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Aphyocharax yekwanae, a new species of bloodfin tetra (Teleostei: Characiformes: Characidae) from the Guyana Shield of Venezuela

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Aphyocharax yekwanae, new species, is described from the upper Río Caura basin, Bolívar State, Venezuela. It differs from other species of *Aphyocharax* by having brilliant red coloration extending from vertical through second to fifth branched anal-fin ray to vertical through apex of fork in caudal fin, 11-16 maxillary teeth, and lacking black markings on the anal fin. It is compared morphometrically to the other species of *Aphyocharax* reported from Venezuela. *Aphyocharax yekwanae* has only been collected in the Río Caura headwaters above Salto Pará, a 40 meter waterfall. Endemism of fishes in Guyana Shield rivers is probably more common than currently thought, particularly upstream from major waterfalls.

Se describe *Aphyocharax yekwanae*, una nueva especie, proveniente de la cuenca alta del Río Caura, Estado Bolívar, Venezuela. Esta especie difiere de las otras especies de *Aphyocharax* por tener una coloración roja brillante la que se extiende desde vertical por el segundo o quinta rayo de la aleta anal hasta vertical por el ápice de la horquilla de la aleta caudal, entre 11-16 dientes maxilares, y la ausencia de marcas negras en la aleta anal. Se presenta una comparación morfométrica con las otras especies de *Aphyocharax*, reportadas para Venezuela. *Aphyocharax yekwanae* ha sido colectada solamente en las cabeceras del Río Caura sobre Salto Pará, una catarata de 40 meters. Poblaciónes endémicas de peces es probablemente mas común de lo que se pensaba, especialmente sobre grandes cataratas.

Introduction

The Aquatic Rapid Assessment Program (AquaRAP), a joint cooperative program between The Field Museum and Conservation International, surveyed the Río Caura basin, Bolívar State, Venezuela in November-December, 2000. The impetus for the survey was the encroachment of development and plans to divert significant amounts of water from the basin for hydroelectric facilities (Machado-Allison et al., 1999; Chernoff et al., 2003). Documentation of the regional biodiversity is imperative for the conservation of the watershed. During the expedition, a new species of *Aphyocharax* Günther was collected.

The most comprehensive revisions of *Aphyo-*

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Fig. 1. *Aphyocharax yekwanae*, holotype, MBUCV-V-30140, 50.7 mm SL; Venezuela: Bolívar State: Río Erebato, 5 km upstream from Entreríos.

charax are by Eigenmann (1915) and Géry (1977). The latter was based largely on Eigenmann's earlier work. Up to 14 species found from Argentina to Venezuela are currently considered valid. Three species have been reported from the Orinoco basin: *Aphyocharax alburnus* (Günther, 1869), widely distributed throughout the Amazon and Orinoco; *A. erythrurus* Eigenmann, 1912 widely distributed on the Guyana Shield; and *A. colifax* Taphorn & Thomerson, 1991 restricted to the Río Caroní and some adjacent Orinoco drainages (Mago Leccia, 1970; Géry, 1977; Taphorn & Thomerson, 1991). *Aphyocharax alburnus* and *A. erythrurus* are difficult to distinguish, and their distinctness is sometimes questioned (Taphorn & Thomerson, 1991; Taphorn, 1992). This paper presents a description and diagnosis of the new species from Venezuela.

Materials and methods

Counts and measurements are as described in Fink & Weitzman (1974), unless otherwise noted. For fin ray counts, roman numerals are used for unbranched rays and arabic numerals are used for branched rays. Rudimentary dorsal and anal-fin rays were not counted because some were buried underneath skin and scales and were not associated with pterygiophores. Lateral scales were counted from the supracleithrum to the posterior margin of the hypural plate along the row of scales that would bear the lateral line (if complete). In the description, values for the holotype are marked with an asterisk. One specimen was cleared and stained according to Taylor & Van Dyke (1985) and Springer & Johnson (2000).

