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A new killifish genus and species from the coastal plains of north-eastern Brazil (Teleostei: Cyprinodontiformes: Rivulidae)

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Abstract

Prorivulus auriferus, new genus and species, from the coastal plains of northeastern Brazil, is described. It is a member of a monophyletic unit, including *Rivulus* and the clade comprising all annual fish rivulid genera, diagnosed by two unambiguous synapomorphies: unossified interhyal and distal process of the second epibranchial absent. *Prorivulus* is hypothesized to be the sister group of the monophyletic assemblage including *Rivulus* and the clade comprising all annual fish rivulid genera, which is defined by four unambiguous synapomorphies: shortened uncinate process of the third epibranchial, articular face of the distal edge of first hypobranchial anteriorly expanded, ventral process of angulo-articular narrowed, and posterior flange of cleithrum absent. *Prorivulus* is distinguished from other basal rivulid taxa by having five branchiostegal rays.

Key words: Killifish, Cyprinodontiformes, Rivulidae, Neotropica, systematics, taxonomy, new genus, new species

Resumo

Prorivulus auriferus, novo gênero e espécie, das baixadas costeiras do nordeste do Brasil, é descrita. Ela é um membro de uma unidade monofilética incluindo *Rivulus* e o clado compreendendo todos os gêneros rivulídeos de peixes anuais, diagnosticado por duas sinapomorfias não ambíguas: interial não ossificado e processo distal do segundo epibranquial ausente. *Prorivulus* é hipotetizado ser o grupo irmão do agrupamento monofilético incluindo *Rivulus* e o clado compreendendo todos os gêneros rivulídeos de peixes anuais, que é definido por quatro sinapomorfias não ambíguas: processo uncinado do terceiro epibranquial encurtado, face articular da margem distal do primeiro hipobranquial expandida anteriormente, processo ventral de angulo-articular estreito, e aba posterior de cleitro ausente. *Prorivulus* se distingüe de outros táxons de rivulídeos basais por possuir cinco raios branquiostegais.

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Introduction

The Aplocheiloidei includes three families: the Aplocheilidae, from southern Asia and Madagascar, the Nothobranchidae, from continental Africa, and the Rivulidae, from the Americas (Costa, 2004a). Rivulidae presently comprises 27 genera: *Aphyolebias* Costa, *Austrofundulus* Myers, *Austrolebias* Costa, *Campellolebias* Vaz-Ferreira and Sierra, *Kryptolebias* Costa, *Cynolebias* Steindachner, *Cynopoecilus* Regan, *Pterolebias* Garman, *Gnatholebias* Costa, *Leptolebias* Myers, *Maratecoara* Costa, *Megalebias* Costa, *Micromoema* Costa, *Millerichthys* Costa, *Moema* Costa, *Neofundulus* Myers, *Papiliolebias* Costa, *Pituna* Costa, *Plesiolebias* Costa, *Rachovia* Myers, *Renova* Thomerson & Taphorn, *Rivulus* Poey, *Simpsonichthys* Carvalho, *Spectrolebias* Costa & Nielsen, *Stenolebias* Costa, *Terranatos* Taphorn & Thomerson, and *Trigonectes* Myers (Costa, 1998, 2003a, 2004a). All the rivulid genera except the basal genera *Rivulus* and *Kryptolebias* are annual fishes, living in seasonal pools (e. g. Myers, 1952; Parenti, 1981; Costa, 1995, 1998) and possessing derived developmental patterns including diapause stages (e. g. Wourms, 1972), elaborated reproductive behavior and unique morphological traits (e. g. Costa, 1998, 2004a). Basal rivulids inhabit perennial aquatic biotopes, including streams and mangroves (Costa, 1998, 2004a).

Parenti (1981) first proposed *Rivulus* to be a paraphyletic assemblage. Monophyly of a group containing the great majority of species traditionally placed in *Rivulus*, including its type species (*R. cylindraceus* Poey), and all annual fish rivulid genera is strongly supported (Costa, 2004a). However, this clade does not comprise some species previously placed in *Rivulus*, now placed in *Kryptolebias*: *K. brasiliensis* (Valenciennes), *K. marmoratus* Poey, *K. ocellatus* Hensel, and *K. caudomarginatus* Seegers, which form a basal rivulid monophyletic assemblage, constituting the sister group of the remaining rivulids (Costa, 2004a).

