

# Five new species of the aplocheiloid killifish genus *Rivulus*, subgenus *Melanorivulus*, from the middle Araguaia river basin, central Brazil (Teleostei: Cyprinodontiformes: Rivulidae)

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## Abstract

Five new species of the genus *Rivulus*, subgenus *Melanorivulus*, are described from the middle Araguaia river basin: *R. salmonicaudus* new species, from streams and swamps directly associated to the main Araguaia river channel; *R. rubromarginatus* new species, from the Peixe river drainage; *R. crixas* new species, from the Crixás Açú river drainage; *R. javahe* new species, from the Verde river and Crixás Açú river drainages; and, *R. karaja* new species, from the Formoso river drainage. All new species are members of the clade here referred as the *R. zygonectes* species group, diagnosed by the presence of a diffuse dark gray stripe between postorbital region and caudal-fin base, in which each included species is diagnosed by unique color patterns of caudal fin in males.

## Resumo

Cinco novas espécies do gênero *Rivulus*, subgênero *Melanorivulus*, são descritas para a bacia do médio rio Araguaia: *R. salmonicaudus* sp. n., de riachos e alagados diretamente associados ao canal principal do rio Araguaia; *R. rubromarginatus* sp. n., da drenagem do rio do Peixe; *R. crixas* sp. n., da drenagem do rio Crixás Açú; *R. javahe* sp. n., das drenagens dos rios Verde e Crixás Açú; e, *R. karaja* sp. n., da drenagem do rio Formoso. Todas as espécies são membros do clado aqui referido como o grupo de espécies *R. zygonectes*, diagnosticado pela presença de uma faixa difusa cinza escura entre a região pós-orbital e a base da nadadeira caudal, no qual cada espécie incluída é diagnosticada por padrões de colorido exclusivo de nadadeira caudal em machos.

## Introduction

*Melanorivulus* Costa, 2006, a subgenus of *Rivulus* Poey, 1860, is endemic to a broad geographic region of the central part of South America, including the southern drainages of the Amazonas river basin (Tocantins, Araguaia, Xingu and Tapajós river drainages), and the Paraná-Paraguay-Uruguay, Parnaíba and São Francisco river basins, in Brazil, Bolivia, Paraguay and Argentina (Costa, 2006a). Species of *Melanorivulus* are found in streams and swamps of open vegetation habitats, usually in the savanna-like Cerrado, highly contrasting with other *Rivulus* lineages, in which their members inhabit forest creeks or streams at the forest border (Costa, 2006a).

Both morphological (*e. g.*, Costa, 1998; 2006a) and molecular studies (*e. g.*, Hrbek & Larson, 1999; Murphy *et al.*, 1999) support monophyly of *Melanorivulus*, which is diagnosed by: dorsal portion of preopercle short and pointed, two oblique bars on postorbital region, melanophores concentrated on margins of unpaired and pelvic fins in females, black spot on upper portion of caudal fin not close to fin margin in females (Costa,

2006a). However, hypotheses of relationships between *Melanorivulus* and other rivulids are still controversial. According to morphological studies, *Melanorivulus* is member of a clade of *Rivulus* also including the subgenera *Owiye* Costa, 2006, and *Laimosemion* Huber, 1999, the latter two subgenera endemic to western and northern tributaries of the Amazonian basin, and river basins draining into northern coast of South America (Costa, 2006a). However, some molecular analyses corroborate *Melanorivulus* as the sister group to a clade including seasonal rivulid genera endemic to central, western and northern South America: *Aphyolebias* Costa, 1998, *Austrofundulus* Myers, 1932, *Gnatholebias* Costa, 1998, *Maratecoara* Costa, 1995, *Micromoema* Costa, 1998, *Moema* Costa, 1989, *Neofundulus* Myers, 1924, *Papiliolebias* Costa, 1998, *Pituna* Costa, 1989, *Plesiolebias* Costa, 1989, *Pterolebias* Garman, 1895, *Rachovia* Myers, 1927, *Renova* Thomerson & Taphorn, 1995, *Terranatos* Taphorn & Thomerson, 1978, and *Trigonectes* Myers, 1925 (Hrbek & Larson, 1999; Murphy *et al.*, 1999).

The greatest species diversity of *Melanorivulus* is concentrated in the highlands of the central Brazilian plateau, where each species is endemic to small sections of river basins (Costa, 1989, 2005, 2006b). Contrastingly, only *R. zygonectes* Myers has been reported to occur in the huge southern Amazonian region comprising the middle and lower courses of the Tocantins, Araguaia, Xingu and Tapajós river basins (Costa, 1995a, 2006b). However, the study of recent collections in the Tocantins and Araguaia basins, directed to a taxonomic revision of *Melanorivulus* in progress by the author, revealed that *R. zygonectes* is restricted to the Tocantins river basin, and there are five new species in the middle Araguaia basin, which are herein described.

## Material and methods

Measurements and counts follow Costa (1995b). Measurements are presented as percentages of standard length (SL), except for those related to head morphology, which are expressed as percentages of head length. Fin-ray counts include all elements. Number of vertebrae, gill-rakers, and pectoral, pelvic and caudal-fin rays were recorded only from cleared and stained specimens; the compound caudal centrum was counted as a single element. Osteological preparations were made according to Taylor and Van Dyke (1985). Terminology for frontal squamation follows Hoedeman (1958) and for cephalic neuromast series Costa (2001). The abbreviation c&s means specimens cleared and stained for bone and cartilage. Material is deposited in Departamento de Zoologia, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil (UFRJ).

## *Rivulus salmonicaudus*, new species

(Figs. 1-2)

**Holotype:** UFRJ 6481, male, 25.2 mm SL; Brazil: Estado de Goiás: Montes Claros de Goiás: córrego Dom Bill, a tributary to rio Araguaia, road BR-070, about 44 km W of Aparecida do Rio Claro, 15°53' 10.8"S 51°43' 23.8"W, altitude 320 m; W. J. E. M. Costa, C. P. Bove & J. Paz, 12 April 2007.

**Paratypes:** UFRJ 6419, 11 males, 14.7-23.7 mm SL, 9 females, 15.3-17.8 mm SL; UFRJ 6420, 1 male, 24.7 mm SL, 2 females, 18.9-22.2 mm SL; UFRJ 6482, 3 males, 20.2-21.4 mm SL, 3 females, 18.3-19.7 mm SL (c&s); collected with holotype. UFRJ 1567, 2 males, 20.2-23.7 mm SL, 3 females, 16.2-24.7 mm SL; same locality; W. J. E. M. Costa *et al.*, 30

Aug. 1993. UFRJ 1575, 1 male, 23.1 mm SL, 2 females, 19.7-20.1 mm SL; W. J. E. M. Costa *et al.*, 29 Aug. 1993.

