

Redescription of *Rivulus luelingi* and *R. haraldsiolii* (Teleostei: Cyprinodontiformes: Rivulidae), two valid killifish species from the Atlantic forest of the coastal plains of southern Brazil

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Rivulus luelingi and *R. haraldsiolii*, two poorly known species of the *R. santensis* group from southern Brazil, are redescribed. *Rivulus luelingi* is endemic to the area between the Guaratuba bay and the Itapocu river, and *R. haraldsiolii* to the area between the Cubatão river and the Tijucas river. The two species are found between Cubatão and Itapocu river basins, but they are never syntopic; *R. luelingi* inhabits temporary pools and swamps in open areas or near the forest border, and *R. haraldsiolii* inhabits shallow creeks within dense forest. *Rivulus luelingi* and *R. haraldsiolii* are diagnosed by the number of caudal-fin rays, vertebrae, scales on longitudinal series and scale rows around caudal peduncle, relative position of dorsal and anal fins, and caudal-fin length. *Rivulus luelingi* is distinguished from all other species of the *R. santensis* group in having unique color patterns of flank and caudal fin in males. *Rivulus luelingi* and *R. haraldsiolii* differ from all other congeners by having multiple contact organs per flank scale in males.

Rivulus luelingi Seegers e *R. haraldsiolii* Berkenkamp, duas espécies pouco conhecidas do grupo *Rivulus santensis* do sul do Brasil, são redescritas. *Rivulus luelingi* é endêmica da área entre a baía de Guaratuba e o rio Itapocu, e *R. haraldsiolii*, da área entre os rios Cubatão e Tijucas. As duas espécies são encontradas entre os rios Cubatão e Itapocu, mas jamais são sintópicas; *R. luelingi* vive em poças temporárias e alagados em áreas abertas ou perto da borda de florestas, e *R. haraldsiolii* vive em riachos rasos dentro de floresta densa. *Rivulus luelingi* e *R. haraldsiolii* são diagnosticadas pelo número de raios da nadadeira caudal, vértebras, escamas da série longitudinal e fileiras de escamas em torno do pedúnculo caudal, posição relativa de nadadeiras dorsal e anal, e comprimento da nadadeira caudal. *Rivulus luelingi* se distingue de todas as outras espécies do grupo *Rivulus santensis* por possuir padrões de colorido exclusivo de flanco e nadadeira caudal em machos. *Rivulus luelingi* e *R. haraldsiolii* diferem de todos os outros congêneres por ter múltiplos órgãos de contato por escama do flanco em machos.

Introduction

Rivulus is a speciose genus of Neotropical killifishes, with a great species diversification in Middle America and northern and central South

America (e.g., Costa, 2003, 2006). It is represented only by a few species in the Atlantic coastal plains of eastern South America, all included in the assemblage known as the *R. santensis* species group (Costa, 1991, 2004, in press; Costa & Brasil, 1991).

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Two species of this assemblage have been reported to occur in brooks and pools of the Atlantic forest coastal basins of southern Brazil: *R. luelingi* and *R. haraldsiolii*. Both species were first described in 1984, but are still poorly known. For example, Huber (1992) considered *R. haraldsiolii* as a possible "simple color variation" of *R. santensis*, but listed material of *R. luelingi* from Guaratuba as belonging to *R. haraldsiolii*. In addition, the type localities of *R. luelingi* and *R. haraldsiolii* are situated in the same river basin (the rio Itapocu basin, a small isolated costal drainage of northern Santa Catarina state) and both species are recorded from other neighboring localities, but accurate data on their geographic range are still unavailable. The objective of the present paper is to clarify the status of *R. luelingi* and *R. haraldsiolii*, providing redescriptions and data on their geographic distribution.

Material and methods

Measurements and counts follow Costa (1995). 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 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). Abbreviations for names of institutions are: BMNH, Natural History Museum, London; 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; UFRJ, Instituto de Biologia, Universidade Federal do Rio de Janeiro, Rio de Janeiro; USNM, National Museum of Natural History, Washington; ZFMK, Zoologisches Forschungsinstitut und Museum Alexander Koenig, Bonn; and, ZMH, Zoologisches Museum der Universität Hamburg, Hamburg.

