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Description of *Dicrossus foirni* sp. n. and *Dicrossus warzeli* sp. n. (Teleostei: Perciformes: Cichlidae), two new cichlid species from the Rio Negro and the Rio Tapajós, Amazon drainage, Brazil

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> Abstract

Dicrossus foirni sp. n. and *Dicrossus warzeli* sp. n. are described from the Brazilian Amazon River system. Both species are differentiated from all other Neotropical cichlids by exhibiting three rows of longitudinal lateral spots. *Dicrossus foirni* sp. n., which is distributed in the northern Rio Negro drainage, exhibits a pattern of lateral spots formed by the clustering of individual dots. By contrast, *Dicrossus warzeli* sp. n., which is endemic to the Rio Tapaj□s, exhibits three longitudinal rows of horizontal dash-like spots on the sides of the body. Furthermore, the two species are distinguished by having different relationships between body height and body length.

> Resumen

Dicrossus foirni sp. n. y *Dicrossus warzeli* sp. n. son descritas en la region del R□o Amazonas. Ambas especies se differencian de todos los otros ciclides neotropicales en la composici□n y localizaci□n de sus tres bandas laterales. *Dicrossus foirni* sp. n., que se distribuye en la regi□n Norte del R□o Negro, muestra un patr□n de manchas laterales la cual es formada por grupos de puntos individuales. Al contrario, el *Dicrossus warzeli* sp. n, que es endemico del R□o Tapaj□s, muestra bandas delgadas continuas a ambos lados del abdomen. Adem□s, ambas especies se distinguen por tener diferentes relaciones entre la altura corporal y el largo corporal.

> Kurzfassung

Dicrossus foirni sp. n. und *Dicrossus warzeli* sp. n. werden aus dem brasilianischen Amazonaseinzug beschrieben. Die beiden Arten unterscheiden sich durch eine Anordnung von jeweils drei l□nglichen Fleckenreihen von allen anderen neotropischen Cichliden. *Dicrossus foirni* sp. n., die im n□rdlichen Rio Negro-Einzugsgebiet verbreitet sind, sind durch aus Einzelflecken zusammengesetzten Lateralmuster gekennzeichnet. Die im Rio Tapaj□s endemischen *Dicrossus warzeli* sp. n tragen hingegen Reihen durchgehender schmaler L□ngsstriche auf den K□rperseiten. Beide Arten sind au□erdem durch im Vergleich zur Kopfbreite unterschiedliche relative K□rperh□he voneinander zu unterscheiden.

> Key words

Systematics, ichthyology, biogeography, freshwater ecology, Neotropics, Amazon River, new taxa.

Introduction

The Neotropical cichlid genus *Dicrossus* STEINDACHNER, 1875 at present includes three described dwarf cichlid species: *Dicrossus maculatus* STEINDACHNER, 1875 (the type species of the genus), *Dicrossus filamentosus* (LADIGES, 1958), and *Dicrossus gladicauda* SCHINDLER & STAECK, 2008. Two more species, both from the Brazilian Amazon basin, have been known for at least two decades (KULLANDER, 1990; RÖMER, 2000, 2006; STAWIKOWSKI & WERNER, 2004). In this paper these two species, known since 1981 under various □ in some cases confusing □ provisional names [i. e. *Dicrossus* sp. □A□ (KULLANDER, 1990) *Dicrossus* sp. □Peru□ (TOMEY, 1983), *Dicrossus* sp. □Rotflossen□ (LINKE & STAECK, 1992), *Dicrossus* sp. □Rio Negro□ (WINDISCH, 1992), *Dicrossus* sp. □Doppelfleck□ (MAYLAND & BORK, 1997), and *Dicrossus* sp. □B□ (KULLANDER, 1990), *Dicrossus* sp. □Tapaj□s□ (WARZEL, 1996), *Dicrossus* sp. □Tapaios□ (WARZEL, 1996)], will be formally described below.

Material and Methods

Measurements and counts were taken as described in detail in RÖMER (2006) and RÖMER *et al*. (2003, 2004, 2006) All type specimens were preserved in 75% ethanol. A small number of fish were preserved in the field, the rest after various periods of maintenance in the aquarium. The latter specimens were treated before preservation as described in detail by RÖMER & HAHN (2008). Voucher specimens were deposited in the fish collections of the Museum for Natural History, Dresden (MTD F), California Academy of Sciences, San Francisco (CAS), Museu de Zoologia da Universidade de S□o Paulo (MZUSP), and the personal collection of the senior author (UR). Tissue samples for future genetic analysis have been taken from all specimens, preserved in pure ethanol, and registered under the same individual numbers as the originating specimens. Descriptions are based mainly on holotypes, with additional information taken from all paratypes. Information for colour descriptions of voucher specimens was taken from fish preserved in 75 % ethanol. Colour of dry specimens in some cases differs significantly. RÖMER (2000, 2006) has presented numerous photographs of the species described herein. These figures are included as supplementary pictorial reference material. Behaviour was observed in the laboratory under conditions given in RÖMER & HAHN (2008).

The coloration of live specimens is well known. It may be seen from numerous colour photographs in various publications, especially RÖMER (2000, 2006), STAWIKOWSKI & WERNER (2004), and STAECK (2003). In this work only a few illustrations and notes on some basic colour patterns useful for identification will be included. GPS data for station F9/91R were taken with a Garmin GPS 50 (Garmin Int. Inc., Lenexa, USA), and extracted from ONC Flight Navigation Charts (Ministry of Defence, UK) and Google Earth for the *igarap*□ near Sao Luiz. Statistical analysis was carried out using the PC program Statistika 6.0 for Windows (StatSoft Inc. Tulsa, USA).

Comparative material

Crenicara punctulata: MTD F 32159, 1 male, 81.8 mm SL, 1 female, 60.1 mm SL, collected March 1994 by M. WÖHLER, Anavillhanas archipelago, lower Rio Negro, federal state of Amazonas, Brazil.

Crenicara latruncularium: UR.2010.06.113, 1 male, 1 female, not measured, commercial import, September 2009, C. EON, Bordeaux.

Dicrossus filamentosus: MTD F 32160, 6 specimens, 27.9 mm SL to 37.4 mm SL, collected October 13th 1991 by A. SCHNEIDER. Location: few hundred meters upriver from the mouth of the Igarap□ Pr□sperit□ (station F9/91R: 00□09′47″S / 64□07′11″W), a small right hand tributary of the Rio Preto near Lago Urubu about 12.5 km NNW from the junction with the Rio Negro, federal state Amazonas, Brazil. 35 specimens (UR 2010.Df.1001) from vicinity of Puerto Inirida, imported by Aquapool (Wuppertal), March 2007.