### Diagnosis

Distinguished from all other species of *Melanorivulus* by the following combination of features: diffuse broad midlateral dark gray stripe between postorbital region and caudal-fin base, caudal fin orangish pink with bluish white stripe on dorsal and ventral margins in males, body depth 20.4-22.2 % SL in males, caudal peduncle depth 13.4-14.5 % SL in males, caudal-fin length 39.3-42.3 % SL in males, posterior border of pectoral fin reaching vertical through pelvic-fin base in males, and 4-5 vomerine teeth.

### Description

Morphometric data appear in Table I. Largest male examined 25.2 mm SL, largest female 24.7 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 anal-fin origin, nearly straight along caudal peduncle. Body slender, compressed, greatest body depth at level of pelvic-fin base. Snout short, rounded.

Dorsal and anal fins rounded and without filaments in both sexes. Caudal fin elliptical. Pectoral fin rounded, its posterior margin reaching vertical through pelvic-fin base in males, about 80 % of distance between base of pectoral and pelvic-fin bases in females. Pelvic fin short, elliptical; tip of pelvic fin reaching between base of 1st and 2nd anal-fin rays in males, reaching anus in females. Pelvic-fin bases medially in close proximity. Dorsal-fin origin in vertical through base of 9th anal-fin ray, between neural spines of vertebrae 18 and 20. Anal-fin origin between pleural ribs of vertebrae 13 and 15. Dorsal-fin rays 9-10; anal-fin rays 14-16; caudal-fin rays 29-32; pectoral-fin rays 12-13; pelvic-fin rays 7.

Scales large, cycloid. Body and head entirely scaled, except on ventral surface of head. No scales on dorsal and anal-fin bases. Scales extending on anterior 25 % of caudal fin. Frontal squamation F-patterned; E-scales not overlapping; row of scales anterior to H-scale; supraorbital scales 9. Longitudinal series of scales 33-34; transverse series of scales 8; scale rows around caudal peduncle 16. No contact organs on scales and fin rays.

Cephalic neuromasts: supraorbital 3 + 3, parietal 1, anterior rostral 1, posterior rostral 1, infraorbital 1 + 12-14 + 1, preorbital 2, otic 1, post-otic 2, supratemporal 1, median opercular 1, ventral opercular 1, preopercular 2 + 4, mandibular 3 + 1, lateral mandibular 1-2, paramandibular 1. One neuromast on each scale of lateral line, or sometimes absent. Two neuromasts on caudal-fin base.

Basihyal subtriangular, greatest width about 45 % 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 + 7-8. Vomerine teeth 4-5. Dermosphenotic present. Ventral process of posttemporal absent. Total vertebrae 30-31.

**Coloration:** Males. Sides of body light purplish blue, with small red spots, arranged in oblique rows; broad midlateral dark gray stripe between postorbital region and caudal-fin base, more conspicuous anteriorly when fish exposed to sunlight. Dorsum light brown. Venter light gray to white. Sides of head pale golden with two or three faint red oblique post-orbital stripes. Upper jaw light brown, lower jaw dark gray to black. Iris pale yellow. Dorsal fin light yellow with short oblique red bars on basal and posterior portions. Anal fin light blue, white on basal portion, with series of red spots along fin base and posterior

margin of fin. Caudal fin orangish pink orange, with broad bluish white stripe both on dorsal and ventral margins of fin. Pectoral fins yellowish hyaline. Pelvic fins light blue.

Females. Sides of body and head pale purplish blue, with small red spots, arranged in oblique rows of dark red dots, usually united to form oblique dark red bars; broad midlateral gray stripe between postorbital region and caudal-fin base, more anteriorly conspicuous when fish exposed to sunlight. Dorsum light brown. Venter light gray to white. Upper jaw light brown, lower jaw dark gray. Iris pale yellow, to brown on median portion. Dorsal fin light yellow, with three oblique dark gray bars on basal and posterior portion of fin; distal margin dark gray. Anal fin light yellow, base light blue with red dots; distal margin dark gray. Caudal fin light yellow with four or five dark gray bars; fin margin dark gray to black; rounded black spot on dorsal portion of caudal-fin base, not contacting dorsal margin of fin, posteriorly adjacent to bright yellow spot. Paired fins hyaline.

### **Distribution**

Streams and swamps close to the middle Araguaia river channel, southern Amazonas river basin (Fig. 3).

### **Habitat**

The type locality of *R. salmonicaudus* is a clear water stream in the open vegetation of the Brazilian Cerrado. It was collected in shallow parts of the stream (about 10-20 cm deep), where the bottom was orange clay, the water temperature 28.6-29.8° C at 11:30 AM, pH 6.2.

### **Etymology**

From the Latin *salmonicaudus* (salmon tail), referring to the salmon color of the caudal fin in males.

### ***Rivulus rubromarginatus*, new species**

(Figs. 4-5)

**Holotype:** UFRJ 6474, male, 25.2 mm SL; Brazil: Estado de Goiás: stream tributary to rio Espingarda, rio do Peixe drainage, rio Araguaia basin, road GO-164, 14°28'27.5"S 50°28'21.7"W, altitude 275 m; W. J. E. M. Costa, C. P. Bove & B. B. Costa, 19 January 2007.

**Paratypes:** UFRJ 6475, 1 male, 28.1 mm SL, 1 female, 24.8 mm SL; UFRJ 6476, 3 males, 23.5-24.5 mm SL, 11 females, 17.3-25.2 mm SL; UFRJ 6477, 2 males, 23.0-23.1 mm SL, 2 females, 21.5-21.9 mm SL (all c&s); collected with holotype.

### **Diagnosis**

Distinguished from all other species of *Melanorivulus* by the following combination of features: diffuse broad midlateral dark gray stripe between postorbital region and caudal-fin base, body depth 17.4-19.8 % SL in males, caudal peduncle depth 11.2-13.1 % SL in males, caudal-fin length 35.4-38.7 % SL in males, posterior border of pectoral fin anterior to vertical through pelvic-fin base in males, 2 vomerine teeth, caudal fin pale brown with bright red stripe on dorsal and ventral margins in males, and red dots of flank separated, never forming bars in males.

