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A new species of *Pseudocrenilabrus* (Perciformes: Cichlidae) from Lake Mweru in the Upper Congo River System

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Abstract

Pseudocrenilabrus pyrrhocaudalis **sp. nov.** is described from Lake Mweru in the upper Congo River drainage, on the border of the Democratic Republic of Congo and Zambia. This species, which appears to be endemic to the lake, lives in sympatry with *P. philander*. *Pseudocrenilabrus pyrrhocaudalis* **sp. nov.** is distinguished from *P. philander* in nuptial males by the presence of an orange colour on the ventral part of the body and the proximal parts of the anal and caudal fins, a broad band of bright white on the distal edge of anal and caudal fins, a uniform grey head and dorsum, and a subtruncate caudal fin. In addition, *P. pyrrhocaudalis* has a shorter snout, a narrower head, a smaller interorbital distance, a smaller pre-anal distance, a more slender caudal peduncle and fewer scales around the caudal peduncle in both sexes.

Key words: *Pseudocrenilabrus pyrrhocaudalis,* description, south-eastern Africa

Introduction

The genus *Pseudocrenilabrus* Fowler, 1934 is widely distributed in Africa, ranging in the north from Egypt to Sudan, over eastern Africa and parts of the eastern Congo basin, down to south eastern Africa and Namibia in the West (Greenwood, 1989; Katongo *et al.*, 2005). This genus currently includes three valid species: *P. philander* (Weber, 1897) described from the Umhloti river in KwaZulu-Natal, South Africa; *P. multicolor* (Schoeller, 1903) from Lake Mareotis in the Nile River system in Egypt; and *P. nicholsi* (Pellegrin, 1928) from Ankoro on the Lualaba River system of the Congo River basin. Within the major African cichlid groups, the genus *Pseudocrenilabrus* belongs to the tribe Haplochromini within the C-lineage that comprises ten mouthbrooding tribes. Within the Haplochromini, it represents a rather basal lineage (Poll, 1986, Salzburger *et al*., 2002, Salzburger *et al*., 2005, Koblmüller *et al*., 2008, Takahashi and Koblmüller, 2011).

The genus *Pseudocrenilabrus* has hitherto been characterized by a single, non-ocellate and distinctly red or orange coloured spot or blotch at the trailing edge of the anal fin in males, a reductional trend in the canal bones of the infraorbital series, a rounded or subtruncate caudal fin, and a specific male courtship pattern (in which the male prepares a nest and chases away all other male intruders and induces a female to lay eggs which he fertilises; immediately after she has picked them up, the male chases her away in preparation for the next suitable female) as synapomorphic features (Greenwood, 1989; Skelton, 2001). *Pseudocrenilabrus* species are maternal mouthbrooders with up to 120 fry per clutch (Katongo *et al*., 2005).

Pseudocrenilabrus multicolor consists of two subspecies; *P. multicolor multicolor* is present in the Nile River Basin, only in the stretch downstream of Lake Albert (Daget *et al*., 1991), while *P. multicolor victoriae* Seegers, 2000 occurs in the region of Lake Victoria and in the major part of the Nile River Basin from Lake Albert

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southhwards. The second nominal species, *P. nicholsi*, has only been reported from the Yangambi area in Central, to Upemba lakes in Upper Congo basin (Daget *et al*., 1991), but excluding the Bangweulu-Mweru ecoregion. The third nominal species, *P. philander*, is widely distributed in the Orange, Limpopo, Zambezi and Upper Congo River Basins. *Pseudocrenilabrus philander* includes three sub-species and a complex of distinct geographically separated populations pointing to a considerable sub-structuring of this species in southern Africa: *P. philander luebberti* (Hilgendorf, 1902) in the area of Otavi in SW-Africa, *P. philander dispersus* (Trewavas, 1936) in Lake Otjikoto, Namibia and generally in the SW-Africa region, and *P. philander philander* in south eastern Africa (Skelton, 1991).