Dicrossus gladicauda: 80 specimens: MTD F 32155, 13 specimens, 22.8 mm SL to 37.7 mm SL; CAS 229 773, 13 specimens, 26.0 mm SL to 39.5 mm SL; CAS 229 774, 15 specimens, 23.7 mm SL to 38.9 mm SL; MTD F 32156, 10 specimens all male, 24.9 mm SL to 42.1 mm SL; MTD F 32157, 14 specimens, 31.2 mm SL to 43.0 mm SL; MTD F 32158, 5 males, 36.4 mm SL to 41.5 mm SL, cleared and stained; UR.2010.06.112, 10 specimens, 26.0 mm SL to 40.6 mm SL. All from Rio Vichade, Eastern Colombia, collected May 2002.

Dicrossus maculatus: UR.2010.06.113, 1male, 1 female, not measured, commercial import, October 2005.

Supplementary material (non types). 6 live specimens (not preserved) of each of both *Dicrossus* species described below, maintained in the aquarium for behavioural and ontogenetic observation, to be kept in the personal collection of UR after preservation, and figures in RÖMER (2000, 2006).

Dicrossus foirni sp. n.

Figs. 1□7, 17 & 18, Tabs. 1□3)

Holotype. (fig. 1) MZUSP 106589, female, 42.8 mm SL, collected by A. SCHNEIDER, October 15th 1992. Location: few hun-

Fig. 1. *Dicrossus foirni* sp. n., holotype (MZUSP 106589), female, colour pattern in 75 % ethanol, about six months after preservation.

Fig. 2. *Dicrossus foirni* sp. n., topotype (MTD F 32146), male, colour pattern in 75 % ethanol, about six months after preservation.

dred meters above mouth of the Igarap□ Pr□sperit□e (station F9/91R: 00□09′47″S / 64□07′11″W), a small right-hand tributary of the Rio Preto near Lago Urubu about 12.5 km NNW from the junction with the Rio Negro, federal state of Amazonas, Brazil.

Paratypes. 6 specimens. MTD F 32146 (topotype), male, 70.9 mm SL (fig. 2), and MZUSP 106590, male, 57.9 mm SL, M. Geismann, S. Leissner, and A. Schneider, other data as for holotype. MTD F female, 32147, 35.0 mm SL, MTD F 32148, sex undetermined, 26.0 mm SL, cleared & stained, CAS 220 433, male, 45.8 mm SL, CAS 220 434, female, 37.5 mm SL, collected by Martin Wöhler, March 9th 1994, in a shallow swamp lake in the Igarap□ Pr□sperit□e about 1 kilometre upriver from its junction with the Rio Preto, about 1 hour upstream from the junction with the Rio Negro, federal state of Amazonas, Brazil.

Diagnosis. *Dicrossus foirni* sp. n. is a medium-sized crenicaratine cichlid species (males up to 71 mm SL, females to 45 mm SL) sharing all typical characteristics of the genus *Dicrossus* Steindachner, 1875 as stated in particular by Kullander (1990). The species exhibits pronounced sexual size and colour dimorphism. It is unmistakeably characterised by three rows of round to vertical-ovoid, alternating dark grey to blackish, double or triple spots on the sides of the body; adult males with a black spot on the dorsum and basal part of the dorsal fin at the position of hard rays 7 to 8, and a pointed rhombic caudal fin.

Fig. 3. *Dicrossus foirni* sp. n., adult male, dominant, territorial, not preserved.

Fig. 4. *Dicrossus foirni* sp. n., adult female, dominant, in brood care coloration, not preserved.

Description. Morphological data taken from 7 specimens (26.0 to 70.9 mm SL). For biometric data see tables 1 & 2, for meristic data see table 3.

Habitus. (figs. 1□7, 17 & 18) Body moderately elongate, laterally compressed, about two to two and a half times deeper than wide, significantly deeper in adult males and females than in small to medium-size specimens (depth 34.1 % of SL vs. up to about 37 % in adults of both sexes). Dorsal contour from tip of snout to posterior end of dorsal-fin base regularly arched in adult males, in smaller specimens and females only predorsally curved, in larger males interrupted by concave interorbital notch. Preventral contour generally straight, in adult males slightly concave vertically below orbit. Abdominal contour almost straight in small individuals, slightly to progressively convex in medium-size to large specimens of both sexes. Head elongate (about 31 % of SL), in adults comparatively deep (up to 26.5 % of SL), with (depending on SL) small subterminal, narrow, and pointed mouth (fig. 5). Positive allometry of snout length (about 5.2 % of SL in small specimens up to nearly 11 % in large). Premaxillary fold of lip very short. Distal edge of preoperculum serrated, with 33 to 54 denticuli. Cheeks completely scaled (fig.6).

Dorsal fin [D. XV.7 (n = 6), XVI.6 (n = 1)] about half as high as body in juveniles and females to about one third of depth of body in adult males. Membranes not

Fig. 5. *Dicrossus foirni* sp. n., juvenile male, frontal view of head showing the small terminal, narrow, and pointed mouth, not preserved.

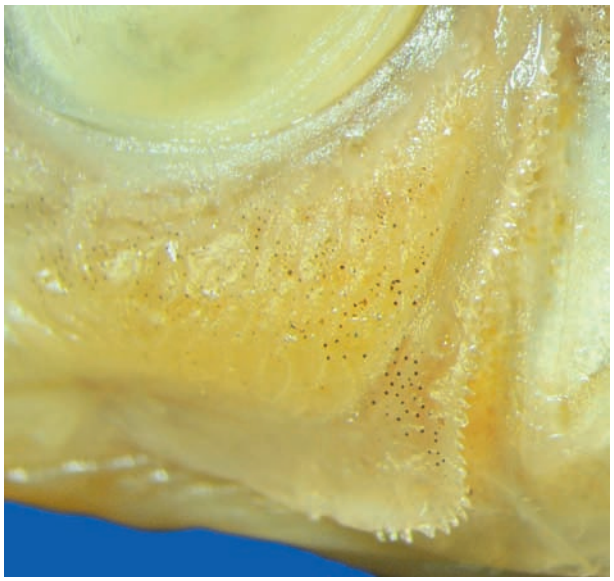

Fig. 6. Close-up view of head of *Dicrossus foirni* sp. n., holotype (MZUSP 106589), female, showing serrated preoperculum and complete squamation of cheek.

Fig. 7. Lateral view of typical teeth rows in *Dicrossus foirni* sp. n., topotype, (MTD F 32146).

extending above fin spines, tips rectangular. Dorsal-fin spines increasing rapidly from first to seventh, which more than three times longer than first; spines seven to ten of about equal length, posterior spines about 10 % longer than spine ten, except last which even longer. Soft portion of dorsal fin pointed in males, rounded in females. Caudal fin [C. 16 (n = 7)] in adult males rhombic and pointed, in medium-size males spatulate to rhombic, and rounded in smaller males and in females. Anal fin (A: III.6 (n = 1), III.7 (n = 6) pointed in males, rounded in juveniles and females. Ventral fins [V. I.5 (n = 7)] short and rounded in juveniles and females (20 to 26 % of SL), extending back to genital papilla; in large males pointed with long filamentous extensions (up to 56 % of SL), extending back to soft part of anal-fin base. Pectoral fins [V. 11 (n = 6), 12 (n = 1)] rounded in all specimens examined.

