Taxonomic status of the six-band morph of *Cyphotilapia frontosa* (Perciformes: Cichlidae) from Lake Tanganyika, Africa

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Abstract Six- and seven-band morphs have been identified in a cichlid, *Cyphotilapia frontosa*, that is endemic to Lake Tanganyika. These color morphs have allopatric distributions; the six-band morph is widespread in the northern half of the lake while the seven-band morph is restricted to Kigoma on the east coast of the lake. Because no specimens of the seven-band morph have been available for taxonomic study except for the holotype of *C. frontosa*, the taxonomic status of these morphs has not been discussed. In a recent survey at the lake, 21 specimens of the seven-band morph were collected. A comparison of these with existing collection specimens of the six-band morph showed significant differences in morphometric and meristic characters; however, because all characters largely overlapped between these morphs, they are regarded as conspecific.

Key words Cyphotilapiini · Color morph · Morphology · ANOVA · Canonical discriminant analysis

Lake Tanganyika is located in the Great Rift Valley in central East Africa. Approximately 200 species of cichlid fishes have been described from this lake, and new species continue to be discovered (e.g., Takahashi et al., 2002; Takahashi and Nakaya, 2003; Hanssens and Snoeks, 2003). Snoeks (2000) estimated the total number of Tanganyikan cichlid species would be 250.

Cyphotilapia Regan, 1920, a genus endemic to Lake Tanganyika, is characterized by a hump on the forehead and broad vertical bands on the body. This genus includes two nominal valid species, *Cyphotilapia frontosa* (Boulenger, 1906) and *Cyphotilapia gibberosa* Takahashi and Nakaya, 2003. Takahashi and Nakaya (2003) reported six- and seven-band morphs in *C. frontosa* (Fig. 1) (they referred to them as six- and seven-band types; however, because of the nomenclatorial connotation of the word "type," the term "morph" is preferred in the present study). These morphs have allopatric distributions, i.e., the six-band morph inhabits the northern half of the lake while the seven-band morph is limited to the area of Kigoma on the east coast of the lake (Fig. 2). Photographs of the latter morph from Kigoma are shown in various publications (e.g., Konings, 1988: 120; 1998: 120; Konings and Dieckhoff, 1992: 43). However, except for the holotype of *C. frontosa*, no other specimen of the seven-band morph was available for further taxonomic study. Therefore, up to now, a detailed comparison of both morphs has not been done. During a recent survey at the lake in 2005, 21 specimens of the seven-band morph were collected at Kigoma. The purpose of this study is to compare the six-band morph with the seven-band morph of *C. frontosa* to assess their taxonomic status.

Materials and Methods

Twenty-one specimens of the seven-band morph of *C. frontosa* were collected from Kigoma, Tanzania, between 13 and 17 January 2005. Twenty specimens were collected by chasing the fish into a screen net from 1–3 m above the rocky bottom at a depth of 24–25 m by scuba diving; 1 specimen was purchased at a market. All specimens were fixed in 10% formalin and then preserved in 50% 2-propanol. All type specimens of *C. gibberosa* and *C. frontosa*, and non-type materials from a museum and two private collections, were examined. In total, 22 specimens of the seven-band morph of *C. frontosa* from Kigoma, 32 specimens of the six-band morph from eight localities, and 26 specimens of *C. gibberosa* from six localities were examined (Fig. 2).

Abbreviations used are as follows: BMNH, The Natural History Museum, London; FAKU, Fish collection of Kyoto University, Kyoto and Maizuru, Japan; HUMZ, Laboratory of Marine Biodiversity, Graduate School of Fisheries Sciences, Hokkaido University, Japan; LBM, Lake Biwa Museum, Shiga Prefecture, Japan; MRAC, Musée Royale de l'Afrique Centrale, Tervuren, Belgium; TT, private collection of T. Takahashi, Kyoto University, Japan; and T and Zm, private collection of M. Hori, Kyoto University, Japan.