## Description

Morphometric data appear in Table I. Largest male examined 28.1 mm SL, largest female 25.2 mm SL. Dorsal profile gently convex from snout to end of dorsal-fin base, approximately straight on caudal peduncle. Ventral profile weakly convex from lower jaw to anal-fin origin, about straight along caudal peduncle. Body slender, compressed, greatest body depth at level of pelvic-fin base. Snout short, rounded.

Dorsal and anal fins rounded and without filaments in both sexes. Caudal fin elliptical. Pectoral fin rounded, its posterior margin reaching about 80 % of distance between base of pectoral and pelvic-fin bases. Pelvic fin short, elliptical; tip of pelvic fin reaching between urogenital papilla and base of 1st anal-fin ray in males and anus in females. Pelvic-fin bases medially in close proximity. Dorsal-fin origin in vertical through base of 9th or 10th anal-fin rays, between neural spines of vertebrae 19 and 21. Anal-fin origin between pleural ribs of vertebrae 14 and 15. Dorsal-fin rays 9-10; anal-fin rays 13-14; caudal-fin rays 30-33; pectoral-fin rays 13-14; pelvic-fin rays 7.

Scales large, cycloid. Body and head entirely scaled, except on ventral surface of head. No scales on dorsal and anal-fin bases. Scales extending on anterior 30 % of caudal fin. Frontal squamation F-patterned; E-scales not overlapping; row of scales anterior to H-scale; supraorbital scales 9. Longitudinal series of scales 33-35; transverse series of scales 7-8; scale rows around caudal peduncle 16. No contact organs on scales and fin rays.

Cephalic neuromasts: supraorbital 3 + 3, parietal 1, anterior rostral 1, posterior rostral 1, infraorbital 1 + 10-12 + 1, preorbital 2, otic 1, post-otic 2, supratemporal 1, median opercular 1, ventral opercular 1, 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 50 % of length; basihyal cartilage about 15 % of total length of basihyal. Six branchiostegal rays. Second pharyngobranchial teeth absent. Gill-rakers on first branchial arch 1 + 7. Vomerine teeth 2. Dermosphenotic present. Ventral process of posttemporal absent. Total vertebrae 31-32.

**Coloration:** Males. Sides of body light greenish blue, with small red spots, irregularly arranged in oblique chevron-like rows; broad midlateral gray stripe between postorbital region and caudal-fin base, more conspicuous when fish exposed to sunlight. Dorsum light brown. Venter light gray to white. Sides of head pale golden with two faint red oblique post-orbital stripes. Upper jaw light pinkish brown, lower jaw dark gray with red lip. Iris pale yellow to brown on median portion. Dorsal fin light blue with minute red dots on posterior margin and narrow bright red distal stripe. Anal fin light blue, white on basal portion, with series of red spots along fin base and posterior margin of fin, and narrow bright red distal stripe. Caudal fin pale brown, with broad bright red stripe, sometimes reddish orange, both on dorsal and ventral margins of fin. Pectoral fins hyaline. Pelvic fins light blue with red anterior margin.

Females. Sides of body and head pale purplish blue, with small red spots, irregularly arranged in oblique chevron-like rows of red dots; broad midlateral gray stripe between postorbital region and caudal-fin base, more conspicuous when fish exposed to sunlight. Dorsum light brown. Venter light gray to white. Upper jaw light pinkish brown, lower jaw dark gray. Iris pale yellow, to brown on median portion. Dorsal fin light gray, with two oblique dark gray bars on basal and posterior portion of fin; distal margin dark gray. Anal fin light gray, base light blue with red dots; distal margin dark gray. Caudal fin light gray with three or four dark gray bars; fin margin dark gray to black; rounded black spot on

dorsal portion of caudal-fin base, not contacting dorsal margin of fin. Pectoral fins hyaline. Pelvic fins light blue with dark gray anterior margin.

### **Distribution**

Known only from the type locality, a stream of the Peixe river drainage, a right tributary to Araguaia river, Amazonas river basin (Fig. 3).

### **Habitat**

*Rivulus rubromarginatus* was collected in shallow pools and creeks adjacent to a stream (about 10-20 cm deep), with orange clay bottom, in open vegetation of the Brazilian Cerrado. Water was clear, pH 6.2.

### **Etymology**

From the Latin, the name *rubromarginatus* (with red margin) refers to the red marginal stripe of caudal, dorsal and anal fins in males, a feature not found in other species of *Melanorivulus*.

### ***Rivulus crixas*, new species**

(Figs. 6-7)

**Holotype:** UFRJ 6458, male, 27.3 mm SL; Brazil: Estado de Goiás: stream tributary to rio Crixás Mirim, rio Crixás Açu drainage, rio Araguaia basin, road GO-164, about 5 km S from Nova Crixás, 14°8'11.8"S 50°21'15.5"W, altitude 284 m; W. J. E. M. Costa, C. P. Bove, J. Paz & A. Oliveira, 14 April 2006.

**Paratypes:** UFRJ 6459, 3 males, 20.0-24.1 mm SL, 4 females, 19.8-26.3 mm SL; UFRJ 6460, 2 males, 20.9-22.0 mm SL, 3 females, 18.6-22.6 mm SL (all c&s); collected with holotype.

### **Diagnosis**

Distinguished from all other species of *Melanorivulus* by the following combination of features: diffuse broad midlateral dark gray stripe between postorbital region and caudal-fin base, body depth 18.2-20.1 % SL in males, caudal peduncle depth 11.6-13.0 % SL in males, caudal-fin length 34.6-37.4 % SL in males, posterior border of pectoral fin anterior to vertical through pelvic-fin base in males, 2 vomerine teeth, caudal fin hyaline with dorsal edge light blue to yellow and ventral edge light orangish red in males, and red dots of flank separated, never forming bars in males.

### **Description**

Morphometric data appear in Table II. Largest male examined 27.3 mm SL, largest female 26.3 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 anal-fin origin, approximately straight to slightly concave along caudal peduncle. Body slender, compressed, greatest body depth at level of pelvic-fin base. Snout short, rounded.

Dorsal and anal fins rounded and without filaments in both sexes. Caudal fin elliptical. Pectoral fin rounded, its posterior margin reaching about 80 % of distance between base of pectoral and pelvic-fin bases. Pelvic fin short, elliptical; tip of pelvic fin reaching between base of 1st and 2nd anal-fin rays in males and anus in females. Pelvic-fin bases medially in

close proximity. Dorsal-fin origin in vertical through base of 9th or 10th anal-fin rays, between neural spines of vertebrae 20 and 21. Anal-fin origin between pleural ribs of vertebrae 14 and 15. Dorsal-fin rays 9-10; anal-fin rays 13-15; caudal-fin rays 30-32; pectoral-fin rays 13-14; pelvic-fin rays 7.

