

## Two new species of *Melanorivulus* from the Caiapós hill, upper Araguaia river basin, Brazil (Cyprinodontiformes: Rivulidae)

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*Melanorivulus ubirajarai*, new species, and *Melanorivulus kunzei*, new species, are described from the upper Araguaia river basin, central Brazil; both are considered as closely related to other species endemic from the same area. *Melanorivulus ubirajarai* shares with *M. litteratus* a unique colour pattern of caudal fin in females (short grey stripe between caudal spot and bar on the middle of the fin). *Melanorivulus kunzei* shares with *M. kayapo* a unique colour pattern of flank in males (irregular horizontal rows of red dots forming reticulate pattern). *Melanorivulus ubirajarai* is mainly distinguished from *M. litteratus* by having a distinct colour pattern of flank and dorsal fin in males, consisting of not overlapping chevron-like red oblique bars on the flank and rows of light grey spots on the dorsal fin in males, dorsal fin at vertical through the base of the 9th anal-fin ray, and 33–35 scales on the longitudinal series. *Melanorivulus kunzei* mainly differs from *M. kayapo* by having 29–30 caudal-fin rays and the presence of dark grey dots on the sub-distal portion of the dorsal fin and middle of caudal fin in males. The discovery of the two new species supports the recent report of a unique high species diversity of *Melanorivulus* in the area drained by rivers originating in the Caiapós hill. The combination of high species diversity with quick habitat loss makes rivulid species endemic to the Caiapós hill area highly threatened with extinction, deserving special concern.

### Introduction

*Melanorivulus* is a diversified genus of killifishes living in shallow marginal parts of streams and swamps in Brazil, Bolivia, Paraguay and Argentina (Costa, 2011). A great diversity of species is concentrated in the savannah-like Cerrado of the highlands of central Brazil, including the upper Paraná river basin and an adjacent portion of the upper Araguaia river basin, in altitudes between 500 and 900 m (Costa, 2005, 2006, 2007a, 2008a–b).

A total of nine species of *Melanorivulus* have been described from this area, which is characterized by a series of mesa formations associated to the Caiapós hill, the watershed separating the Paraná and Araguaia river basins. This area has been severely altered in recent years by agricultural activities, which today occupy huge plain areas, making the typical habitat of *Melanorivulus* quickly rare. During recent field studies directed to survey killifish diversity in that area, two new species were found, which are herein described.

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## Material and methods

Morphological characters were obtained from specimens fixed in formalin just after collection, for a period of 10 days, and then transferred to 70 % ethanol. Material is deposited in the ichthyological collection of the Instituto de Biologia, Universidade Federal do Rio de Janeiro, Rio de Janeiro (UFRJ). Descriptions of colour patterns were based both on direct examination of live specimens in the field immediately after collection, and photographs of both sides of males and females, taken one day after collection. Measurements and counts follow Costa (1995); a complete set of measurements were made only in adult specimens (more than 24 mm SL). 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. Number of vertebrae and gill-rakers were recorded from cleared and stained specimens; the compound caudal centrum was counted as a single element. Osteological preparations were made according to Taylor & Van Dyke (1985). Terminology for frontal squamation follows Hoedeman (1958) and for cephalic neuromast series Costa (2001). Delimitation of species is according to the methodology of the Population Aggregation Analysis (Davis & Nixon, 1992), in which species are delimited by a unique combination of morphological character states.

### *Melanorivulus ubirajarai*, new species (Figs. 1–2)

**Holotype.** UFRJ 8425, male, 29.9 mm SL; Brazil: Estado de Goiás: Município de Mineiros: small stream crossing road BR-384, a tributary to the Babilônia river, itself a tributary to upper section of Araguaia river, 17°23'00" S 52°57'08" W, altitude 787 m asl; W. J. E. M. Costa et al., 18 Sep 2011.

**Paratypes.** UFRJ 8426, 5 males, 23.7–27.2 mm SL, 6 females, 25.5–27.2 mm SL; UFRJ 8427, 2 males, 21.0–22.6 mm SL, 4 females, 21.3–23.9 mm SL (c&s); collected with holotype.