Scales in E1 row 24 (n = 2), 25 (n = 3), or 26 (n = 2). Upper lateral line (14 to 18 scales) continuously arched from head to beginning of soft portion of dorsal fin. Lower lateral line irregular (3 to 10 scales), in some cases interrupted, extending straight to base of caudal fin.

Teeth in three series in both jaws; in large specimens, especially males, series across anterior part of lower jaw irregular; teeth not very close-packed; in some specimens tendency to form fourth and fifth series; unicuspid; normally slightly recurved, occasionally almost straight; white or ivory with brown or reddish outer tip; deeply embedded in fleshy skin tissue (fig. 7).

Coloration of preserved specimens. (After six months to eighteen years preservation in 75 % ethanol; only slight differences in intensity of coloration discernible between specimens after different periods of conservation; fresh material slightly darker, only one specimen partially bleached) (figs. 1, 2, 6 & 7): Ground colour of body light brown or (in adult males) pale lead grey; light brownish on forehead, nape, and above lateral line. Scales on body above horizontal line from upper base of pectoral fin to lower third of caudal-fin base with brown distal edge, centres in some cases strikingly paler brown, exceptionally ivory. Forehead and infraorbital area brown, nape dark blackish brown. Broad black or grey preorbital stripe, subpreorbital stripe ivory. Anterior section of lips dark grey, lateral sections pale bluish grey, in larger males ivory. Edges of upper and lower jaws grey. Row of four round or oval brown spots extending from upper lateral edge of upper jaw parallel to anterior edge of cheek to lower edge of eye. Branchiostegal membrane white, cheeks light brown in females and small males, in adult males white to ivory. Preoperculum and operculum light grey with dense dark pigmentation on upper section of preoperculum and adjacent areas.

Tab. 1. Basic statistics of biometric data taken from type specimens of *Dicrossus foirni* sp. n., and *Dicrossus warzeli* sp. n. (as % of SL, SL given in mm).

	Dicrossus foirni **sp. n.**						*Dicrossus warzeli* **sp. n.**					**Abbreviations**
	n	mean	min	max	st.dev		n	mean	min	max	st.dev	
SL	7	45.1	26.0	70.9	15.1		9	39.4	28.8	58.8	9.92	standard length
HL	7	30.5	28.7	33.0	1.59		9	30,8	27.7	34.0	1.79	head length
HD	7	26.5	23.1	32.5	3.27		9	24.2	22.6	25.6	0.84	head depth
BD	7	34.1	31.8	37.0	2.26		9	30.2	28.5	31.2	0.96	body depth
HW	7	16.7	15.1	17.8	0.88		9	16.0	14.2	16.7	0.83	head width
PDL	7	35.4	33.5	38.1	1.54		9	34.0	31.0	36.6	1.49	pre-dorsal length
TDL	7	83.5	81.5	85.6	1.48		9	83.5	79.4	87.1	2.32	trans-dorsal length
PVL	7	36.9	34.8	41.7	2.72		9	36.1	33.3	39.0	2.07	pre-pelvic length
PAL	7	70.8	67.4	75.4	2.73		9	71.9	68.7	76.0	2.53	pre-anal lengt
TAL	7	82.6	79.0	85.7	2.23		9	83.6	79.6	86.7	2.67	trans-anal length
Eye	7	12.0	10.2	13.9	1.43		9	12.2	10.9	14.4	1.35	eye diameter
SNL	7	8.2	5.2	11.0	2.19		9	7.5	5.7	9.1	1.14	snout length
CHD	7	6.5	4.8	9.4	1.79		9	5.6	4.5	6.9	0.84	cheek depth
POD	7	4.0	3.0	5.5	0.87		9	3.8	3.2	4.8	0.49	pre-orbital depth
IOW	7	8.6	7.8	9.7	0.76		9	7.9	7.3	9.0	0.57	inter-orbital width
UJL	7	7.5	6.4	8.8	0.99		9	7.1	4.7	8.1	1.04	upper jaw length
LJL	7	9.8	8.4	12.1	1.23		9	9.6	6.0	11.8	1.63	lower jaw length
CPD	7	13.2	11.8	14.0	0.74		9	12.3	11.3	13.2	0.74	caudal peduncle depth
CPL	7	16.4	13.3	19.5	1.92		9	16.2	13.4	18.8	1.63	caudal peduncle length
DFB	7	53.7	49.7	57.4	2.48		9	54.2	49.6	58.5	2.47	dorsal fin base length
AFB	7	19.0	16.5	22.3	2.17		9	19.3	16.3	22.6	2.12	anal fin base length
PecL	7	26.0	21.5	28.7	3.11		9	25.2	20.3	27.3	2.27	pectoral fin length
PelL	7	30.6	17.7	56.0	14.30		9	25.4	18.4	35.2	5.01	pelvic fin length
PelSL	7	15.5	13.0	21.7	3.04		9	14.1	12.6	15.7	1.07	pelvic fin spine length
LDS	7	13.3	9.7	20.8	4.27		9	13.4	11.0	15.6	1.38	last dorsal spine length
LAS	7	14.3	13.5	15.7	0.82		9	14.0	9.9	16.2	1.99	last anal spine length

Three longitudinal series of round to vertical-ovoid, alternating dark grey to blackish, double or triple spots on sides of body; spots grouped on two horizontally adjacent scales on centre of lower half of flank, on three adjacent scales midlaterally, and on two or three adjacent scales about two to three scales below imaginary longitudinal line along middle of dorsum. Seven dorsal blotches, one above posterior margin of eye, four along base of dorsal fin, and two on caudal peduncle. In some larger specimens black spot on dorsum immediately below dorsal-fin rays (6) 7 to 8 (9), extending onto proximal third to half of dorsal-fin membranes. Oval spot on median base of caudal fin, covering about half its height, split horizontally into two equal parts by pale grey to whitish stripe on centre.

All fins with irregular pattern of microscopic faint greyish dots. Dorsal fin overall milky whitish with faint submarginal line. Light band running from proximal edge of dorsal-fin membrane 4 to sub-median position on membranes to membrane 12. Caudal fin in juveniles and females overall semi-transparent whitish or hyaline, in males upper lobe with vertical stripe pattern distally, i. e. black margin, translucent submarginal band, followed by second black stripe. Scaled base of caudal fin light brownish or orange brown. Ventral fins overall whitish or hyaline, but first membrane with brown or black pigmentation. Base of anal fin whitish, distal parts hyaline blue or translucent, upper soft portion with up to eight vertical bars.

