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DESCRIPTIONS OF FIVE NEW SPECIES IN THE GENUS *METRIACLIMA* (TELEOSTEI: CICHLIDAE) FROM LAKE MALAŴI, AFRICA

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ABSTRACT

Lake Malaŵi supports an enormous diversity of cichlid species, many of which lack formal descriptions. Five new species of rock-dwelling cichlids from the lake are described. The moderately-sloped vomer, isognathous jaws, and presence of bicuspid teeth in the outer rows of the jaws, among a suite of other morphological characters, place these species in the genus *Metriaclima*. All five species are part of the *M. aurora*-species complex, based on the absence of a black band in the dorsal fin which is congruent with the ecologically similar species *M. aurora* (Burgess). Differences in morphology in conjunction with assortative mating distinguish these new species from each other and previously described species of the *M. aurora*-complex.

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1. INTRODUCTION

The Great Lakes of eastern Africa (Victoria, Tanganyika, and Malaŵi) are home to a large number of species within the family Cichlidae. In Lake Malaŵi alone, there are an estimated 850 species of cichlid fishes (Konings, 2001; Stauffer *et al.*, 2007). Specializations in the jaw structure of cichlids have enabled species to exploit a wide variety of food items leading to trophic specializations and eventually to the great species diversities observed in the lake (Liem, 1979; Stauffer *et al.*, 2006). The speciation of Lake Malaŵi cichlids has been rapid and extensive, with species in the lake arising within the past 100,000 years (Cohen *et al.*, 2007).

The cichlid fishes of the world have been the focus of a vast amount of ecological, behavioral, and evolutionary research due to their remarkably explosive speciation, diverse feeding and mating systems, and global importance in aquaculture (Fryer and Iles, 1972; Stauffer and McKaye, 2001). Studies on the cichlids have often been difficult, however, due to taxonomic uncertainty resulting from a lack of species descriptions for fishes that inhabit all of the African Great Lakes. Environmental pressure from humans and the high inter-lake, with over 99% of species endemic to Lake Malaŵi, and intra-lake endemism (in many cases species are found only at single rock outcroppings) contribute to the vulnerability of the African cichlid species and the need to describe them (Fryer and Iles, 1972; Ribbink *et al.*, 1983; Stauffer *et al.*, 1997). In Lake Victoria, the introduction of the Nile Perch, among other human factors, has lead to the extinction of many cichlid species that were never formally described (Kaufman, 1992; Stauffer and

McKaye, 2001). Such a scenario could be duplicated in Lake Malaŵi with the human population having greater impacts on the environment. A strong motivation thus exists to provide accurate species descriptions and life history accounts of the cichlids of Lake Malaŵi.

In describing and discriminating among new species of organisms, morphological, genetic, and behavioral techniques may be used. Morphology is perhaps the oldest of these tools for systematists, but it still plays an important role today in examining and describing species (Stauffer, 1991; Stauffer *et al.,* 1997; Stauffer and Kellogg, 2002; Collyer *et al.*, 2005). Multivariate morphometric and meristic analyses are useful in examining the inter- and intra-population differences in body form among species of fishes (Humphries *et al.*, 1981; Reyment *et al.*, 1984; Bookstein *et al.*, 1985). Different cichlid species may be morphologically similar, potentially confounding attempts to diagnose different species on morphological characters alone (Stauffer and Van Snik, 1996; Stauffer and McKaye, 2001). Parallel evolution may lead to similar phenotypes within the lake and an examination of morphological characters alone would in some cases fail to detect potentially different species (Kocher *et al.*, 1993).

Genetic techniques are playing a major role in the contemporary research of the evolution and systematics of cichlids (Kocher *et al.,* 1998; Gerrard and Meyer, 2007; Verburg and Bills, 2007). The use of genetics in determining cichlid species has been difficult due to the low genetic divergence as a result of the recent radiation of African cichlids, however (Stauffer *et al.*, 2006). Advances in genetic techniques will further aid evolutionary research, but cichlid taxonomists must rely on morphological and, more recently, behavioral studies to develop correct species descriptions and resolve the questions involved in African cichlid evolution (Stauffer *et al.*, 2002; Kidd *et al.*, 2006).

Assortative mating based on differences in male color and courtship behaviors has proven to be a useful tool in discriminating among different cichlid species (Stauffer *et al.*, 1993; Van Oppen *et al.*, 1998). Unique color patterns among cichlids are now recognized to be sufficient to diagnose valid species (Barlow, 1974; Barel *et al.*, 1977; Stauffer *et al.*, 1995). Even slight coloration differences can suggest different species; however, incorrect species delineations may arise when determining whether geographically distinct populations that differ in color are unique species or different color forms of the same species. Color differences alone may be insufficient in describing new species if populations are similar in behavior, ecology, and morphology, but the descriptions of many species have been corroborated through observations of assortative mating based on color (Holzberg, 1978; Lewis, 1982) and on scent (Plenderleith *et al.*, 2005). Diagnoses based on color become problematic when differences in shape are not detected however (Bowers and Stauffer, 1993). In this thesis, the combination of morphological characters that could indicate different evolutionary lineages and male color differences driving female preference and assortative mating is used to discriminate among species.

Lake Malaŵi cichlids are divided into two major groups; the tilapiines and the highly diverse haplochromines (Stauffer *et al.*, 2006). Included in the haplochromines is the mbuna, or rock-dwelling cichlids of Lake Malaŵi. Twelve closely related genera comprise the mbuna: *Cyathochromis*, *Cynotilapia*, *Genyochromis*, *Gephyrochromis*, *Iodotropheus*, *Labeotropheus*, *Labidochromis*, *Melanochromis*, *Petrotilapia*, *Pseudotropheus*, *Tropheops*, and the most recently described *Metriaclima*, all of which are characterized by a large number of smaller scales on the nape and chest, a reduction of the left ovary, presence of true ocelli on the anal fin, and unique coloration (Stauffer *et al.*, 1997; Genner and Turner, 2005). The mbuna cichlids exhibit a high amount of intra-lake endemism, with some species found on single rock outcroppings, and are thus a target of study for evolutionary biologists and taxonomists (Stauffer *et al.*, 1997).