Rivulus luelingi Seegers (Figs. 1-2)

Rivulus luelingi Seegers, 1984: 273 (type locality: meadow near rio Pirai, Joinville [Estado de Santa Catarina], southern Brazil [about 26°30'S 48°45'W]; holotype: ZFMK 11671).

Material examined. Brazil: Estado de Santa Catarina: UFRJ 161, 8; UFRJ 127, 3 (c&s); UFRJ 128, 14; Araquari; G. Brasil et al., 21 Nov. 1987. – UFRJ 5214, 6; Itapoá; W. J. E. M. Costa et al., 4 Nov 2000. – UFRJ 5216, 4; road Itapoá-Vila da Glória; W. J. E. M. Costa et al., 4 Nov 2000. – UFRJ 6320, 17; UFRJ 6335, 4; temporary swamp within forest, between Araquari and Balneário Barra do Sul, 26°24'32.9"S 48°38'30.9"W; W. J. E. M. Costa et al., 17 Dec 2005. – UFRJ 6351, 21; UFRJ 6352, 1; 6 km S of Balneário Barra do Sul in the road to Barra do Itapocu, 26°30'15.2"S 48°38'45.4"W; W. J. E. M. Costa et al., 18 Dec 2005. – MCP 10662, 1; stream tributary to rio Itapocu, road between the road BR-101 and Barra do Itapocu, Itapocu, 26°35'S 48°48'W; C. A. S. Lucena et al., 19 Sep 1985. Estado do Paraná: UFRJ 6346, 29; swamp near Guaratuba, road PR-412; 25°56'41.7"S 48°35'22.8"W; W. J. E. M. Costa et al., 16 Dec 2005. – UFRJ 6347, 22; swamp near Guaratuba, road PR-412 near the road to Barra do Saí; 25°56'53.3"S 48°36'2.3"W; W. J. E. M. Costa et al., 16 Dec 2005. – MZUSP 38311, 4; Itapoá; W. J. E. M. Costa et al., 21 Dec 1986.

Diagnosis. Distinguished from all other congeners in having the combination of the following features: 1+21-24+1 infraorbital neuromasts, arranged in zigzag row; 3+2 mandibular neuromasts; two to five contact organs per scale on anteroventral portion of flank in males; 30-32 caudal-fin rays; 31-32 total vertebrae; dorsal-fin origin on vertical between base of 10th and 11th anal-fin rays; 32-33 scales on longitudinal series; 16 scale rows around caudal peduncle; and multiple (2-7) contact organs per flank scale in males (*vs.* single or no contact organ). Also distinguished from all other species of the *R. santensis* group in having the following unique color features: flank intense metallic yellowish green in males, and caudal fin dark red to black with broad dark gray to black margin, broad bright greenish yellow submarginal zone, and bright greenish yellow short stripes on middle of fin.

Description. Morphometric data appear in Table 1. Largest male examined 37.6 mm SL; largest female examined 33.7 mm SL. Dorsal profile gently convex from snout to end of dorsal-fin base, approximately straight on caudal peduncle.