Coloration of live specimens (figs. 3–5, 17 & 18) Body of adult males overall pale grey with bluish sheen on abdomen. Forehead, interorbital area, and nape greyish or light brownish. Upper abdominal scales with dark posterior margins. Cheek, lower half of operculum, throat, and breast ivory. Three longitudinal series of double or triple spots on sides. In smaller specimens single spots also appear on caudal peduncle. Spots positioned as described for preserved specimens. Five to six dorsal blotches along dorsum from nape to base of soft portion of dorsal fin. Adult dominant specimens with variably prominent black spot, occupying up to quarter of dorsal-fin base between spines 6 to 9, which not visible in any preserved specimens. Broad preorbital stripe from orbit to tip of snout. Mature males with row of squarish red spots from posterior upper edge of snout to lower edge of orbit below posterior edge of pupil. Upper lip grey in most specimens, but sometimes with

orange or metallic green sheen. Upright oval blotch on upper edge of preoperculum, in most specimens merging into second, half-moon-shaped spot immediately posterior on operculum.

Mature males with light blue submarginal band along complete distal edge of dorsal-fin and upper vertical, distal half of caudal fin, submarginal band, in dorsal fin bordered wine red above and below; round black spots in median position on membranes of dorsal spines 7 to 14, second row of spots on proximal part of membranes 5 to 15. Caudal fin in smaller and female specimens hyaline translucent, in adult males reddish in upper, milky light blue in lower, lobe. Distal part of ventral fins white in adult males, hyaline translucent in smaller males and in females. During reproduction ventral fins of females intense red orange with blue anterior margin. Anal fin of mature males bluish with up to eight vertical hyaline bars, in females generally hyaline translucent, during reproduction with reddish sheen.

Etymology. The species is named in honour of the Federação das Organizações Indígenas do Rio Negro. The official abbreviation of the name of this non-govermental organisation is FOIRN. The name acknowledges the fact that FOIRN has repeatedly given permission to travel on the tribal land of the village communities of different indigenous groups in the middle and upper Rio Negro and its affluent rivers, as well as for carrying out observations on wildlife, especially insects and fish, in these areas. This permitted the observation and collection of the species described herein. The name of the species is also intended to highlight the fact that the basic human rights of indigenous peoples are still in question in most parts of Amazonia when business projects (such as logging, mining, or the building of hydro-electric dams) are planned in the wilderness of the Neotropical rainforests. Indigenous peoples depend on large functional ecosystems that can provide all necessary resources for indigenous life. For these reasons the founding of FOIRN was a reasonable and necessary step by the indigenous peoples along the Rio Negro, creating an organisation capable of taking over responsibilities and decision-making powers from local govermental organisations such as the official Brazilian indian agency FUNAI (Fundacao Nacional do Indio).

Dicrossus warzeli sp. n.

(Figs. 8–13 & 19, Tabs. 1–3)

Holotype. (fig. 8) MZUSP 106591, male 41.2 mm SL, collected during September 1992 by F. Warzel. Location.: a small nameless right-bank tributary (*igarapé*) feeding the Rio Tapajós, upstream from the settlement of Sao Luiz (about 4°34′S / 56° 5′W), federal state of Pará, Brazil, preserved after two weeks in the aquarium.

Paratypes. 8 specimens: MTD F 32152, male, 58.8 mm SL, CAS 220 435, female, 33.8 mm SL; MZUSP 106592, female, 28.8 mm SL; collecting data for all as for holotype, preserved immediately after importation. MTD F 32154, male, 30.8 mm SL, cleared & stained, collecting data as for holotype, preserved after 3 months maintenance in the aquarium. MTD F 32149, male, 46.5 mm SL, MTDF 32150, female, 33.4 mm SL, cleared and stained, preserved after 5 months maintenance in the aquarium. MTD F 32151, male, 47.7 mm SL, CAS 220 436, female, 30.5 mm SL, collecting data as for holotype, preserved after 7 months in the aquarium.

Diagnosis. *Dicrossus warzeli* sp. n. is a medium-size crenicaratine cichlid species (males up to 60 mm SL, females to 35 mm SL) sharing all typical characteristics of the genus *Dicrossus*. It exhibits clear sexual size and colour dimorphism. The species is unmistakeably characterised by three longitudinal rows of dark grey to blackish, horizontally elongate, dash-like spots on the sides of the body; in adult males caudal fin spatulate.

Description. Morphological data taken from 9 specimens (28.8 to 58.8 mm SL). For biometric data see tables 1 & 2, for meristic data see table 3.

Habitus. (figs. 8–13 & 19) Body elongate (depth up to about 30 % of SL in adults of both sexes), laterally compressed, approximately twice as deep as wide, upright oval in frontal view. Predorsal contour regularly arched, preventral contour generally straight. Body contour in juvenile males dorsally almost straight, in adult males slightly convex, ventrally in general slightly concave from ventral fins to beginning of anal fin; in females body contour dorsally slightly convex, ventrally almost straight, in ripe females slightly convex. Head elongate (head length about 31 % of SL) with small terminal, narrow, and pointed mouth (as in *Dicrossus foirni* sp. n., fig. 5). Snout slightly pointed, comparatively long (about 7.5 % of SL). Premaxillary fold of lower lip very short. Distal edge of preoperculum serrated, with 31 to 42 denticuli (fig. 12). Cheeks completely scaled.

Fins unscaled, except caudal fin, which has a few scales on its first fifth to sixth. Dorsal fin [D. XV.6 (n = 4), XV.7 (n = 3), XV.8 (n = 1), XVII.7 (n = 1)] about half as high as body. Membranes not extending above fin spines, tips rounded. Dorsal-fin spines increasing rapidly from first to sixth or seventh; seventh spine about three times longer than first; posterior spines about same length as seventh, increasing in length only slightly to last spine in some specimens. Soft portion of dorsal fin pointed in males, rounded in females. Caudal fin [C. 16 (n = 9)] with eight principle rays in each lobe. Principle rays increasing in length from upper and lower

Tab. 2. Biometric data taken from *Dicrossus foirni* sp. n., and *Dicrossus warzeli* sp. n. (given in mm, for abbreviations see table 1).

