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Description of a geographically variable elongate rock-dwelling cichlid (Cichliformes: Cichlidae) from Lake Malaŵi, Africa

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Abstract

The rock-dwelling cichlids from Lake Malaŵi, known as mbuna, comprise a diverse group of haplochromine fishes that are placed among 14 genera. Within the mbuna, *Pseudotropheus* is a polyphyletic genus, which has served as a catch-all for many of these fishes. Recently, many of the species-groups within *Pseudotropheus* have been elevated to separate genera. Herein, we describe an elongate form that was originally placed in the *Pseudotropheus elongatus* species group but is now described as a member of *Metriaclima*.

Key words: mbuna, Lake Malaŵi, *Metriaclima*

Introduction

Lake Malaŵi, located in the East African countries of Malaŵi, Tanzania, and Mozambique harbors some 850 species of cichlids (Konings 2016), with only about half of the species described (Stauffer *et al.* 2013). Within this species flock is a diverse group of rock-dwelling cichlids, locally known as mbuna, that include the following genera: *Abactochromis, Chindongo, Cyathochromis, Cynotilapia, Genyochromis, Gephyrochromis, Iodotropheus, Labeotropheus, Labidochromis, Melanochromis, Metriaclima, Petrotilapia, Pseudotropheus,* and *Tropheops* (Trewavas 1935, Oliver & Loiselle 1972, Stauffer *et al.* 1997, Oliver & Arnegard 2010, Li *et al.* 2016). Historically, the genus *Pseudotropheus* Regan—with type species *P. williamsi*—contained many of these mbuna species among which Ribbink *et al.* in 1983 discerned several species groups such as the *P. zebra* species-complex, the *P. tropheops* species-complex, the *P. williamsi* species-complex, and the *P. elongatus* species-group. While the species of the former two complexes are now allocated in their own genus, the *P. elongatus* species-group was thought to be polyphyletic (Ribbink *et al.* 1983). Li *et al.* (2016) began a review of these species which were grouped together solely on the basis of an elongate body and found that this group contained at least four different lineages. They placed previously undescribed forms into *Cynotilapia*, *Metriaclima*, or *Tropheops* and diagnosed the genus *Chindongo* to hold the fourth lineage. Herein, we continue to describe forms of the *P. elongatus* species-group that occur along a 12-km stretch of the northwestern shore of the lake near Chilumba, Malaŵi.

Stauffer *et al.* (1997) diagnosed *Metriaclima*, and this diagnosis was expanded by Konings & Stauffer (2006). Condé & Géry (1999) claimed that *Metriaclima* should be regarded as a junior synonym of *Maylandia* Meyer & Foerster (1984), however, Meyer & Foerster (1984) failed to supply a character in which their subgenus *Maylandia*, defined by its type species *M. greshakei*, is distinct from *Pseudotropheus*. Characters were given for a so-called *zebra* complex but *M. greshakei* was not considered part of that complex. The subgenus was thus not diagnosed according to the requirements of Article 13.1.1 of the Code and was therefore regarded a *nomen nudum* by Stauffer *et al.* (1997) and subsequent authors (Konings & Geerts 1999, Geerts 2002, Stauffer & Kellogg 2002).