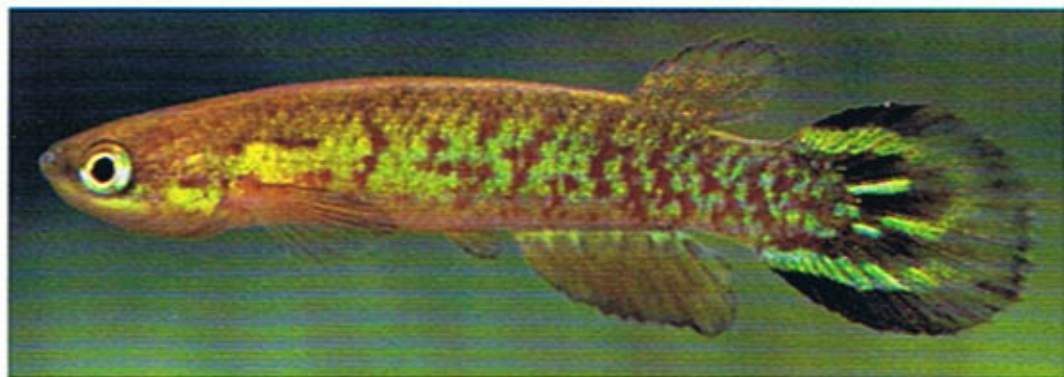


Fig. 1. *Rivulus fuelingi*, UFRJ 6347, male, 29.3 mm SL; Brazil: Paraná: Guaratuba.



Fig. 2. *Rivulus fuelingi*, UFRJ 6347, female, 26.4 mm SL; Brazil: Paraná: Guaratuba.

Ventral profile slightly 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 short and rounded, posterior margin reaching vertical at about 75% of length between pectoral-fin and pelvic-fin bases. Pelvic fin short and elliptical, tip reaching urogenital papilla in males, reaching anus in females. Pelvic-fin bases medially in close proximity. Dorsal-fin origin on vertical between base of 10th and 11th anal-fin rays, and between neural spines of 20th and 21st vertebrae. Anal-fin origin between pleural ribs of 15th and 16th ver-

tebrae. Dorsal-fin rays 7-9; anal-fin rays 13-15; caudal-fin rays 30-32; pectoral-fin rays 13; pelvic-fin rays 6.

Scales small, cycloid. Body and head entirely scaled, except anterior ventral surface of head. Body squamation extending over anterior 30% 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. Two supraorbital scales. Longitudinal series of scales 32-33; transverse series of scales 8; scale rows around caudal peduncle 16. Two to five contact organs per scale on anteroventral portion of flank in males.

Cephalic neuromasts: supraorbital 3+3, parietal 1, anterior rostral 1, posterior rostral 1, in-

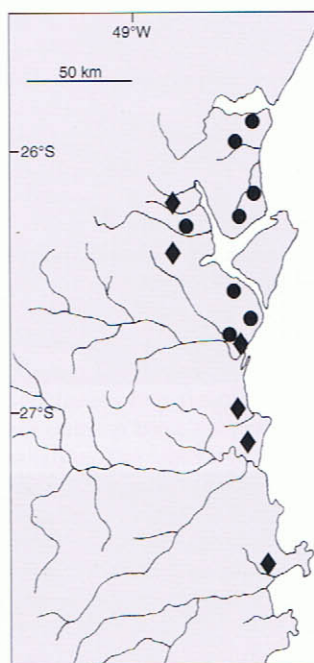


Fig. 3. Geographic distribution of *Rivulus luelingi*, ●, and *R. haraldsiolii*, ◆.

fraorbital 1 + 21-24 + 1, preorbital 2-3, otic 1, postotic 2, supratemporal 1, median opercular 1, ventral opercular 2, preopercular 2 + 4, mandibular 3 + 2, lateral mandibular 2-3, 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 45 % of length; basihyal cartilage about 30 % of total basihyal length. Six branchiostegal rays. One or no tooth on second pharyngobranchial. Gill-rakers of first branchial arch 1 + 8-9. Vomerine teeth 2-3. Ventral process of posttemporal absent. Total vertebrae 31-32.

Coloration. Males. Side of body intense metallic yellowish green with dark red marks irregularly arranged, including oblique lines, spots and short stripes, more concentrated on posterior half of flank. Dorsum light brown. Venter yellow. Side of head light brown, opercular region metallic yellowish green with dark red irregularly shaped lines, suborbital region light greenish yellow; often dark gray postorbital blotch. Lower jaw dark gray. Iris light yellowish with bright green margins. Dorsal fin bright greenish yellow with

dark gray to dark reddish brown oblique stripe between fin origin and middle of posterior margin; narrow black anterodistal margin. Anal fin dark greenish yellow, basal portion light blue. Caudal fin dark red in juveniles to black in some larger adults, with broad dark gray to black margin and broad bright greenish yellow submarginal zone; bright greenish yellow short stripes on middle of fin. Pectoral fin grayish hyaline. Pelvic fin dark greenish yellow.