Measurements were made with a dial caliper to the nearest 0.1 mm. Trusses were the same as described in Fink & Machado-Allison (1992), with the addition of two measurements: body depth as measured immediately anterior to the dorsal fin, and minimum distance from snout to a vertical line through the dorsal-fin origin. STATISTICA 5.0 was used to perform separate principal components analyses based on the covariance matrices of log-transformed or untransformed data from Venezuelan *Aphyocharax* species: *A. alburnus* (23.8-42.3 mm SL, n=9), *A. colifax* (32.5-41.4 mm SL, n=4), *A. erythrurus* (23.5-43.1 mm SL, n=5), and *A. yekwanae* (17.1-56.4 mm SL, n=18). Results indicated that the axes of size and shape discrimination closely paralleled the axes of PC1 and PC2, respectively, hence sheared PCA would not improve our understanding of shape-differences in this case (Bookstein et al., 1985; Chernoff & Machado-Allison, 1999). The raw data of representative characters that loaded highly on PC2 were regressed against standard length in bivariate plots to further discriminate among species.

Specimens were deposited in the Museo de Biología, Instituto de Zoología Tropical, Universidad Central de Venezuela, Caracas (MBUCV) and The Field Museum, Chicago (FMNH).

Aphyocharax yekwanae Willink, Chernoff, and Machado-Allison, new species

(Fig. 1)

Holotype. MBUCV-V-30140, female, 50.7 mm SL; Venezuela: Bolívar: Río Erebato, 5 km upstream from Entreríos, 5°53'59"N 64°28'43"W; B. Chernoff et al., 27 Nov 2000.

Paratypes. FMNH 109275, 2 ex., 23.1-40.3 mm SL; Venezuela: Bolívar: Caño Suajiditu, 5°29'35"N

64°35'10"W; A. Machado-Allison et al., 26 Nov 2000. – MBUCV-V-30141, 2 ex., 23.3-44.5 mm SL; Venezuela: Bolívar: Caño Suajiditu, 5°29'35"N 64°35'10"W; A. Machado-Allison et al., 26 Nov 2000. – FMNH 109277, 1 ex., 28.4 mm SL; Venezuela: Bolívar: Río Caura at Raudal Cejiato, 5°33'28"N 64°18'49"W; A. Rojas et al., 28 Nov 2000. – MBUCV-V-30142, 2 ex., 24.8-28.6 mm SL; Venezuela: Bolívar: Río Caura at Raudal Cejiato, 5°33'28"N 64°18'49"W; A. Rojas et al., 28 Nov 2000. – FMNH 109278, 1 ex., 28.7 mm SL; Venezuela: Bolívar: Río Caura at Cejiato, near mouth of riachuelo, 5°33'28"N 64°18'49"W; A. Machado-Allison et al., 28 Nov 2000. – FMNH 109279, 1 ex., 56.4 mm SL; Venezuela: Bolívar: Río Caura at Pauji, 5°49'41"N 64°24'18"W; B. Chernoff et al., 28 Nov 2000. – MBUCV-V-30143, 2 ex., 47.9-50.3 mm SL; Venezuela: Bolívar: Río Caura at Pauji, sand beach, 5°49'41"N 64°24'18"W; A. Rojas & F. Provenzano, 29 Nov 2000. – FMNH 109281, 2 ex., 26.5-30.5 mm SL; Venezuela: Bolívar: Río Caura at Pauji, backwater, 5°49'41"N 64°24'18"W; A. Machado-Allison & B. Chernoff, 29 Nov 2000. – MBUCV-V-30144, 2 ex., 21.5-28.5 mm SL; Venezuela: Bolívar: Río Caura at Pauji, backwater, 5°49'41"N 64°24'18"W; A. Machado-Allison & B. Chernoff, 29 Nov 2000. – FMNH 109282, 1 ex., 17.1 mm SL; Venezuela: Bolívar: Río Caura at Raudal Culebra del Agua, 6°4'43"N 64°26'14"W; F. Provenzano et al., 1 Dec 2000. – MBUCV-V-30145, 1 ex., 27.8 mm SL; Venezuela: Bolívar: Río Caura at Raudal Culebra del Agua, 6°4'43"N 64°26'14"W; F. Provenzano et al., 1 Dec 2000.