A new non-annual *Rivulus*-like rivulid taxon, having some primitive rivulid traits also occurring in *Kryptolebias*, but sharing some apomorphic conditions with *Rivulus* and all annual rivulid fish genera, was recently collected in a coastal plain area of northeastern Brazil. It is herein described as a new genus and species.

Material and methods

Measurements and counts follow Costa (1995). Measurements are presented as percentages of standard length (SL), except for those relative to head morphology, 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 & Van Dyke (1985). Terminology for frontal squamation follows Hoedeman (1958) and for cephalic neuromast series follows

Costa (2001). Terminology for bones and cartilages follows Costa (1998). Osteological features presented in the descriptions are those considered phylogenetically informative in recent studies on basal rivulids (Costa, 1998, 2004a). The material is deposited in UFRJ, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil. Comparative material is listed in Costa (1998).

Prorivulus new genus

Type species: *Prorivulus auriferus* Costa, Lima & Suzart, new species.

Diagnosis: A non-annual fish genus, similar to *Rivulus* and *Kryptolebias*, and distinguished from the remaining rivulid genera by having anal-fin rays soft in both sexes (vs. hardened in females), urogenital papilla minute in males (vs. prominent and tubular), and absence of a dark bar on iris (vs. presence). Similar to *Kryptolebias* and distinguished from *Rivulus* by possessing frontal E-scales overlapped (vs. not overlapped), third epibranchial with distinct uncinate process (vs. short indistinct process), distal cartilage of the first hypobranchial restricted to articulation with first ceratobranchial (vs. cartilage expanded anteriorly), ventral process of angulo-articular broad (vs. narrow), and posterior flange of cleithrum absent (vs. present). Similar to *Rivulus* and distinguished from *Kryptolebias* by having unossified interhyal (vs. ossified) and by the absence of the distal process of second epibranchial (vs. presence). Differs from other rivulids, except the two species of *Stenolebias* and *Rivulus romeri* Costa, by having five branchiostegal rays (vs. six).

Included taxa: Only the type species.

Etymology: From the Latin *pro* (a prefix meaning priority in space or time) and *rivulus* (stream, and also a nominal rivulid genus), referring to the basal position of the genus regarding *Rivulus* and all the annual fish rivulid genera. Gender masculine.

Prorivulus auriferus Costa, Lima & Suzart, new species
(Figs. 1–2)

Holotype. UFRJ 5932, male, 30.3 mm SL; Brazil: Estado da Bahia: Valença, coastal stream (24L 0503477 UTM 8505050); A. O. Lima & R. R. Suzart, 28 June 2003.

Paratypes. UFRJ 5933, 1 female, 22.9 mm SL, and 3 juveniles, 13.1–15.5 mm SL; UFRJ 5934, 1 male, 28.5 mm SL, and 2 juveniles, 17.0–18.3 mm SL (c&s); collected with holotype.

Diagnosis: As for the genus.

Description: Morphometric data given in Table 1. Male larger than female, largest male 30.3 mm SL. Dorsal profile slightly convex from snout to end of dorsal-fin base, approximately straight on caudal peduncle. Ventral profile convex on head, almost straight from anterior portion of venter to end of anal-fin base, nearly straight to slightly concave

on caudal peduncle. Body slender, subcylindrical anteriorly, slightly deeper than wide, to compressed posteriorly. Greatest body depth at level of pelvic-fin base.

FIGURE 1. *Prorivulus auriferus*, UFRJ 5932, male, holotype, 30.3 mm SL (two weeks after collection); Brazil: Bahia: Valença.

FIGURE 2. *Prorivulus auriferus*, UFRJ 5933, female, paratype, 22.9 mm SL (two weeks after collection); Brazil: Bahia: Valença.

Dorsal and anal fins rounded. Caudal fin oval. Pectoral fin rounded, posterior margin on vertical through pelvic-fin base in male, just anterior to it in female. Tip of pelvic fin reaching between base of 2nd and 3rd anal-fin ray in male, and urogenital opening in female. Pelvic-fin bases in close proximity. Dorsal-fin origin on vertical through base of 8th or 9th anal-fin ray, and between neural spines of 19th and 21st vertebra. Anal-fin origin between pleural ribs of 13th and 15th vertebra. Dorsal-fin rays 9–10; anal-fin rays 14–15; caudal-fin rays 32–33; pectoral-fin rays 13; pelvic-fin rays 7.