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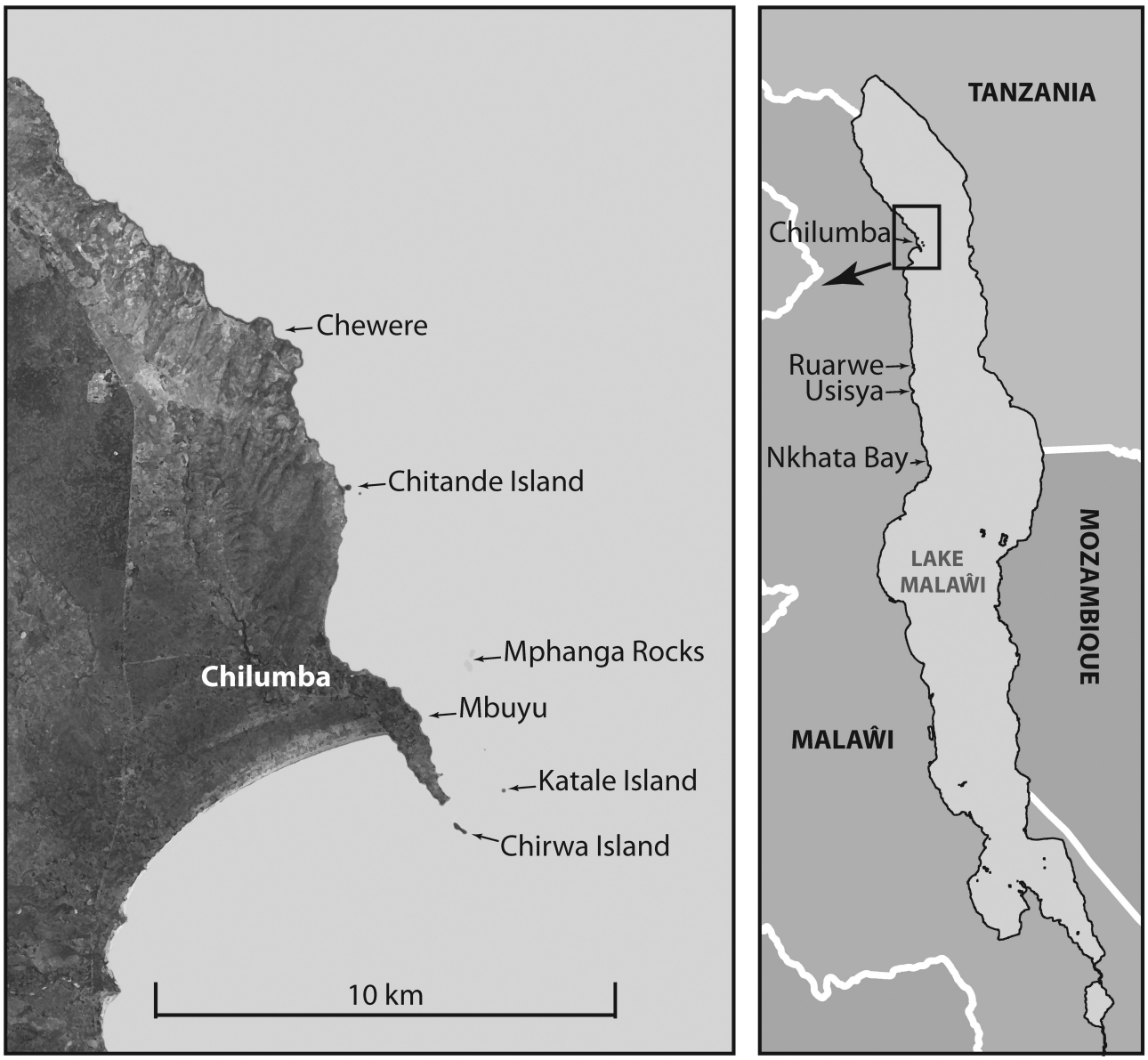

FIGURE 1. Map of Lake Malawi with area of distribution of *M. melissa* enlarged at left.

Methods

Adult fishes were collected in Lake Malawi (Fig. 1) by SCUBA divers who chased individuals into monofilament block nets (7m x 1m; 1.5cm mesh). Permits required for collection of fishes were acquired from the Malawi Department of Fisheries through our contacts (Dr. Wilson Jere) from the Lilongwe University of Agriculture and Natural Resources. Collection and processing of fishes followed methods approved by the Animal Use and Care Committee at the Pennsylvania State University (IACUC #24269). Fishes were anesthetized with clove oil, euthanized in 1% formalin, preserved in 10% formalin, and then placed in 70% ethanol for permanent storage in The Pennsylvania State University Fish Museum (PSUFM).

Color and pigmentation patterns for all individuals were recorded in the field at the time of collection. Variable color patterns were recorded by placing a slash between the two colors between which the specific patterns varied, i.e., blue/white was used to designate that the color ranged from blue to white.