Only *P. philander* and its nominal subspecies have been recorded from the Zambezi and Luapula-Congo drainages in Zambia (Skelton, 1994, 2001). Genetic analysis of the genus *Pseudocrenilabrus* from the study area (Luapula-Congo, and Zambezi basin in Zambia), based on mitochondrial DNA, however, revealed four distinct clades, two of which occur exclusively in the Luapula-Congo drainage, the third in both the Luapula-Congo and Zambezi drainages and the fourth only in the Zambezi drainage. Among the three clades that occur in the Congo River Drainage are *P. philander*, *P.* sp. '*Lunzua*' and *P.* sp. 'orange' (Katongo *et al.*, 2005). Egger *et al*. (2014) reconstructed a Bayesian inference haplotype tree of the genus *Pseudocrenilabrus* represented by all the valid species. This tree, which was based on the mitochondrial control region and rooted with *Pseudocrenilabrus* sp. 'Lufubu A', showed that the *Pseudocrenilabrus* from Lake Mweru formed a distinct clade. The current study provides a formal description of *P.* sp. 'orange' which is herein named *Pseudocrenilabrus pyrrhocaudalis* **sp. nov.**.

Material and methods

Specimens of the genus *Pseudocrenilabrus* used in this study were collected from Lake Mweru in Zambia in the Luapula-Congo River system, using gillnets and seine nets. They were initially fixed in 10% formalin and finally preserved in 70% ethanol. The specimens were then deposited in the Royal Museum for Central Africa (RMCA) at Tervuren, Belgium and at the South African Institute of Aquatic Biodiversity (SAIAB), Grahamstown, South Africa. In addition to the freshly collected specimens, reference material from the Royal Museum for Central Africa (RMCA) collection was also included in the study. For type material, see description below.

Comparative material of *P. philander* (Fig. 1b) was collected from Kashikishi, Nchelenge and Isokwe Island, all from Lake Mweru: SAIAB-191531(1-10); SAIAB-191532(1-3); SAIAB-191533(1-2); MRAC-97-001-P-0129-0139 (1-6). Meristic counts and morphometric measurements were taken according to Barel *et al.* (1977) and Snoeks (1994). Morphometric data were analysed in STATISTICA. Principal component analysis (PCA) based on the correlation matrix, was used to reduce the multivariate data set to a lower dimensional space in order to find characters useful for species discrimination and to examine the *a priori* group structure. This technique is commonly used in taxonomic studies on African cichlids (Snoeks, 1991, 2004; Hanssens *et al*., 1999), as it is basically a model-free and distribution-free technique (Marcus, 1990; Quicke, 1993). It was used here without drawing statistical inferences. All morphometric measurements were logarithmically transformed (Blackith & Reyment, 1971). The loadings on the first principal component (PC) were mainly of similar magnitude and sign, predominantly representing the size factor. All further principal components were interpreted as mainly shape factors (Hanssens *et al*., 1999). PCA was also performed on the raw meristic data. Mann Whitney U-tests were performed using SPSS (version 16) on percentage (morphometric) and on meristic on data of specimens of the same size class to detect diagnostic characters responsible for the differences between *P. pyrrhocaudalis* and sympatric *P. philander* among those characters that had the highest factor loadings. The comparison was confined to *P. pyrrhocaudalis* and *P. philander* of Lake Mweru only because it is generally believed that *P. philander* is a complex of many different species.

Taxonomy

***Pseudocrenilabrus pyrrhocaudalis* sp. nov.**

Fire-tailed Pseudocrenilabrus

Figs. 1, 2. Tables 2, 3.

Holotype. SAIAB-191528, male 62.8 mm SL; Zambia; Kalobwa Beach (1,134 meters above sea level with

coordinates 8°57'0" S and 29°6'0" E), Lake Mweru, Luapula-Congo River system, seine net, C. Katongo and O. Seehausen, 15 September 2005 (Fig. 1a).

Paratypes. MRAC A9-034-P-0238-247, 57.3–73.1 mm SL, Luapula-Congo River system, Mukwakwa, Lake Mweru, Zambia, P. van Zwieten, 1994; MRAC A4-025-P0103-07 and MRAC A4-025-0137-38, 46.5–54 mm SL, Luapula-Congo River system, Mwatishi River/Lake Mweru confluence, gillnet, C. Katongo, 2002; SAIAB 191530(1-13), 45.3–68.3 mm SL, Luapula-Congo River system, Kalobwa beach, Lake Mweru, C. Katongo and O. Seehausen, September, 2005.