**Diagnosis.** *Melanorivulus ubirajarai* differs from all other species of the genus, except *M. litteratus*, by the presence of a short dark yellowish grey stripe on the caudal fin in females, connecting the

black caudal spot present on the fin base to the bar on the middle of the fin (vs. never a horizontal mark in this position). *Melanorivulus ubirajarai* is distinguished from *M. litteratus* by having the dorsal-fin origin placed more posteriorly on trunk (on the vertical through the base of the 9th anal-fin ray, vs. between the base of 7th and 8th anal-fin rays; second proximal radial of dorsal fin between neural spines of 19th and 21st vertebrae, vs. between neural spines of 18th and 19th vertebrae); more vertebrae (31–32 vs. 29–30) and more scales on the longitudinal series (33–35 vs. 30–32); flank in males with well delimited and not overlapped chevron-like red oblique bars (vs. bars broken and highly overlapping, forming lozenge-, Y- and X-shaped red marks); and dorsal fin in males with transverse rows of small light grey spots (vs. transverse red bars).

**Description.** Morphometric data appear in Table 1. Largest male examined 29.9 mm SL; largest female examined 27.2 mm SL. Dorsal profile slightly convex from snout to end of dorsal-fin base, nearly straight on caudal peduncle. Ventral profile gently convex from lower jaw to end of anal-fin base, about straight on caudal peduncle. Body slender, subcylindrical anteriorly, slightly deeper than wide, to compressed posteriorly. Greatest body depth at vertical just in front to pelvic-fin base. Jaws short, snout blunt.

Extremity of dorsal and anal fins slightly pointed in males, rounded in females. Caudal fin oval. Pectoral fin rounded, posterior margin reaching vertical at about 90 % of length between pectoral-fin and pelvic-fin bases. Pelvic fin small, tip reaching between urogenital papilla and base of 2nd anal-fin ray in males, reaching between anus and urogenital papilla in females. Pelvic-fin bases medially in close proximity. Dorsal-fin origin on vertical through base of 9th anal-fin ray; second proximal radial of dorsal fin between neural spines of 19th and 21st vertebrae, first proximal radial of anal fin between pleural ribs of 13th and 15th vertebrae. Dorsal-fin rays 9–10; anal-fin rays 14–16; caudal-fin rays 32–33; pectoral-fin rays 14; pelvic-fin rays 7.

Scales small, cycloid. Body and head entirely scaled, except anterior ventral surface of head. Body squamation extending over anterior 25 % of caudal-fin base; no scales on dorsal and anal-fin bases. Frontal squamation usually F-patterned, sometimes E-patterned; E-scales not overlapping medially; scales arranged in regular circular pat-

tern around A-scale without exposed margins; transverse row of scales anterior to H-scale. Eight supraorbital scales. Longitudinal series of scales 33–35; transverse series of scales 9; scale rows around caudal peduncle 16 or 18. No contact organs on flank and fins.

Cephalic neuromasts: supraorbital 3+3, parietal 1, anterior rostral 1, posterior rostral 1, infraorbital 1+11–12+1, preorbital 2, otic 1, postotic 2, supratemporal 1, median opercular 1, ventral opercular 2, preopercular 2+4, mandibular 3+1, lateral mandibular 3, paramandibular 1. Lateral line interrupted, alternating sets of 3–4 scales with one neuromast and without neuromasts. Two neuromasts on caudal-fin base.

Basihyal subtriangular, greatest width about 50 % of length; basihyal cartilage about 20 % of total length of basihyal. Six branchiostegal rays. Second pharyngobranchial teeth absent. Gill-rakers on first branchial arch 1+8. One vomerine tooth. Dermosphenotic present. Ventral process of posttemporal absent. Total vertebrae 31–32.