Twenty-four measurements and 14 counts were taken for each individual following Barel *et al.* (1977) and Konings & Stauffer (2006). All counts and measurements were made on the left side of the fish except for gill-raker counts, which were taken on the right side. Morphometric data were taken with digital calipers and measured to

the nearest 0.1 mm. All rays of the pectoral fin were counted, including the small splinter on the upper edge of the fin. Lateral-line scales were counted from the cleithrum to the hypural plate—counts do not include scales in the overlapping portion of the lower and upper lateral lines. Pored lateral-line scales posterior to the hypural plate were counted separately.

Analyses of morphometrics and meristics were conducted using sheared principal component analysis (SPCA) and principal component analysis (PCA) respectively, as described by Humphries *et al.* (1981) and Stauffer *et al.* (1997). Principal components analysis was used to analyze meristic data with the correlation matrix factored. Body-shape differences were analyzed using SPCA with the covariance matrix factored. To illustrate differences in counts and measurements among species, the sheared second principal components of the morphometric data were plotted against the first principal components of the meristic data. The first sheared principal component of the morphometric data accounted for variation of individual size. Similarly, the sheared second principal components explain the remaining variation in shape.

Results

Taxonomic account

***Metriaclima melissa* sp. nov.**
Figures 2–4

Pseudotropheus elongatus 'bee' Ribbink *et al.* (1983)
Pseudotropheus sp. 'elongatus chailosi' Konings (1989)
Pseudotropheus sp. 'elongatus chewere' Konings (1989)

Type material

Holotype. PSU 13377 (Fig. 2), adult male, 60.2 mm, S 10° 23.77' E 034° 15.250', Chitande Island, Lake Malawi, Malawi, Africa, 17 Jan. 2007, A. F. Konings & J. R. Stauffer, Jr.

Paratypes. PSU 2240, 25 specimens 51.1–71.9 mm SL; data as for holotype.

Non-type material. S 10° 26.477' E 034° 16.233', Mbuyu, Lake Malaŵi, Malaŵi, Africa, 21 Jan. 2007, A. F. Konings & J. R. Stauffer, Jr. PSU 2260, 19 specimens 48.2–65.9 mm SL, S 10° 22.022' E 034° 14.551'; Chewere, Lake Malaŵi, Malaŵi, Africa 18 Jan. 2007, A. F. Konings & J. R. Stauffer, Jr. PSU 2178, 22 specimens 49.9–72.9 mm SL.

Diagnosis

The presence of bicuspid teeth in the outer row of both the upper and lower jaws, a swollen ethmo-vomer bloc that is angled between 40–54º with the parasphenoid (Fig. 3), jaws that are about isognathic, and its feeding method (see field observations below) place this species in *Metriaclima*. The black dorsal and ventral margins of the caudal fin distinguish *M. melissa* from other *Metriaclima* except for *M. flavifemina, M. nigrodorsalis, M. usiyae, M. ngarae,* and *M. gallireyae*. The 8–10 bars on the flank of *M. flavifemina* and *M. nigrodorsalis* distinguish *M. melissa* which has 5–7 bars. *M. melissa* has distinct dark bars on the flank while such bars are absent in *M. usisyae* and is further distinguished from this species by a shallower body (28.9–31.7 *vs*. 35.2–40.3 %SL) and a shorter snout (25.3–30.6 *vs*. 32.0–37.6 %HL). A shallower body depth distinguishes *M. melissa* (13.7–19.8 %SL) from *M. ngarae* (37.1–40.1 %SL) and *M. gallireyae* (34.9–43.3 %SL).

Description

Morphometric and meristic data in Table 1. Small-sized mbuna, with greatest body depth at about 6th and 7th dorsal-fin spine. Dorsal body profile with gradual curve downward posterior 8th dorsal-fin spine; ventral body profile

nearly straight between pelvic fins and base of anal fin with slight upward line from anal fin to caudal fin. Dorsal head profile with continuous curve between interorbital and dorsal-fin origin.

FIGURE 2. *Metriaclima melissa*. Holotype, PSU 13377, adult male, 60.1 mm SL, S 10° 23.77' E 034° 15.250', Chitande Island, Lake Malaŵi, Malaŵi, Africa.