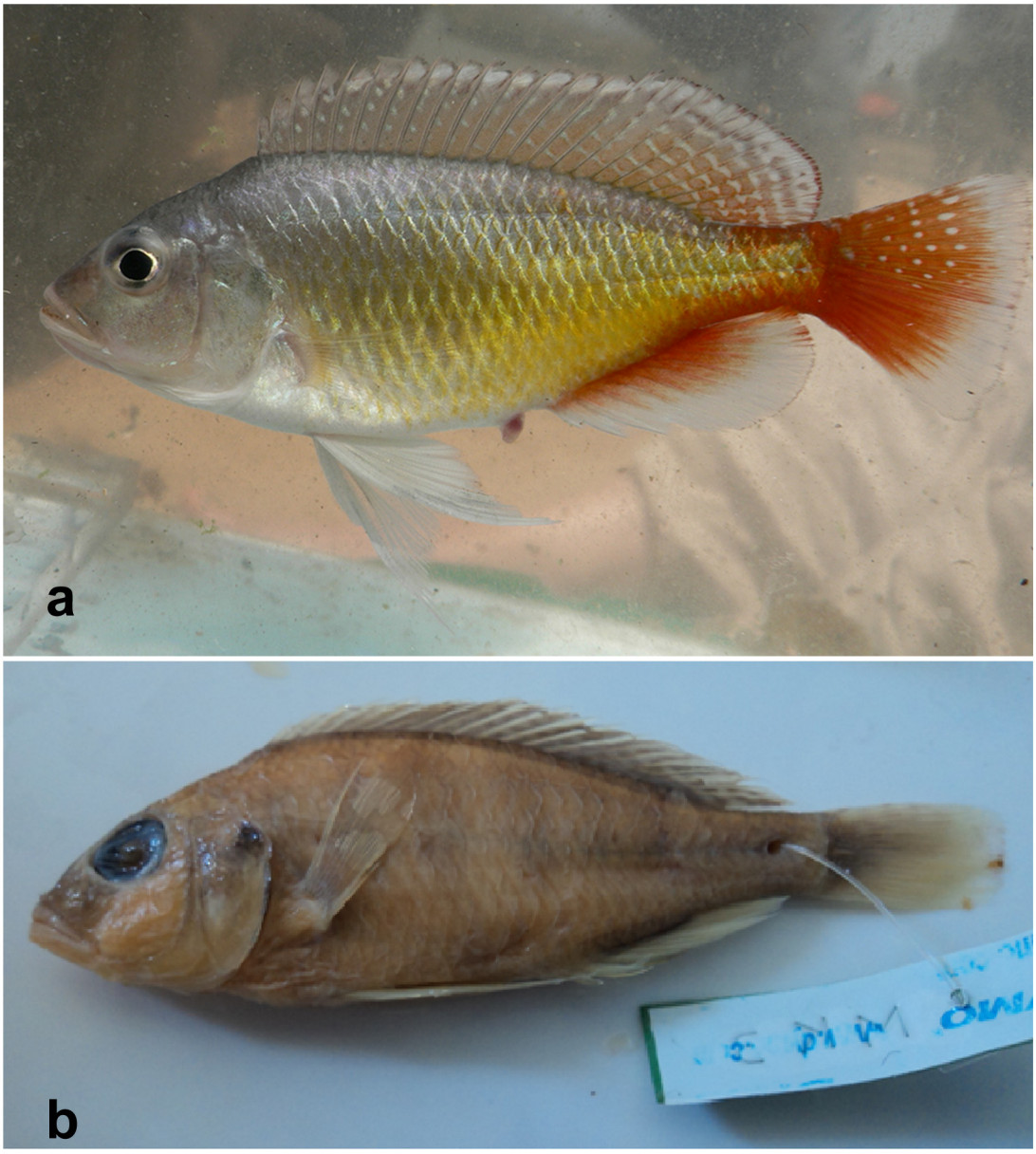


FIGURE 1. *Pseudocrenilabrus pyrrhocaudalis* **sp. nov.**, male holotype (SAIAB 191528, 62.8 mm SL) from Kalobwa Beach, Lake Mweru in live (a) and in preserved colour pattern (b).

