, about 80% maxilla length, slightly curved. Autopalatine subrectangular in dorsal view, compact, lateral and medial margins slightly concave, with small notch on middle part of medial margin; autopalatine posterolateral process almost indistinct. Metapterygoid thin, subtriangular, large, its largest length about equal horizontal length of quadrate excluding dorsal process; anteroventral portion of metapterygoid with short process just anterior to articulatory cartilaginous block. Quadrate slender, dorsal process with constricted base and antero-dorsal projection, dorsoposterior margin separated from hyomandibula outgrowth by interspace. Hyomandibula long, with well-developed anterior outgrowth; middle portion of dorsal margin of hyomandibula outgrowth with shallow concavity. Opercle slender, with 15–20 odontodes; odontodes pointed, nearly straight, arranged in irregular transverse rows; odontode patch depth about half interopercular odontode patch length; dorsal process of opercle short and pointed; ventral process of opercle moderate, about half opercle length. Interopercle moderate, about two thirds hyomandibula length, with 25–30 odontodes; odontodes pointed, arranged in irregular longitudinal rows; anterior margin of interopercle truncate; dorsal interopercular process with deep anterior concavity. Preopercle compact, with minute ventral flap. Paruro-



**Figure 3.** Map of geographical distribution of *Cambeva flavopicta* sp. nov. (triangle), and type localities of *C. diatropoporos* (diamond), *C. pascuali* (pentagon), *C. poikilos* (star) and *C. tropeiro* (dot).

hyal robust, lateral process latero-posteriorly directed, abruptly narrowing distally, tip sharply pointed; parurohyal head well-developed, with distinctive anterolateral paired process; middle foramen small and rounded; posterior process well-developed.

**Colouration in alcohol (Fig. 1).** Flank dark brownish-grey, with two irregular horizontal rows of small pale yellow grey marks with varied shapes, mostly horizontally orientated, often horizontally coalesced on flank longitudinal midline, sometimes vertically coalesced on caudal peduncle; in some specimens, pale yellow marks restricted to small spots. Dorsum pale yellow with longitudinal row of rounded, longitudinally-elongated dark brown to black blotches and small pale brown dots. Venter yellowish-white, with brown chromatophores slightly concentrated on area just anterior to urogenital region and close to pectoral-fin base. Side and dorsal surface of head light yellowish-grey with irregularly-shaped dark brown to black spots; ventral surface of head yellowish-white, with brown chromatophores slightly concentrated anteriorly, to brown on lower jaw. Barbels brown. Opercle dark brown to black, interopercle yellowish-white with minute brown dots. Fins grey with small dark brown to black spots.

**Distribution and habitat.** *Cambeva flavopicta* is only known from the upper Rio Inferno Grande and tributaries, Rio Canoas drainage, upper Rio Uruguai basin, southern Brazil (Fig. 3). The collecting sites were typical mountain

rivers draining the Serra Geral, with fast flowing waters (Fig. 4). The species was found close to the riverbank, buried below marginal vegetation.

**Etymology.** From the Latin, the name *flavopicta* (painted with yellow) refers to the characteristic colouration of this new species, with yellow marks over dark brown ground.

## Discussion

Phylogenetic relationships amongst species of *Cambeva* are still poorly known. With rare exceptions (Bockmann et al. 2004; Ferrer and Malabarba 2013), osteological data that have been broadly used to diagnose species and establish morphological phylogenetic hypotheses in trichomycterid groups (e.g. Baskin 1973), have been broadly omitted even in recent taxonomical studies on *Cambeva* (e.g. Wosiacki and Garavello 2004; Ferrer and Malabarba 2011; Ochoa et al. 2017b). Similarly, trichomycterid molecular phylogenies have included only a few species of this genus (Ochoa et al. 2017a, 2020; Katz et al. 2018). Therefore, the phylogenetic position of the new species herein described is still uncertain, but some derived osteological character states, shared by *C. flavopicta* and other congeners here examined or with available osteological data from literature, highly suggest possible relationships as below discussed.



**Figure 4.** Rio Inferno Grande (upper Rio Uruguai basin, Santa Catarina, Brazil), at the exact point where the holotype and paratypes of *Cambeva flavopicta* sp. nov. were collected.