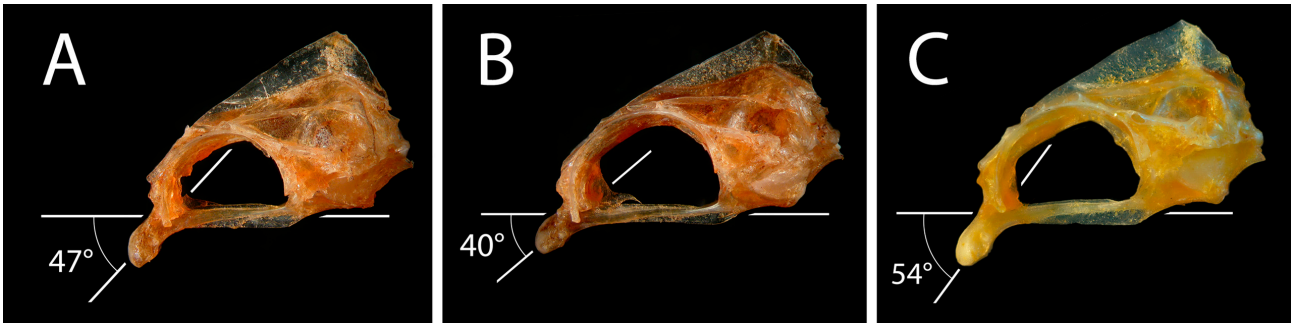

FIGURE 3. Skull of *Metriaclima melissa* from Chitande Island (A), Mbuyu (B), and Chewere (C) showing the swollen rostral tip of the ethmo-vomerine bloc and its angle with the parasphenoid.

TABLE 1. Morphometric and meristic data for paratypes of *Metriaclima melissa* from the type locality Chitande Island (n=26), and for non-type material from Chewere (n=19), and from Mbuyu (n=22), Lake Malaŵi. Ranges for the population from Chitande Island include holotype.

Variable	Holotype			Chitande		Chewere		Mbuyu	
				Min	Max	Min	Max	Min	Max
Standard length (mm)	60.2			51.1	71.9	48.2	65.9	49.9	72.9
Head length (mm)	17.3			15.1	21.4	15.0	19.9	15.4	21.9
Percent head length (%)		Mean	Std Dev						
Snout length	28.8	28.4	1.4	22.6	32.3	24.5	33.2	25.3	30.6
Postorbital head length	44.0	42.0	1.7	40.0	47.8	39.0	46.4	39.7	45.5
Horizontal eye diameter	30.5	32.8	1.8	27.3	35.9	28.7	34.5	30.1	35.7
Vertical eye diameter	29.7	33.2	3.0	26.7	37.2	27.1	35.4	25.8	38.3

...Continued on the next page

TABLE 1. (Continued)