Diagnosis. A species of *Aphyocharax* distinguished from all congeners by uniquely possessing bright red coloration on the body from vertical through second to fifth branched anal-fin ray to vertical through apex of fork in caudal fin; adipose and posterior two-thirds of anal fin red. This coloration is believed to be autapomorphic (in *A. colifax* the red coloration is located posterior to the adipose and anal fins; in *A. rathbuni* and *A. anisitsi* the red coloration does not extend dorsal to the lateral midline of the body). The following characters further distinguish *A. yekwanae* from all congeners: distal margin of anal fin clear (with dark band in *A. rathbuni*), 11-16 maxillary teeth (1-3 maxillary teeth in *A. rathbuni*), and incompletely toothed maxilla.

Description. Morphometric data in Table 1. Body shape generally fusiform, slightly elongate. Caudal peduncle relatively long, adipose fin to base of caudal fin 10-14 % SL. Dorsal-fin origin slightly posterior to mid-body, 49-55 % SL. Pelvic-fin insertion anterior to vertical through dorsal-fin origin, and anal-fin origin posterior to vertical through termination of dorsal fin. Adipose fin close to vertical through anal-fin termination. Largest known specimen is 56.4 mm SL. Body thin, but not compressed. Pectoral fin to pectoral fin 8-11 % SL.

Head 22-27 % SL. Snout rounded. Mouth terminal, approximately level with middle of eye.

Table 1. Truss measurements of *Aphyocharax yekwanae* (n=18). All but Standard Length are as percent standard length. H: holotype.

	H	range	mean
Standard length (mm)	50.7	17.1-56.4	33.3
Snout-epiphyseal bar	10.9	10.8-13.7	12.2
Snout-pectoral fin	23.9	22.9-28.1	25.2
Snout-jaw joint	9.9	8.7-11.2	10.1
Epiphyseal-supraoccipital	8.1	7.2-12.9	8.9
Epiphyseal-pectoral fin	18.7	17.4-19.9	18.7
Epiphyseal-jaw joint	12.2	11.5-14.6	13.3
Pectoral fin-jaw joint	16.2	15.1-19.3	17.0
Supraoccipital-dorsal-fin origin	34.1	29.8-35.2	32.6
Supraoccipital-pelvic fin	33.1	28.2-35.0	32.0
Supraoccipital-pectoral fin	16.8	15.8-18.2	17.1
Supraoccipital-jaw joint	18.2	16.4-21.7	19.7
Pectoral fin-pelvic fin	21.9	20.3-24.2	22.5
Dorsal-fin base	10.3	8.7-11.9	10.4
Dorsal-fin origin-anal-fin origin	28.6	21.1-28.7	26.2
Dorsal-fin origin-pelvic fin	25.4	20.5-28.0	24.2
Dorsal-fin origin-pectoral fin	36.5	32.2-36.7	35.1
Pelvic fin-anal-fin origin	21.3	17.3-21.3	19.4
Dorsal-fin termination-adipose fin	24.7	23.4-26.2	24.8
Dorsal-fin termination-anal-fin termination	26.6	22.8-28.2	26.0
Dorsal-fin termination-anal-fin origin	22.5	15.2-22.9	20.9
Dorsal-fin termination-pelvic fin	27.6	22.8-29.1	26.5
Anal-fin base	18.7	18.4-21.5	20.2
Adipose fin-caudal base	13.2	9.8-14.3	12.6
Adipose fin-anal-fin termination	12.0	9.4-12.9	11.5
Adipose fin-anal-fin origin	27.8	25.7-31.0	28.6
Anal-fin termination-pelvic fin	38.3	36.7-42.0	39.0
Upper jaw length	8.9	7.7-9.4	8.6
Eye diameter	6.1	6.1-11.1	8.4
Head length	22.7	21.8-27.0	24.4
Interorbital distance	7.7	7.4-9.3	8.2
Pectoral fin-pectoral fin	9.7	7.7-10.9	9.5
Body depth	25.4	22.6-25.8	24.2
Snout-vertical through dorsal-fin origin	51.9	49.3-54.5	51.8