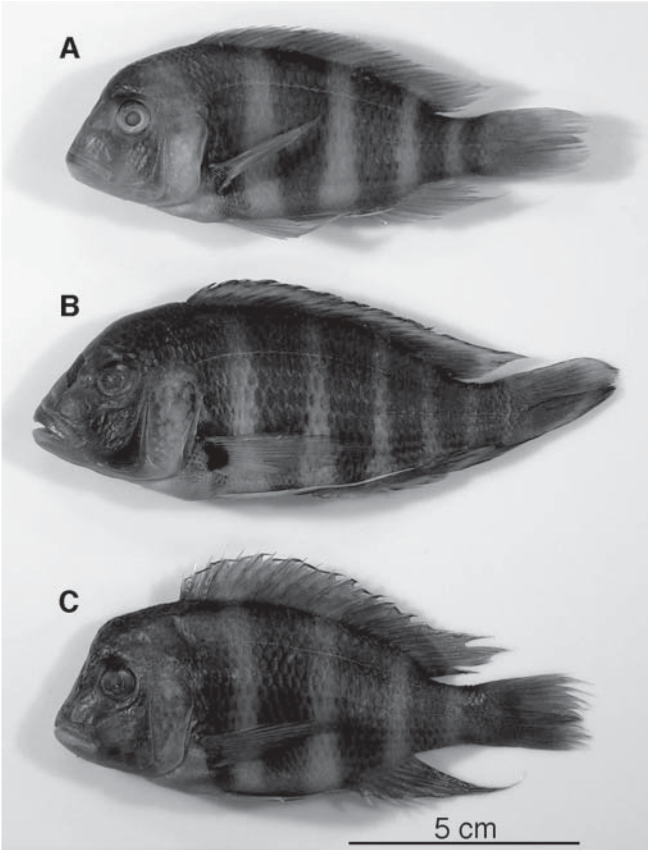

Fig. 1. Species of *Cyphotilapia*. **A** Six-band morph of *C. frontosa* (HUMZ 128573); **B** seven-band morph of *C. frontosa* (TT 1330); **C** *C. gibberosa* (HUMZ 122873, paratype)

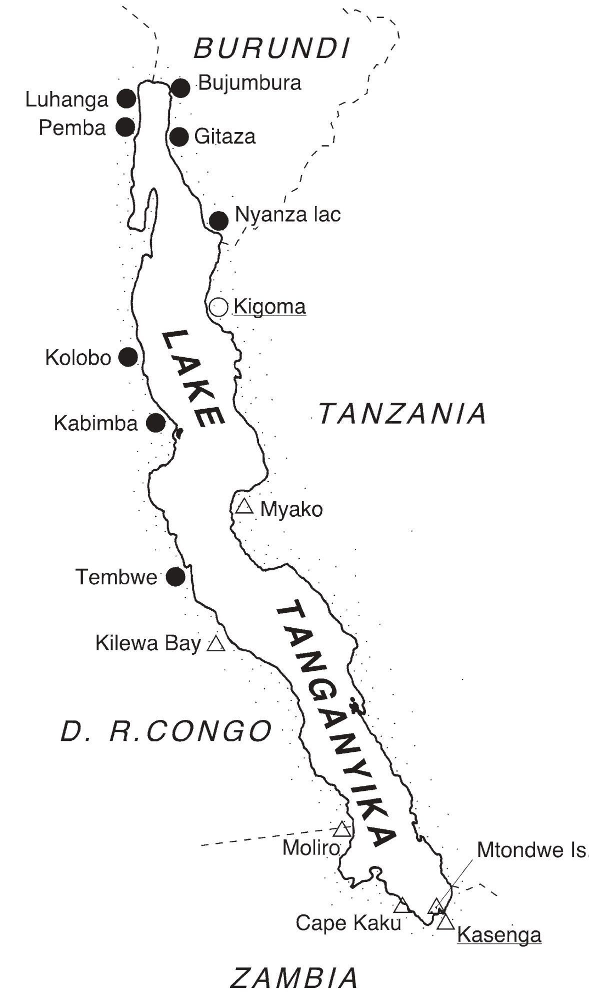

Fig. 2. Map of Lake Tanganyika showing sampling localities for six- (●) and seven-band morphs (○) of *Cyphotilapia frontosa* and *C. gibberosa* (△)

Sixteen morphometric (Table 1) and 12 meristic characters (Tables 2–4; spines and soft rays in dorsal and anal fins are considered separately) were taken in accordance with the method of Snoeks (2004), with the following exceptions. The scales between lateral lines were counted from (and exclusive of) the scale on the upper lateral line, downward and backward to (and exclusive of) the scale on the longitudinal scale row bearing the lower lateral line. This number differed between the center and posterior parts of body in some individuals, and the arrangement of scales at the anterior part of body was irregular in many specimens. This number was, therefore, counted from each scale between the sixth and the last upper lateral line scales, and the average of these numbers was calculated (average scale number between the upper and lower lateral lines). Vertebral numbers were counted on radiographs; they were counted from the first vertebra posterior the neurocranium to the compound centrum comprising the first preural and ural vertebrae. Measurements were taken to the nearest 0.1 mm with dividers or calipers under a binocular microscope.