**Colouration.** Males. Flank metallic greenish blue, with red dots on anterior portion of flank and along dorsal and anteroventral part of flank, and red oblique bars between vertical just anterior to pelvic-fin base and caudal peduncle; bars often forming chevron-like marks with angle on

midline of flank and anteriorly directed; rectangular, horizontally elongated brownish red humeral spot. Dorsum light brown, with few small dark brown spots. Venter light grey. Side of head pale blue, with oblique, postorbital reddish brown bars; ventral part of opercular region greenish golden; lower jaw dark grey. Iris yellow. Dorsal fin grey with transverse rows of small light grey spots; row of red dots on fin base. Anal fin yellowish grey, basal portion light blue with row of small, triangular red spots, distal margin yellowish brown. Caudal fin yellowish grey, with 5–7 reddish grey bars, not extending to ventral third of fin. Pectoral fin yellowish hyaline. Pelvic fin yellowish grey.

Females. Flank pale greenish blue, with red oblique bars between vertical just anterior to pelvic-fin base and caudal peduncle; bars often forming chevron-like marks with angle on midline of flank and anteriorly directed; rectangular, horizontally elongated brownish red humeral spot. Dorsum light brown with small dark brown spots. Venter light grey. Side of head light brown with small dark brown dots; opercle pale golden; lower jaw grey. Iris pale yellow. Dorsal fin pale yellowish white, with 3–4 dark yellowish grey transverse stripes; distal margin dark grey to black. Anal fin light yellowish grey, with dark grey dots on sub-basal and posterior portions;

**Table 1.** Morphometric data of *Melanorivulus ubirajarai* and *M. kunzei*.

	<i>Melanorivulus ubirajarai</i>			<i>M. kunzei</i>		
	holotype	paratypes		holotype	paratypes	
	male	males (4)	females (6)	male	males (7)	females (6)
Standard length (mm)	29.9	25.4–27.2	25.5–27.2	33.4	25.2–30.9	24.3–32.2
<b>Percent of standard length</b>						
Body depth	23.4	21.8–22.8	21.1–23.1	24.9	23.8–26.3	22.9–25.7
Caudal peduncle depth	14.6	13.3–14.1	13.2–14.0	15.4	13.9–15.2	13.3–15.2
Predorsal length	75.8	76.3–78.1	75.1–79.2	74.5	76.3–80.1	77.4–81.5
Prepelvic length	55.7	53.3–56.8	53.3–56.7	59.7	57.1–59.8	56.0–59.9
Length of dorsal-fin base	12.5	11.5–13.6	11.3–13.6	12.2	11.1–14.0	10.7–12.5
Length of anal-fin base	22.8	20.9–22.7	20.0–21.2	20.3	17.6–19.6	15.9–17.4
Caudal-fin length	35.9	32.6–36.3	32.6–36.6	36.7	34.7–38.0	32.9–34.9
Pectoral-fin length	21.4	21.9–23.1	20.6–22.3	21.5	20.2–22.6	19.6–22.0
Pelvic-fin length	11.9	11.4–13.0	9.3–10.6	11.9	10.0–11.3	8.6–10.4
Head length	26.5	26.6–28.1	26.2–28.4	27.0	27.6–28.8	26.8–29.2
<b>Percent of head length</b>						
Head depth	71	65–68	64–69	76	70–72	69–73
Head width	78	74–78	73–78	81	78–82	77–80
Snout length	14	14–15	14–15	14	14–15	14–15
Lower jaw length	17	16–20	18–21	21	19–21	20–22
Eye diameter	31	32–34	31–35	26	27–31	28–32



Fig. 1. *Melanorivulus ubirajarai*, UFRJ 8425, holotype, male, 29.9 mm SL; Brazil: Goiás: Mineiros.



Fig. 2. *Melanorivulus ubirajarai*, UFRJ 8426, paratype, female, 25.5 mm SL; Brazil: Goiás: Mineiros.

basal portion light blue; distal margin dark grey to black. Caudal fin pale yellow, with 5–6 dark yellowish grey bars; round, often slightly horizontally elongated, black spot on dorsal portion of fin base, dorsally and ventrally bordered by small yellowish white areas; short yellowish grey stripe connecting black caudal spot to middle caudal-fin bar, better visible in preserved specimens; fin margins dark grey to black. Pectoral fin hyaline. Pelvic fin yellowish white, anterior margin dark grey.