The genus *Metriaclima*, which contains 40-50 species, differs from the other mbuna genera in a variety of morphological characters, as described by Stauffer *et al.* (1997) and Konings and Stauffer (2006), most of which are observed in the mouth parts. Species of *Metriaclima* have bicuspid teeth in the anterior portions of the outer rows of the jaws, in contrast to the unicuspid, tricuspid, and other tooth shapes found in several of the other mbuna genera. The jaws of *Metriaclima* are isognathous and the mouth is terminal, differentiating the genus from *Genyochromis* and *Labeotropheus*, respectively. *Metriaclima* species lack the two horizontal stripes observed in the genus *Melanochromis*. Species described in the genus *Metriaclima* were previously grouped in the genus *Pseudotropheus*; however the presence of a moderately sloped ethmo-vomerine block and a swollen rostral tip were synapomorphies that were used to diagnose *Metriaclima* (Stauffer *et al.*, 1997). Other diagnostic characters include: lower jaw often slightly longer and thicker than upper jaw; large part of upper dental arcade normally exposed when the mouth is closed; tips of teeth in the premaxilla and dentary in a V-shaped line with the anteriormost in upper and lower jaw furthest apart; and the placement of the bicuspid teeth in the outer row along the side of the jaws does not follow the contour of the jaw bone. The lateral teeth are rotated so that the plane of their two prolonged tips runs parallel with those in the anterior part of the jaw. The genus is further diagnosed by behavior. It feeds at a perpendicular angle to the substrate and is able to align the teeth of both upper and lower jaws in the same plane by abducting its jaws to a near 180° angle. Numerous bites follow in rapid succession and loose algae and diatoms are extracted without the algal matrix being torn from the substrate (Konings and Stauffer, 2006).

Metriaclima aurora was originally described in the genus *Pseudotropheus* and was earlier considered representing *Pseudotropheus lucerna*. Unlike *P. lucerna*, the teeth rows in *Metriaclima aurora* are curved rather than straight and the eyes tend to be smaller (although larger than in many other mbuna) (Burgess, 1976). The species is native to Likoma Island and several localities in northern and central Mozambique. An introduced population exists along Cape Maclear after an initial transplantation to Thumbi West Island (Trendall, 1988; Stauffer and Hert, 1992; Konings, 2001). *Metriaclima aurora* inhabits the areas around boulder and rock surfaces and the rocky/sand interfaces, typically at depths between 2-5 m but as deep as 20 m, feeding on plankton in the substrate and occasionally in the water column (Ribbink *et al*., 1983; Hert, 1990). *Metriaclima aurora* forms the basis for the informal *aurora*-group species of the genus discussed throughout this thesis. The *aurora*-group cichlids lack a black band in the dorsal fin and are less prominently barred than other *Metriaclima* species. Females of the group are generally lighter in color than those of the black dorsal group of species (Konings, personal communication), another informal grouping within *Metriaclima*. Cichlid species similar in color pattern to *M. aurora* that are found at the rocky/sand transition zones are classified as *aurora*-group species (Konings, 2001).

The purpose of this thesis is to formally describe five new *aurora*-group species from Lake Malaŵi by examining the color and morphology of the following populations: *Metriaclima aurora* from Likoma Island (12^{0} 00.742’ S 34^{o}37.110’ E), Mara Point North (12°11.254’ S 34°41.968’ E), Tumbi Point (12°20.297’ S 34°41.853’ E), Mbweca Rocks (12^{o} 17.513’ S 34^{o} 42.392’ E), N’kolongwe (12°47.671’ S 34°47.159’ E), and West Thumbi Island (14^{o} 01.528’ S 34^{o} 49.388’ E); *M*. sp. “aurora blue” from Cobwe (12°08.243’ S 34°45.391’ E); *M*. sp. “blue reef” from Nkhungu (12^{o} 58.801’ S 34^{o} 45.837’ E); *M. chrysomallos* from Gome (12°13.30744’ S 34°52.021’ E) and Nametumbwe (13^{o} 37.001’ S 34^{o} 55.385’ E); *M*. sp. “aurora black tail” from Chiloelo (13°12.541’ S 34°48.523’ E); *M*. sp. “aurora yellow” from Lumessi (13°08.196’ S 34°47.844’ E); *M*. sp. “aurora chinumi” from Chinumi (13°03.753’ S 34°47.909’ E); *M*. Sp. “aurora lumbaulo” from Lumbaulo (11°54.024’ S 34°54.307’ E); *M*. sp. “aurora north” from Makonde (09°56.862’ S 34°27.296’ E), Magunga (10°19.344’ S 34°34.849’ E), and Ngwazi (10°10.490’ S 34°32.927’ E) (Figs. 1A-1C).

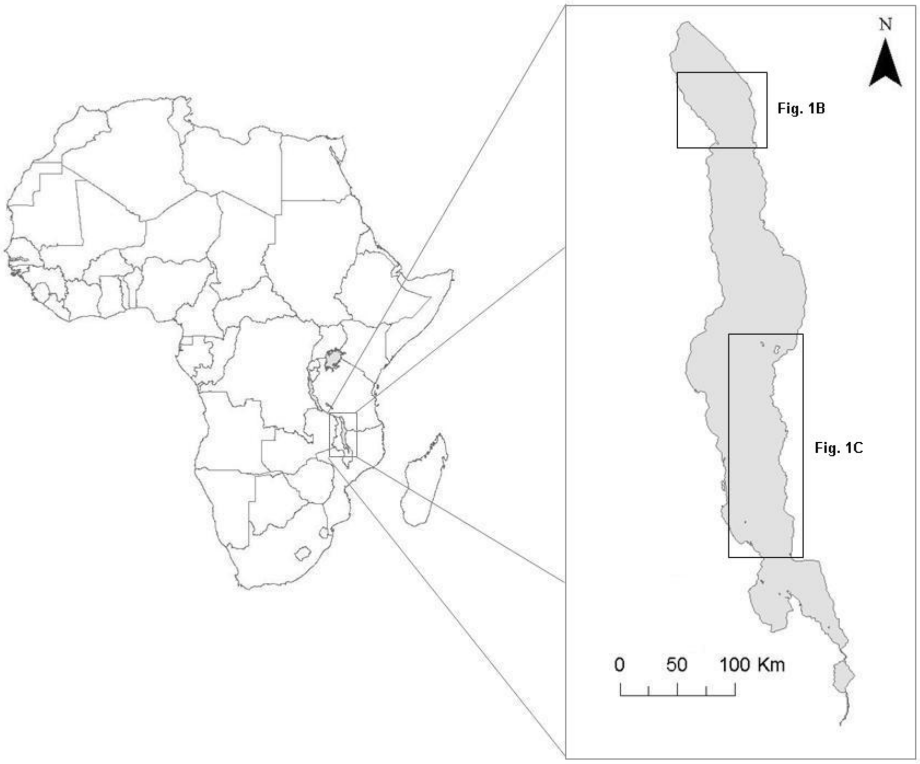

Fig. 1A. Africa and Lake Malaŵi.

