

***Atlantirivulus*, a new subgenus of the killifish genus *Rivulus* from the eastern Brazilian coastal plains (Teleostei: Cyprinodontiformes: Rivulidae)**

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Received on November 16, 2007, accepted on February 18, 2008.

Published online at www.vertebrate-zoology.de on May 12, 2008.

> Abstract

Atlantirivulus, new subgenus of *Rivulus* POEY, is described to include a well defined, geographically isolated species assemblage, endemic to eastern Brazil, formerly known as the *Rivulus santensis* species group. It includes eight species, all inhabiting Atlantic forest habitats: *R. santensis* KÖHLER, the type species of the new subgenus, *R. depressus* COSTA, *R. haraldsiolii* BERKENKAMP, *R. janeiroensis* COSTA, *R. lazzarotoi* COSTA, *R. luelingi* SEEGER, *R. nudiventris* COSTA & BRASIL, and *R. simplicis* COSTA. *Atlantirivulus* is diagnosed by a curved ventral process of angulo-articular and infraorbital neuromasts numerous, arranged in a zigzag pattern, morphological features that are unique among aplocheiloid fishes.

> Resumen

Atlantirivulus, novo subgênero de *Rivulus* POEY, é descrito para incluir um agrupamento de espécies bem definido e isolado geograficamente, endêmico do leste do Brasil, anteriormente conhecido como grupo de espécies *Rivulus santensis*. Ele inclui oito espécies, todas vivendo em ambientes da Mata Atlântica: *R. santensis* KÖHLER, a espécie tipo do novo subgênero, *R. depressus* COSTA, *R. haraldsiolii* BERKENKAMP, *R. janeiroensis* COSTA, *R. lazzarotoi* COSTA, *R. luelingi* SEEGER, *R. nudiventris* COSTA & BRASIL e *R. simplicis* COSTA. *Atlantirivulus* é diagnosticado pelo processo ventral curvo do ângulo-articular e neuromastos infra-orbitais numerosos, dispostos em padrão de zig-zag, características morfológicas exclusivas entre peixes aplocheilóideos.

> Key words

Killifishes, Cyprinodontiformes, Rivulidae, *Rivulus*, Atlantic forest, Systematics.

Introduction

Rivulus Poey is a widespread, speciose and poorly diagnosed assemblage of American aplocheiloid killifishes (COSTA, 2006). Over 100 nominal species are placed in *Rivulus*, ranging from Mexico to southern Brazil, but no unique apomorphic condition is known to occur in all species (COSTA, 2006). *Rivulus* has been diagnosed by a combination of characters not occurring in other rivulid genera (*e. g.*, HUBER, 1992), and monophyly is poorly supported by morphological characters (COSTA, 2006), whereas molecular analyses suggest that *Rivulus* is not monophyletic (HRBEK & LARSON, 1999; MURPHY *et al.*, 1999). However, monophyly of some species groups, sometimes formally recognized as subgenera, are well corroborated both

by morphology and molecular studies (COSTA, 1998, 2006; HRBEK & LARSON, 1999; MURPHY *et al.*, 1999).

COSTA & BRASIL (1991) first recognized monophyly of a geographically isolated, species assemblage from eastern Brazil based on the apomorphic morphology of the angulo-articular bone. Six species were assigned to this unnamed assemblage: *Rivulus santensis* KÖHLER, *R. luelingi* SEEGER, *R. haraldsiolii* BERKENKAMP, *R. nudiventris* COSTA & BRASIL, *R. janeiroensis* COSTA, and *R. depressus* COSTA (COSTA, 1991). This assemblage was named as “the *santensis* super-species” by HUBER (1992), “the *R. janeiroensis* group” by COSTA (1998), and “the *R. santensis* species group” by COSTA (2004). Two new species were described in recent years (COSTA, 2004, 2007a), and a new diagnostic feature for the group (a unique pattern of infra-orbital neuromasts) was described (COSTA, 2007a,

2007b). Monophyly of the *R. santensis* species group, first supported by morphology (COSTA & BRASIL, 1991; COSTA, 1998, 2007a), was tested and also corroborated by independent molecular analyses (HRBEK & LARSON, 1999; MURPHY *et al.*, 1999). The objective of the present study is to formally designate a new subgenus for this well supported group.

Materials and methods

Fin-ray counts include all elements. Number of vertebrae, gill-rakers, 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).