For testing the significant differences between the morphs and between sexes, morphometric characters were logarithmically transformed to base 10 because some characters were likely to fit the allometric growth (see Table 1) (Sokal and Rohlf, 1995). Multivariate analysis of covariance (MANCOVA) was used for the analysis of 15 transformed morphometrics; logarithmic standard length was used as a covariate. Eleven selected meristic characters (except the number of anal-fin spines, see Results) were examined by the multivariate analysis of variance (MANOVA). When a significant difference was observed, a canonical discriminant analysis was carried out to examine which character was different.

Materials examined. Six-band morph of *Cyphotilapia frontosa*, 32 specimens: HUMZ 116585, 116839, 117965, 137776–137781, 1 male and 8 females, 69.1–126.8 mm in standard length (SL), Pemba, D.R. Congo; HUMZ 116618, 138292, 2 males, 70.0–170.0 mm SL, Luhanga, D.R. Congo; HUMZ 127120, 127212, 127245, 127249, 127301, 127302, 127575, 127576, 128573, 128687, 6 males and 4 females, 55.0–137.2 mm SL, Gitaza, Burundi; MRAC P.47369-47372, 4 males, 136.3–192.1 mm SL, Nyanza lac, Burundi; MRAC P.106309, 1 male, 158.3 mm SL, baie de Kolobo, D.R. Congo; MRAC 106310, 1 male, 238.2 mm SL, baie de Tembwe, D.R. Congo; MRAC 106311–106313, 106315, 2 males and 2 females, 114.2–205.3 mm SL, baie de Kabimba, D.R. Congo; MRAC 92-084-P-5, 1 male, 89.0 mm SL, Bujumbura, Burundi.

Table 1. Morphometric characters of species of *Cyphotilapia*

	C. frontosa				*C. gibberosa* ($n = 26$)	
	Six-band morph ($n = 32$)		Seven-band morph ($n = 22$)			
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
Standard length (mm)	55.0–238.2		100.7–212.5		42.5–210.1	
Percent of standard length						
Body depth	37.2–46.1	42.0 ± 2.0	39.9–44.4	41.5 ± 1.1	42.4–51.2	46.5 ± 2.2
Head length	34.8–40.5	36.6 ± 1.3	31.8–37.7	35.7 ± 1.1	34.4–41.4	36.7 ± 1.1
Caudal peduncle length	13.6–17.7	15.9 ± 0.9	14.2–17.2	15.7 ± 0.9	13.2–18.4	15.8 ± 1.2
Caudal peduncle depth	12.4–14.4	13.6 ± 0.4	12.8–14.6	13.4 ± 0.5	13.2–14.6	13.8 ± 0.4
Dorsal-fin base length	53.2–61.5	58.5 ± 1.7	54.5–60.4	57.4 ± 1.6	58.1–63.3	60.4 ± 1.4
Anal-fin base length	15.3–18.8	17.0 ± 0.9	15.3–18.0	16.7 ± 0.7	14.9–18.4	16.4 ± 0.8
Predorsal length	36.3–41.9	38.5 ± 1.3	34.5–39.1	37.5 ± 1.1	34.9–45.1	39.7 ± 2.3
Prepectoral length	34.2–40.4	36.6 ± 1.6	34.2–38.0	36.1 ± 1.2	34.9–40.8	36.8 ± 1.5
Prepelvic length	38.0–48.3	41.9 ± 2.2	38.0–43.9	41.1 ± 1.8	38.6–48.7	41.7 ± 2.3
Percent of head length						
Head width	42.3–52.9	47.3 ± 2.3	43.8–53.4	48.5 ± 2.2	41.4–50.5	46.9 ± 2.3
Snout length	37.3–49.5	$0.245\ L_H^{1.15}$	39.4–46.9	43.2 ± 2.1	30.1–48.0	$0.179\ L_H^{1.23}$
Eye length	18.4–34.1	$0.912\ L_H^{0.661}$	19.8–31.5	$1.16\ L_H^{0.596}$	21.3–34.4	$0.804\ L_H^{0.700}$
Interorbital width	28.8–37.2	$0.199\ L_H^{1.14}$	31.8–39.2	34.3 ± 1.8	24.1–37.7	$0.167\ L_H^{1.18}$
Lower jaw length	36.8–50.9	$0.257\ L_H^{1.13}$	37.7–48.6	41.9 ± 3.0	36.4–48.5	42.1 ± 2.6
Lachrymal depth	19.3–26.6	23.6 ± 1.7	22.1–26.8	24.7 ± 1.4	18.1–26.9	$0.119\ L_H^{1.19}$