Fig. 1B. Locations of populations in Tanzania.

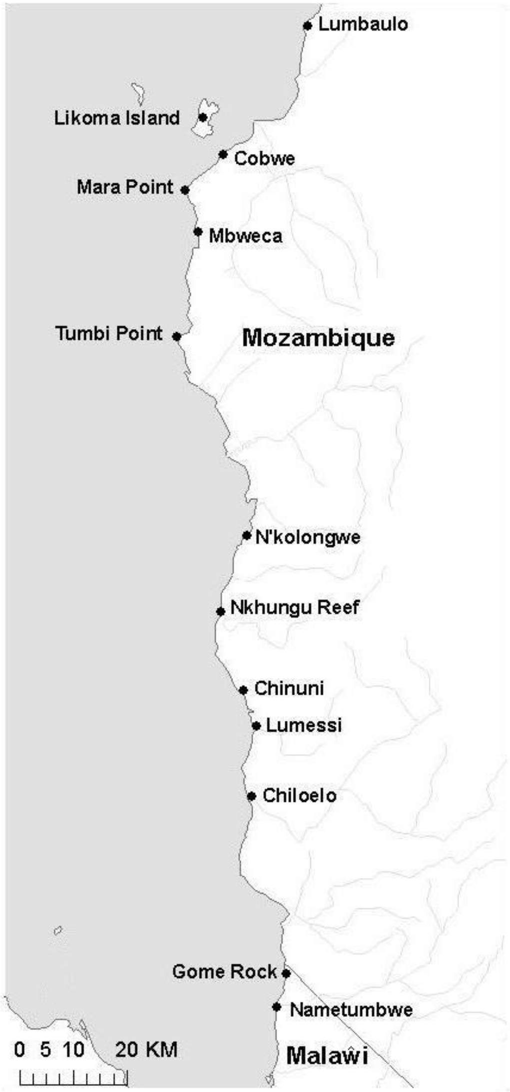

Fig. 1C. Locations of populations in Mozambique and Malaŵi.

2. METHODS

Prior to describing a new species, the species concepts used need to be defined. The Evolutionary Species Concept (ESC) defines a species as “a single lineage of ancestral descendant populations of organisms which maintains its identity from other such lineages and which has its own evolutionary tendencies and historical fate” (Wiley, 1978:18), and does not prevent the recognition of some populations, or lineages, as species because of operational constraints (Mayden, 2002). The ESC is advocated in diagnosing the new species discussed throughout as it is the only species concept that theoretically applies to all organisms (e.g., asexual, allopatric) (Stauffer *et al.*, 1997). This concept, however, is not operational in itself, and as a result surrogate species concepts, such as the biological species concept, must be utilized under the theoretical framework of the ESC (Stauffer and McKaye, 2001). The biological species concept defines a species as a group of reproductively isolated populations that interbreed only with members of the same group (Mayr and Ashlock, 1991). One of the main issues with the biological species concept is that it does not apply to unisexual organisms; however, as cichlids are sexually reproducing organisms, the biological species concept is valid for sympatric populations (Stauffer and McKaye, 2001; Wägele, 2001). To diagnose reproductive isolation between the cichlid populations discussed throughout, differences in male breeding color were examined under the proposal that species assortatively mate based on color cues to at least some degree. Color differences alone, however, may be insufficient in diagnosing different species, specifically if a species is variable in color. Morphological comparisons of the populations in question are made to address this potential problem. Traditionally, an examination of morphological traits was used by taxonomists to differentiate groups that differ morphologically as separate species. True biological species may share identical or very similar morphological characters, lending to 1) an under estimation of the number of species based on using these morphological analyses alone and 2) a greater emphasis on the need for the use of the biological species concept (Mayr, 2000). Therefore, a combination of biological and morphological species concepts is used as a surrogate to the ESC, where unique colorations are potentially indicative of reproduction isolation and morphological differences are used to delimit unique evolutionary lineages (Stauffer and McKaye, 2001). Populations that differ in coloration and morphology are thus considered separate species, if there are clear breaks in these characters when many populations exist (Stauffer *et al.*, 1997).

Fishes were collected while SCUBA diving, using monofilament nets for capture. For each population collected, the coloration of the brightest male was recorded. Variation in the color of other males was noted, and added to the description of the brightest male to provide a detailed color description of the males for each population. Color descriptions were conducted by Jay Stauffer and corroborated with underwater photographs by Ad Konings (2001), and interpreted here (Jay Stauffer, personal communication). Fishes were then anesthetized with clove oil, fins were pinned so that they were all erect, preserved in 10% formalin, and later transferred into 70% ethanol for permanent storage.

External measurements were made with digital calipers. All counts and measurements were made on the left side of the fish, with the exception of gill-raker counts, and follow Barel *et al.* (1977), Stauffer (1991), and Konings and Stauffer (2006). The posterior simple ray of the anal fin, if present, was not counted if it was preceded by another simple ray, because it shared the same pterygiophore. If the last simple ray was preceded by a branched ray, both were counted as separate rays (Stauffer, 1994). Pored scales in the same transverse columns of the upper and lower lateral lines were not counted. In the pectoral fin, all rays were counted including the small splinter on the upper edge. A list of measurements and counts is presented in Table 1.

The mean, standard deviation, and range, of the morphometric data and the mode, frequency, and range of the meristic data are presented for each species or population in question. For the measurement data, ratios were calculated with either head length or standard length, depending on the measurement of interest. The use of ratios in systematics has been criticized, but remains useful in examining general differences in anatomical shape and in creating artificial dichotomous keys (Boltz, 1988).