Diagnosis. *Pseudocrenilabrus pyrrhocaudalis* can be differentiated from the other species of the genus *Pseudocrenilabrus* on the basis of its colour pattern and its subtruncate caudal fin. Male *P. pyrrhocaudalis* have a unique colour pattern characterized by some orange colour on their anal and caudal fins that can become bright orange-red in breeding males, extending over the proximal parts of the anal and caudal fins and the distal part of the caudal and the upper and lower parts of the caudal peduncle (Fig. 1a). In addition, *P. pyrrhocaudalis* can be distinguished from its sympatric congener *P. philander* (Fig. 3), by a combination of the following characters

(Figs.1, 2, 4; Tables 2, 3): pelvic fin white (vs. black), posterior part of dorsal fin orange (vs. olive green in the other species), comparatively thinner lips (vs. comparatively thicker lips), larger eye diameter 27.0–39.3% HL (vs 22.9–33.1% HL), narrower head width 37.0–47.3% HL (vs. 38.5–53.7% HL), narrower interorbital distance 14.6–22.3% HL (vs. 20.5–29.4% HL) and a more slender caudal peduncle 8.8–11.8% SL (vs. 11.3–13.9% SL), and 50.0–64.7% CPL (vs 64.3–93.5% CPL).



FIGURE 2. *Pseudocrenilabrus pyrrhocaudalis* **sp.nov**, female, paratype (SAIAB 191530, 66.7 mm SL) from Kalobwa Beach, Lake Mweru in live (a) and in preserved colour pattern (b).



FIGURE 3. *Pseudocrenilabrus philander philander*, male (SAIAB 191531, 70.4 mm SL) from Isokwe Island, Lake Mweru.

Description. In both sexes: body relatively deep, head profile somewhat convex, mouth inclined upwards with relatively thin lips, interorbital distance narrow, caudal fin sub-truncate. Lower pharyngeal bone relatively slender and slightly longer than wide. Pharyngeal teeth all fine; those of the posterior row clearly larger than the others. Teeth of the two median rows somewhat enlarged. There is a small gradient in the orientation of the major cusp of the pharyngeal teeth from slightly backwards on the anterior parts of the pharyngeal jaw towards more erect posteriorly and slightly forward in the posteriormost rows. Breeding males with a bright orange coloration on caudal and anal fins; an orange spot on the anal fin, distal parts of caudal and anal fins white. Base of the caudal fin bright orange more than 2/3 of fin. Head and upper lateral part of body grey, while the lower part yellowish orange. Dorsal fin with white lateral dots arranged as stripes radiating from base to tips of dorsal-fin rays. Pelvic fins bright white (Fig. 1a). Females generally grey, with no anal-fin spot; pelvic fins bright white; bright orange lower half of caudal; some orange flashes at base of caudal and anal fins; some spots and streaks on dorsal and caudal fins (Fig. 2a).

A scatter plot of mainly male specimens of *P. pyrrhocaudalis* **sp. nov.** and Lake Mweru *P. philander* on the first and second axes of a PCA on log transformed measurements (Figure 4) shows that there are clear morphological differences between the two species. The characters with the highest loadings on the second axis (responsible for the observed morphological differences) are caudal peduncle length (CPL), interorbital width (IOW), eye diameter (ED), anal fin base (AFB), head width (HW) and caudal peduncle depth (CPD), (Table 1). Comparisons of morphometric ratios between *P. pyrrhocaudalis* **sp. nov.** and *P. philander* (Table 2) indicate that the characters responsible for the observed morphological differences are eye diameter as a proportion of head length (ED_HL), interorbital width as a proportion of head length (IOW_HL) and as a proportion of head width (IOW_HW), head width as a proportion of head length (HW_HL), caudal peduncle depth as a proportion of standard length (CPD_ SL) and as a proportion of caudal peduncle length (CPD_ CPL). Comparisons of meristic counts between *P. pyrrhocaudalis* **sp. nov.** and *P. philander* (Table 3) indicate that the characters responsible for the differences are number of upper jaw teeth (UJT), number of upper jaw inner rows (UJIR), dorsal spiny rays (Dspiny), anal soft rays (Asoft) and number of scales around the caudal peduncle (CP). The columns with Mann Whitney U test results (probabilities) in both Tables 2 and 3 were generated using *P. pyrrhocaudalis* **sp. nov.** and *P. philander* specimens of similar size class (44–73mm SL). These results (in the last column of each of Tables 2 and 3) indicate the relative contribution of the highlighted characters to the differences between the two species.