**Distribution.** *Melanorivulus ubirajarai* is known only from the type locality, a stream tributary to the Babilônia river, upper Araguaia river basin, Goiás, central Brazil.

**Etymology.** The name *ubirajarai* is in honour of Ubirajara Martins, entomologist at Museu de Zoologia, Universidade de São Paulo, professor of principles of taxonomy, who was teacher and friend during my early formation in Systematics, providing great enthusiasm for studying taxonomy of killifishes about 30 years ago.

*Melanorivulus kunzei*, new species  
(Figs. 3–4)

**Holotype.** UFRJ 8423, male, 33.4 mm SL; Brazil: Estado de Goiás: Município de Jataí: road BR-158, about 64 km N of Jataí town, in a small stream tributary to upper Caiapó River, an upper tribu-



Fig. 3. *Melanorivulus kunzei*, UFRJ 8423, holotype, male, 33.0 mm SL; Brazil: Goiás: Jataí.



Fig. 4. *Melanorivulus kunzei*, UFRJ 8422, paratype, female, 32.2 mm SL; Brazil: Goiás: Jataí.

tary to Araguaia River, 17°01'55"S 51°51'03"W, altitude 729 m; W. J. E. M. Costa et al., 16 Sep 2011.

**Paratypes.** UFRJ 8422, 6 males, 25.9–30.9 mm SL, 5 females, 24.3–32.2 mm SL; UFRJ 8421, 4 males, 18.7–26.9 mm SL, 4 females, 19.9–25.6 mm SL (c&s); collected with holotype.

**Diagnosis.** *Melanorivulus kunzei* is distinguished from all other species of *Melanorivulus*, except *M. kayapo*, by having a colour pattern of flank in males consisting of irregular horizontal rows of red dots arranged to form a red reticulate pattern on the posterior part of flank, including caudal peduncle region (vs. never a similar colour pat-

tern; usually oblique red bars on the flank, reticulated areas when present are symmetrical and derived from overlapping bars). *Melanorivulus kunzei* is distinguished from *M. kayapo* by having fewer caudal-fin rays (29–30 vs. 32–34), more neuromasts in the infraorbital series (1+11+1 vs. 1+7–9+1), and by the presence of dark grey dots on the subdistal portion of dorsal fin and middle of caudal fin in males (vs. absence) and small red spots on the caudal fin in males (vs. horizontally elongated red spots).

**Description.** Morphometric data appear in Table 1. Largest male examined 33.0 mm SL; largest female examined 32.2 mm SL. Dorsal profile weakly convex from snout to end of dorsal-fin

base, approximately straight on caudal peduncle. Ventral profile gently convex from lower jaw to end of anal-fin base, about straight on caudal peduncle. Body slender, subcylindrical anteriorly, slightly deeper than wide, to compressed posteriorly. Greatest body depth at vertical just in front to pelvic-fin base. Jaws short, snout blunt.

Extremity of dorsal and anal fins rounded. Caudal fin rounded. Pectoral fin rounded, posterior margin reaching vertical at about 75 % of length between pectoral-fin and pelvic-fin bases. Pelvic fin small, tip reaching between urogenital papilla and anal-fin origin in males, reaching anus in females. Pelvic-fin bases medially in close proximity. Dorsal-fin origin on vertical through base of 8th anal-fin ray; second proximal radial of dorsal fin between neural spines of 19th and 20th vertebrae, first proximal radial of anal fin between pleural ribs of 14th and 15th vertebrae. Dorsal-fin rays 10–11; anal-fin rays 11–13; caudal-fin rays 29–30; pectoral-fin rays 14; pelvic-fin rays 7.

Scales small, cycloid. Body and head entirely scaled, except anterior ventral surface of head. Body squamation extending over anterior 35 % of caudal-fin base; no scales on dorsal and anal-fin bases. Frontal squamation E-patterned; E-scales not overlapping medially; scales arranged in regular circular pattern around A-scale without exposed margins; no transverse row of scales anterior to H-scale. Seven supraorbital scales. Longitudinal series of scales 30–31; transverse series of scales 7; scale rows around caudal peduncle 16. No contact organs on flank and fins.