Variable	Holotype			Chitande		Chewere		Mbuyu	
				Min	Max	Min	Max	Min	Max
Interorbital width	27.3	27.8	2.1	24.6	33.5	24.4	36.2	24.0	31.4
Premaxillary pedicel length	22.4	24.6	4.0	18.7	31.8	19.0	29.8	16.9	30.6
Preorbital depth	17.8	18.7	1.7	15.3	21.6	16.8	21.9	16.0	22.8
Cheek depth	24.4	25.7	1.7	22.2	31.4	18.6	30.6	23.2	29.0
Lower jaw length	39.8	38.0	2.2	31.2	43.3	30.2	42.1	33.4	42.8
Head depth	81.9	88.3	4.2	81.9	99.5	82.1	97.5	81.2	99.9
Percent standard length (%)									
Head length	28.8	30.9	0.9	28.3	32.3	29.2	32.4	28.9	32.7
Body depth	27.2	30.3	0.9	26.5	32.0	27.9	31.1	28.9	31.7
Snout to dorsal-fin origin	30.3	32.5	1.3	29.8	33.8	28.9	34.9	29.5	35.6
Snout to pelvic-fin origin	32.7	35.4	1.8	32.7	37.3	33.3	39.5	31.4	38.6
Dorsal-fin base length	64.5	62.5	1.5	57.5	67.4	53.0	66.0	59.0	65.2
Anterior dorsal fin to anterior anal fin	50.6	50.6	1.8	45.7	50.9	46.4	52.3	46.4	53.9
Anterior dorsal fin to posterior anal fin	65.4	64.4	1.5	58.8	67.1	60.2	66.1	61.7	67.1
Posterior dorsal fin to anterior anal fin	30.2	30.9	1.1	28.5	34.1	28.1	35.3	29.0	33.4
Posterior dorsal fin to posterior anal fin	15.4	15.5	0.6	13.4	18.1	12.7	18.9	14.2	16.6
Posterior anal fin to dorsal caudal fin	18.7	20.0	1.4	17.5	22.0	15.5	22.4	16.9	23.4
Posterior dorsal fin to ventral caudal fin	17.1	17.3	0.9	14.3	20.8	13.9	20.0	15.2	19.2
Posterior dorsal fin to pelvic-fin origin	57.3	57.4	1.3	51.7	61.6	54.7	61.4	54.9	60.9
Anterior dorsal fin to pelvic-fin origin	28.7	32.1	1.6	28.7	33.8	28.6	34.8	29.6	35.3
Caudal peduncle length	15.1	15.3	0.8	13.1	18.5	12.2	18.0	13.6	16.7
Least caudal peduncle depth	10.2	11.2	0.8	9.4	13.0	9.9	11.9	9.1	12.3
Meristics		mode	%freq						
Dorsal-fin spines	18	18	49.3	17	19	16	18	17	18
Dorsal-fin rays	9	9	63.8	8	10	8	10	8	10
Anal-fin spines	3	3	100	3	3	3	3	3	3
Anal-fin rays	8	8	75.4	7	9	7	9	8	9
Pectoral-fin rays	13	13	84.1	13	14	13	14	13	14
Pelvic-fin rays	5	5	100	5	5	5	5	5	5
Lateral-line scales	32	32	59.4	31	33	31	33	31	33
Pored scales posterior to hypural plate	1	1	50.7	1	2	1	2	1	2
Cheek scale rows	4	4	76.8	4	4	3	4	4	4
Gill rakers 1st ceratobranchial (lower)	14	13	33.3	11	14	11	15	10	14
Gil rakers 1st epibranchial (upper)	3	3	84.1	3	3	2	4	3	4
Teeth in outer row of left lower jaw	11	11	44.9	10	13	10	12	9	12
Tooth rows upper jaw	3	3	100	3	3	3	3	3	3
Tooth rows lower jaw	3	3	100	3	3	3	3	3	3

Mouth wide with both upper and lower jaw broadly rounded. Teeth in upper and lower jaws in 3 rows with only outer row extending onto lateral arm, premaxilla, and dentary; teeth in outer row bicuspid anteriorly becoming unicuspid in main lateroposterior dentigerous area; inner rows tricuspid or unicuspid in innermost row. Dorsal fin with XVI or XVIII (mode XVII) spines and 8–10 (mode 9) rays. Anal fin with III spines and 8–9 (mode 8) rays. First 5–6 dorsal-fin spines gradually longer posteriorly. Anal fin spines progressively longer posteriorly; 4th or 5th

anal-fin ray longest. Caudal fin weakly emarginate, covered with 2–4 rows of minute scales. Length of pectoral fin to 12–13th dorsal-fin spine. Flank scales ctenoid with abrupt change to small scales on breast and belly; 31–33 lateral-line scales with 1–2 pored scales posterior to hypural plate; cheek with 4 rows of scales.

FIGURE 4. A male *Metriaclima melissa* at the type locality Chitande Island, Lake Malaŵi, Malaŵi, Africa.

FIGURE 5. A male *Metriaclima melissa* at Mbuyu (A), at Chewere (B), and at Chirwa Island (C). A female *M. melissa* at Chewere (D), Lake Malaŵi, Malaŵi, Africa.

Coloration; population at Chitande Island. Head of male black with two light blue interorbital bars (Fig. 4); blue opercle spot with blue highlights; yellow gular with melanophores. Flank bright yellow; five dark brown/black bars followed by two fainter bars; breast black; belly gray; caudal peduncle yellow. Dorsal fin with yellow lappets; spinous portion dorsal fin dark brown/black with 2–3 yellow patches; posterior half rayed portion yellow/brown with blue spots. Dorsal and ventral three rays and membranes of caudal fin black with thin white upper and light blue lower margin; interior rays black with yellow and blue membranes. Anal fin dark gray to black with narrow light blue margin, gray/light blue posterior 5th ray with 1–3 yellow/orange ocelli; Pectoral fin clear. Pelvic fin black with light blue leading edge.