Morphometric character, in which allometric formula against standard length (L_S) or head length (L_H) ($\log Y = a \log X + b$) is significantly different from isometry ($\log Y = \log X + b'$) (F test, $df = 1, 30$ in six-band morph, 1, 20 in seven-band morph, and 1, 24 in *C. gibberosa*; significance level of $P < 0.0011$, Dunn–Sidak method in 45 tests), is indicated in allometric formula instead of average and standard deviation

Table 2. Frequency distribution of fin ray counts in species of *Cyphotilapia*

	Dorsal						Anal				Pectoral		
	XVII,10	XVIII,8	XVIII,9	XVIII,10	XIX,8	XIX,9	III,6	III,7	III,8	III,9	15	16	17
C. frontosa (six-band morph)	1	—	21	8	1	1	1	23	7	1	6	24	2
C. frontosa (seven-band morph)	—	—	7	3	8[h]	4	—	20[h]	2	—	1	20[h]	1
C. gibberosa	—	2	13[h]	6	—	6	—	20[h]	7	—	1	24[h]	2

[h] Holotype

Seven-band morph of *Cyphotilapia frontosa*, 22 specimens. BMNH 1906.9.8.140 (holotype), TT1206, 1310–1327, 1329, 1330, 9 males and 13 females, 100.7–212.5 mm SL, Kigoma, Tanzania.

Cyphotilapia gibberosa, 26 specimens. HUMZ 157314 (holotype), 122873, 157312, 157313, FAKU 83368, 83369, MRAC A2-33-P1, 2-33-P2 (paratypes), Zm 95070, 95396-1, 95396-2, 95777, 9 males and 3 females, 53.3–154.6 mm SL, Kasenga, Zambia; HUMZ 182844–182849 (paratypes), Zm 95729-1, 95729-2, 19729-3, 2 males and 7 females, 42.5–210.1 mm SL, off Mtondwe Is., Zambia; LBM 25919, 1 female, 108.1 mm SL, Cape Kaku, Zambia; MRAC 14154, 1 male, 150.1 mm SL, Moliro, D.R. Congo; MRAC 14173, 1 male, 162.6 mm SL, Kilewa, D.R. Congo; T 83531, 83816, 2 males, 93.8–159.3 mm SL, Myako, Tanzania.

Results

As described by Takahashi and Nakaya (2003), six- and seven-band morphs of *C. frontosa* possessed fewer scales between upper and lower lateral lines (see Table 3) and a more elongated body (see Table 1).

Morphometric and meristic characters are shown in Tables 1–4. The morphological differences between the six- and seven-band morphs of *C. frontosa* and between the sexes were statistically tested. The interactions in the MANCOVA on morphometric characters were not significant, and a significant difference was observed between the morphs (Table 5). The result of the canonical discriminant analysis on the residuals from the regression line showed that the six- and seven-band morphs are largely overlapping (Fig. 3). Although the dorsal-fin base length is the main contributor to this CV1 axis, the range of this

Table 3. Frequency distribution of scale counts in species of *Cyphotilapia*

	Scales on longitudinal line				Scales on upper lateral line							
	33	34	35	36	22	23	24	25	26	27	28	29
C. frontosa (six-band morph)	4	20	8	—	—	1	9	12	5	5	—	—
C. frontosa (seven-band morph)	2	13	6[h]	1	—	1	4	14[h]	3	—	—	—
C. gibberosa	—	10[h]	10	7	1	1	1	7[h]	10	5	—	1