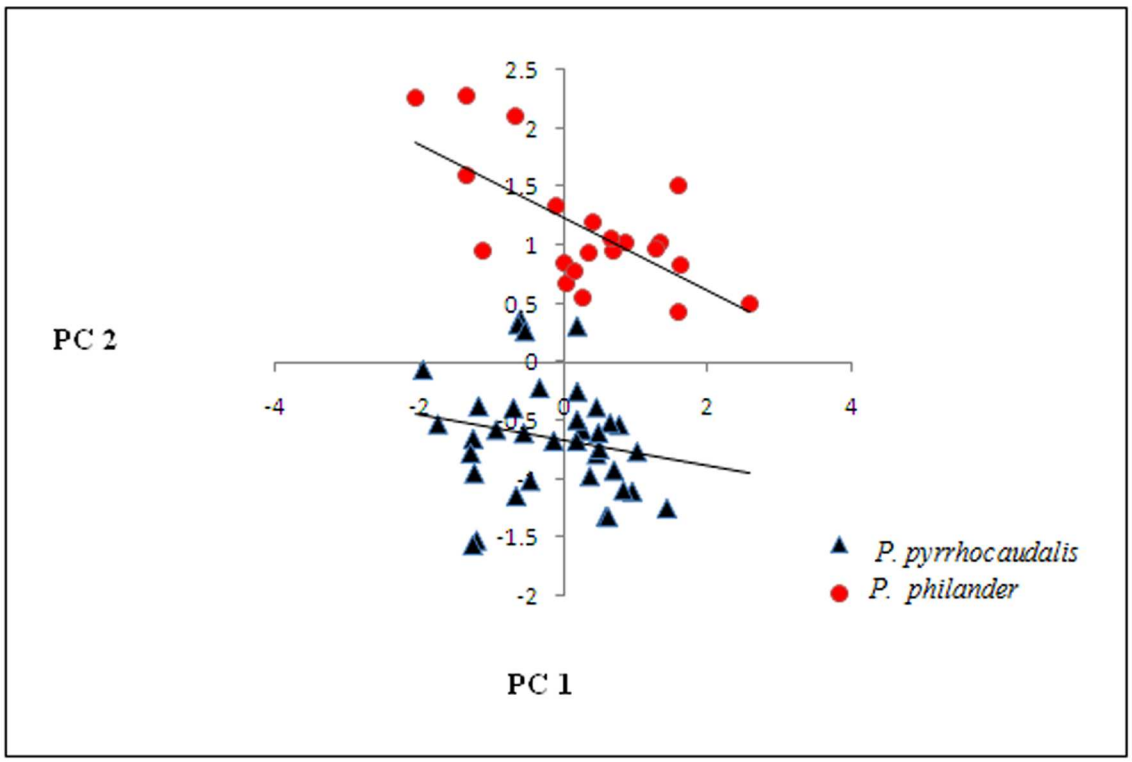


FIGURE 4. Scatter plot of the specimens of *Pseudocrenilabrus pyrrhocaudalis* **sp. nov.** (n = 31) and *P. philander* (n = 21) on the first and second axes of a Principal Component analysis on log-transformed measurements.

Etymology. Named *Pseudocrenilabrus pyrrhocaudalis* because this species has a bright orange tail which resembles a flame of fire. The common name fire-tailed Pseudocrenilabrus is proposed for this species.