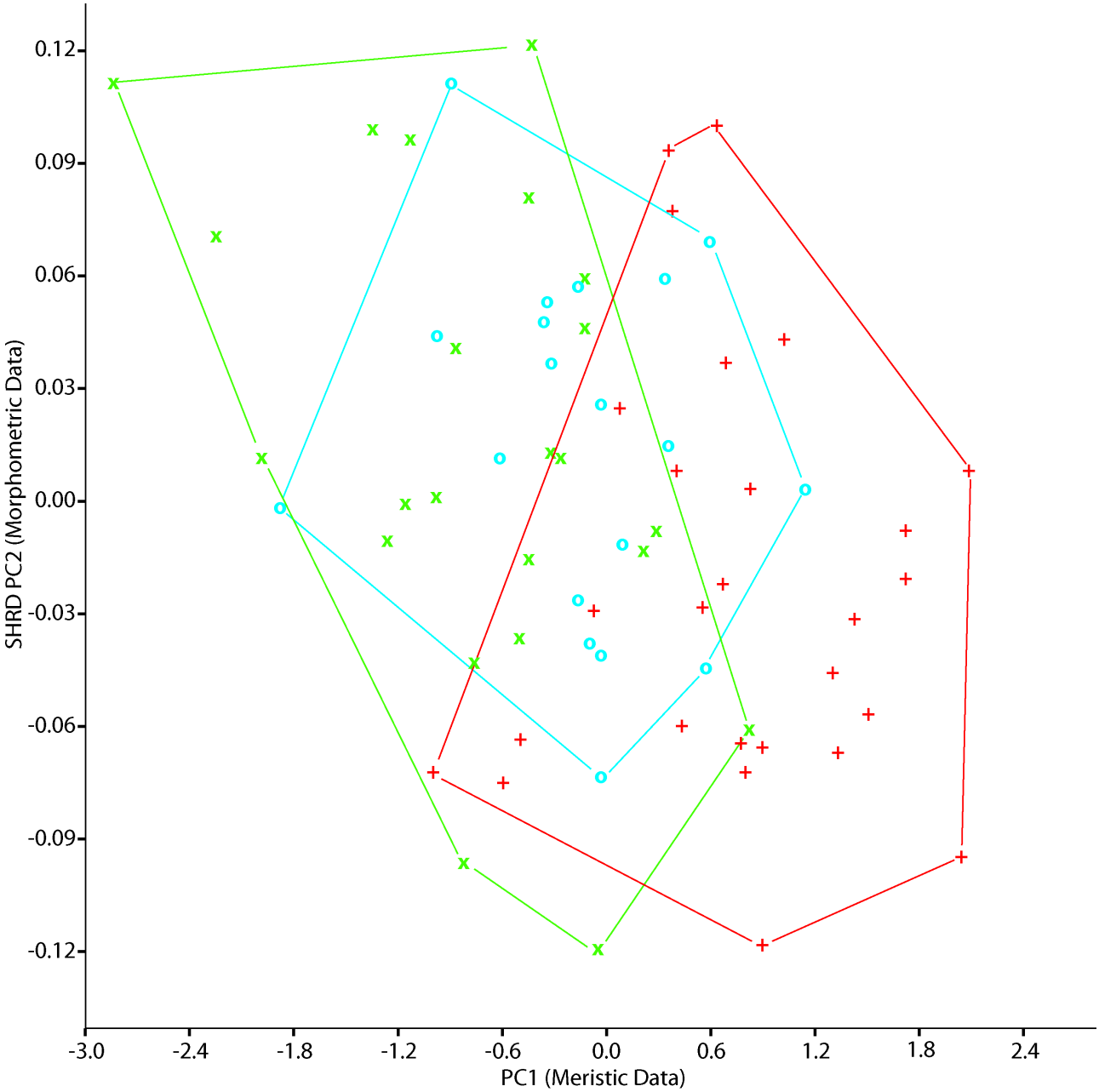

FIGURE 6. Plot of the second sheared principal components of the morphometric data (SHRD PC2) of the morphometric data and the first principal components of the meristic data (PC1) for three populations of *Metriaclima melissa* (blue: Chitande o; red: Mbuyu +; and green: Chewere x).