	Scales on lower lateral line											
	7	8	9	10	11	12	13	14	15	16	17	18
C. frontosa (six-band morph)	—	—	1	—	2	1	5	6	7	8	1	1
C. frontosa (seven-band morph)	—	—	—	—	1	—	4	5	7[h]	2	1	2
C. gibberosa	1	—	2	—	1	1	1	8[h]	7	5	—	—

	Average scale number between upper and lower lateral lines													
	~2.0	~2.1	~2.2	~2.3	~2.4	~2.5	~2.6	~2.7	~2.8	~2.9	~3.0	~3.1	~3.2	~3.3
C. frontosa (six-band morph)	6	18	5	1	—	—	2	—	—	—	—	—	—	—
C. frontosa (seven-band morph)	—	14	3	3[h]	—	1	1	—	—	—	—	—	—	—
C. gibberosa	—	—	—	—	—	—	—	—	1	5[h]	14	4	—	1

[h] Holotype

Table 4. Frequency distribution of numbers of gill rakers, vertebrae, and outer teeth on premaxillae in species of *Cyphotilapia*

	Gill rakers			Vertebrae			
	10	11	12	30	31	32	33
C. frontosa (six-band morph)	8	22	2	1	4	27	—
C. frontosa (seven-band morph)	7	14	1[h]	—	3	19[h]	—
C. gibberosa	4	20[h]	2	—	3	20[h]	4

	Outer teeth on premaxillae							
	~30	~35	~40	~45	~50	~55	~60	~65
C. frontosa (six-band morph)	—	—	2	5	14	6	4	1
C. frontosa (seven-band morph)	—	—	—	8[h]	12	2	—	—
C. gibberosa	2	12[h]	13	6	1	3	—	—

[h] Holotype

character in the six-band morph almost completely overlapped with that of the seven-band morph (see Table 1).

Among the meristic characters, the number of anal-fin spines is invariable (three in all specimens) and was therefore excluded from the statistical tests. The 11 other meristic characters are not significantly related to standard length ($F = 0.711$, $df = 11, 40$, $P = 0.7212$); therefore, differences among morphs and between sexes were tested by the MANOVA. The interaction between the morph and sex is not significant, and no significant sexual dimorphism was observed (see Table 5). However, the meristic characters significantly differed between morphs. The results of the canonical discriminant analysis on the meristic characters showed that the six- and seven-band morphs are largely overlapping on the CV1 axis (Fig. 4). Although the number of dorsal-fin spines is the main contributor to this axis, the range of this character in the six-band morph almost completely overlapped with that of the seven-band morph (see Table 2). Furthermore, no difference was observed in any other meristic characters between these morphs (Tables 2–4).

Discussion

Takahashi and Nakaya (2003) reported two color morphs in *C. frontosa*, i.e., a six-band morph inhabiting the northern half of Lake Tanganyika and a seven-band morph that inhabits Kigoma, Tanzania. However, they were unable to further examine these morphs taxonomically because of lack of specimens. For the present study, a sufficient num-

Table 5. Test of morphological character differences between six- and seven-band morphs of *Cyphotilapia frontosa* and between the sexes

	F value	Degree of freedom	*P* value
MANCOVA on 15 morphometrics			
Morphs	2.292	15, 33	0.0232*
Sexes	1.941	15, 33	0.0553
Log (SL)	814.6	15, 33	0.0000*
Morphs × sexes	1.554	15, 33	0.1424
Morphs × log (SL)	0.9616	15, 33	0.5129
Sexes × log (SL)	1.697	15, 33	0.1020
MANOVA on 11 meristics			
Morphs	3.846	11, 40	0.0008*
Sexes	1.270	11, 40	0.2763
Morphs × sexes	0.6099	11, 40	0.8092

MANCOVA, multivariate analysis of covariance; SL, standard length
* Significant differences ($P < 0.05$)