Scales large, cycloid. Body and head entirely scaled, except on ventral surface of head. No scales on dorsal and anal-fin bases. Scales extending on anterior 30 % of caudal fin. Frontal squamation F-patterned; E-scales not overlapping; row of scales anterior to H-scale; supraorbital scales 9. Longitudinal series of scales 34-36; transverse series of scales 8; scale rows around caudal peduncle 16. No contact organs on scales and fin rays.

Cephalic neuromasts: supraorbital 3 + 3, parietal 1, anterior rostral 1, posterior rostral 1, infraorbital 1 + 11-14 + 1, preorbital 2, otic 1, post-otic 2, supratemporal 1, median opercular 1, ventral opercular 1, 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 15 % of total length of basihyal. Six branchiostegal rays. Second pharyngobranchial teeth absent. Gill-rakers on first branchial arch 1 + 8. Vomerine teeth 2. Dermosphenotic present. Ventral process of posttemporal absent. Total vertebrae 31-33.

**Coloration:** Males. Sides of body light purplish blue, with small red spots, irregularly arranged in oblique chevron-like rows; broad midlateral gray stripe between postorbital region and caudal-fin base, more conspicuous when fish exposed to sunlight. Dorsum light brown. Venter light gray to white. Sides of head pale golden with two dark red oblique post-orbital stripes. Upper jaw light brown, lower jaw dark gray with red lip. Iris pale yellow. Dorsal fin pale yellow with six or seven short red bars on basal and posterior portion of fin. Anal fin light blue to yellow on distal part, with row of six or seven short red bars along fin base and posterior margin of fin. Caudal fin hyaline, with light blue stripe, with light yellow traces on dorsal margin, and orangish red stripe on ventral margin, ventral stripe shorter and wider than dorsal stripe. Pectoral and pelvic fins yellowish hyaline.

Females. Sides of body and head pale purplish blue, with small red spots, irregularly arranged in oblique chevron-like rows of red dots; broad midlateral gray stripe between postorbital region and caudal-fin base, more conspicuous when fish exposed to sunlight. Dorsum light brown. Venter light gray to white. Upper jaw light brown, lower jaw dark gray with pink lip. Iris pale yellow. Dorsal fin light yellow, with four or five oblique gray bars on basal and posterior portion of fin; anterodistal margin dark gray. Anal fin light yellow, base light blue with red dots; distal margin dark gray. Caudal fin yellow with four to seven dark gray bars; fin margin dark gray; rounded dark gray to black spot on dorsal portion of caudal-fin base, not contacting dorsal margin of fin. Pectoral and pelvic fins yellowish hyaline, anterior margin of pelvic fin dark gray.

### **Distribution**

Known only from the type locality, a stream of the Crixás Açu river drainage, a right tributary to Araguaia river, Amazonas river basin (Fig 3).

### **Habitat**

*Rivulus crixas* was collected in the shallowest parts of a small stream (about 10-20 cm deep), larger specimens in places with more dense aquatic vegetation, juveniles in places more exposed to sunlight. It is a typical stream of central Brazil, locally known as Vereda

or Buritizal (*i. e.*, streams dominated by the buriti-palm *Mauritia flexuosa* L.), with orange clay bottom, in open vegetation of the Brazilian Cerrado. Water was clear, pH 5.3.

### Etymology

The epithet *crixas* refer to the occurrence of the new species in the Crixas river basin, which is an allusion to the indigenous tribe of people Crixas, formerly inhabiting this region.

### *Rivulus javahe*, new species

(Figs. 8-9)

**Holotype:** UFRJ 6386, male, 21.0 mm SL; Brazil: Estado de Goiás: stream tributary to rio Verde, rio Araguaia basin, serra dos Javaés, road GO-164, about 30 km N from São Miguel do Araguaia, 13°4'5.3"S 49°57'20.0"W, altitude 323 m; W. J. E. M. Costa, C. P. Bove, J. Paz & A. Oliveira, 14 April 2006.

**Paratypes:** UFRJ 6387, 2 males, 19.6-22.0 mm SL, 1 female, 19.1 mm SL; UFRJ 6388, 1 male, 17.6 mm SL, 1 female, 18.7 mm SL; collected with holotype. UFRJ 1482, 3 males, 19.9-24.0 mm SL, 3 females, 20.8-23.0 mm SL, and 12 juveniles of undetermined sex, 12.4-18.2 mm SL; UFRJ 2108, 2 males, 22.7-24.0 mm SL, 2 females, 19.1-22.8 mm SL (c&s); same locality; W. J. E. M. Costa, M. R. Britto, F. Autran, E. Vicente & R. D'Arrigo, 25 Aug. 1993.

**Additional material (non-types):** Brazil: Estado de Goiás: UFRJ 1748, 6; Vereda in the rio Verde drainage, 30 km L of São Miguel do Araguaia, W. J. E. M. Costa *et al.*, 25 Aug. 1993. Estado do Tocantins: UFRJ 1712, 7; stream tributary to rio Verde, 50 km N of São Miguel do Araguaia, W. J. E. M. Costa *et al.*, 25 Aug. 1993. UFRJ 1597, 2; stream 12 km N of Sandolândia; W. J. E. M. Costa *et al.*, 27 Aug. 1993.

### Diagnosis

Distinguished from all other species of *Melanorivulus* by the following combination of features: diffuse broad midlateral dark gray stripe between postorbital region and caudal-fin base, body depth 17.1-18.6 % SL in males, caudal peduncle depth 11.7-12.7 % SL in males, caudal-fin length 34.3-37.8 % SL in males, posterior border of pectoral fin anterior to vertical through pelvic-fin base in males, 1-3 vomerine teeth, caudal fin hyaline with light blue dorsal and ventral margins and four or five narrow red bars in males, red dots of dorsal portion of flank coalesced to form oblique bars in males, caudal fin subtruncate in males, 29-30 caudal-fin rays, pelvic fin tip not reaching anal-fin origin, 4-5 dark gray bars on caudal fin in females, and anal fin with short red bars on basal and posterior portion.

### Description

Morphometric data appear in Table II. Largest male examined 24.0 mm SL, largest female 23.0 mm SL. Dorsal profile slightly convex from snout to end of dorsal-fin base, about straight on caudal peduncle. Ventral profile gently convex from lower jaw to anal-fin origin, approximately straight to end of caudal peduncle. Body slender, compressed, greatest body depth at level of pelvic-fin base. Snout short, rounded.