Head of female brown with white and green highlights on opercle; gular brown. Flank light brown with blue bordered scales; brown breast; light brown belly. Dorsal fin light brown with black submarginal band; white to yellow lappets. Dorsal and ventral two rays of caudal fin black; interior rays brown with clear membranes. Anal fin

with broad black band distally and clear/gray proximally with 1–3 small yellow ocelli; Pectoral fin with gray rays and clear membranes. Spine and first ray of pelvic fin black with white leading edge; remainder clear.

Population at Mbuyu. Head of male gray/green with two blue interorbital bars (Fig. 5A); dorsal ¼ of preopercle and opercle light blue; light blue opercle spot with light blue highlights; yellow gular with melanophores. Ventral third flank yellow/brown anterior to anal fin; dorsal flank light blue with 6–7 gray bars; caudal peduncle light blue/yellow; breast brown; belly light gray; yellow spot posterior base pectoral. Dorsal fin yellow with brown bar extensions sometimes covering entire spinous part; with thin light blue submarginal band and yellow lappets; posterior five rays yellow with blue membranes. Dorsal and ventral two rays and membranes of caudal fin black; interior rays yellow with clear membranes. Anal fin proximally gray fading to black with 2–4 yellow/orange ocelli. Pectoral fin clear. Pelvic fin with white leading edge, brown/yellow anteriorly to clear posteriorly.

Head of female gray/brown; two light gray interorbital bars; gular light gray; black opercle spot with green highlights. Scales on upper 2/3rd flank light brown with light blue border; ventral 1/3rd light brown; 5–6 gray rays extending 2/3rd of body; light gray breast and belly. Dorsal fin gray with yellow marks on membranes and yellow lappets. Dorsal and ventral two rays of caudal fin black; interior rays yellow with blue membranes. Anal fin gray/brown with 1–2 small yellow ocelli. Pectoral fin clear. Spine and first ray of pelvic fin black; remainder brown to clear.

Population at Chewere. Head of male black/brown with black gular; light blue patches on opercle and preopercle (Fig. 5B). Flank light blue with five broad black bars laterally but united on both dorsal and ventral part flank with 4–5 light blue ovals mid-flank between bars; caudal peduncle light blue with ventral quarter black continuous with ventral black margin caudal fin; breast dark brown/black with brown belly. Dorsal fin black/dark brown with blue/white lappets over spinous portion and yellow/brown lappets over rayed portion; posterior five rays yellow with blue membranes. Dorsal 2–3 rays and ventral 3–5 rays and membranes of caudal fin black; interior rays yellow/brown with light blue membranes with brown spots; upper and lower edge caudal light blue. Anal fin black anteriorly to brown posteriorly with posterior three rays yellow with blue membranes; 1–3 yellow ocelli. Pectoral fin with gray rays and clear membranes. Pelvic fin with light blue leading edge, black rays, and clear membranes.

Head of female brown. Flank beige/light blue with five gray bars; ventral 1/3rd gray; caudal peduncle gray (Fig. 5D). Dorsal fin gray with black submarginal bar and white/yellow lappets. Dorsal and ventral two rays of caudal fin black; interior rays brown with clear membranes and brown spots. Anal fin dark brown with 1–2 brown ocelli. Pectoral fins clear. Spine and first ray of pelvic fin black with white leading edge; remainder clear.

Distribution

The type material of *Metriaclima melissa* was collected from Chitande Island (S 10° 23.77’ E 034° 15.250’), on submerged reefs near Mbuyu (S 10° 26.477’ E 034° 16.233’) and near Chewere (S 10° 22.022’ E 034° 14.551’), Lake Malaŵi, Malaŵi, Africa. The species was also encountered on a reef in Chilumba Bay (S 10° 25.844’ E 034° 15.738’), at Katale Island (S 10° 27.312’ E 34° 17.143’), and at Chirwa Island (S 10° 27.789’ E 034° 16.536’) (Fig. 5C).