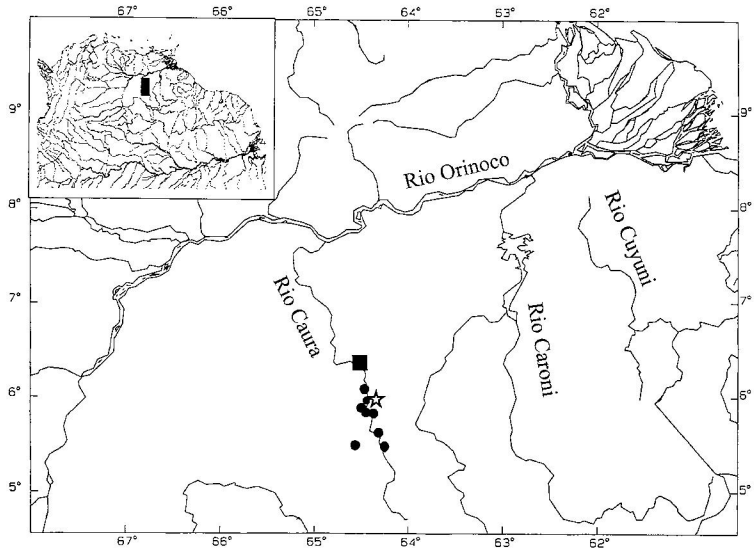

Fig. 2. Map showing Salto Pará (■) and distribution of *Aphyocharax yekwanae* (●; type locality, ☆) in Venezuela.

Lower jaw protrudes slightly beyond upper jaw when mouth closed. Posterior border of maxilla rounded, extends beyond vertical through anterior margin of orbit, but does not reach third infraorbital. Eye diameter 6-11 % SL. Third and fourth infraorbitals hypertrophied in comparison to most characids. Fifth infraorbital reduced in comparison to most characids. Posterior margin of opercle rounded. Branchiostegal membrane free from isthmus.

Teeth unicuspid or tricuspid. Lateral cusps small when present. Single row of teeth on premaxilla. Single row of teeth on medial side of maxilla, extending approximately half the length of maxilla. Single row of teeth on dentary, with anterior teeth larger, followed by several smaller teeth.

Scales cycloid and generally same size over entire body. Predorsal scales mostly regular, but sometimes irregular immediately posterior to supraoccipital and/or immediately anterior to dorsal fin. Half to one row of scales along base of anal fin. Scales covering anterior third of caudal fin, with up to seven scales beyond posterior margin of hypural plate. Axillary scale present dorsal to pelvic-fin insertion.

Distal margin of dorsal fin convex. First branched ray longest. Adipose fin rounded. Caudal fin forked. Lobes rounded and equal. Pectoral fin not reaching pelvic-fin insertion; distal margin convex. Pelvic fin not reaching anal-fin origin; distal margin convex. Distal margin of anal fin falcate.

Precaudal vertebrae: 18*(16). Caudal vertebrae: 18*(15), 19 (1). Upper gill rakers: 5 (1), 6 (9), 7 (6), 8*(2). Lower gill rakers: 10 (1), 11 (6), 12*(11). Premaxillary teeth: 7*(4), 8 (14). Maxillary teeth: 11 (3), 12 (4), 13 (2), 14 (3), 15*(3), 16 (3). Large teeth on dentary: 7 (1), 9 (12), 10*(3), 11 (1), 12(1). Lateral scales: 35 (2), 36*(10), 37 (6). Lateral scales with pores: 9 (2), 10 (7), 11*(9). Transverse scales: 10*(18). Dorsal-fin rays: i,9*(18). Anal-fin rays: i,15 (2), i,16*(6), i,17 (10). Pectoral-fin rays: i,12*(18). Pelvic-fin rays: ii,7*(18).

Coloration. In life, anterior of fish straw-colored to greenish with scattered melanophores. Melanophores most densely distributed dorsally, fading ventrally, and completely absent on belly. Melanophores concentrated near base of an individual scale. Dorsally this produces a slight cross-hatching pattern across body. Bright red coloration on body from vertical through second to fifth branched anal-fin ray to vertical through apex of fork in caudal fin; adipose and posterior two-thirds of anal fin red. Anterior to vertical through distal part of anal fin red pigmentation becomes diffuse, especially above lateral midline. Melanophores absent from red area except along dorsal midline.