Females. Side of body light brownish gray, with black dots on dorsal portion of flank. Dorsum light brown. Venter pale yellow. Side of head light brown, opercular region pale golden, suborbital region pale yellow. Lower jaw gray. Iris light greenish yellow. Dorsal fin hyaline with two dark gray oblique stripes. Anal fin dark yellow with narrow light blue base. Caudal fin hyaline with short dark gray traces parallel to fin rays; black rounded spot on dorsal portion of caudal-fin base, dorsoposteriorly bordered by triangular light yellow spot. Pectoral fin hyaline. Pelvic fin yellow.

Distribution. Coastal plain rivers of southern Brazil, between rivers draining into Guaratuba bay, Paraná state, and Itapocu river, Santa Catarina state (Fig. 3).

Habitat. *Rivulus luelingi* is found in the shallowest parts of small streams and temporary swamps, both in open vegetation and in forest border. The water in these habitats is light yellow to reddish brown, pH 4.3-5.7. Usually sympatric with the poeciliid *Phalloceros* sp. in streams, sometimes with the annual rivulid *Campellolebias chrysolineatus* in temporary swamps.

Rivulus haraldsiolii Berkenkamp (Figs. 4-5)

Rivulus haraldsiolii Berkenkamp, 1984: 430 (type locality: lower rio Itapocu, Estado de Santa Catarina, Brazil, 27°16'30"S 48°43'00"W [equivocal coordinates for lower rio Itapocu; correctly about 26°30'S 48°40'W]; holotype: ZMH 6530).

Material examined. Brazil: Estado de Santa Catarina: UFRJ 125, 6; UFRJ 6295, 2(c&s); Joinville; G. C. Brasil et al., 21 Nov 1987. - UFRJ 6333, 23; UFRJ 6334, 4; creek in forest, Pedreiras, Navegantes, 26°50'56.0"S 48°39'

53.2°W; W. J. E. M. Costa et al., 19 Dec 2005. – MCP 10661, 1; arroio Lindo, rio Cubatão basin, road SC-301 near the road BR-101, Pirabeiraba, Joinville, about 26°13'S 48°54'W; C. Lucena et al., 19 Sep 1985. – MCP 23369, 1; stream tributary to rio Piçarras, about 26°45'S 48°42'W; G. A. Souza F., 29 Jan 1998. – MZUSP 38356, 6; near Tijucas; P. S. Santos F., 5 Dec 1975.

Diagnosis. Differs from all other species of the genus by possessing the following features in combination: 1 + 19-22 + 1 infraorbital neuromasts, arranged in zigzag row; 4 + 2 mandibular neuromasts; two to seven contact organs per scale on anteroventral portion of flank in males; 32-34 caudal-fin rays; 34-35 total vertebrae; dorsal-fin origin on vertical between base of 12th and 13th anal-fin rays; 35-36 scales on longitudinal series; scale rows around caudal peduncle; and, multiple (2-7) contact organs per flank scale in males (*vs.* single or no contact organ).

Description. Morphometric data appear in Table 1. Largest male examined 42.3 mm SL; largest female examined 42.7 mm SL. Dorsal profile weakly convex from snout to end of dorsal-fin base, about straight on caudal peduncle. Ventral profile slightly convex from lower jaw to end of anal-fin base, approximately straight on caudal peduncle. Body slender, subcylindrical anteri-

orly, 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 short and rounded, posterior margin reaching vertical at about 75 % of length between pectoral-fin and pelvic-fin bases. Pelvic fin short and elliptical, tip reaching urogenital papilla in males, reaching anus in females. Pelvic-fin bases medially in close proximity. Dorsal-fin origin on vertical between base of 12th and 13th anal-fin rays, and between neural spines of 22nd and 23rd vertebrae. Anal-fin origin between pleural ribs of 15th and 16th vertebrae. Dorsal-fin rays 7-9; anal-fin rays 14-16; caudal-fin rays 32-34; pectoral-fin rays 14; pelvic-fin rays 6.