Dicrossus foirni sp. n.	Sex	SL	TL	HL	HD	BD	HW	PDL	TDL	PPL	PAL	TAL
MZUSP 106589	♀ HT	42.8	53.4	12.7	10.9	14.3	6.82	14.3	34.9	15.2	26.9	33.8
MZUSP 106590	♂ PT	57.9	82.3	17.2	16.2	21.4	9.8	20.3	48.5	21.6	36.4	47.9
MTD F 32146	♂ PT	70.9	97.9	20.3	23.1	26.2	10.7	24.8	58.2	24.8	43.4	57.7
MTD F 32147	♀ PT	35.0	46.0	10.5	8.7	11.3	6.2	12.8	29.2	12.2	22.3	28.9
MTD F 32148	? PT	26.0	33.9	8.6	6.1	8.4	4.3	9.9	22.1	10.9	17.8	22.1
CAS 220 433	♂ PT	45.8	59.0	13.7	12.7	16.2	7.9	15.6	39.2	18.0	30.5	39.2
CAS 220 434	♀ PT	37.4	48.8	12.1	8.6	11.9	6.4	13.2	31.1	13.1	24.2	30.8
Dicrossus warzeli sp. n.												
MZUSP 106591	♂ HT	41.2	53.0	12.5	10.5	11.7	6.8	14.3	32.7	13.7	25.7	32.7
MZUSP 106592	♀ PT	28.8	36.6	9.0	7.1	8.4	4.7	10.0	24.0	11.0	18.4	24.7
MTD F 32149	♂ PT	46.5	58.2	13.6	11.1	14.2	7.0	15.7	40.0	16.0	31.4	39.2
MTD F 32150	♀ PT	33.4	41.5	10.7	8.1	9.9	5.3	11.3	27.5	12.0	21.6	27.2
MTD F 32151	♂ PT	47.7	65.0	14.2	11.8	14.9	7.7	15.8	41.5	18.5	31.2	41.3
MTD F 32152	♂ PT	58.8	75.2	16.3	14.1	18.1	8.4	18.2	47.9	20.4	38.1	47.0
MTD F 32154	♂ PT	33.8	44.3	10.8	7.7	10.4	5.6	12.4	28.7	11.7	23.0	29.0
CAS 220 435	♀ PT	33.8	42.5	11.5	8.1	10.2	5.7	11.4	28.1	12.4	21.2	28.2
CAS 220 436	♀ PT	30.5	39.1	9.4	7.6	9.5	5.0	10.5	25.6	11.9	21.1	26.1

Fig. 8. *Dicrossus warzeli* sp. n., holotype, MZUSP 106591, male, colour pattern in 75 % ethanol, about five years after preservation.

margins to centre of fin. In adult males rays D1 and V1 slightly less than twice as long as outermost D8 and V8. Caudal fin spatulate in adult males, except rhombic in some exceptionally large specimens; rounded in smaller males and in females. Anal fin (A: III.6 (n = 4), III.7 (n = 5) pointed in males, rounded in juveniles and females. Ventral fins [V. I.5 (n = 9)] rounded in juveniles and females, extending back to genital papilla, in larger males pointed with filamentous extensions, extending back to soft part of anal-fin base. Pectoral fins [P. 11 (n = 7) 12 (n = 2)] rounded in all specimens examined. Scales in E1 row 24 (n = 3) or 25 (n = 5) (one specimen lacking scales in E1 row). Upper lateral line (13 to 18 scales, one specimen with only 7 scales) continuously arched from head to beginning of soft portion of dorsal fin, in some specimens interrupted. Lower lateral line variably developed (2 to 10 scales), in most cases with interruptions, extending on to the base of the caudal fin. Teeth in three regular (in all specimens) series in both jaws; teeth close-packed; teeth unicuspid, recurved in distal third; upper two thirds brown with darker tip, prominent in fleshy skin tissue (fig. 13).

Coloration of preserved specimens. (described after six months to eight years preservation in 75 % ethanol; only slight differences in intensity of coloration discernible between specimens after different periods of conservation; fresh material slightly darker) (fig. 8): Ground colour medium copper brown; slightly darker above lateral line. Head overall darker than body. Broad black preorbital stripe, subpreorbital stripe light grey. Infraorbital area dark grey, nape dark blackish brown.

Tab. 2. Continuation.

Eye	SNL	CHD	POD	IOW	UJL	LJL	CPD	CPL	DFB	AFB	PecL	Pell	PelSL	LDS	LAS
5.3	2.8	2.4	1.5	3.4	2.8	3.9	5.1	6.4	21.3	7.6	9.4	11.0	9.3	5.4	6.1
6.6	6.2	5.0	3.2	5.6	5.0	6.1	7.9	9.7	32.1	12.9	16.6	26.2	8.6	10.2	9.1
7.2	7.8	6.7	3.4	6.7	6.3	8.6	9.9	11.6	38.9	15.2	20.2	39.7	9.8	14.7	9.7
3.9	1.8	2.1	1.2	2.7	2.3	3.0	4.7	6.1	18.3	6.11	7.5	7.2	4.7	3.4	4.8
3.6	2.0	1.2	0.8	2.3	1.8	2.5	3.6	5.1	14.9	4.3	7.0	6.9	4.4	2.5	3.9
5.2	4.2	2.8	1.9	4.1	3.6	4.1	5.9	6.1	24.4	9.0	13.1	10.4	5.9	5.1	6.5
5.2	2.6	1.9	1.5	3.0	2.8	3.6	4.9	6.2	19.8	6.8	9.8	6.6	5.4	4.2	5.0
4.5	3.7	2.2	1.6	3.7	3.2	3.9	4.8	6.8	20.4	7.5	10.9	12.3	5.4	5.8	4.1
3.6	1.6	1.4	1.2	2.1	1.8	3.1	3.6	5.0	15.6	5.3	5.9	6.6	3.9	3.9	4.2
5.3	3.5	3.2	2.2	3.5	3.4	4.6	6.1	7.6	26.1	10.5	10.8	8.5	5.9	5.1	5.8
3.8	2.1	1.7	1.1	2.5	2.5	3.6	4.0	6.3	17.5	5.7	8.3	8.4	4.9	4.1	5.4
5.2	4.1	2.8	1.9	3.8	3.6	4.5	6.3	6.4	27.9	10.5	12.4	16.8	7.5	7.1	7.3
6.7	4.6	4.1	2.3	4.3	4.8	5.2	6.7	9.8	31.8	12.1	14.8	12.1	7.9	9.2	7.8
4.8	2.3	1.8	1.2	2.9	2.6	3.3	4.4	5.2	18.8	6.4	9.1	9.0	4.7	4.5	5.0
4.9	2.5	1.5	1.1	2.8	1.6	2.0	3.8	4.8	18.1	5.5	9.2	8.9	4.7	4.3	4.5
4.0	2.7	1.7	1.1	2.3	2.2	3.6	3.6	5.3	16.6	6.1	8.3	7.3	4.7	4.2	4.9

Fig. 9. *Dicrossus warzeli* sp. n., adult male, dominant, territorial, not preserved. Photo: Frank Warzel.

Anterior section of lips dark grey, lateral sections pale grey to whitish, edges of upper and lower jaws grey. Branchiostegal membrane grey, cheek light brown, preoperculum and operculum grey with dense pigmentation composed of numerous black dots on preoperculum and adjacent areas.