Cephalic neuromasts: supraorbital 3+3, parietal 1, anterior rostral 1, posterior rostral 1, infraorbital 1+11+1, preorbital 2–3, otic 1, post-otic 1–2, supratemporal 1, median opercular 1, ventral opercular 2, preopercular 2+4, mandibular 3+1, lateral mandibular 2, paramandibular 1. Lateral line interrupted, alternating sets of 3–4 scales with one neuromast and without neuromasts. Two neuromasts on caudal-fin base.

Basihyal subtriangular, greatest width about 60 % of length; basihyal cartilage about 25 % of total length of basihyal. Six branchiostegal rays. Second pharyngobranchial teeth absent. Gill-rakers on first branchial arch 1+8. One vomerine tooth. Dermosphenotic present. Ventral process of posttemporal absent. Total vertebrae 31–32.

**Colouration.** Males. Flank metallic green, with irregular horizontal rows of red dots; red dots coalesced on posterior part of flank, mainly on caudal peduncle, forming irregular reticulate pattern. Dorsum light brown, with few small dark brown spots. Venter light grey. Side of head pale brown, opercular region metallic green or greenish golden, with small patches of melanophores; lower jaw grey. Iris yellow on middle, greenish brown on anterior and posterior portions. Dorsal fin pale blue, with small red spots, sometimes transversely elongated, sub-distal portion dark grey dots overlapping small red spots, marginal region pale brownish yellow without marks. Proximal half of anal fin light blue, with red dots on fin base and sub-basal series of red dots; distal half pale brownish yellow. Caudal fin pale blue, with dark grey dots overlapping small red spots; marginal zone pale brownish yellow without dots; often narrow dark grey distal margin. Pectoral fin yellowish hyaline. Pelvic fin yellow to light blue with anterior and distal parts pale brownish yellow.

Females. Flank light metallic green, with horizontal and oblique rows of red dots. Dorsum light brown with dark brown dots. Venter light grey. Side of head light brown with small dark brown dots; opercle pale golden; lower jaw grey. Iris pale yellow. Dorsal fin pale yellow, with red dots on basal portion; distal margin dark grey to black. Anal fin light yellowish grey, with red dots on basal region; distal margin dark grey to black. Caudal fin pale yellow, with black dots; horizontally elongated black spot on dorsal portion of fin base, ventrally adjacent to light yellow to white submarginal zone; fin margins dark grey to black. Pectoral fin yellowish hyaline. Pelvic fin pale yellow, anterior margin grey.

**Distribution.** *Melanorivulus kunzei* is known only from the type locality, a stream tributary to the upper Caiapó River, which is an upper tributary to the Araguaia River, about 64 km N of the town of Jataí in the road BR-158, Goiás, central Brazil.

**Etymology.** The name *kunzei* is in honour of Eduardo Kunze Bastos, author of an unpublished dissertation written in 1979 comprising a pioneering study on the ecology of *Rivulus punctatus* (correctly, *Melanorivulus pictus*) from central Brazil, providing initial stimulus for studying taxonomy of the killifishes today placed in the genus *Melanorivulus*.

## Discussion

Examination of details of the colour pattern of the two new species here described for the upper Araguaia river basin indicates that their closest relatives are species endemic to the same area. The presence, on the caudal fin in females, of a horizontal dark yellowish grey mark connecting the black caudal spot present on the fin base and a dark yellowish grey bar on the middle of the fin is uniquely found in *M. ubirajarai* (Fig. 2) and in *M. litteratus* (Costa, 2005: fig. 7), a species also endemic to the upper Araguaia river basin (Costa, 2005). In all other species of the genus, a similar colour pattern is never present. *Melanorivulus ubirajarai* is easily distinguished from *M. litteratus* by the colour pattern of males, consisting of well delimited and not overlapped chevron-like red oblique bars on the flank in *M. ubirajarai*, whereas in *M. litteratus*, the bars are broken and highly overlapped, forming lozenge-, Y- and X-shaped red marks (Costa, 2005: fig. 6). Males of both species also differ by the presence of transverse rows of small light grey spots on the dorsal fin of *M. ubirajarai*, contrasting with the transverse red bars present on the dorsal fin of *M. litteratus*. Other diagnostic characters permitting a prompt distinction are the relative position of the dorsal fin (on the vertical through the base of the 9th anal-fin ray in *M. ubirajarai*, vs. between base of 7th and 8th anal-fin rays in *M. litteratus*) and number of scales on the longitudinal series (33–35 in *M. ubirajarai*, vs. 30–32 in *M. litteratus*).