To examine differences in body shape, sheared principal component analysis of the morphometric data was used in which the covariance matrix was factored (Humphries *et al.*, 1981; Bookstein *et al.*, 1985). Principal component analysis restructures the correlated variables into smaller sets of components, which are related but uncorrelated, and is useful here for a variety of reasons. First, principal component analysis accounts for the multicollinearity that is observed in the morphometric data and eliminates the redundancy of separate univariate analyses for each measurement. Additionally, no *a priori* grouping is necessary for the data, allowing for the identification of patterns in the set (Reyment *et al.*, 1984; Iezzoni and Pritts, 1991). Specifically, color is not inputted into the principal component analysis because there would be a total difference between the populations, biasing the morphometric and meristic data. A population in which the males varied in color patterns, however was weighted differently from a population where males were all the same color pattern when determining whether populations are con- or heterospecific. Shearing in principal component analysis eliminates variation due to size. In the shear, the morphometric data are $\log_{10}$ transformed and the covariance matrix is used to compute the first and second principal components. The first component explains all the variation due to size. This second component is a linear combination made of coefficients equal to the partial covariance and is only related to shape (Humphries *et al.*, 1981; Bookstein *et al.*, 1985; Boltz, 1988). The meristic data were analyzed through a principal component analysis, in which the correlation matrix was used. To illustrate differences among species and/or populations, the first principal components (meristic data) were plotted against the sheared second or third principal components (morphometric data). If there was no overlap in the minimum polygons formed, the groups were considered significantly different. If the minimum polygon plots overlapped, an ANOVA was run for the sheared principal component axis of the morphometric data and the first principal component axis of the meristic data to determine if the clusters were significantly different along one axis, independent of the other. If the minimum polygon clusters did not differ along one axis, independent of the other, a MANOVA in conjunction with a Hotelling-Lawley trace was conducted to determine if the clusters were significantly different. Additionally, a Duncan's Multiple Range Test was used to determine differences among the clusters of 3 or more groups if mean multivariate scores were significantly different along one axis independent of the other (Stauffer *et al.*, 1997).

Table 1. List of measurements (morphometrics) and counts (meristics). Abbreviations, when applicable, are in parentheses.

Measurements
Standard length
Head length
Snout length
Postorbital length
Horizontal eye diameter
Vertical eye diameter
Preorbital depth
Cheek depth
Lower-jaw length
Head depth
Body depth
Snout to dorsal-fin origin
Snout to pelvic-fin origin
Dorsal-fin base length
Anterior dorsal to anterior anal (ADAA)
Anterior dorsal to posterior anal (ADPA)
Posterior dorsal to anterior anal (PDAA)
Posterior dorsal to posterior anal (PDPA)
Posterior dorsal to ventral caudal (PDVC)
Posterior anal to dorsal caudal (PADC)
Anterior dorsal to pelvic-fin origin (ADP2)
Posterior dorsal to pelvic-fin origin (PDP2)
Caudal-peduncle length
Least caudal-peduncle depth
Counts
Dorsal-fin spines
Dorsal-fin rays
Anal-fin spines
Anal-fin rays
Pelvic-fin rays
Pectoral-fin rays
Lateral-line scales
Pored scales posterior to lateral line
Scale rows on cheek
Gill rakers on first ceratobranchial
Gill rakers on first epibranchial
Teeth in outer row of left lower jaw
Teeth rows on upper jaw
Teeth rows on lower jaw

3. RESULTS

3.1 ***Metriaclima aurora*** Burgess

Diagnosis.- The following characters place this species in the genus *Metriaclima*: moderately sloped head; isognathous jaws; presence of bicuspid teeth in the outer row along the side of the jaws that do not follow the contour of the jaw bone; lower jaw often slightly longer and thicker than upper jaw; large part of upper dental arcade normally exposed when the mouth is closed; tips of teeth in the premaxilla and dentary in a V-shaped line with the anteriormost in upper and lower jaw furthest apart; lateral teeth are rotated so that the plane of their two prolonged tips runs parallel with those in the anterior part of the jaw; feeding at a perpendicular angle to the substrate and has ability to align the teeth of both upper and lower jaws in the same plane by abducting its jaws to a near 180° angle (Konings and Stauffer, 2006). *Metriaclima aurora* is distinguished from most other members of the *aurora*-group based on the blue males that have the ventral half to third of the head and breast yellow with dark blue or brown barring laterally. Other species similar in color include some populations of *M. chrysomallos*, where males have a blue rather than a yellow dorsal fin, *M. xanthos* n. sp., of which specimens have a longer lower-jaw length, expressed as percent head length, (mean 35.4, range 34.6-36.7; Table 20) than *M. aurora* (mean 31.2, range 28.4-33.5; Table 2), and *Metriaclima mossambiquensis* n. sp. from Lumessi, of which specimens have a generally larger head depth, expressed as percent head length (mean 96.0, range 83.3-111.8; Table 27) compared to *M. aurora* (mean 86.8, range 75.8-95.4; Table 2).

Description.- Jaws isognathous; teeth on jaws in 3-4 rows; outer row teeth typically bicuspid anteriorly and unicuspid posteriorly; those in inner rows tricuspid, if fourth row present usually unicuspid; 12-26 teeth in outer row of left lower jaw. Dorsal fin with 17-19 spines and 8-10 rays. Pectoral fins with 13-15 rays; anal fin with 3 spines (sometimes 4 in certain populations) and 7-8 rays. Lateral scales ctenoid; 29-33 lateral-line scales. First gill arch with 10-14 rakers on ceratobranchial, 2-5 on epibranchial, and 1 between epibranchial and ceratobranchial (Table 2).

Lateral body coloration of breeding males blue dorsally, with anterior portion of scales dark blue and as many as 7 faint blue bars; caudal peduncle dark blue; yellow belly and breast fading to blue towards anal fin. Head blue with preorbital, ventral half of cheek, operculum and preoperculum yellow; dark blue/green opercular spot; gular yellow. Dorsal fin yellow with submarginal blue band and blue blotches throughout. Caudal-fin rays yellow with blue membranes. Anal fin pale blue to pale yellow with 1 ocellus. Pelvic fin with blue leading edge, remaining yellow. Pectoral-fin rays pale yellow and membranes clear. Female lateral ground coloration blue with center of scales orange/brown; belly white. Head brown; cheek and operculum with purple highlights; black opercular spot; white gular. Dorsal fin brown with brown lappets. Caudal-fin rays brown with clear membranes. Anal fin gray proximally and brown distally with single small orange/brown ocellus. Pelvic fins with white leading edges; first two rays and membranes brown, remainder clear. Pectoral fins clear (Fig. 2A).

Metriaclima aurora was originally described with specimens from Likoma Island with the color description above. The populations at Mbweca and Tumbi Point are unique in having a yellow/brown ground coloration in the dorsal three-quarters of the body with blue bars in the males (Fig. 2B), rather than the blue ground and blue bar colorations of the males from Likoma Island, Mara Point, and N’kolongwe. Populations at Mara Point and N'kolongwe are very similar in coloration to those at Likoma Island, with the exception of the ventral one-third rather than half of the cheek being yellow in some of the males from the population at N'kolongwe. When the first principal components of the meristic data are plotted against the sheared second principal components of the morphometric data for these 5 populations, the minimum polygons formed overlap, but were significantly different (Fig. 3).