Dorsal and anal fins rounded and without filaments in both sexes. Caudal fin subtruncate in males, rounded in females. Pectoral fin rounded, its posterior margin reaching about 90

% of distance between base of pectoral and pelvic-fin bases in males, about 75 % in females. Pelvic fin short, elliptical; tip of pelvic fin reaching urogenital papilla in males and anus in females. Pelvic-fin bases medially in close proximity. Dorsal-fin origin in vertical through base of 9th or 10th anal-fin rays, between neural spines of vertebrae 19 and 21. Anal-fin origin between pleural ribs of vertebrae 14 and 16. Dorsal-fin rays 8-9; anal-fin rays 13-14; caudal-fin rays 29-30; pectoral-fin rays 13-14; pelvic-fin rays 7.

Scales large, cycloid. Body and head entirely scaled, except on ventral surface of head. No scales on dorsal and anal-fin bases. Scales extending on anterior 30 % of caudal fin. Frontal squamation F-patterned; E-scales not overlapping; row of scales anterior to H-scale; supraorbital scales 9. Longitudinal series of scales 34-35; transverse series of scales 8; scale rows around caudal peduncle 16. No contact organs on scales and fin rays.

Cephalic neuromasts: supraorbital 3 + 3, parietal 2, anterior rostral 1, posterior rostral 1, infraorbital 1 + 13 + 1, preorbital 2-3, otic 1, post-otic 2, supratemporal 1, median opercular 1, ventral opercular 2, preopercular 2 + 4, mandibular 3-4 + 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 55 % 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 + 7. Vomerine teeth 1-3. Dermosphenotic present. Ventral process of posttemporal absent. Total vertebrae 32-33.

**Coloration:** Males. Sides of body and head pale brown, to light blue on ventral portion of flank, and pale golden on opercular region; oblique rows of small dark red spots on opercular region and flank, coalesced on caudal peduncle to form chevron-like bars; broad midlateral gray stripe between postorbital region and caudal-fin base, more conspicuous when fish exposed to sunlight. Dorsum light brown. Venter light gray to white. Upper jaw orange, lower jaw dark gray with light red lip. Iris pale yellow. Dorsal fin hyaline on anterior portion, pale golden with three oblique red bars on basal and posterior portion of fin. Anal fin light blue, pale yellow on distal portion, with row of seven or eight short, oblique red bars along fin base and posterior margin of fin. Caudal fin hyaline to light blue on dorsal and ventral portions, with four or five narrow red bars, sometimes interrupted to form vertical rows of elongate spots. Pectoral and pelvic fins yellowish hyaline.

Females. Sides of body and head pale yellowish brown, to pale blue on ventral portion of flank, and pale golden on opercular region; oblique rows of small dark red spots on opercular region and flank; broad midlateral gray stripe between postorbital region and caudal-fin base, more conspicuous when fish exposed to sunlight. Dorsum light yellowish brown. Venter light gray to white. Upper jaw orange, lower jaw dark gray with pink lip. Iris pale yellow. Dorsal fin light yellow, with three or four transverse rows of gray dots; distal margin dark gray. Anal fin light yellow, base and posterior region light blue with row of seven short, oblique red bars. Caudal fin hyaline to light yellow on dorsal and ventral portions, with four or five narrow dark gray bars, sometimes interrupted to form vertical rows of elongate spots; fin margin dark gray; rounded dark gray to black spot on dorsal portion of caudal-fin base, not contacting dorsal margin of fin and posteriorly adjacent to narrow vertical white mark. Pectoral and pelvic fins yellowish hyaline.

### **Distribution**

Verde river and Crixas Açu drainages at Javaés hill, right tributaries to Araguaia river, Amazonas river basin (Fig. 3).

## Habitat

*Rivulus javahe* is found in the shallowest parts of small streams (about 10-20 cm deep) locally known as Veredas or Buritizais (*i. e.*, streams dominated by the buriti-palm *Mauritia flexuosa*), with orange clay bottom, in open vegetation of the Brazilian Cerrado. During collection of the type series the water was clear, pH 5.8.

## Etymology

The name *javahe* is derived from the Javaés hill, where the type locality area is situated, which is based on the name of an indigenous tribe of people inhabiting the middle Araguaia river basin.

## *Rivulus karaja*, new species

(Figs. 10-11)

**Holotype:** UFRJ 6485, male, 30.1 mm SL; Brazil: Estado do Tocantins: Município de Dueré: stream tributary to rio Dueré, near road BR-153, 10 km S of rio Dueré, rio Formoso drainage, rio Araguaia basin, 11°12'36.9"S 48°55'52.6"W, altitude 270 m; W. J. E. M. Costa, C. P. Bove & B. B. Costa, 23 January 2007.

**Paratypes:** UFRJ 6486, 1 female, 28.1 mm SL; UFRJ 6487, 1 male, 16.4 mm SL, 1 female, 20.9 mm SL (c&s); collected with holotype.

## Diagnosis

Distinguished from all other species of *Melanorivulus* by the following combination of features: diffuse broad midlateral dark gray stripe between postorbital region and caudal-fin base, body depth 19.0 % SL in male, caudal peduncle depth 13.0 % SL in males, caudal-fin length 35.0 % SL in males, posterior border of pectoral fin anterior to vertical through pelvic-fin base in males, 1 vomerine tooth, caudal fin light blue with five or six narrow dark gray bars in males, red dots of dorsal portion of flank coalesced to form oblique bars in males, caudal fin elliptical in males, 31-33 rays caudal-fin, pelvic fin tip reaching anterior portion of anal fin, 2-3 dark gray bars on caudal fin in females, and anal fin with red dots on basal and posterior portion.

## Description

Morphometric data appear in Table III. Largest male examined 30.1 mm SL, largest female 28.1 mm SL. Dorsal profile weakly convex from snout to end of dorsal-fin base, nearly straight on caudal peduncle. Ventral profile gently convex from lower jaw to anal-fin origin, approximately straight to end of caudal peduncle. Body slender, compressed, greatest body depth at level of pelvic-fin base. Snout short, rounded.