Distribution. Probably endemic to Lake Mweru where it has been found near the beaches at Kalobwa, Kabuta, Ntoto and Kashikishi and at the Mwatishi River estuary (Fig. 5).

TABLE 1. Loadings of the variables on the first three principal components of a PCA on the log-transformed measurements of specimens of *Pseudocrenilabrus pyrrhocaudalis* **sp. nov.** (n = 31) and *P. philander* (n = 21). The highlighted results indicate the characters with the highest loadings on PC2 and PC3. These characters are eye diameter, interorbital width, head width, anal fin base, caudal peduncle length and caudal peduncle depth.

Variable	PC1	PC2	PC3
Lachrymal depth	0.851	0.142	-0.207
Snout length	0.893	0.241	-0.044
Lower jaw length	0.872	-0.250	0.249
Premaxillary pedicel length	0.958	0.025	0.056
Cheek depth	0.934	-0.034	0.061
Eye diameter	0.613	**-0.465**	**-0.596**
Interorbital width	0.810	**0.485**	0.043
Head width	0.905	**0.310**	-0.007
Head length	0.983	0.023	-0.030
Standard length	0.978	-0.124	0.062
Body depth	0.952	0.006	0.106
Dorsal fin base length	0.964	-0.081	0.118
Anal fin base length	0.824	**-0.316**	**0.323**
Predorsal distance	0.972	0.040	-0.064
Prepelvic distance	0.933	0.024	0.012
Preventral distance	0.976	-0.023	-0.064
Pre-anal distance	0.972	0.044	-0.057
Caudal peduncle length	0.685	**-0.579**	0.041
Caudal peduncle depth	0.888	**0.280**	-0.166
Explained variance	15.333	1.231	0.646
Proportion of total variance	0.807	0.065	0.034

Discussion

Pseudocrenilabrus pyrrhocaudalis lives sympatrically with *P. philander*, from which it is genetically and morphologically different and uses different habitats. Whereas *P. philander* is confined to inshore shallow water areas in Lake Mweru, *P. pyrrhocaudalis* was found in demersal seine catches at open beaches. Differences in life history, behaviour, and habitat use between *P. pyrrhocaudalis* and *P. philander* need to be studied. As earlier stated, recent mitochondrial DNA phylogenetic studies by Katongo *et al*. (2005) have indicated three distinct clades of *Pseudocrenilabrus* from the Luapula-Congo drainage of Zambia suggesting that there may be three or even more historically distinct lineages of the genus *Pseudocrenilabrus* in the Luapula-Congo drainage. *Pseudocrenilabrus* sp. 'Lunzua' was only reported from the Lunzua River (Congo drainage) and *P. sp.* 'orange' (now *P. pyrrhocaudalis*) only from Lake Mweru in the Luapula-Congo River drainage (Katongo *et al*., 2005). Results from a recent study by Stelkens and Seehausen (2009) found that *P. philander* and two other phenotypically distinct species from Lake Mweru mated strongly assortatively in the laboratory suggesting that behavioural mechanism and habitat specialization may be important in the origin of the sympatric species of *Pseudocrenilabrus* in Lake Mweru much like in the haplochromine cichlids of Lakes Victoria and Malawi. The full range of distribution of *P. pyrrhocaudalis* is yet to be mapped although it appears to be endemic to Lake Mweru.

TABLE 2. Morphometric ratios for *Pseudocrenilabrus pyrrhocaudalis* **sp. nov.** (n = 31) and *P. philander* (n = 21) from Lake Mweru. Ranges of *P pyrrhocaudalis* include holotype. The highlighted results indicate the characters which are different between the two. The Mann Whitney U-test results (probabilities) in the last column which were based on specimens within a similar size class (44–73mm SL), indicate the relative contribution of the highlighted characters to the differences between the two species. These characters are eye diameter, interorbital width, head width and caudal peduncle depth.