Three longitudinal series of horizontal, dash-like spots on sides, first extending in straight line from dorsal edge of orbit to upper scales of caudal peduncle, second from upper edge of operculum onto imaginary line between upper and middle thirds of caudal base, third from behind upper edge of pectoral fin insertion onto imaginary line between middle and lower thirds of caudal base, both second and third terminating on first quarter of caudal fin. Individual dash-like spots forming lateral series, each covering centres of two to four, in most cases three longitudinally adjacent scales in row. Intervals between dash-like spots about equal, except often narrower on caudal peduncle. Vertical intervals between rows of dash-like spots about one scale wide. Series of seven dorsal spots, one above posterior margin of eye, four along base of dorsal fin often merging into first series of dash-like spots below it, two on caudal peduncle, not completely visible in all specimens, in some specimens adjacent spots may be merged. Black spot of variable shape, mostly oval, on dorsum immediately below and on lower fifth of membranes between dorsal-fin rays 7 and 8, most prominent where coincident with greyish lateral band on E1 scales, extending from upper edge of operculum to distal edge of caudal peduncle. Squarish spot on centre of caudal-fin base, covering about half depth of latter height.

Fig. 10. *Dicrossus warzeli* sp. n., juvenile female, subdominant, showing typical clear dash line pattern, not preserved. Photo: Frank Warzel.

Fig. 11. *Dicrossus warzeli* sp. n., adult female, dominant, brood care coloration, guarding fry, not preserved. Photo: Frank Warzel.

All fins with irregular pattern of microscopic black dots. Dorsal fin overall milky whitish with light submarginal stripe; central parts of membranes along hard rays pigmented dusky grey in females, in males bordered translucent milky white; males with light submarginal stripe along entire fin, continuing on caudal fin. Caudal fin in males with faint submarginal stripe (rather difficult to detect) on distal edge of upper lobe; remainder of caudal fin overall semi-transparent hyaline, rarely milky white; scaled base of caudal fin pale yellowish brown (females) or ash grey (most males). Ventral fins overall hyaline whitish, with pattern of small pigmented spots along soft rays, more concentrated along spine. Base of anal fin whitish in males, hyaline translucent in females, upper soft portion with up to four vertical bars.

Coloration of live specimens. (figs. 9□11 & 19) Body of adult males overall beige; upper half of head and abdomen greyish or light brown, partially light mossy green in aggression; ventral region, cheeks, and throat ivory. Three longitudinal series of dash-like spots on sides (fig. 10 & 11), positioned as described for preserved specimens. Four dorsal spots along dorsal-fin base. Adult dominant or aggressive males with prominent black spot covering up to a fifth of the height of dorsal fin between spines 6 to 8, also present in females guarding fry. Broad preorbital stripe from orbit to tip of snout, in some female specimens extending onto upper surface of anterior half of snout. Upper lip metallic blue to shiny turquoise in mature males, greyish to pale orange in females. Upright oval blotch on upper edge of preoperculum, second triangular to

Tab. 3. Meristic data taken from *Dicrossus foirni* sp. n., and *Dicrossus warzeli* sp. n. (SL given in mm, for abbreviations see last column of table).

	Collection Number	Sex	SL	DF (h)	DF (s)	AF (h)	AF (s)	PF (h)	PF (s)	PecF	CF	LRS	Abbreviations
Dicrossus foirni sp. n.	MZUSP	♀ HT	42.8	15	7	3	7	1	5	11	16	25	
	MZUSP	♂ PT	57.9	15	7	3	6	1	5	11	16	26	DF :
	MTD F 32146	♂ PT	70.9	15	7	3	7	1	5	11	16	26	dorsal fin
	MTD F 32147	♀ PT	35.0	15	7	3	7	1	5	11	16	24	AF:
	MTD F 32148	? PT	26.0	15	7	3	7	1	5	11	16	25	anal fin
	CAS 220433	♂ PT	45.8	16	6	3	7	1	5	11	16	24	PF:
	CAS 220434	♀ PT	37.4	15	7	3	7	1	5	12	16	25	pelvic fin
Dicrossus warzeli sp. n.	MZUSP	♂ HT	41.2	15	7	3	7	1	5	11	16	25	PecF:
	MZUSP	♀ PT	28.8	15	6	3	7	1	5	11	16	def.	pectoral fin
	MTD F 32149	♂ PT	46.5	15	8	3	7	1	5	12	16	25	CF:
	MTD F 32150	♀ PT	33.4	15	6	3	6	1	5	11	16	25	caudal fin
	MTD F 32151	♂ PT	47.7	15	7	3	6	1	5	11	16	24	(h):
	MTD F 32152	♂ PT	58.8	15	7	3	7	1	5	11	16	24	hard rays
	MTD F 32154	♂ PT	33.8	17	7	3	7	1	5	11	16	25	(s):
	CAS 220435	♀ PT	33.8	15	6	3	6	1	5	12	16	24	soft rays
	CAS 220436	♀ PT	30.5	15	6	3	6	1	5	11	16	25	

Fig. 12. Close-up view of head of *Dicrossus warzeli* sp. n., paratype (MTD F 32149), male, demonstrating serrated preoperculum and complete squamation of cheek (cleared & stained)

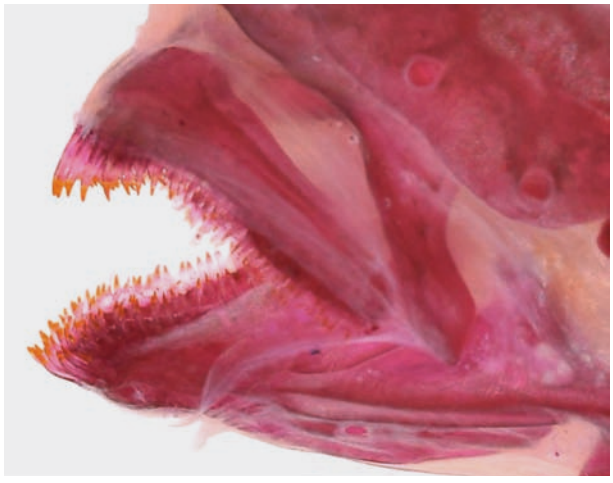

Fig. 13. Lateral view of typical teeth rows in a male *Dicrossus warzeli* sp. n. paratype (MTD F 32149).

half-moon-shaped spot immediately posterior on operculum.