The five populations of *Metriaclima aurora* are considered conspecific due to the overall similarities in ecology (Konings, personal communication) and morphology. Morphological gradation, similar to that observed in populations of *M. zebra* (Stauffer *et al.*, 1997) and *M. flavifemina* (Konings and Stauffer, 2006) is exhibited by these populations of *M. aurora*. While there is geographic variation between individual populations, analysis of the entire natural range of the species indicates morphological similarity which would not reflect different evolutionary lineages. The brown barred populations are considered a geographic race rather than a different species due to the similarity in shape and meristics with the other *M. aurora* populations. Similarities in morphology may indicate a relatively recent change in the color differences observed at Mbweca and Tumbi Point, which can develop in a short period of time in some mbuna species (Streelman *et al.*, 2004).

The observed morphological divergence among the populations of *Metriaclima aurora* may be attributed to post-isolation mechanisms and/or phenotypic plasticity in response to environmental variation (Chernoff, 1982; Stauffer and Hert, 1992; Stauffer and Gray, 2004). A population of *M. aurora* was transplanted to Cape Maclear from Likoma Island over 30 years ago and was found to differ morphologically over the time span of approximately 20 years, indicating the relatively rapid pace for populations to diverge in morphological features (Stauffer and Hert, 1992). Specimens from Thumbi West Island, where the original translocation occurred, were examined again and compared to the fish at Likoma Island. The minimum polygon clusters formed by plotting the first principal components of the meristic data with the sheared second principal components of the morphological data differ for these two populations do not overlap (Fig. 4). Size accounted for 74.8% of the observed variance and the second principal component accounts for 11.4%. The first principal component of the meristic data accounted for 18.1% of the total variance. Variables with the highest loadings on the sheared second principal components were vertical eye diameter (0.63) and horizontal eye diameter (0.60) (Table 4). The eye diameter of *M. aurora* at Thumbi West Island (Table 3) is generally smaller than the eye diameter of *M. aurora* from Likoma Island and the other native populations (Table 2). The variables with the highest loadings on the principal components of the meristic data were dorsal spines (0.36) and anal rays (0.30) (Table 5). Although there is a significant difference in morphology between the populations of *M. aurora* from Likoma Island and Thumbi West Island, they are not considered separate species because they were presumably the same color at the time of the transplantation. The difference in morphology observed here is the result of a founder effect, rather than separate evolutionary lineages. The remaining populations from Likoma Island, Mara Point, Mbweca, and Tumbi Point may differ as a function of environmental factors, such as food availability and the physical or chemical parameters of the water, which has been observed in other fish species (Chernoff, 1982; Stauffer and Gray, 2004; Collyer *et al.*, 2005).

Distribution.- Metriaclima aurora is native at Likoma Island and along the coast of Mozambique at Mara Point, Mbweca, Tumbi Point, and a relatively isolated location to the south in N'kolongwe. Populations have been transplanted to Thumbi West Island, where the species has spread to several locations around Cape Maclear (Stauffer and Hert, 1992; Konings, 2001).

Material Examined.- USNM 215292, holotype, USNM 215292, paratypes, 16, Likoma Island, Lake Malaŵi, Malaŵi, 5 May 1976; PSU 4480, 20, Mara Point North, Lake Malaŵi, Mozambique, 17 Feb. 2002; PSU 4481, 19, Mbweca, Lake Malaŵi, Mozambique, 28 Feb. 2006; PSU 4482, 20, Tumbi Point, Lake Malaŵi, Mozambique, 17 Feb. 2002; PSU 4483, 20, N'kolongwe, Lake Malaŵi, Mozambique, 16 Feb. 2002; PSU 4484, 20, Thumbi West Island, Lake Malaŵi, Malaŵi, 13 June 1989.

Fig. 2A. Breeding male from Likoma Island.

Fig. 2B. Breeding male from Tumbi Point.

Table 2. Morphometric and meristic values of *Metriaclima aurora* from Likoma Island, Mara Point, Mbweca, Tumbi Point, and N'kolongwe. Mean, standard deviation, and range include the holotype (n = 96).

	Holotype	**Mean**	**Standard Deviation**	**Range**
Standard length, mm	80.5	70.4	6.7	53.4-83.8
Head length, mm	24.9	21.7	2.1	16.3-25.8
Percent standard length				
Head length	30.9	30.8	0.8	28.9-33.0
Snout to dorsal	32.9	33.8	1.2	31.3-37.4
Snout to pelvic	40.3	38.1	1.4	34.1-42.2
Greatest body depth	30.4	32.6	1.3	29.5-36.0
Caudal peduncle length	15.4	14.3	0.8	12.2-16.5
Least caudal peduncle depth	11.1	11.7	0.6	10.5-13.0
Dorsal fin base length	61.5	60.1	1.1	56.8-62.6
ADAA	53.2	52.4	1.3	48.8-56.5
ADPA	63.8	63.6	1.2	60.2-66.6
PDAA	29.9	29.4	1.0	27.0-31.4
PDPA	16.3	15.0	0.8	12.5-17.2
ADP2	34.4	36.0	1.5	32.5-39.9
PDP2	53.2	57.4	2.0	49.5-60.6
Percent head length				
Horizontal eye diameter	36.6	37.0	1.5	32.3-40.3
Vertical eye diameter	36.4	36.8	1.6	33.0-40.3
Snout length	29.8	26.9	1.6	23.4-30.5
Postorbital head length	39.0	39.3	1.7	36.4-44.2
Preorbital depth	26.4	21.8	1.9	18.6-26.4
Lower-jaw length	30.2	31.2	1.1	28.4-33.5
Cheek depth	23.8	23.1	1.8	18.8-26.2
Head depth	85.2	86.8	4.2	75.8-95.4
	Holotype	**Mode**	**% Freq.**	**Range**
Counts				
Dorsal spines	17	18	67.7	17-19
Dorsal rays	9	9	60.4	8-10
Anal spines	3	3	97.9	3-4
Anal rays	8	8	88.5	7-8
Pelvic fin rays	5	5	100.0	5-5
Pectoral fin rays	14	14	84.4	13-15
Lateral line scales	31	31	51.0	29-33
Pored scales posterior to lateral line	2	2	62.5	0-2
Cheek scales	4	4	54.2	3-7
Gill rakers on first ceratobranchial	11	12	55.2	10-14
Gill rakers on first epibranchial	3	3	67.7	2-5
Teeth in outer row of left lower jaw	17	20	22.9	12-26
Teeth rows on upper jaw	3	3	74.0	3-4
Teeth rows on lower jaw	4	3	62.5	3-4

Table 3. Morphometric and meristic values of *Metriaclima aurora* from West Thumbi Island (n = 20).