Material examined is deposited in MCP, Museu de Ciências e Tecnologia da Pontifícia Universidade Católica, Porto Alegre; MNRJ, Museu Nacional, Universidade Federal do Rio de Janeiro, Rio de Janeiro; MZUSP, Museu de Zoologia, Universidade de São Paulo, São Paulo; and, UFRJ, Instituto de Biologia, Universidade Federal do Rio de Janeiro, Rio de Janeiro:

Rivulus depressus: Brazil: Bahia: Porto Seguro: UFPB 2213, holotype, 33.0 mm SL; UFPB 1749, 17 paratypes (2 c&s); stream into Estação Ecológica Pau-Brasil, rio João de Tiba basin; R.T.C. RAMOS, 2 Mar. 1986. UFRJ 2118, 1 (c&s); same locality.

Rivulus haraldsiolii: Brazil: Estado de Santa Catarina: UFRJ 125, 6; UFRJ 6295, 2(c&s); MCP 10661, 1; Joinville. UFRJ 6333, 23; UFRJ 6334, 4; Navegantes. MCP 23369, 1; Piçarras. MZUSP 38356, 6; near Tijucas.

Rivulus janeiroensis: Brazil: Rio de Janeiro: MUZUP 41383, holotype, 30.0 mm SL; MZUSP 41384, 6 paratypes; near Silva Jardim. MNHG 2512.85, 2 paratypes; UFRJ 130, 2 paratypes (c&s); UFRJ 152, 9; UFRJ 187, 11; UFRJ 5238, 23; UFRJ 5239, 13; UFRJ 5256, 12; UFRJ 5258, 2; UFRJ 5260, 8; UFRJ 5331, 11; UFRJ 5333, 8; UFRJ 5366, 6; UFRJ 5389, 7; UFRJ 5391, 8; UFRJ 5416, 7 (c&s); UFRJ 5420, 6; MNRJ 28081, 7; Citrolândia, near Magé. UFRJ 129, 2 paratypes; near Macaé. UFRJ 131, 5; Parque Florestal do Desengano. MNRJ 25304, 4; MNRJ 25371, 13; MNRJ 24777, 19; MNRJ 24775, 11; MNRJ 25023, 7; MNRJ 25421, 2; MNRJ 25436, 4; MNRJ 25429, 5; MNRJ 25514, 7; Rio de Janeiro city.

Rivulus lazzarotoi: Brazil: Estado do Rio de Janeiro: UFRJ 6435, holotype; UFRJ 6436, 6 paratypes; UFRJ 7211, 9 paratypes; UFRJ 7213, 4 paratypes (c&s); Angra dos Reis.

Rivulus luelingi: Brazil: Estado de Santa Catarina: UFRJ 161, 8; UFRJ 127, 3 (c&s); UFRJ 128, 14; Araquari. UFRJ 5214, 6; MZUSP 38311, 4; Itapoá. UFRJ 5216, 4; road Itapoá-Vila da Glória. UFRJ 6320, 17; UFRJ 6335, 4; between Araquari and

Balneário Barra do Sul. UFRJ 6351, 21; UFRJ 6352, 1; Balneário Barra do Sul. MCP 10662, 1; Itapocu. Estado do Paraná: UFRJ 6346, 29; UFRJ 6347, 22; near Guaratuba.

Rivulus nudiventris: Brazil: Espírito Santo: Itapemirim: MZUSP 40283, holotype, 35.9 mm SL; MZUSP 40284, 3 paratypes; MNRJ 11740, 2 paratypes (c&s); swamp on right bank of rio Itapemirim.

Rivulus santensis: Brazil: Estado de São Paulo: UFRJ 123, 4 paraneotypes; UFRJ 6321, 2; UFRJ 6322, 2; UFRJ 278, 1 (c&s); Bertioga. MZUSP 38315, 41 paraneotypes; 5 km N of Itanhaém. MZUSP 38331, 15 paraneotypes; near Cubatão. UFRJ 5441, 8; UFRJ 6294, 5 (c&s); UFRJ 6366, 4; Boracéia. UFRJ 6298, 14; UFRJ 6299, 4; Itanhaém. MZUSP 38385, 21 paraneotypes; Estação Ecológica da Juréia. MZUSP 35305, 2 paraneotypes; Miracatu. UFRJ 6329, 16; UFRJ 6330, 2; MNRJ 24352, 1; Juquiá. UFRJ 6328, 3; UFRJ 6327, 10; Iguape. UFRJ 6326, 3; UFRJ 6325, 12; between Iguape and Sabaúna. UFRJ 5439, 12; ilha do Cardoso. MNRJ 19467, 14; MNRJ 25773, 4; MNRJ 19454, 1; Registro. MNRJ 19486, 1; Pariqueira-Açu. Estado do Paraná: MZUSP 38359, 11 paraneotypes; Ponta da Pita. UFRJ 5237, 7; near Matinhos. UFRJ 6362, 17; UFRJ 6363, 4; Praia de Leste. MZUSP 35413, 3; Paranaguá. MNRJ 19494, 24; MNRJ 19551, 24; Praias road.