Aggressive specimens with prominent brown to black, rarely mossy green spot on operculum, usually occurring in conjunction with dark band on proximal

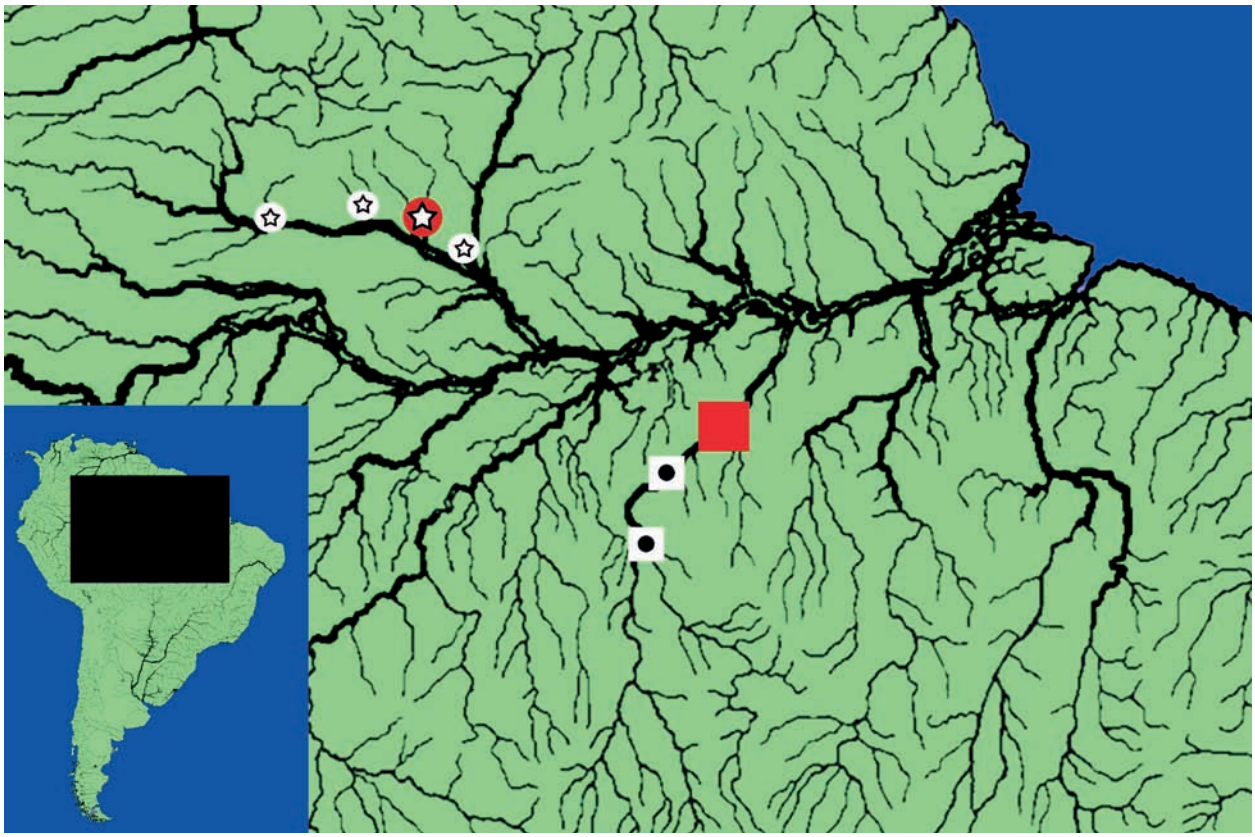

Fig. 14. Map of Brazil showing distribution of *Dicrossus foirni* sp. n. (type locality: white star in red dot; other collecting sites: stars in white dots), and *Dicrossus warzeli* sp. n.. (type region: red square; other collecting sites: black dots in white squares).

part of dorsal fin. Also in aggression, conspicuous black spot on dorsum below and on lower fifth of dorsal-fin membranes 6 to 9, usually when greyish midlateral band also apparent; some specimens also exhibiting faint round black lateral spot directly behind gill cover, and another below dorsal-fin spines 8 and 9. Light blue to metallic green sub-marginal band along entire distal edge of dorsal fin and upper distal half of caudal fin. Caudal fin overall hyaline translucent, in adult males milky white, in some cases with reddish base and bluish distal portion. Distal part of ventral fins in adult males bluish, in females hyaline translucent; during reproduction, in males overall light violet or reddish with turquoise anterior margin, in females yellowish to intense orange. Anal fin of mature males bluish violet to wine red, in females generally hyaline translucent.

Etymology. The species is named in honour and memory of the skilled German aquarist Frank Martin WARZEL. Frank not only collected the type specimens, but was also the first to import the species from the Rio Tapajos to Germany, as well as to observe its behaviour, including reproduction, in the field and in the aquarium (WARZEL, 1996). He dedicated most of his life to research on Neotropical cichlids, especially those of the genus *Crenicichla*. Dozens of publications dealing with Neotropical cichlids resulted from his numerous field trips to Brazil and Colombia. In his later years he also focussed on dwarf cichlids of the genera *Teleocichla*, *Apistogramma*, and *Dicrossus*. Born on December 21st 1960, Frank unexpectedly passed away, much too early, after heart surgery on April 27th 2004.

Geographical distribution and ecological notes

As far as is known at present, *Dicrossus foirni* sp. n. occurs in the middle to upper Rio Negro system (fig. 14). Collecting sites are restricted exclusively to left-hand tributaries of the main channel of the Rio Negro, from the mouth of the Rio Branco in the east upriver to the settlement of Santa Isabell in the west. Observation or collecting has been reported from the drainages of the Rios Ararira, Demini, Marauiâ Padauiri, and Preto (KULLANDER, 1984, 1990; RANK, 1994; own observations).

Dicrossus foirni sp. n. has been found in all types of water. Juveniles have been found exclusively in very soft and acid, clear and black water (WINDISCH, 1992; WILHELM, pers. comm. 2007, 2008; own observations),

Fig. 15. View of typical habitat of *Dicrossus foirni* sp. n., Station F1/91R, lower Igarapé Preperitá, March 1994.

Fig. 16. View of typical habitat of *Dicrossus warzeli* sp. n., small tributary of lower Tapajós river from *cachoeiras* (rapids) near Sao Luiz, September 1992. Photo: Frank Warzel.

while sub-adults have also been found in whitewater brooks (Eon, pers. comm., May 2010). In 1992 UR observed half-grown individuals shoaling with several hundred *Dicrossus filamentosus* in the mouth of the Igarapé Preperitá (type locality), lower Rio Preto, and in 1994 adult specimens in only small numbers in a shallow forest lake about 30 minutes away by canoe from that location (fig. 15). In the Igarapé Preperitá *Dicrossus foirni* sp. n. were found together with the cichlids *Aequidens* sp., *Apistogramma gibbiceps* Meinken, 1969, *Apistogramma paucisquamis* Kullander & Staeck, 1988, *Apistogramma pertensis* (Haseman, 1911), *Crenicichla inpa* Ploeg, 1991, *Crenicichla notophthalmus* Regan, 1913, the characins *Hoplias malabaricus* (Bloch, 1794), and *Paracheirodon axelrodi* (Schultz, 1956). More detailed data on habitat structure, sociobiology, and further biotic and abiotic factors may be found in Römer (1992a & b, 1994, 1998, 2000).