*Melanorivulus kunzei* shares uniquely with *M. kayapo*, a species also endemic to the upper Araguaia river basin, a colour pattern consisting of irregular horizontal rows of red dots arranged to form a reticulate pattern on the posterior part of flank in males (Fig. 3). Although the colour pattern of the flank in males is highly variable among species of *Melanorivulus*, often including chevron-like bars or rows of dots, the reticulate pattern exhibited by *M. kunzei* and *M. kayapo* is never found in other congeners. *Melanorivulus kunzei* is readily distinguished from *M. kayapo* by the number of caudal-fin rays (29–30 in *M. kunzei*, vs. 32–34 in *M. kayapo*) and by the presence of dark grey dots overlapping small red spots on the sub-distal portion of the dorsal fin and middle of caudal fin in males (vs. presence of horizontally elongated red spots and absence of dark grey dots in *M. kayapo*; Costa, 2006: fig. 1). Both species

are members of the *Melanorivulus pinima* clade (Costa, 2007a), also including *M. pinima* and *M. illuminatus* from the upper Paraná river basin. This clade is diagnosed by the apomorphic presence of longitudinal rows of red dots on flank in males and white to light yellow sub-marginal zone on dorsal portion of the caudal fin in females, and reduction of black pigmentation on head and humeral region (Costa, 2007a).

The two new taxa herein described confirm the previous report about the occurrence of an uncommon high species diversity of *Melanorivulus* in the area drained by rivers originating in the Caiapós hill (e.g., Costa, 2008b), which occupies about 85 000 km<sup>2</sup> of the savannah-like Brazilian Cerrado. This area is inhabited by 11 endemic species of *Melanorivulus*, thus contrasting with all areas where the genus occurs, in which the number of species is always much lower. For example, only one species is known from the middle Xingu river basin (Costa, 2009) and another one from the middle Tapajós river basin (Costa, 2008c), whereas only two species has been recorded from the whole São Francisco river basin after over 20 years of intense field studies directed to killifish habitats (e.g., Costa, 2003). Even in adjacent highland areas of central Brazil with ecological conditions similar to the Caiapós hill area, species diversity is lower: two species in the highlands between the upper Paraná and upper Tocantins river basins (Costa, 1989; Costa & Brasil, 2008), two species in the hill between the upper Paraguay and upper Tapajós river basins (Costa, 2008d), and two species in the hill between the upper Paraguay and upper Araguaia river basins (Costa, 1992, 2008d). In addition, all the four species of the 'western clade' of the rivulid genus *Simpsonichthys* are also endemic to this area (Costa, 2012), reinforcing its importance as a centre of high diversity of rivulid killifishes.

Historical factors responsible for the highest species diversity in the Caiapós hill area are still unknown. Ironically, this area is under strong process of habitat loss due to the broad expansion of lands used for agriculture. Huge soya plantations have entirely substituted the original savannah vegetation in plain areas. The narrow buritipalm swampy areas associated to small streams, the typical habitat of species of *Melanorivulus* in central Brazil, are quickly disappearing due to diversion of water source for plantation irrigation, small dams interrupting water flow, and deforestation of stream banks. A small portion of the

Caiapós hill area is protected, the Emas National Park, but only two rivulids are present there, *Melanorivulus formosensis* and *Simpsonichthys parallelus* (Costa, 2007b, 2008b). The combination of high species diversity with intense and continuous habitat loss makes rivulid species endemic to the Caiapós hill area highly threatened with extinction, deserving special concern.

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