Field observations

Metriaclima melissa occurs in an intermediate habitat which consists of a mixture of rocks and sand at a depth of 5–40 m. Non-breeding individuals normally occurred in the shallower part of the range. It feeds from plankton and from Aufwuchs on the rocks in the habitat. Individuals of all populations have been observed combing algae from the Aufwuchs in a manner typical of *Metriaclima* species (Konings & Stauffer 2006), i.e., perpendicular to the substrate. Juveniles and non-breeding female occur in small groups while feeding from the algal matrix on the rocks. Males are territorial and usually occur in deeper (10–30 m) areas that comprise mostly of sand with some scattered rocks. They defend a spawning site burrowed alongside or beneath a, usually isolated, rock. Mouthbrooding females hide in the rockier part of the habitat and usually are solitary. Fry-guarding females have not been encountered and the brood is probably abandoned once expelled from the female’s mouth.

Etymology. The specific epithet *melissa,* the Greek word for bee, is a noun in apposition and it alludes to the bee-like coloration of adult males at the type locality, Chitande Island.

Remarks

When the morphometric and meristic data for the three populations of *M. melissa* were compared, the first principal components (size) explained 77.4% of the observed variance, and the sheared second principal component explained 4.3%. Variables that had the highest loadings on the sheared second principal components were premaxillary pedicel length (0.77), distance between the posterior anal fin and the dorsal caudal fin (-0.34), and the preorbital depth (0.24). The first principal components of the meristic data explained 20.0% of the variance. Variables with the highest loading on the first principal components of the meristic data were dorsal-fin rays (0.42), anal-fin rays (0.39), and number of rows of cheek scales (0.36). A plot of the second sheared principal component of the morphometric data and the first principal component of the meristic data (Fig. 6) showed that the clusters of the three populations examined largely overlapped.

Discussion

Historically, *Pseudotropheus* was a catch-all genus for many species of rock-dwelling cichlids (mbuna) in Lake Malaŵi. Currently, it still is a polyphyletic group with only two described species closely associated with the type species *P. williamsi*, i.e. *P. brevis* Trewavas and *P. galanos* Stauffer and Kellogg. When Ribbink *et al.* (1983) introduced the *P. elongatus* species group they included 24 forms of which 23 had not formally been described. They assumed that an elongate mbuna at Nkhata Bay represented *P. elongatus* Fryer, but it later turned out that also that species had not been described (Konings 1995). Thus, of the 24 undescribed forms reported by Ribbink *et al.* (1983), nine have now formally been described (Stauffer 1988, Li *et al.* 2016) while a tenth species, *Pseudotropheus elongatus* 'bar', had been described earlier as *P. modestus* (Johnson 1974). The mbuna Ribbink *et al.* (1983) referred to as *Pseudotropheus elongatus* 'bee' turned out to be comprised of two species, one of which, *Metriaclima usisyae*, was described by Li *et al.* in 2016. The other form is here described as *M. melissa*. For distribution Ribbink *et al.* (1983) give Chitande Island and Mara Rocks and refer to a photo (1983:219 plate 7g) that was purportedly taken at Ruarwe. We have never found a species similar to *M. melissa* or *M. usisyae* at Ruarwe or at any other site between Usisya and Chirwa Island and believe the locality is in error. The species in the photograph is *M. melissa* and may have been taken at Chilumba instead of Ruarwe. When we compared the morphometric and meristic data for *M. melissa* with those of *M. usisyae* we found a wide separation of the two species' clusters in a plot of the second sheared principal component of the morphometric data and the first principal component of the meristic data. Morphologically the two species can easily be distinguished by a shallower body, a shorter snout, and a longer lower jaw in *M. melissa* compared to *M. usisyae*.

Initially we anticipated to describe each of the three populations as different species as they had been treated as such for a long time (Konings 1995) based on the male breeding coloration. We failed to find any morphological features, however, that could distinguish the three populations (Fig. 6). Since these are neighboring populations, we believe we need an additional characteristic besides differing male coloration to accept them as separate species instead of geographical variants of *M. melissa*. The same conclusion was reached by Bowers and Stauffer (1993) when describing *Melanochromis heteropictus*, by Stauffer *et al.* (1997) when examining allopatric populations of *Metriaclima zebra*, and by Konings and Stauffer (2006) when describing *Metriaclima flavifemina*.

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