At first glance, the absence of pelvic fin and girdle in all specimens of *C. flavopicta* could be considered as evidence of close relationships with the only two congeners sharing this condition, *C. pascuali* from the Rio Parapanema drainage, Rio Paraná basin and *C. tropeiro* from the Lagoa dos Patos system. However, a recent unilocus phylogeny (Donin et al. 2020) indicates that *C. pascuali* and *C. tropeiro* are not closely-related species. The former species appears as being closer to *C. zonata*, a species from the Rio Ribeira do Iguape basin in south-eastern Brazil, whereas the latter is sister to *C. balios* (Ferrer & Malabarba, 2013), a species also endemic to the Lagoa dos Patos system and sharing with *C. tropeiro* a similar colour pattern consisting of rounded dark brown spots on the flank (Ferrer and Malabarba 2011: fig. 1, 2013: fig. 1). On the other hand, osteological evidence described below supports *C. flavopicta* as being closely related to species having a well-developed pelvic fin.

The long premaxilla recorded for *C. flavopicta*, with its longest length greater than the distance between the extremities of the mesethmoid cornua (Fig. 2A), is similar to the long premaxilla shared only by some congeners (Ferrer and Malabarba 2013: fig. 2) belonging to a molecularly well-supported clade from rivers of the Lagoa dos Patos system draining the Serra Geral (e.g. Katz et al. 2018; hereafter the *C. balios* group). Amongst species of the *C. balios* group, *C. flavopicta* shares with *C. diatropoporos* (Ferrer & Malabarba, 2013) and *C. poikilos* (Ferrer & Malabarba, 2013), a derived com-

pact autopalatine with an almost indistinct posterolateral process (Fig. 2A; Ferrer and Malabarba 2013: fig. 2b, c), not present in any congener here examined. Amongst species herein examined, the presence of a short process on the anteroventral portion of the metapterygoid, just anterior to the articulatory cartilaginous block, is shared only by *C. flavopicta* and *C. poikilos*, but the metapterygoid of *C. diatropoporos*, which is possibly more closely related to *C. flavopicta* than to *C. poikilos*, was not illustrated in previous studies and specimens were not available to this study. According to Ferrer and Malabarba (2013: fig. 2c), *C. diatropoporos* has a long antorbital, about half the length of the fronto-lacrima tendon bone length, a derived condition here recorded only for *C. flavopicta* (Fig. 2A). In addition, *C. diatropoporos* possesses a colour pattern similar to that of *C. flavopicta*, including flank dark brownish-grey with small pale yellow grey marks with varied shapes (Ferrer and Malabarba 2013: fig. 10), corroborating a hypothesis of close relationships between *C. flavopicta* and *C. diatropoporos*. Besides lacking pelvic fin and girdle, *C. flavopicta* also differs from *C. diatropoporos* and *C. poikilos* in having more dorsal procurent rays in the caudal fin (21–23 vs. 15–19), more ventral procurent rays in the caudal fin (16–17 vs. 10–15), the posterior margin of the caudal fin convex (vs. straight) and presence of a small filament on the tip of the first pectoral-fin ray (vs. absence); from *C. diatropoporos* by having the extremity of the parurohyal lateral process sharply pointed (Fig. 2C; vs. broad and rounded, Ferrer

and Malabarba 2013: fig. 5b) and fewer pectoral-fin rays (6 vs. 7); and from *C. poikilos* by the presence of the anterior section of the infra-orbital canal (vs. absence).

As discussed above, this study indicates that the pelvic fin and pelvic-fin support have been lost independently in three lineages of the genus *Cambeva*, corresponding to three species in a total of 27 (11.1%). This result highly contrasts with the closely-related trichomycterine genus *Trichomycterus*, in which only one species, *T. candidus*, does not have pelvic fin and girdle, amongst a total of 50 valid species (0.2%), as well as *Scleronema*, the sister group of *Cambeva* (Katz et al., 2018), with all the nine included species having well-developed pelvic fin and girdle (Ferrer and Malabarba 2020). These data suggest a stronger tendency to losing pelvic fin in *Cambeva* than in these closely-related genera, but factors favouring this evolutionary event are still unknown. Amongst trichomycterids of the TSVSGM-clade (Costa and Bockmann 1994; Costa et al. 2020a), parallel loss of pelvic fin and reduction or loss of other fins in the subfamilies Glanapteryginae and Microcambevininae have been related to their interstitial habits (Costa et al. 2020a). On the other hand, conflicting field reports about the habitat of pelvic-less species of *Cambeva* do not indicate that they share similar habits. Specimens of *C. flavopicta* were found buried in terrestrial marginal vegetation of a fast flowing stream (see above), whereas specimens of *C. pascuali* were found under rocks and aquatic vegetation of a muddy bottom area bordered by riparian vegetation (Ochoa et al. 2017b), but no data are available about the specific habitat of *C. tropeiro*. Therefore, little is still known about the ecology and behaviour in species of the genus *Cambeva*, presently not allowing explanations involving habits for the evolutionary meaning of multiple pelvic fin losses.

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