Scales small, cycloid. Body and head entirely scaled, except anterior ventral surface of head. Body squamation extending over anterior 40 % 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. Three to five supraorbital scales. Longitudinal series of scales 35-36; transverse

Table 1. Morphometric data of *Rivulus luelingi* and *R. haraldsiolii*.

	<i>R. luelingi</i>		<i>R. haraldsiolii</i>	
	males (n = 10)	females (n = 10)	males (n = 10)	females (n = 10)
Standard length (mm)	26.0-37.6	23.9-33.7	27.8-42.3	23.0-42.7
Percent of standard length				
Body depth	21.1-23.0	19.6-24.2	19.7-22.5	19.3-22.2
Caudal peduncle depth	14.3-14.8	13.1-14.2	13.1-14.2	12.0-13.9
Predorsal length	73.6-78.6	74.7-80.2	75.6-78.5	76.3-80.3
Prepelvic length	53.1-56.1	53.2-57.6	53.6-55.6	53.8-58.1
Length of dorsal-fin base	9.0-11.4	9.1-10.4	7.8-10.0	7.1-9.5
Length of anal-fin base	20.8-22.9	17.9-21.1	21.5-24.1	17.6-21.9
Caudal-fin length	38.2-43.7	37.1-42.7	34.6-37.0	33.3-37.6
Pectoral-fin length	20.9-23.4	19.2-22.4	17.5-21.4	16.6-21.1
Pelvic-fin length	8.5-9.8	7.5-9.2	7.2-8.3	5.4-8.1
Head length	23.8-26.8	23.8-27.2	23.3-26.1	23.8-27.2
Percent of head length				
Head depth	69.0-74.4	66.4-75.0	68.4-76.1	70.3-78.3
Head width	76.8-80.0	75.9-83.7	76.8-87.2	77.1-88.1
Snout length	12.2-15.1	12.9-15.9	13.2-16.4	13.2-15.6
Lower jaw length	19.4-23.0	18.0-22.8	20.7-25.1	17.4-25.0
Eye diameter	29.9-36.9	30.8-36.4	30.9-34.7	29.6-33.9



Fig. 4. *Rivulus baraldsiolii*, UFRJ 6334, male, 38.6 mm SL; Brazil: Santa Catarina: Navegantes.



Fig. 5. *Rivulus baraldsiolii*, UFRJ 6334, female, 34.9 mm SL; Brazil: Santa Catarina: Navegantes.

series of scales 7; scale rows around caudal peduncle 14. Two to seven contact organs per scale on anteroventral portion of flank in males.

Cephalic neuromasts: supraorbital 3+3, parietal 1, anterior rostral 1, posterior rostral 1, infraorbital 1+19-22+1, preorbital 3, otic 1, postotic 2, supratemporal 1, median opercular 1, ventral opercular 2, preopercular 2+4, mandibular 4+2, lateral mandibular 3, 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 60% of length; basihyal cartilage about 30% of total basihyal length. Six branchiostegal rays. Second pharyngobranchial teeth 1-2. Gill-rakers of first branchial arch 1+8. Vomerine teeth 3. Ventral process of posttemporal absent. Total vertebrae 34-35.

Coloration. Males. Side of body light purplish brown with bright yellowish green oblique bars, more conspicuous on ventral portion of flank. Dorsum light brown. Venter light yellow. Side of head light brown, opercular region greenish golden, infraorbital region light yellow; usually dark brown postorbital blotch. Lower jaw gold. Iris light yellowish to greenish brown. Dorsal fin pale yellow with three pale brown oblique stripes. Anal fin yellow with transverse rows of pale brown dots, basal portion light blue; reddish brown distal stripe. Caudal fin pale yellow, with reddish brown dorsal and ventral marginal stripes, ventral stripe wider and darker; pale greenish yellow submarginal stripes on dorsal and ventral portions of fin; and, transverse rows of pale brown dots on middle of fin. Pectoral fin yellowish hyaline. Pelvic fin yellow.