	***mweruensis* sp nov.**				***philander* (N=21)**			**Mann Whitney U Test p values**
		Paratypes (N=31)						
Character	**Holotype**	**Mean**	**SD**	**Range**	**Mean**	**SD**	**Range**	
Standard length(mm)	68.3	56.7	7	44.5–73.1	59.1	11.9	39.0–87.0	
As % of head length (HL)								
Lachrymal depth	20.0	19.2	1.8	15.6–23.5	20.0	2.1	16.0–23.2	0.051
Snout length	33.3	33.1	2.5	27.5–39.1	36.4	3.7	30.6–46.9	0.003**
Lower jaw length	40.3	38.7	3.3	30.9–46.3	34.8	3.3	27.3–39.0	0.001 **
Pre-maxillary pedicel length	28.8	28.5	2.3	22.8–32.7	29.1	2.3	26.1–34.1	0.818
Cheek depth	25.2	25.7	3.4	18.4–31.6	26.0	2.7	21.4–30.5	0.905
Eye diameter	**29.0**	**31.2**	**3.7**	**27.0–39.3**	**27.2**	**2.4**	**22.9–33.1**	**0.000** ***
Interorbital width	**17.4**	**18.4**	**2.3**	**14.6–22.3**	**24.3**	**2.2**	**20.5–29.4**	**0.000** ***
Head width	**44.7**	**42.1**	**2.4**	**37.0–47.3**	**48.0**	**3.2**	**38.5–53.7**	**0.000** ***
As % of standard length								
Head length	32.1	33.9	1.3	32.0–36.3	35.2	1.7	32.6–37.6	0.005 **
Body depth	32.4	32.6	2.7	25.7 – 36.9	33.9	2.3	29.0–40.3	0.062
Dorsal fin base length	57.8	55.7	2.1	50.5–59.4	56.6	2.5	49.8–60.1	0.119
Anal fin base length	17.2	19.9	1.8	16.7–23.7	18.7	1.8	14.8–21.8	0.056
Pre-dorsal distance	33.9	34.7	1.7	30.7–38.3	36.8	1.5	34.6–40.2	0.001**
Pre-ventral distance	34.1	35.0	1.8	31.6–38.3	35.7	1.9	33.3–38.9	0.412
Pre-anal distance	62.7	64.1	3.2	50.9–70.6	68.0	2.5	63.5–72.9	0.001**
Caudal peduncle length (CPL)	17.8	18.2	1.0	16.0–20.8	16.0	1.7	12.6–19.1	0.001 **
Caudal peduncle depth (CPD)	**9.8**	**10.2**	**0.8**	**8.8–11.8**	**12.4**	**0.8**	**11.3–13.9**	**0.000** ***
Interorbital width % head width	**38.9**	**43.7**	**4.8**	**34.2 – 51.2**	**50.8**	**5.7**	**42.6–60.8**	**0.000*****
CPD as % of CPL	**55.1**	**57.0**	**4.3**	**50.0–64.7**	**78.3**	**8.3**	**64.3–93.5**	**0.000** ***

* Significant (p = 0.010 – 0.050); ** Highly significant (p = 0.001– 0.009) ; *** Very highly significant (p< 0.001)

TABLE 3. Meristic counts for *Pseudocrenilabrus pyrrhocaudalis* **sp.nov.** (n = 31) and *P. philander* (n = 21) from Lake Mweru. Summary values include holotype. The highlighted results indicate the characters which are different between the two. The Mann Whitney U-test results (probabilities) in the last column which were based on specimens within a similar size class (44–73mm SL), indicate the relative contribution of the highlighted characters to the differences between the two species. These characters are number of; upper jaw teeth, dorsal spiny rays and scales around the caudal.