Scales large, cycloid. Body and head entirely scaled, except anterior ventral surface of head. Few scales on caudal-fin base; no scales on dorsal and anal fins. Frontal squamation E-patterned; E-scales overlapping medially; scales arranged in circular pattern around central A-scale without exposed margins. Longitudinal series of scales 31–33; transverse

series of scales 8; scale rows around caudal peduncle 16. Contact organs absent. Supraorbital neuromasts 3 + 3.

Ventral process of angulo-articular broad. Rostral cartilage longer than wide, width about 65 % of length. Basihyal narrow, subrectangular, greatest width about 30 % of length; basihyal cartilage about 25 % of basihyal length. Interhyal vestigial, not ossified. Five branchiostegal rays. One or two teeth on second pharyngobranchial. First epibranchial straight. Distal process of second epibranchial absent. Uncinate process of third epibranchial long. Gill-rakers of first branchial arch 1 + 8. Two vomerine teeth. Dorsal tip of preopercle with short canal. Dermosphenotic present. Ventral process of posttemporal short. Neural prezygapophyses short, about 10 % of neural spine length in fifth caudal vertebra. Epipleural ribs rod-like. Total vertebrae 31–32.

TABLE 1. Morphometric data of *Prorivulus auriferus* sp. n..

	males holotype UFRJ 5932	male paratype UFRJ 5934	female paratype UFRJ 5933
Standard length (mm)	30.3	28.5	22.9
Percents of standard length			
Body depth	20.5	19.7	19.9
Caudal peduncle depth	14.3	13.7	13.0
Predorsal length	75.7	77.2	77.6
Prepelvic length	53.7	53.3	57.7
Length of dorsal-fin base	10.3	9.5	10.1
Length of anal-fin base	22.1	22.0	21.3
Caudal-fin length	38.9	40.3	39.3
Pectoral-fin length	23.5	25.2	23.0
Pelvic-fin length	13.6	14.6	11.2
Head length	25.8	26.8	27.1
Percents of head length			
Head depth	60.6	61.8	59.0
Head width	72.7	70.6	68.6
Snout length	13.3	15.6	13.2
Lower jaw length	20.5	18.6	17.8
Eye diameter	35.5	37.9	38.1

Coloration in life: Male: Side of body light gray with irregular shaped golden blotches below lateral midline, and zigzag dark purplish gray stripe on lateral midline overlapped by oblique bars of same color scattered over flank. Dorsum light yellowish brown, venter light yellow. Postorbital pale brown, golden on ventral portion of opercle.

Infraorbital region and ventral surface of head light yellow. Lower jaw dark brown. Iris light yellow. Dorsal fin hyaline with pale gray dots and narrow yellow distal margin. Anal fin yellow with narrow black margin, light blue on base. Caudal fin light blue with pale yellow dots and dark gray distal margin. Pelvic fin yellow. Pectoral fin yellowish hyaline.

Female: Side of body light gray with zigzag dark gray to black stripe on lateral midline. Dorsum light brown, venter light gray. No distinctive black spot on posterior portion of caudal peduncle nor on caudal-fin base. Postorbital region with black stripe, pale golden on ventral portion of opercle. Infraorbital region and ventral surface of head light gray. Lower jaw dark gray to black. Iris light yellow. Dorsal and anal fins pale yellow with transverse rows of small dark gray spots; distal margin of anal fin black. Caudal fin light yellow with narrow dark gray bars. Paired fins hyaline.

Distribution: Known only from the type locality, a coastal plain brook in the Município de Valença, northeastern Brazil.

Habitat notes: The type series was collected in a shallow (about 40 cm deep), small freshwater brook within a forest, near a salt water canal. It is situated in a coastal region, with a net of canals forming a series of small islands. The water was reddish brown, acid (pH 4.0), not turbid. The only other fish species found was the characid *Hyphessobrycon* cf. *itaparicensis* Lima & Costa.

Etymology: From the Latin *auriferus* (auriferous), referring to the male color pattern consisting of golden spots on the flank.