Dorsal fin rounded in both sexes, anal fin slightly pointed in males, rounded in females. No filaments on fins. Caudal fin rounded. Pectoral fin rounded, its posterior margin reaching about 90 % of distance between base of pectoral and pelvic-fin bases in males, about 75 % in females. Pelvic fin short, slightly pointed in males, elliptical in females; tip of pelvic fin reaching anal-fin origin in males and anus in females. Pelvic-fin bases medially in close proximity. Dorsal-fin origin in vertical through base of 9th or 10th anal-fin rays, between neural spines of vertebrae 19 and 20. Anal-fin origin between pleural ribs

of vertebrae 13 and 14. Dorsal-fin rays 8-9; anal-fin rays 13-14; caudal-fin rays 31-33; pectoral-fin rays 13; pelvic-fin rays 7.

Scales large, cycloid. Body and head entirely scaled, except on ventral surface of head. No scales on dorsal and anal-fin bases. Scales extending on anterior 25 % of caudal fin. Frontal squamation F-patterned; E-scales not overlapping; row of scales anterior to H-scale; supraorbital scales 6. Longitudinal series of scales 35-36; transverse series of scales 8; scale rows around caudal peduncle 16. No contact organs on scales and fin rays.

Cephalic neuromasts: supraorbital 3 + 3, parietal 1, anterior rostral 1, posterior rostral 1, infraorbital 1 + 12-13 + 1, preorbital 2, otic 1, post-otic 2, supratemporal 1, median opercular 1, ventral opercular 1-2, 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.

**Coloration:** Males. Sides of body to light purplish blue, with oblique rows of red dots, coalesced on dorsal portion of caudal peduncle to form bars; broad midlateral gray stripe between postorbital region and caudal-fin base, more conspicuous when fish exposed to sunlight. Dorsum light brown. Venter light gray to white. Opercular region pale golden, with two oblique dark reddish brown stripes. Upper jaw orange, lower jaw dark gray with light red lip. Iris pale yellow to brown. Dorsal fin light blue with narrow transverse dark gray bars. Anal fin light blue with red dots along fin base and posterior margin of fin. Caudal fin light blue with 5-6 narrow dark gray bars, not extending to dorsal and ventral portions of fin. Pectoral fins yellowish hyaline. Pelvic fins light blue.

Females Sides of body and head pale purplish brown with oblique rows of dark red dots; broad midlateral gray stripe between postorbital region and caudal-fin base, more conspicuous when fish exposed to sunlight. Dorsum light yellowish brown. Venter light gray to white. Upper jaw orange, lower jaw dark gray with pink lip. Iris pale yellow. Dorsal fin yellowish white, with two transverse gray bars; distal margin dark gray. Anal fin yellowish white, base and posterior region light blue with row of red dots. Caudal fin yellowish white, with 2-3 gray bars; fin margin dark gray; rounded dark gray to black spot on dorsal portion of caudal-fin base, not contacting dorsal margin of fin and posteriorly adjacent to narrow vertical yellowish white mark. Pectoral fins hyaline. Pelvic fins light blue with dark gray anterior margin.

### **Distribution**

Known only from a stream of the Formoso river drainage, a right tributary to Araguaia river, Amazonas river basin (Fig. 3).

### **Habitat**

*Rivulus karaja* was collected in interconnected small pools, adjacent to a Vereda (about 20 cm deep).

### **Etymology**

The epithet *karaja* is a reference to the name of an indigenous tribe of people inhabiting the region of the middle Araguaia basin.

## Discussion

*Rivulus zygonectes* was reported to occur in a vast geographic region encompassing the middle section of all southern Amazonian tributaries (Costa, 1995a). This formerly proposed distribution was based on material obtained in collections directed to all freshwater fish groups, when some specimens of *Rivulus* were sporadically collected and rarely live colors were recorded. The study of material from recent collections directed to sample typical *Rivulus* habitats and to record live color patterns of all populations has demonstrated that species diversity is much greater in that region.

The species included in the present study are typical members of the subgenus *Melanorivulus*, exhibiting all diagnostic features of the genus: dorsal portion of preopercle short and pointed, two oblique bars on post-orbital region, melanophores concentrated on margins of unpaired and pelvic fins in females, and black spot on upper portion of caudal fin not close to fin margin in females. In addition, they are members of a subclade of *Melanorivulus*, hereafter referred as the *R. zygonectes* species group, diagnosed by the presence of a diffuse broad midlateral dark gray stripe between postorbital region and caudal-fin base, conspicuous when the fish is exposed to sunlight or it is stressed (Costa, 2006a). This derived condition is also present in *R. zygonectes* from the rio Tocantins basin, *R. parnaibensis* Costa from the rio Parnaíba basin, and *R. punctatus* Boulenger, *R. dapazi* Costa, *R. rossoi* Costa, and *R. cyanopterus* Costa, from the rio Paraguay basin, which contrasts with all other species of *Melanorivulus*, in which the dark zone is restricted to the anterior portion of flank, when present.

Each species of the *R. zygonectes* group is diagnosed by their unique color patterns of caudal fin in males: orangish pink with bluish white stripe on dorsal and ventral margins in *R. salmonicaudus*; pale brown with bright red stripe on dorsal and ventral margins in *R. rubromarginatus*; hyaline with dorsal edge light blue and yellow, ventral edge light orangish red in *R. crixas*; hyaline with light blue dorsal and ventral margins and four or five narrow red bars in *R. javahe*; light blue with five or six narrow dark gray bars in *R. karaja*; light blue with dark red dots and light yellow dorsal and ventral edges in *R. zygonectes*; pale yellow with red spots, ventral and dorsal margins bright yellow in *R. parnaibensis*; light blue with red dots, entire margin white, in *R. punctatus*; dark yellow with entire marginal region dark orange with black outline in *R. dapazi*; hyaline, with red dots on anterior half, light orange on anterior portion of dorsal and ventral margins, in *R. rossoi*; and, homogeneous light greenish yellow in *R. cyanopterus* (Costa, 1995a, 2003, 2005, the present study). Species from the middle Araguaia basin are distinguished from *R. parnaibensis*, *R. punctatus*, *R. rossoi*, and *R. cyanopterus*, in having more scales on the longitudinal series (33-36 vs. 30-33), and distinguished from *R. dapazi* by having oblique rows of red dots on flank, sometimes dots coalesced to form oblique bars on dorsal portion of flank (vs. oblique, chevron-like bars). *Rivulus javahe* differs from all species of this subclade in having caudal fin subtruncate (vs. oval). Species of the *R. zygonectes* group from the middle Araguaia basin are distinguished among themselves by the features presented in the key below.