Rivulus simplicis: Brazil: Rio de Janeiro: UFRJ 5940, holotype; UFRJ 5976, 3 paratypes; UFRJ 5941, 31 paratypes; UFRJ 5942, 5 paratypes (c&s); Paraty. MNRJ 20249, 3; Mamanguá.

Atlantirivulus, new subgenus

Type species: *Rivulus santensis* Köhler (Fig. 1)

Diagnosis. Distinguished from all other subgenera of *Rivulus* and from all other aplocheiloid genera in having species of the *R. santensis* group by the following features: ventral process of the angulo-articular curved (*vs.* straight) (Fig. 2), infraorbital neuromasts numerous (1+19–28+1, *vs.* 1+9–16+1) and arranged in a zig-zag pattern (*vs.* aligned around orbit) (Fig. 3).

Description. Small, maximum adult length 31.4–42.7 mm SL. Dorsal profile gently convex from snout to end of dorsal-fin base, nearly straight on caudal peduncle. Ventral profile about straight to slightly convex from lower jaw to end of anal-fin base, approximately straight on caudal peduncle. Body slender, cylindrical anteriorly, about so deep as wide, to compressed posteriorly. Greatest body depth at vertical just in front to pelvic-fin base. Jaws short, lateral profile of snout slightly pointed.

Extremity of dorsal and anal fins rounded. Caudal fin rounded to subtruncate. Pectoral fin rounded, posterior margin anterior to vertical through pelvic-fin base. Pelvic fin short and elliptical, tip reaching between anus and base of first anal-fin rays; pelvic fin and pel-



Fig. 1. *Rivulus santensis* Köhler, the type species of *Atlantirivulus*; UFRJ 6322, male, 29.2 mm SL; Brazil: São Paulo: Itanhaém.

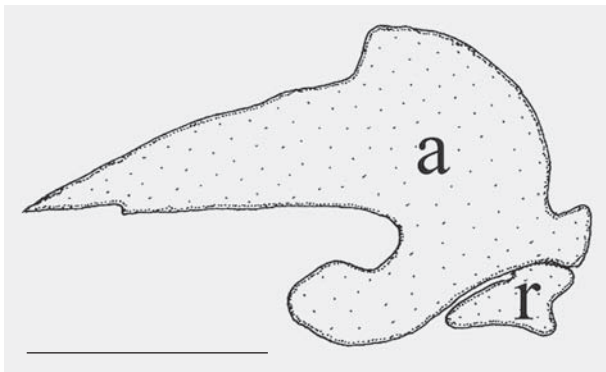


Fig. 2. Left angulo-articular (a) and retro-articular (r) bones, lateral view of *Rivulus santensis*, UFRJ 278. Scale bar: 1 mm.

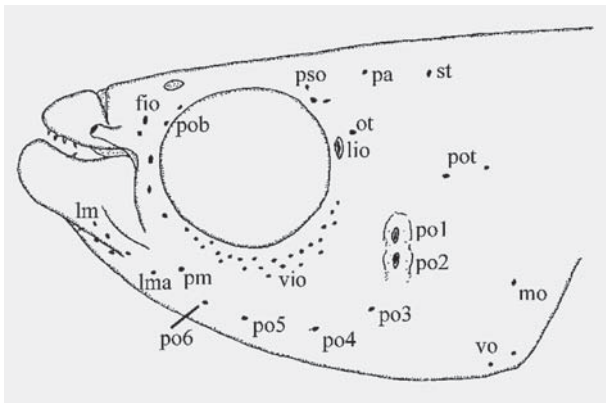


Fig. 3. Diagrammatic representation of neuromasts of the head, lateral view, of *Rivulus* sp. n., UFRJ 6435, male, 29.7 mm SL. Abbreviations: fio, first infraorbital neuromast; lio, last infraorbital neuromast; lma, last mandibular neuromast; lm, lateral mandibular series; mo, median opercular neuromast; ot, otic neuromast; pa, parietal neuromast; pm, paramandibular neuromast; po1-6, preopercular neuromast 1-6; pob, preorbital series; pot, post-otic series; pso, posterior supraorbital series; st, supratemporal neuromast; vio, ventral infraorbital series; vo, ventral opercular series.

vic girdle absent in one species (*R. nudiventris*). Pelvic-fin bases medially in close proximity. Dorsal-fin origin on vertical through posterior portion of anal-fin base. Dorsal-fin rays 7–10; anal-fin rays 13–17; cau-

dal-fin rays 28–34; pectoral-fin rays 13–15; pelvic-fin rays 4–6.