Humeral spot two to three scales posterior to opercle. Spot approximately two scales wide by

three scales high, with ventral scales belonging to incomplete lateral line. Scattered melanophores cover dorsal surface of head, ventrally to level of premaxilla and dorsal third of opercle. Scattered melanophores on lower lip, maxilla, and gular membrane.

Pectoral fin with thin dark leading edge. Few melanophores on rest of fin, concentrated anteriorly. Pelvic fin with few melanophores, concentrated anteriorly. Anal fin with melanophores from anterior margin to second to fifth branched ray; rest of fin red; lacking melanophores. Dorsal fin with few melanophores along anterior and posterior edges of rays. Adipose fin red. Anterior to vertical through apex of fork in caudal fin red, posterior hyaline to light red. Few melanophores, concentrated near base of dorsal edge.

Red color disappears in alcohol. Area once colored red recognized by being paler than rest of fish and lacking melanophores. Otherwise, coloration similar to that in life.

Sexual dimorphism. Mature males with lateral hooks on almost all rays of anal fin.

Habitat. *Aphyocharax yekwanae* was most common in the lee side of islands and protected backwaters of the main river channel. Substrates were typically sand with some rocks. It was also collected near the mouths of streams, where the bottom could be muddy and covered with terrestrial plant leaves. Aquatic vegetation was almost always absent. Water was clear to moderately turbid.

Distribution. The only known localities for *A. yekwanae* are in the Río Caura basin upstream from Salto Pará (6°16'56"N 64°29'11"W) (Figs. 2-3).

Etymology. The species-group name, *yekwanae*, refers to the Ye'Kwana tribe that lives in and oversees most of the Río Caura basin. The new species is named in honor of them because of their fervid desire to protect and manage their home territory and its environment.

Discussion

The new species can be assigned to the genus *Aphyocharax* because of its incomplete lateral line, a single row of uni- and tricuspid teeth on the premaxilla, the position of the dorsal fin near middle of the body, 17-27 total anal-fin rays, hypertrophied third and fourth infraorbitals, and a reduced fifth infraorbital (Géry, 1977). Without a rigorous phylogenetic framework and accompanying informative characters, we are unable to ascertain the position of *A. yekwanae* within the genus. Interestingly, all the Guyana Shield species, *A. yekwanae*, *A. colifax*, and *A. alburnus*/*A. erythrurus* key out together in Eigenmann (1915) and Géry (1977). This occurs because each possesses an incompletely toothed maxilla, general lack of significant pigmentation on the dor-

Table 2. Character loadings and eigenvalues from principal components analysis of *Aphyocharax alburnus* (n=9), *A. colifax* (n=4), *A. erythrurus* (n=5) and *A. yekwanae* (n=18). All PC2 loadings greater than 0.200 are in bold.

	PC1	PC2
% variance	98.61	0.45
Eigenvalue	254.40	1.16
Standard length	9.292	**–0.419**
Snout-epiphyseal bar	0.884	0.011
Snout-pectoral fin	1.992	**0.216**
Snout-jaw joint	0.885	0.157
Epiphyseal-supraoccipital	0.578	**0.226**
Epiphyseal-pectoral fin	1.727	**0.325**
Epiphyseal-jaw joint	1.092	**0.240**
Pectoral fin-jaw joint	1.238	0.120
Supraoccipital-dorsal-fin origin	3.159	–0.199
Supraoccipital-pelvic fin	3.244	0.029
Supraoccipital-pectoral fin	1.634	**0.281**
Supraoccipital-jaw joint	1.557	**0.340**
Pectoral fin-pelvic fin	2.197	–0.102
Dorsal-fin base	1.065	0.144
Dorsal-fin origin-anal-fin origin	2.994	0.088
Dorsal-fin origin-pelvic fin	2.616	0.145
Dorsal-fin origin-pectoral fin	3.636	0.134
Pelvic fin-anal-fin origin	2.150	0.018
Dorsal-fin termination-adipose fin	2.391	**–0.395**
Dorsal-fin termination-anal-fin termination	2.717	–0.108
Dorsal-fin termination-anal-fin origin	2.350	–0.032
Dorsal-fin termination-pelvic fin	2.845	0.166
Anal-fin base	1.844	0.081
Adipose fin-caudal base	1.291	0.013
Adipose fin-anal-fin termination	1.258	0.072
Adipose fin-anal-fin origin	2.719	–0.153
Anal-fin termination – pelvic fin	3.909	–0.005
Upper jaw length	0.823	0.120
Eye diameter	0.417	0.049
Head length	1.862	0.144
Interorbital distance	0.653	0.037
Pectoral fin-pectoral fin	1.127	**0.265**
Body depth	2.588	0.108
Snout-vertical through dorsal-fin origin	4.746	0.145