Dicrossus warzeli sp. n. seems to be endemic to the middle to upper Rio Tapajos system (Kullander, 1984, Warzel, 1995, Stawikowski & Werner, 2004) (fig. 14). Collecting sites are located in small *igarapés* near São Luiz (type locality) (Warzel, *in lit*.) (fig. 16), in the Igarapé Pimental (Kullander, 1990; Warzel, *in lit*.), and in a small river about 56 km south of Babuçu (Stawikowski & Werner, 2004).

Dicrossus warzeli sp. n. has been found exclusively in clearwater rivers. Frank Warzel collected several juveniles of about 20 mm SL in small brooks with sandy bottoms and patches of leaf litter. The fish were searching the bottom substrate for small invertebrates and detritus by picking up and turning the leaves. These fish have been collected exclusively in very soft water (no detectable hardness) with high acidity (pH value regularly measured at less than 5, in most cases less than 4). Intensive field research on the ecology of both species is still required.

There is no evidence of any overlap of the ranges of the two species. Remarkably, *Dicrossus warzeli* sp. n. and *Dicrossus maculatus* seem to be the only species of the genus known exclusively from south of the main channel of the Amazon river. Compared to the species described here, *Dicrossus maculatus* is known to be far less sensitive to shifting water conditions, especially pH and water hardness. *Dicrossus warzeli* sp. n., by contrast, seems to be stenoecious (restricted to very low acidity values and extreme soft water). Initially this also seemed to be the case with *Dicrossus foirni* sp. n., but surprisingly more recent observations of the species (Eon, pers. comm. May 2010) contradict this earlier assumption (*cf*. Römer, 2000; Staeck 1993).

Fig. 17. *Dicrossus foirni* sp. n., juvenile male, dominant, showing colour pattern of □bleeding□spots, not preserved.

Fig. 18. *Dicrossus foirni* sp. n., juvenile male, aggressive pattern, not preserved.

Discussion

The genus *Dicrossus* consists of at least five distinct species, which are unmistakable amongst all other Neotropical cichlid genera and species. *Dicrossus foirni* sp. n. and *Dicrossus warzeli* sp. n. are the fourth and fifth species described. The genus *Dicrossus* apparently falls into two major groups: on the one hand *Dicrossus filamentosus*, *Dicrossus gladicauda*, and *Dicrossus maculatus*, with two rows of large spots in each case, while on the other hand *Dicrossus foirni* sp. n. and *Dicrossus warzeli* sp. n. exhibit three rows of, respectively, double spots or dash-like spots on the sides of the body. The colour patterns of the two species described herein are unique amongst Neotropical cichlids, hence no other cichlid species known to date can be mistaken for either of the two. Sharing several morphological and behavioural traits, *Dicrossus foirni* sp. n. and *Dicrossus warzeli* sp. n. appear to be more closely related to each other than to other members of the genus. Detailed genetic studies of the phylogenetic relationships between the species of the genus are in progress.

Live as well as preserved specimens of *Dicrossus foirni* sp. n. and *Dicrossus warzeli* sp. n. can be easily distinguished from one another by their clearly different spot patterns. *Dicrossus foirni* sp. n. exhibits longitudinal rows of upright oval, double spots versus horizontal dash-like spots in *Dicrossus warzeli* sp. n.. Furthermore, in smaller aggressive or adult dominant males of *Dicrossus foirni* sp. n. the spots in the two lower rows appear to be □bleeding□vertically (fig. 17)

Fig. 19. *Dicrossus warzeli* sp. n., adult male, aggressive pattern, not preserved. Note the narrow and pointed mouth of this species, visible here. Photo: Frank Warzel.

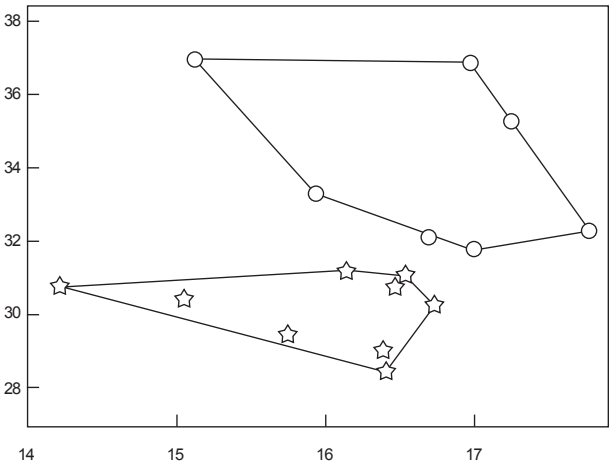

Fig. 20. Scatterplot of biometric data for *Dicrossus foirni* sp. n. (circles), and *Dicrossus warzeli* sp. n.. (stars), (x-axis: head width, y-axis: body depth, both given as % of SL). Missing overlap of polygons represents diagnostic stage of data sets given in tabs. 1 & 2.

and merging into one another via more or less intense grey to blackish vertical stripes, which often have a washed-out appearance. Differences in the aggressive colour patterns of the males of the two species also offer diagnostic features. While the aggressive pattern of *Dicrossus foirni* sp. n. is dominated by vertical bars which often look washed out (fig. 18), *Dicrossus warzeli* sp. n. exhibits a distinct lateral band combined with a prominent spot on the operculum and a dark stripe on the proximal part of the dorsal fin (fig. 19).

Statistical analysis of biometric data taken from preserved specimens shows that both species are similar overall. However, relative body depth plotted against relative head width reveals significantly differentiated polygons for *Dicrossus foirni* sp. n. and *Dicrossus warzeli* sp. n. (fig. 20). Tooth morphology is another diagnostic character, especially useful in small preserved specimens.

With the description of *Dicrossus foirni* sp. n. and *Dicrossus warzeli* sp. n. all taxonomic problems in the genus *Dicrossus* might appear to be resolved. However, when Kullander (1978) re-described *Dicrossus filamentosus* he used material exclusively from the Colombian and Venezuelan Rio Orinoco drainage. But the original type material of the species originates from the Brazilian Rio Negro.

In fact *Dicrossus filamentosus* from the middle and upper Rio Negro system are easily distinguished from specimens of the Orinoco population. There are at least significant differences in the pattern of black lateral blotches and in the coloration of the caudal fin. In addition, specimens from the Rio Negro seem to be more slender than those collected from the Colombian and Venezuelan Rio Orinoco drainage. More importantly, preliminary genetic studies (Ready, *in lit*.) have also indicated differences between specimens from the two regions.

The material available for study is still too limited to produce sufficient data to confirm the status of the two populations, but there does seem to be a strong probability that the specimens on which the description and re-description are based represent two different species. With this in mind, the two populations should be treated as potentially different species: *Dicrossus filamentosus* from the Brazilian Amazon system and *Dicrossus* sp. □C□ from the Orinoco drainage, awaiting description. Further research to resolve this dilemma is strongly encouraged.

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