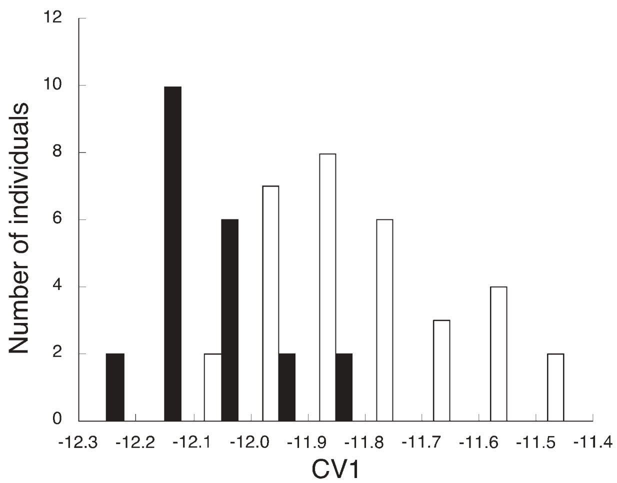

Fig. 3. Frequency distribution of individual scores on the first canonical variate axis on morphometric characters for six- (*closed bars*) and seven-band morphs (*open bars*) of *Cyphotilapia frontosa*

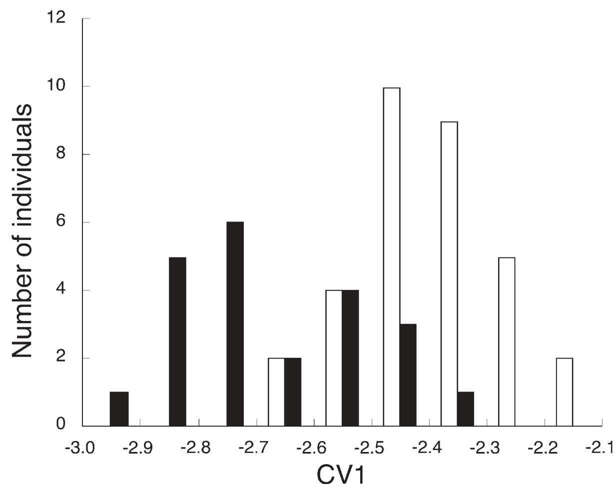

Fig. 4. Frequency distribution of individual scores on the first canonical variate axis on meristic characters for six- (*closed bars*) and seven-band morphs (*open bars*) of *Cyphotilapia frontosa*

ber of specimens were collected to determine the taxonomic status of these morphs.

The six- and seven-band morphs of *C. frontosa* could be easily distinguished from *C. gibberosa* because *C. frontosa* has fewer scales between the upper and lower lateral lines and a more elongated body (see Tables 1 and 3; also see Takahashi and Nakaya, 2003). The six-band morph is easily distinguished from the seven-band morph by its color pattern and geographical distribution. Although the dorsal-fin base length and the number of dorsal-fin spines differed significantly, these characters are not judged useful for distinguishing the two morphs because of great overlap (see Tables 1, 2).

Ribbink et al. (1983) and Seehausen (1996) applied the specific mate recognition system (SMRS) described by Paterson (1978) to define species of cichlids in Lakes Malawi and Victoria, respectively. In this system, cichlids that recognize each other as reproductive partners are included in a single species, but they are separated into different species if no such recognition is shown. Ribbink et al. (1983) assumed that five characters are important in species recognition, namely, body shape, coloration, melanin pattern, behavior, and microhabitat. In allopatric populations, differences in one or more (Ribbink et al., 1983) or two or more (Seehausen, 1996) of these characters suggest that these populations would not recognize each other. In the case of Tanganyikan cichlids, when the allopatric populations do not show any differences in any character other than color pattern, they are usually treated as a single species showing local color variations (e.g., species of *Ophthalmotilapia*, *Cyprichromis*, *Tropheus*; Konings, 1998). In *C. frontosa*, no obvious differences were observed between the six- and seven-band morphs except for the color patterns; therefore, the six-band morph is considered to be a local color variation of *C. frontosa*, not a different species.

The genus *Cyphotilapia* Regan, 1920 was originally placed in the tribe Tropheini Poll, 1986. Subsequently, some molecular (Kocher et al., 1995; Salzburger et al., 2002) and lepidological (Lippitsch, 1998) studies have questioned the affiliation of this genus to the tribe Tropheini. Thus, Salzburger et al. (2002) suggested placing *Cyphotilapia* in a new monotypic tribe Cyphotilapiini. The following year, Takahashi (2003) reframed the tribal classification of Tanganyikan cichlid fishes based on internal and external morphological features. In his classification, Cyphotilapiini Salzburger et al., 2002 was overlooked, and he proposed a new tribe, Cyphotilapiini Takahashi, 2003. Based on ICZN (1999: article 50.1), the author of Cyphotilapiini is Salzburger et al. (2002), not Takahashi (2003).

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