Fig. 3. Salto Pará on the Río Caura (6°16'56"N 64°29'11"W).

sal and anal fins, more than nine maxillary teeth, and a maxilla not reaching the third infraorbital. Coloration is then used to make specific identifications among the four species.

Principal components analyses separated *A. yekwanae* from the other three Guyanan species on the basis of PC2 (Fig. 4). There was no difference between using log-transformed or untransformed data. Principal Component 1 was heavily influenced by standard length and PC2 primarily loaded by standard length, anterior truss elements, plus dorsal-fin termination – adipose fin (Table 2). In other words, there is an increase in the distance between the dorsal fin and adipose fin, and a decrease in the head height and head width in *A. yekwanae*, particularly among adults (Fig. 5). It is also worth noting that there is no separation between *A. alburnus* and *A. erythrurus* collected in the lower Caura basin, although the sample size is small.

Aphyocharax yekwanae is interesting from a biogeographic viewpoint because it has only been collected in the Río Caura basin above Salto Pará (Fig. 2), whereas *A. alburnus* and *A. erythrurus* were not found above Salto Pará (Machado-Allison et al., 2003). Fish must occasionally be washed over the falls, but there is no evidence that *A. yekwanae* is able to maintain distinct populations when sympatric with congeners (i.e., *A. alburnus*/*A. erythrurus*). The 40 meter falls are an effective upstream migration barrier. Very few fishes would be able to climb the falls, and *Aphyocharax* species certainly would be unable to, hence *A. yekwanae* is isolated. Endemism of fishes in Guyana Shield rivers has been documented (Lasso, 1989), yet this phenomenon is probably even more common than currently thought, particularly upstream from major waterfalls.

There are at least two scenarios for the history of *A. yekwanae*: 1) the ancestral population was present prior to the formation of the falls, or 2) afterwards dispersed to the region via stream capture. There is evidence for stream captures in the nearby Gran Sabana (López et al., 1942; Lasso et al., 1989). Fish distribution patterns indicate possible past connections with the Caroní/Cuyuní/Essequibo (Chernoff et al., 1991; Provenzano et al., 1995; Bonilla et al., 1999) and upper Orinoco/Negro (Chernoff et al., 1991; Armbruster & Provenzano, 2000; Garavello, 2000). It is difficult to choose between these two scenarios without knowing when the falls were formed, the timing of stream capture events, and the phylogenetic position of *A. yekwanae*, none of which are currently known. Additional surveys and systematic work are needed to understand the regional biodiversity and to provide information for making conservation decisions.

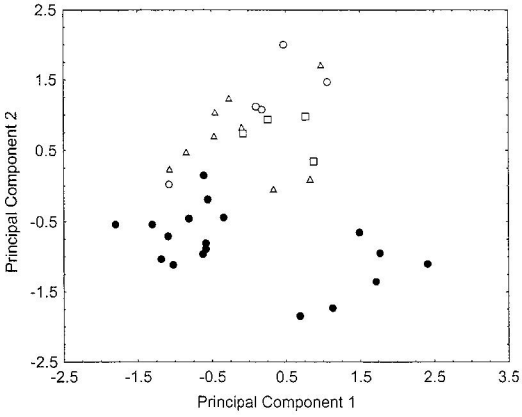

Fig. 4. Scatterplot of scores on first two principal components for *Aphyocharax alburnus* (△, n=9), *A. colifax* (□, n=4), *A. erythrurus* (○, n=5) and *A. yekwanae* (●, n=18).