Discussion

Five synapomorphies listed by Costa (2004a) for the group including *Rivulus* and the clade comprising all annual rivulids, are not present in *P. auriferus*: E-scales not overlapped (Fig. 3A; reversed in the clade comprising *Simpsonichthys*, *Cynolebias*, *Megalebias*, *Austrolebias*), shortened uncinate process of the third epibranchial (Fig. 4D; unambiguous), articular face of the distal edge of the first hypobranchial anteriorly expanded (Fig. 4F; unambiguous), ventral process of the angulo-articular narrowed (Fig. 4H; unambiguous), and posterior flange of the cleithrum absent (Fig. 4J; unambiguous). These synapomorphies support the monophyly of the group comprising *Rivulus* and the annual fish clade (Fig. 5). *Prorivulus auriferus* present the plesiomorphic conditions for these characters, as occurring in *Kryptolebias* and in aplocheiloids non-rivulids (i. e., nothobranchids and aplocheilids): E-scales overlapped (Fig. 3B), uncinate process of the third epibranchial long (Fig. 4C), articular face of the distal edge of the first hypobranchial not anteriorly expanded (Fig. 4E), ventral process of the angulo-articular broad (Fig. 4G), and posterior flange of the cleithrum present (Fig. 4I).

Two synapomorphies listed by Costa (2004a) support monophyly of the group comprising *Prorivulus*, *Rivulus* and the annual fish clade (Fig. 5): unossified interhyal (unambiguous) and absence of the distal process of the second epibranchial (Fig. 4B;

unambiguous). In *Kryptolebias* and in aplocheiloids non-rivulids the interhyal is ossified and there is a conspicuous distal process on the second epibranchial (Fig. 4A).

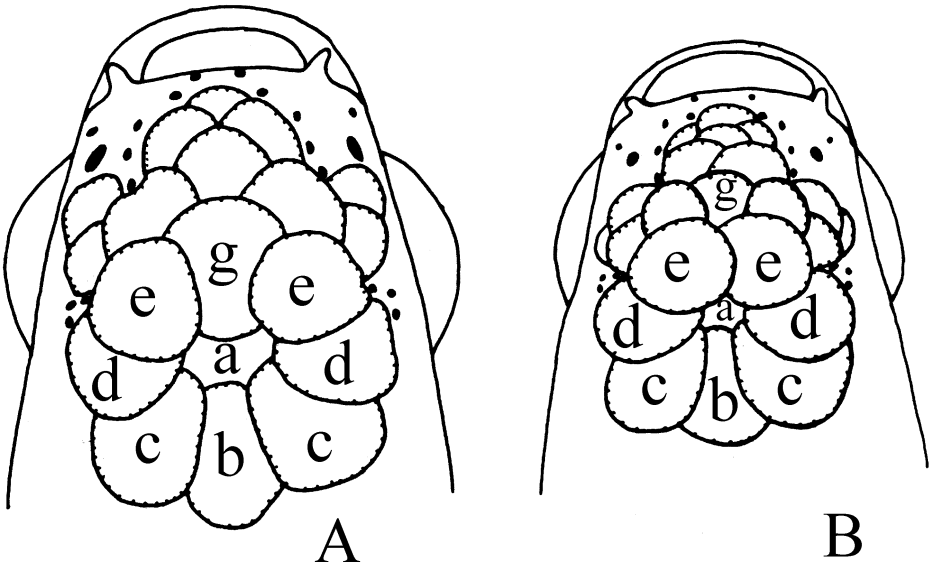

FIGURE 3. Diagrammatic representation of the frontal squamation in: A, *Rivulus* and most annual fish genera, B, *Prorivulus* and *Kryptolebias*.

The presence of five branchiostegal rays in *Prorivulus* is interpreted as autapomorphic. Other aplocheiloids have six branchiostegal rays, except the cynolebiatine *M. wolterstorffi* (Ahl) with eight rays, the Plesiolebiatini genus *Stenolebias* and *Rivulus romeri* also with five rays (Costa, 1998, 2003b). *Stenolebias* is an annual fish genus, member of the Plesiolebiatini clade, which includes other genera with six rays (Costa, 1998), and *R. romeri* is a member of the *Rivulus atratus* species group, which also includes several species with 6 rays (Costa, 2004b). Therefore, reduction to five branchiostegal rays is considered a homoplastic condition, occurring in three distinct rivulid lineages.