	***mweruensis* sp. nov**			***philander* (N=21)**		**Mann Whitney U Test p values**
		Paratypes (N=31)				
Character	**Holotype**	**Median**	**Range**	**Median**	**Range**	
Upper jaw teeth	**56**	**54**	**38–70**	**42**	**30–58**	**0.000 *** **
Lower jaw teeth	40	40	32–48	38	26–56	0.037 *
Upper jaw inner rows	2	2.5	1–4	3	2–4	0.001**
Lower jaw inner rows	2	2	1–3	3	2–4	0.003**
Ceratobranchial gill rakers	10	10	7–12	9	7–12	0.900
Articular gill rakers	1	1	1	1	1	1.000
Epibranchial gill rakers	4	2.5	1–4	3	2 – 4	0.034 *
Gill rakers total	15	13	10–16	13	11–17	0.900
Dorsal spines	**14**	**14**	**13–15**	**16**	**14 – 17**	**0.000 *** **
Dorsal soft rays	9	10	8–12	9	8–11	0.007 **
Anal spines	3	3	3	3	3	1.000
Anal soft rays	9	8	6–10	8	7– 9	0.001**
Pectoral fin rays	12	11.5	10–13	12	11–13	1.000
Upper lateral line scales	19	20	17–23	19	17–21	0.404
Lower lateral line scales	12	11.5	8–13	11	6–13	0.001**
Longitudinal line scales	31	30.5	28–33	30	25–33	0.259
Transverse scales below lateral line	7	6.5	5–8	5	4–7	0.074
Scales between pectoral and ventral fins	5	4	3–5	7	5–8	0.002 **
Scales around the caudal peduncle	**12**	**12**	**12**	**16**	**16**	**0.000 *** **
Cheek scales	3	3.5	3–4	3.5	3–4	0.491

* Significant (p = 0.010 – 0.050); ** Highly significant (p = 0.001 – 0.009) ; *** Very highly significant (p< 0.001)

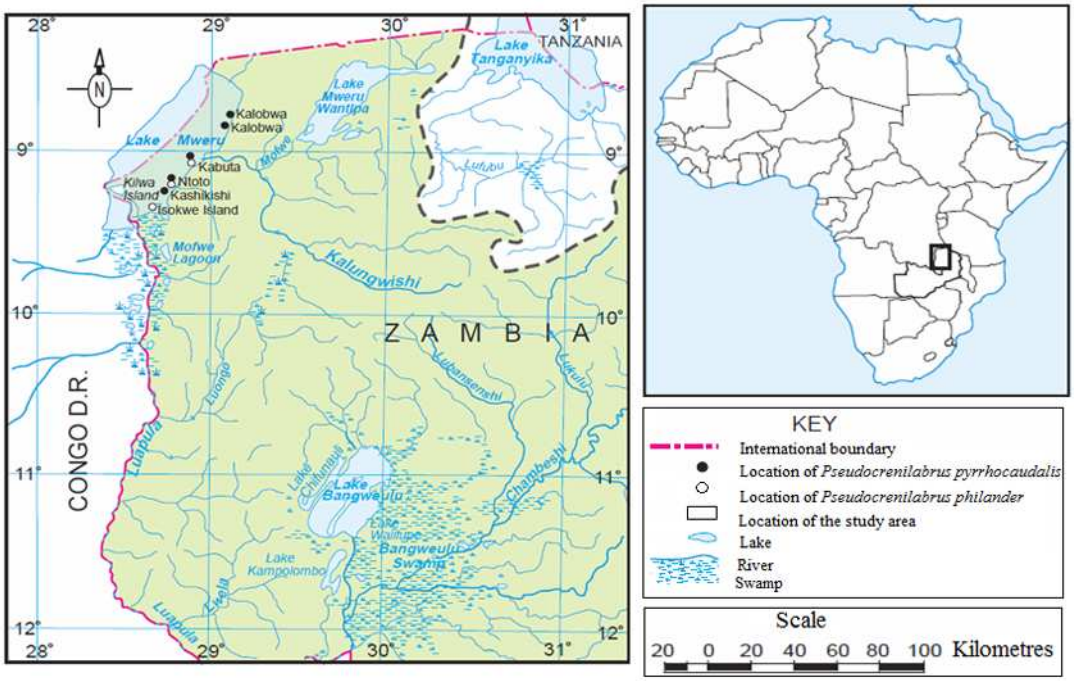


FIGURE 5. Known distribution of *Pseudocrenilabrus pyrrhocaudalis* **sp. nov.** in Lake Mweru and the location of the study area within Africa .

Acknowledgements

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