### Key to species of *Rivulus* from the middle rio Araguaia basin

1a. Body slender in males (body depth 17.1-20.1 % SL; caudal peduncle depth 11.2-13.1 % SL); caudal fin short in males (caudal-fin length 34.3-38.7 % SL); posterior border of pectoral fin in vertical anterior to pelvic-fin base in males; 1-3 vomerine teeth. .... 2

- 1b. Body moderately deep in males (body depth 20.4-22.2 % SL; caudal peduncle depth 13.4-14.5 % SL); caudal fin long in males (caudal-fin length 39.3-42.3 % SL); posterior border of pectoral fin reaching vertical through pelvic-fin base in males; 4-5 vomerine teeth ..... *Rivulus salmonicaudus*
- 2a. Caudal fin without bars on middle of fin, with yellow or red stripes on dorsal and ventral margins of fin; red dots of flank separated, never forming bars in males. .... 3
- 2b. Caudal fin with dark bars on middle of fin, without yellow or red stripes on fin margins in males; red dots of dorsal portion of flank coalesced to form oblique bars. .... 4
- 3a. Caudal fin of males orange to red stripe on dorsal and ventral margins of fin, both stripes reaching posterior margin of fin; dorsal fin of males without bars on basal and posterior portions of fin, and with orange to red distal stripe. .... *R. rubromarginatus*
- 3b. Caudal fin of males with blue and yellow stripe on dorsal margin of fin and reddish orange stripe on ventral margin of fin, ventral stripe not reaching posterior margin of fin; dorsal fin of males with short red bars on basal and posterior portions of fin, and without distal stripes. .... *R. crixas*
- 4a. Caudal fin subtruncate in males, with dark red bars; 29-30 caudal-fin rays; pelvic fin short in males, tip not reaching anal-fin origin; 4-5 dark gray bars on caudal fin in females; anal fin with short red bars on basal and posterior portion. .... *R. javahe*
- 4b. Caudal fin elliptical in males, with dark gray bars; 31-33 rays caudal-fin; pelvic fin with moderate size in males, tip reaching anterior portion of anal fin; 2-3 dark gray bars on caudal fin in females; anal fin with red dots on basal and posterior portion. .... *R. karaja*

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**Table I.** Morphometric data for *Rivulus salmonicaudus* and *R. rubromarginatus*.

	<i>Rivulus salmonicaudus</i>		<i>Rivulus rubromarginatus</i>	
	males (n = 6)	females (n = 4)	males (n = 5)	females (n = 5)
Standard length (mm)	22.6-25.2	18.9-24.7	23.5-28.1	23.9-25.2
<b>Percents of standard length</b>				
Body depth	20.4-22.2	20.9-22.3	17.4-19.8	17.3-18.5
Caudal peduncle depth	13.4-14.5	13.6-14.5	11.2-13.1	10.9-12.3
Predorsal length	73.9-76.2	76.2-77.8	74.8-78.6	75.2-77.9
Prepelvic length	51.5-54.2	55.0-56.3	52.2-55.1	52.2-55.8
Length of dorsal-fin base	11.3-12.4	11.5-12.4	10.9-12.8	9.0-10.4
Length of anal-fin base	21.3-24.7	20.8-21.8	18.4-22.7	17.3-18.9
Caudal-fin length	39.3-42.3	36.6-39.7	35.4-38.7	33.9-36.8
Pectoral-fin length	21.4-23.7	20.4-22.9	19.9-23.4	19.2-21.1
Pelvic-fin length	11.5-13.7	9.8-11.2	11.5-14.1	9.5-10.9
Head length	25.3-26.4	24.9-27.9	24.4-26.1	25.4-26.0
<b>Percents of head length</b>				
Head depth	64.9-71.8	62.0-72.3	57.2-61.1	58.2-61.5
Head width	73.2-79.3	71.9-82.5	73.4-82.4	75.0-78.9
Snout length	12.0-14.4	11.2-13.8	13.5-15.4	13.2-15.5
Lower jaw length	15.8-17.3	13.7-17.9	18.7-21.9	18.6-20.6
Eye diameter	33.1-35.1	35.6-37.6	32.0-35.8	32.0-35.3

**Table II.** Morphometric data for *Rivulus crixas* and *R. javahe*.

	<i>Rivulus crixas</i>		<i>Rivulus javahe</i>	
	males	females	males	females

	(n = 6)	(n = 6)	(n = 6)	(n = 3)
Standard length (mm)	20.0-27.3	19.8-26.3	19.6-24.0	19.1-23.0
<b>Percents of standard length</b>				
Body depth	18.2-20.1	16.9-18.7	17.1-18.6	17.5-19.1
Caudal peduncle depth	11.6-13.0	10.8-12.0	11.7-12.7	11.3-12.3
Predorsal length	75.3-76.5	76.7-77.8	74.6-77.7	74.6-76.3
Prepelvic length	51.8-56.2	53.5-55.5	52.0-53.4	53.6-54.8
Length of dorsal-fin base	9.7-11.9	9.0-12.1	9.7-11.0	9.9-11.5
Length of anal-fin base	18.7-21.1	18.1-20.6	18.6-20.1	19.4-19.9
Caudal-fin length	34.6-37.4	34.0-37.0	34.3-37.8	34.4-36.0
Pectoral-fin length	19.3-22.0	18.4-20.4	19.7-21.7	20.0-20.9
Pelvic-fin length	9.9-13.6	7.9-10.7	10.1-12.0	9.7-10.8
Head length	24.8-26.7	24.2-26.2	23.6-25.8	25.2-26.0
<b>Percents of head length</b>				
Head depth	59.2-63.1	59.1-64.1	58.0-63.4	59.0-63.6
Head width	71.6-74.7	71.9-75.8	69.8-76.4	73.5-76.8
Snout length	13.0-14.2	12.3-14.9	12.9-15.6	11.5-14.2
Lower jaw length	17.5-22.2	18.6-23.3	17.9-23.3	17.7-21.4
Eye diameter	32.1-36.2	33.5-37.1	33.5-37.0	33.6-37.3