	Mean	**Standard Deviation**	**Range**
Standard length, mm	73.2	6.0	63.7-84.3
Head length, mm	22.5	1.8	18.8-24.9
Percent standard length			
Head length	30.8	0.8	29.4-32.1
Snout to dorsal	33.8	1.1	31.9-36.6
Snout to pelvic	38.8	0.9	36.6-40.1
Greatest body depth	32.1	1.2	30.0-33.7
Caudal peduncle length	13.9	0.8	12.8-15.4
Least caudal peduncle depth	11.8	0.8	10.5-12.8
Dorsal fin base length	60.4	1.4	58.4-63.2
ADAA	52.8	1.2	50.4-54.6
ADPA	63.9	1.3	61.3-67.1
PDAA	29.7	1.2	27.1-31.3
PDPA	15.6	0.6	14.2-16.7
ADP2	35.8	1.7	32.4-38.9
PDP2	57.4	1.4	55.1-59.8
Percent head length			
Horizontal eye diameter	33.5	2.3	29.4-37.7
Vertical eye diameter	33.1	2.3	29.9-36.6
Snout length	28.2	1.7	24.8-30.7
Postorbital head length	40.6	0.9	38.6-42.0
Preorbital depth	22.1	1.3	20.4-25.1
Lower-jaw length	31.0	1.2	27.7-32.5
Cheek depth	23.9	2.1	20.9-29.0
Head depth	88.6	2.6	83.4-94.1
	Mode	**% Freq.**	**Range**
Counts			
Dorsal spines	18	80.0	16-18
Dorsal rays	9	75.0	8-10
Anal spines	3	100.0	3-3
Anal rays	8	85.0	7-8
Pelvic fin rays	5	100.0	5-5
Pectoral fin rays	14	90.0	14-15
Lateral line scales	31	45.0	30-33
Pored scales posterior to lateral line	2	55.0	0-2
Cheek scales	5	65.0	4-7
Gill rakers on first ceratobranchial	12	65.0	11-14
Gill rakers on first epibranchial	3	55.0	2-4
Teeth in outer row of left lower jaw	17,18	25.0	15-23
Teeth rows on upper jaw	3	80.0	3-4
Teeth rows on lower jaw	3	80.0	2-4

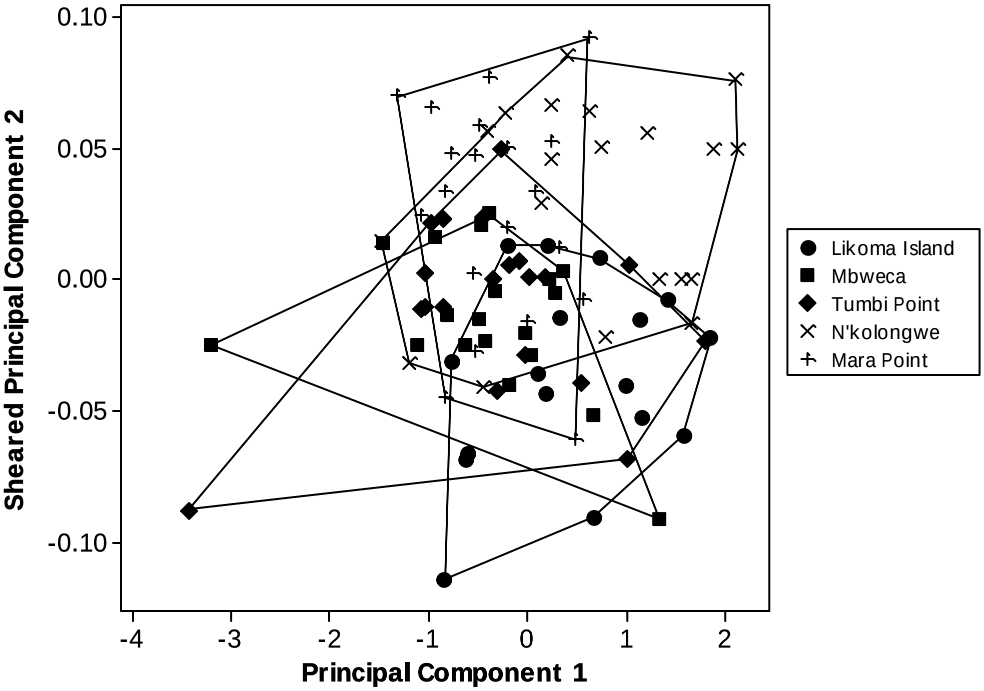

Fig. 3. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima aurora* from Likoma Island, Mbweca, Tumbi Point, N'kolongwe, and Mara Point.

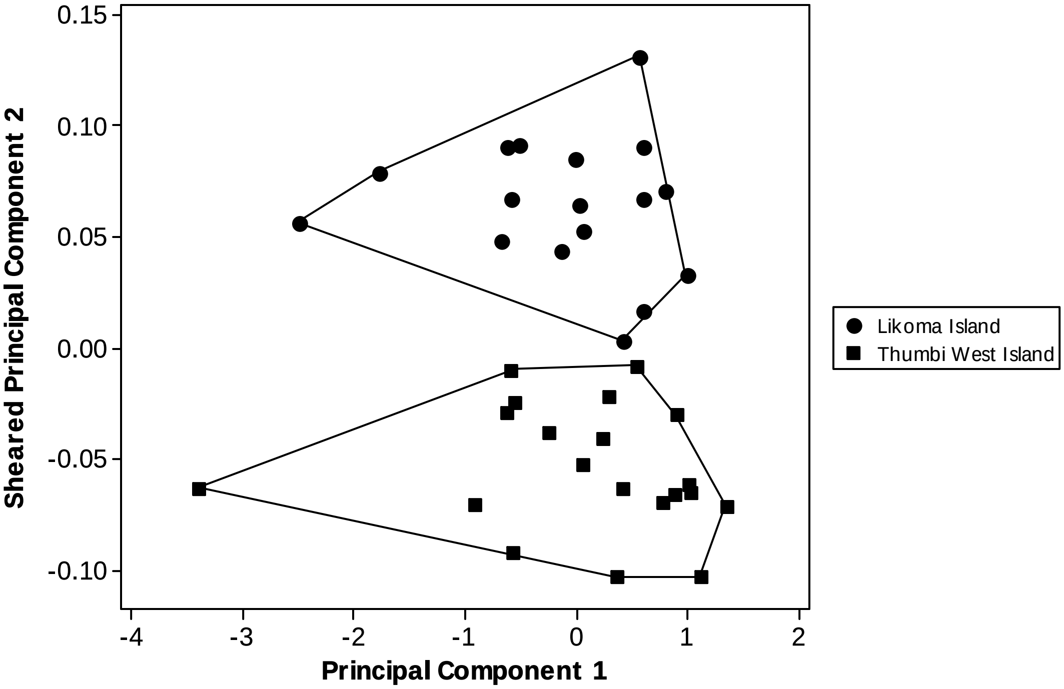

Fig. 4. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima aurora* from Likoma Island and Thumbi West Island.