Comparative material. *Aphyocharax alburnus*: FMNH 103415, 4 ex., 25.5-32.5 mm SL; Venezuela: Barinas: Playa Los Chicos in the Río Suripa. – FMNH 109289, 5 ex., 23.8-42.3 mm SL; Venezuela: Bolívar: Río Nichare. *A. anisitsi*: FMNH 107798, 3 ex., 26.1-31.1 mm SL; Paraguay: Alto Paraguay: Río Paraguay in front of Valle Mi. *A. colifax*: FMNH 97153, 4 ex., paratypes, 32.5-41.4 mm SL; Venezuela: Bolívar: Middle Oris River. *A. dentatus*: FMNH 108375, 1 ex., 48.9 mm SL; Brasil: Mato Grosso do Sul: Brejo do Santa Sofia. *A. erythrurus*: FMNH 109300, 5 ex., 23.5-43.1 mm SL; Venezuela: Bolívar: Laguna about 1 km downstream from the mouth of Río Tawadu into Río Nichare. *A. paraguayensis*: FMNH 107807, 2 ex., 22.1-22.3 mm SL; Paraguay: Alto Paraguay: Río Paraguay behind Estancia Cerrito. *A. pusillus*: FMNH 106084, 3 ex., 34.2-42.9 mm SL; Bolivia: Pando: Río Orthon. *A. rathbuni*: FMNH 108378, 46 ex., 14.6-21.1 mm SL; Brasil: Mato Grosso do Sul: Corrego Anhuma.

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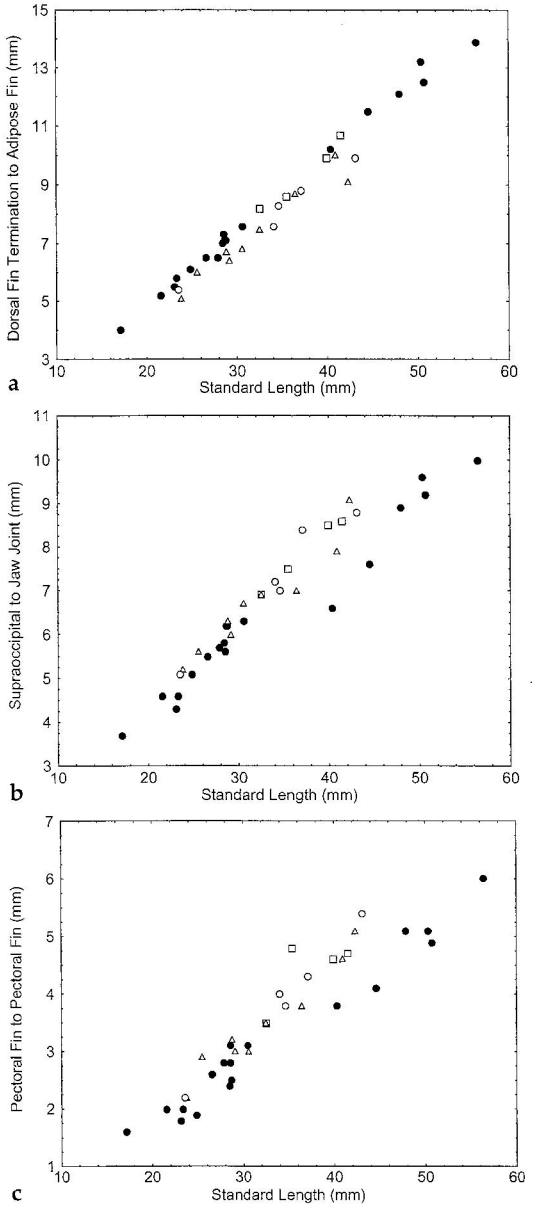

Fig. 5. Bivariate relationships between standard length and distance between (a) dorsal-fin termination and adipose fin, (b) supraoccipital and jaw joint and (c) pectoral fin and pectoral fin for *Aphyocharax alburnus* (△, n=9), *A. colifax* (□, n=4), *A. erythrurus* (○, n=5) and *A. yekwanae* (●, n=18).

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