**Table II.** Morphometric data for *Rivulus karaja*.

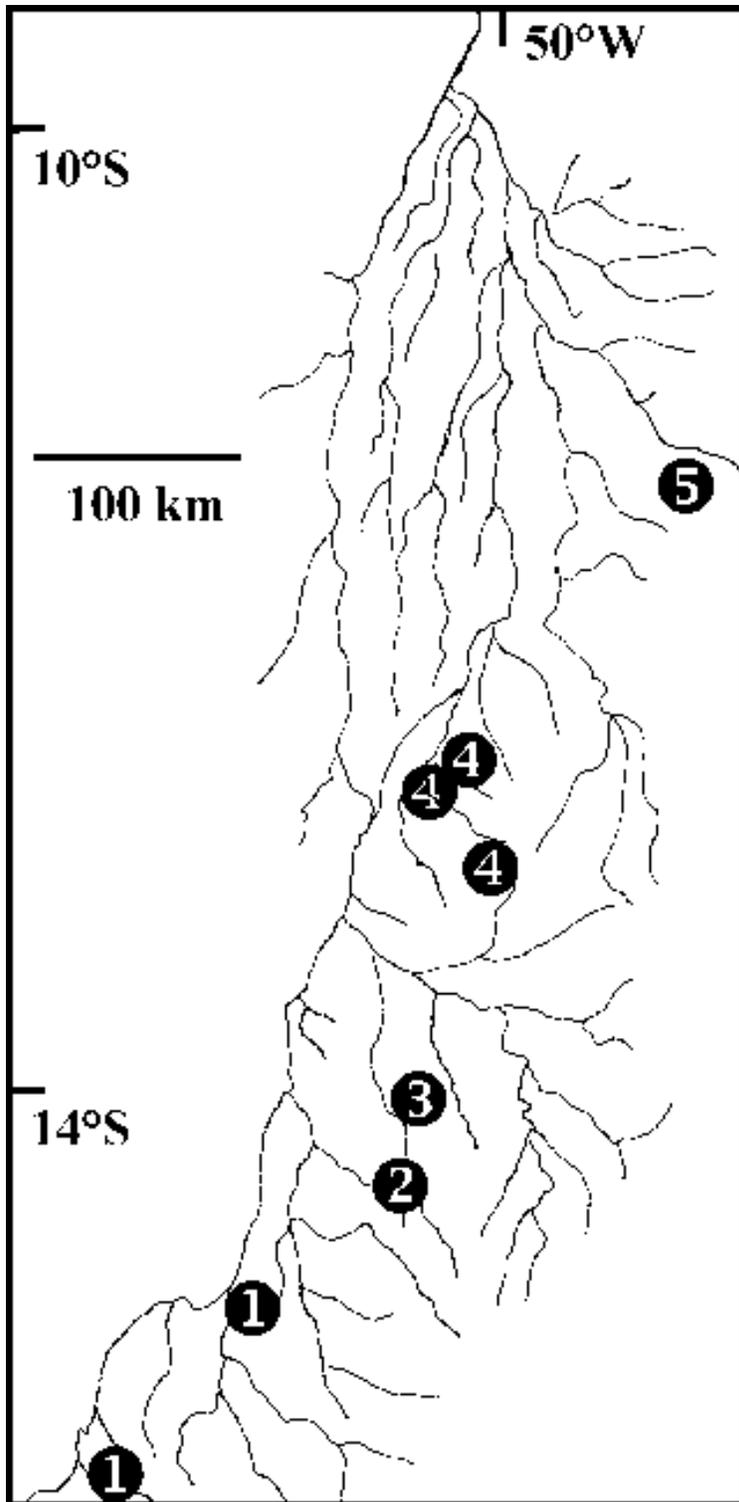
	<i>Rivulus karaja</i>	
	male (n = 1)	females (n = 2)
Standard length (mm)	30.1	20.9-28.1
<b>Percents of standard length</b>		
Body depth	19.0	20.2-20.3
Caudal peduncle depth	13.0	11.5-12.1
Predorsal length	76.3	77.5-78.7
Prepelvic length	54.4	53.7-55.1
Length of dorsal-fin base	9.6	8.8-10.7
Length of anal-fin base	21.1	18.4-19.2
Caudal-fin length	35.0	33.3-35.7
Pectoral-fin length	20.4	19.2-21.4
Pelvic-fin length	13.3	10.0-10.4
Head length	24.1	24.1-25.6
<b>Percents of head length</b>		
Head depth	68.1	65.9-71.1
Head width	78.8	79.7-85.7
Snout length	14.3	14.1-14.9
Lower jaw length	19.0	17.1-18.7
Eye diameter	32.8	31.1-33.0



**Fig. 1.** *Rivulus salomonicaudus*, UFRJ 6481, male, holotype, 25.2 mm SL (one day after collection); Brazil: Estado de Goiás: córrego Dom Bill (Photo by W.J.E.M. Costa).



**Fig. 2.** *Rivulus salomonicaudus*, UFRJ 6420, female, paratype, 18.9 mm SL (one day after collection); Brazil: Estado de Goiás: córrego Dom Bill (Photo by W.J.E.M. Costa).



**Fig. 3.** Geographic distribution of species of the genus *Rivulus* in the middle rio Araguaia basin, central Brazil: 1, *R. salmonicaudus*; 2, *R. rubromarginatus*; 3, *R. crixas*; 4, *R. javahe*; 5, *R. karaja*.



**Fig. 4.** *Rivulus rubromarginatus*, UFRJ 6474, male, holotype, 25.2 mm SL (one day after collection); Brazil: Estado de Goiás: stream tributary to rio Espingarda (Photo by W.J.E.M. Costa).



**Fig. 5.** *Rivulus rubromarginatus*, UFRJ 6475, female, paratype, 24.8 mm SL (one day after collection); Brazil: Estado de Goiás: stream tributary to rio Espingarda (Photo by W.J.E.M. Costa).



**Fig. 6.** *Rivulus crixas*, UFRJ 6458, male, holotype, 27.3 mm SL (one day after collection); Brazil: Estado de Goiás: Nova Crixás (Photo by W.J.E.M. Costa).



**Fig. 7.** *Rivulus crixas*, UFRJ 6459, female, paratype, 26.3 mm SL (one day after collection); Brazil: Estado de Goiás: Nova Crixás (Photo by W.J.E.M. Costa).



**Fig. 8.** *Rivulus javahe*, UFRJ 6386, male, holotype, 21.0 mm SL (one day after collection); Brazil: Estado de Goiás: São Miguel do Araguaia (Photo by W.J.E.M. Costa).



**Fig. 9.** *Rivulus javahe*, UFRJ 6387, female, paratype, 19.1 mm SL (one day after collection); Brazil: Estado de Goiás: São Miguel do Araguaia (Photo by W.J.E.M. Costa).



**Fig. 10.** *Rivulus karaja*, UFRJ 6485, male, holotype, 30.1 mm SL (one day after collection); Brazil: Estado do Tocantins: Dueré (Photo by W.J.E.M. Costa).



**Fig. 11.** *Rivulus karaja*, UFRJ 6486, female, paratype, 28.1 mm SL (one day after collection); Brazil: Estado do Tocantins: Dueré (Photo by W.J.E.M. Costa).