Table 4. Variable loadings on size and the first two sheared principal components (shape factors) for *Metriaclima aurora* from Likoma Island and West Thumbi Island.

		Sheared Components	
	Size	PC2	PC3
Standard length	-0.186	*	*
Head length	-0.173	0.137	*
Snout length	-0.208	*	0.516
Postorbital length	-0.158	*	-0.106
Horizontal eye diameter	-0.073	0.597	*
Vertical eye diameter	-0.070	0.626	*
Preorbital depth	-0.251	*	0.597
Cheek depth	-0.295	*	*
Lower-jaw length	-0.142	0.165	*
Head depth	-0.227	-0.110	*
Body depth	-0.213	*	*
Snout to dorsal-fin origin	-0.158	*	*
Snout to pelvic-fin origin	-0.188	0.119	*
Dorsal-fin base length	-0.205	*	-0.150
Anterior dorsal to anterior anal	-0.211	*	-0.156
Anterior dorsal to posterior anal	-0.214	*	-0.179
Posterior dorsal to anterior anal	-0.255	*	-0.145
Posterior dorsal to posterior anal	-0.237	-0.290	*
Posterior dorsal to ventral caudal	-0.167	*	*
Posterior anal to dorsal caudal	-0.179	*	*
Anterior dorsal to pelvic-fin origin	-0.242	*	*
Posterior dorsal to pelvic-fin origin	-0.217	-0.159	-0.125
Caudal-peduncle length	-0.174	*	0.209
Least caudal-peduncle depth	-0.282	*	-0.421

* = Absolute loading values <0.1 for loadings on shape factors.

Table 5. Standardized scoring coefficients for principal component analysis on meristic data for *Metriaclima aurora* from Likoma Island and West Thumbi Island.

	Factor 1	Factor 2
Dorsal-fin spines	0.357	-0.105
Dorsal-fin rays	-0.181	0.095
Anal-fin spines	0.000	0.000
Anal-fin rays	0.303	0.210
Pelvic-fin rays	0.000	0.000
Pectoral-fin rays	-0.290	-0.062
Lateral-line scales	0.284	-0.063
Pored scales posterior to lateral line	0.119	-0.130
Scale rows on cheek	0.001	-0.136
Gill rakers on first ceratobranchial	0.026	-0.229
Gill rakers on first epibranchial	0.157	-0.121
Teeth in outer row of left lower jaw	0.044	0.225
Teeth rows on upper jaw	0.010	0.393
Teeth rows on lower jaw	0.052	0.343

3.2 *Metriaclima chrysomallos* Stauffer, Bowers, Kellogg, and McKaye

Diagnosis.- The following characters place this species in the genus *Metriaclima*: moderately sloped head; isognathous jaws; presence of bicuspid teeth in the outer row along the side of the jaws that do not follow the contour of the jaw bone; lower jaw often slightly longer and thicker than upper jaw; large part of upper dental arcade normally exposed when the mouth is closed; tips of teeth in the premaxilla and dentary in a V-shaped line with the anteriormost in upper and lower jaw furthest apart; lateral teeth are rotated so that the plane of their two prolonged tips runs parallel with those in the anterior part of the jaw; feeding at a perpendicular angle to the substrate and has ability to align the teeth of both upper and lower jaws in the same plane by abducting its jaws to a near 180° angle (Konings and Stauffer, 2006). The blue dorsal fin of the males separates this species from *M. aurora*. There are typically more teeth in the outer row of the lower left jaw of *M. chrysomallos* (mode 22, range 15-25; Tables 6 and 7) than *M. glaucos* n. sp. (mode 16, range 14-19; Table 10), a similarly colored species.

Description.- Jaws isognathous; teeth on jaws in 3-4 rows; outer row teeth typically bicuspid anteriorly and unicuspid posteriorly; those in inner rows tricuspid, if fourth row present usually unicuspid; 15-25 teeth in outer row of left lower jaw. Dorsal fin with 16-19 spines and 8-10 rays. Pectoral fin with 14-15 rays; anal fin with 3 spines and 7-9 rays. Lateral scales ctenoid; 30-32 lateral-line scales. First gill arch with 9-13 rakers on ceratobranchial, 2-4 on epibranchial, and 1 between epibranchial and ceratobranchial (Tables 6 and 7).

At Nametumbwe, lateral body coloration of breeding male blue with gold highlights and 6 faint bars, fading to white ventrally; breast orange fading to white at pelvic fins. Dorsal half of head, operculum, and cheek blue; ventral portions orange/yellow; snout orange. Dorsal fin pale blue, posterior membranes orange distally. Caudal-fin rays orange with clear membranes. Anal-fin rays blue/gray with 2 orange ocelli. Distal portion of pelvic fins orange, remaining clear. Pectoral fins clear (Fig. 5A). Females brown/gray with blue highlights laterally; belly white. Head dark brown with blue/green highlights, black opercular spot, and white gular. Dorsal fin brown. Caudal-fin rays brown and membranes clear. Anal-fin rays brown with clear membrane. Leading edge of pelvic fins white, rays brown; membranes clear. Pelvic fins clear.

At Gome, lateral body coloration of breeding male blue, with 6 faint bars. Head blue with gray highlights; interorbital area gray with 1 blue bar; gular white with yellow blotches. Dorsal fin gray proximally fading to white distally. Caudal-fin rays clear with blue membranes. Anal-fin rays gray with light blue/white membrane and 2 orange ocelli. Leading edge of pelvic fins white, rays clear; first 2 membranes gray, remaining clear. Pectoral fins clear (Fig. 5B). Females brown with blue/green highlights laterally; belly white. Head dark brown with blue/green highlights and white or yellow gular. Dorsal fin brown with light green spots. Caudal-fin rays brown; clear membrane with light green spots. Anal-fin rays brown with clear membrane. Leading edge of pelvic fins white, rays brown; membranes clear. Pelvic fins clear.