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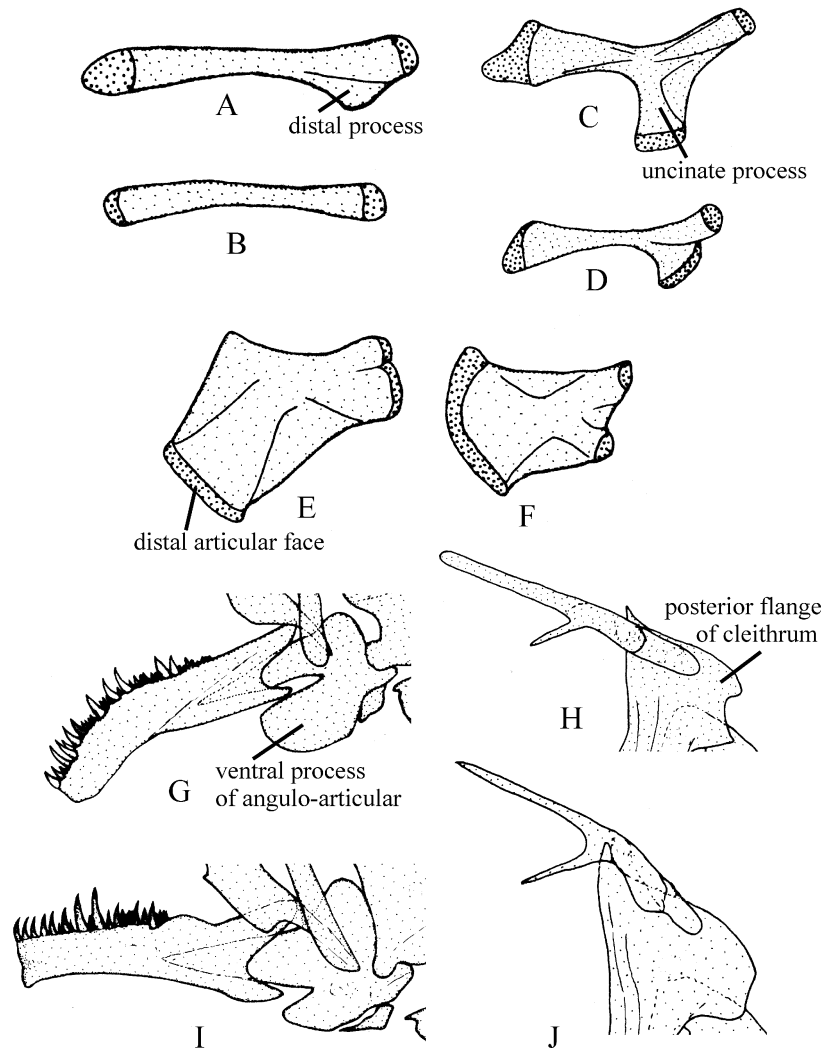

FIGURE 4. Osteological features of some rivulids: left second epibranchial, ventrosagittal view: A, in *Kryptolebias* (sketch based on *K. brasiliensis*), B, in *Prorivulus*, *Rivulus* and all the annual rivulid genera (sketch based on *Rivulus janeiroensis*); left third epibranchial, ventrosagittal view: C, in *Kryptolebias* and *Prorivulus* (sketch based on *K. brasiliensis*), D, in *Rivulus* and all the annual rivulid genera (sketch based on *Rivulus janeiroensis*); left first hypobranchial, dorsal view: E, in *Kryptolebias* and *Prorivulus* (sketch based on *K. brasiliensis*), F, in *Rivulus* and all the annual rivulid genera (sketch based on *Rivulus janeiroensis*); left lower jaw, lateral view: G, in *Kryptolebias* and *Prorivulus* (sketch based on *K. brasiliensis*), H, in *Rivulus* and all the annual rivulid genera (sketch based on *Cynolebias griseus* Costa, Lacerda & Brasil); dorsal portion of left shoulder girdle, lateral view: I, in *Kryptolebias* and *Prorivulus* (sketch based on *K. brasiliensis*), J, in *Rivulus* and all the annual rivulid genera (sketch based on *Trigonectes balzanii* (Perugia)).

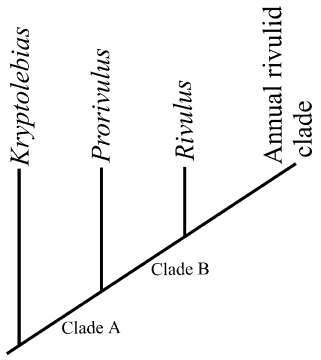

FIGURE 5. Phylogenetic relationships of basal rivulid lineages, according to synapomorphies established in Costa (2004a): clade A: unossified interhyal, absence of the distal process of the second epibranchial; clade B: E-scales not overlaped, shortened uncinate process of the third epibranchial, articular face of the distal egde of the first hypobranchial anteriorly expanded, ventral process of the angulo-articular narrowed, posterior flange of the cleithrum absent.

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