Scales small, cycloid. Trunk 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 E-patterned; E-scales not overlapping medially; scales arranged in regular circular pattern around A-scale without exposed margins; transverse row of scales anterior to H-scale. Longitudinal series of scales 31–36; transverse series of scales 8; scale rows around caudal peduncle 14–16. Contact organs on scales of flank in males.

Cephalic neuromasts: supraorbital 3+3, parietal 1–2, anterior rostral 1, posterior rostral 1, infraorbital 1+19–28 + 1, preorbital 2–3, otic 1, post-otic 2, supratemporal 1, median opercular 1, ventral opercular 2, preopercular 2+4–5, mandibular 3–4+2, lateral mandibular 2–5, paramandibular 1. One neuromast by scale of lateral line, sometimes neuromast absent in some scales; two neuromasts on caudal-fin base.

Basihyal subtriangular, greatest width about 40–60 % of basihyal length; basihyal cartilage about 25–30 % of total basihyal length. Six branchiostegal rays. Second pharyngobranchial teeth 1–3. Gill-rakers of first branchial arch 1+7–8. Vomerine teeth 1–4. Ventral process of posttemporal absent. Total vertebrae 31–36.

Color pattern variable among species. Females often with black spot on upper portion of caudal-fin base.

Included species. *Rivulus depressus* COSTA, *R. haraldioli* BERKENKAMP, *R. janeiroensis* COSTA, *R. lazzarotoi* COSTA, *R. luelingi* SEEGER, *R. nudiventris* COSTA & BRASIL, *R. santensis* KÖHLER, and *R. simplicis* COSTA.

Distribution. Coastal river basins of eastern Brazil.

Habitat. Small, shallow streams and surrounding pools, usually within forest, or sometimes in open places adjacent to the forest. Water often light yellow to orange and acid (pH 3.5–6.0).

Etymology. The name *Atlantirivulus* is derived from the Latin *Atlanticus* (Atlantic) and *rivulus* (stream), referring to the occurrence in the streams of the Atlantic forest of eastern Brazil. Gender masculine.

Discussion

Species of *Atlantirivulus* were placed in *Cynodonichthys* MEEK, a poorly defined, putatively basal subgenus

of *Rivulus* (COSTA, 2006). This placement was partially congruent to a molecular study (neighbor-joining analysis of MURPHY *et al.*, 1999), in which *Atlantirivulus* is considered the sister group to species from Mesoamerica, including *R. tenuis* (MEEK), the type species of *Cynodonichthys*. Other molecular analyses suggest *Atlantirivulus* as a basal rivulid clade, sister group to large assemblage comprising both other lineages of *Rivulus* and several other genera (parsimony analyses of MURPHY *et al.*, 1999 and HRBEK & LARSON, 1999). However, the absence of ventral process of post-temporal suggests that *Atlantirivulus* may be closely related to other subgenera of *Rivulus* as *Laimosemion* HUBER and *Owiyye* COSTA from northern South America, and *Melanorivulus* COSTA, from central South America, which exhibit a similar loss of the post-temporal ventral process (COSTA, 2006).

Atlantirivulus is diagnosed by a curved shape of the ventral process of the angulo-articular (*vs.* straight) (Fig. 2), and a unique pattern of infraorbital neuromasts, which are numerous (1+19–28+1, *vs.* 1+9–16+1) and arranged in a zigzag pattern (*vs.* aligned around orbit). These conditions are not found in other aplocheiloid fishes.

Acknowledgements

I am especially grateful to C.P. BOVE and B.B. COSTA for help in most collecting trips. Thanks are due to O. OYAKAWA, J.L. FIGUEIREDO, M.R. BRITTO, G.W. NUNAN, P. BUCKUP, G.C. BRASIL, J. PEZZI, Z.M. LUCENA, and R. REIS for support during visits to their institutions or for sending material to study, and to J.L. MATTOS, F. OTTONI, L. VILLAVERDE, and E. MATTOS for technical assistance during collections. This study was supported by FAPERJ (Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro – Programa Cientista do Nosso Estado) and CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico – Ministério de Ciência e Tecnologia).

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