Females. Side of body light brownish gray, with brown marks forming reticulate pattern;

dark brown dots on dorsal portion of flank; dorsally elongated brown spot on posterodorsal portion of caudal peduncle, usually inconspicuous. Dorsum light brown. Venter pale yellow. Side of head light brown, postorbital region dark brown, ventral portion of opercle pale golden, suborbital light yellow. Lower jaw gray. Iris light yellowish brown. Dorsal and caudal fins hyaline with transverse rows of dark brown dots; small dark gray spot on dorsal portion of caudal fin base, sometimes inconspicuous. Anal fin orangish hyaline with transverse rows of dark brown dots. Paired fins yellowish hyaline.

Distribution. Coastal plain rivers of Santa Catarina state, southern Brazil, between the Cubatão river and the Tijucas river (Fig. 3).

Habitat. *Rivulus haraldsiolii* inhabits small streams within dense forest. In Navegantes, the stream was narrow (about 50 cm wide) and shallow (about 10 cm deep); the water was dark yellow, pH 6.3. The only other fish found was the poeciliid *Phalloxerus* sp.

Discussion

Monophyly of the *R. santensis* species group is supported by the curved shape of the ventral process of the angulo-articular bone (Costa, 1998, 2006) and the numerous infraorbital neuromasts (1+19-28+1 vs. 1+9-16+1), disposed in a zigzag pattern (vs. aligned around orbit), three features not found elsewhere among aplocheiloids. The three diagnostic features of the *R. santensis* species group are present in *R. luelingi* and *R. haraldsiolii*.

Rivulus luelingi and *R. haraldsiolii* differ among themselves in several characters. The first one is a very distinct member of the *R. santensis* species group, with flank intense metallic yellowish green in males (vs. purplish brown to pale blue) and caudal fin in males dark red to black fin with broad dark gray to black margin, broad bright greenish yellow submarginal zone, and bright greenish yellow short stripes on middle of fin (vs. never a similar color pattern), whereas *R. haraldsiolii* has a general color pattern typical for species of the group (Fig. 4). *Rivulus luelingi* also differs from *R. haraldsiolii* by having 30-32 caudal-fin rays

(vs. 32-34), 31-32 total vertebrae (vs. 34-35), dorsal-fin origin on vertical between base of 10th and 11th anal-fin rays (vs. between base of 12th and 13th anal-fin rays), 32-33 scales on longitudinal series (vs. 35-36), 16 scale rows around caudal peduncle (vs. 14), and longer caudal fin in males (caudal-fin length 38.2-43.7 % SL, vs. 34.6-37.0 % SL). However, *R. luelingi* and *R. haraldsiolii* share the presence of multiple (2-7) contact organs per flank scale in males (vs. single or no contact organ), a condition not found in other congeners, suggesting that the two species are sister taxa.

The geographic range of *R. luelingi* overlaps the geographic range of *R. haraldsiolii* between the Cubatão river and the Itapocu river (Fig. 3). However, both species are never found in the same habitat. *Rivulus luelingi* is usually found in open vegetation swamps, sometimes in seasonal swamps in the marginal portion of forests, whereas *R. haraldsiolii* inhabits shallow creeks within forests.

In the beginning of the 1980's, Pêrsio de Santos-Filho, then a graduate student of Museu de Zoologia, Universidade de São Paulo, prepared a description of a new species of *Rivulus* based on specimens collected in Guaratuba, Paraná state (N. Menezes, pers. comm., 1986). Some material from Guaratuba was deposited in Museu de Zoologia (not catalogued), in National Museum of Natural History, Washington (USNM 227790, 2, USNM 227791, 2), and in the Natural History Museum, London (BMNH 1981.7.7:1-4), as types of a new species, but the description was never published. Examination of those specimens deposited in Museu de Zoologia revealed that Pêrsio's species was *R. luelingi*, and not *R. haraldsiolii* as suggested by Huber (1992).

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