The minimum polygon clusters formed by plotting the first principal components of the meristic data against the sheared second principal components of the morphometric data for *Metriaclima chrysomallos* from Gome and Nametumbwe were significantly ($p < 0.05$) different (Fig. 6). Size accounted for 86.7% of the observed variance and the second principal component accounted for 3.3%. The variables with the highest loadings were snout length (-0.49), vertical eye diameter (0.42), preorbital depth (-0.40), and horizontal eye diameter (0.36) (Table 8). The first principal component of the meristic data accounted for 18.7% of the variance. Teeth rows on the upper jaw (0.27) and teeth rows on the lower jaw (0.27) had the highest loadings (Table 9).

Metriaclima chrysomallos exhibits variable color patterns depending on the population. The population at Gome is believed to be *M. chrysomallos* (Konings, 2001), although the principal component analysis indicates differences in morphology. Coloration differences are prominent between these populations, as orange pigment in the dorsal fin in addition to an orange breast and ventral half of the head are present in the males at Nametumbwe. The *M. chrysomallos* population of Mumbo Island has gold in the dorsal fins, but lacks the orange pigment on the lower half of the head (Stauffer *et al.*, 1997). At Gome, *M. chrysomallos* males are entirely blue. South of Gome, below the Nsinje River, half of the males are all blue and the other half possess a yellow gular region all at the same locality. If one were to move north of Gome however, males at one particular locality could have black pigment in the tail without any yellow. Various sub-populations appeared to have been forming into potentially different species differing in yellow coloration of the head or black coloration in the caudal fin, but isolation could not occur to keep these color forms separate (Konings, personal communication). Specimens of the *M. chrysomallos* group from Liwani, south of the Nsinje River, in addition to Nametumbwe need to be examined and compared with the population north of the river at Gome. Stronger evidence to support the Gome population of *M. chrysomallos* as a separate species would be provided if the population from Liwani falls within the Nametumbwe population in the principal component analysis, thus separating the populations north (Gome) and south (Liwani and Nametumbwe) of the Nsinje River in their morphological features. These two populations are considered conspecific until all of the populations of this group are examined.

Distribution.- Stauffer *et al.* (1997) originally described the species with specimens from Mumbo Island, where the breast and ventral half of the head of males was blue rather than orange. *Metriaclima chrysomallos* is also found between Makanjila Point and up to Meponda in the southeastern portion of the lake. In the populations at Nametumbwe and Ntekete, males possess the orange coloration on the ventral portions of the head and breast to some extent. At Gome within that range, *M. chrysomallos* is found where males lack the orange coloration on the head, breast, and posterior portion of the dorsal fin (Konings, 2001).

Materials Examined.- PSU 4485, 20, Gome Rock, Lake Malaŵi, Malaŵi, 12 Feb. 2001; PSU 4486, 20, Nametumbwe, Lake Malaŵi, Malaŵi, 25 Jan. 2007.

Fig. 5A. Breeding *Metriaclima chrysomallos* male from Nametumbwe.

Fig. 5 B. Breeding *Metriaclima chrysomallos* male from Gome.

Table 6. Morphometric and meristic values of *Metriaclima chrysomallos* from Nametumbwe (n = 20).

	Mean	**Standard Deviation**	**Range**
Standard length, mm	65.1	4.9	53.6-71.9
Head length, mm	20.6	1.5	16.7-22.6
Percent standard length			
Head length	31.6	0.8	30.0-32.8
Snout to dorsal	33.4	1.3	30.7-35.7
Snout to pelvic	37.9	0.7	36.5-39.8
Greatest body depth	33.5	1.0	31.8-36.0
Caudal peduncle length	13.5	0.6	12.1-14.6
Least caudal peduncle depth	12.1	0.5	11.2-13.1
Dorsal fin base length	61.4	1.0	58.9-63.0
ADAA	52.9	1.2	50.5-54.6
ADPA	64.0	0.9	62.3-65.9
PDAA	29.5	0.8	28.4-31.2
PDPA	14.7	0.5	13.9-16.0
ADP2	37.2	1.1	35.1-39.2
PDP2	58.5	1.0	56.3-60.1
Percent head length			
Horizontal eye diameter	36.9	0.9	35.1-39.1
Vertical eye diameter	36.9	1.2	34.0-39.4
Snout length	24.5	1.5	20.3-27.3
Postorbital head length	38.4	0.8	37.0-39.9
Preorbital depth	19.6	1.4	16.5-22.2
Lower-jaw length	32.0	1.1	29.6-33.8
Cheek depth	22.7	2.0	17.8-25.4
Head depth	86.2	2.7	80.4-91.0
	Mode	**% Freq.**	**Range**
Counts			
Dorsal spines	18	75.0	17-19
Dorsal rays	9	55.0	8-10
Anal spines	3	100.0	3-3
Anal rays	8	80.0	7-8
Pelvic fin rays	5	100.0	5-5
Pectoral fin rays	14	75.0	14-15
Lateral line scales	31	50.0	30-32
Pored scales posterior to lateral line	0,2	40.0	0-2
Cheek scales	4	50.0	3-6
Gill rakers on first ceratobranchial	12	50.0	10-12
Gill rakers on first epibranchial	3	80.0	2-3
Teeth in outer row of left lower jaw	21,22	20.0	15-24
Teeth rows on upper jaw	3	95.0	3-4
Teeth rows on lower jaw	3	80.0	3-4

Table 7. Morphometric and meristic values of *Metriaclima chrysomallos* from Gome (n = 20).

	Mean	**Standard Deviation**	**Range**
Standard length, mm	69.6	3.1	65.3-73.3
Head length, mm	20.9	0.9	19.8-22.3
Percent standard length			
Head length	30.1	0.8	29.1-31.0
Snout to dorsal	31.1	1.4	29.8-33.1
Snout to pelvic	37.5	0.6	36.5-38.1
Greatest body depth	32.9	1.1	31.6-34.1
Caudal peduncle length	14.0	0.8	12.9-15.3
Least caudal peduncle depth	12.2	0.3	11.7-12.7
Dorsal fin base length	61.4	1.6	58.5-62.6
ADAA	52.6	0.9	51.5-53.7
ADPA	63.7	0.9	62.1-64.9
PDAA	29.6	1.4	28.0-32.0
PDPA	15.2	0.9	14.1-16.4
ADP2	36.1	1.0	34.6-37.5
PDP2	59.5	0.7	58.3-60.2
Percent head length			
Horizontal eye diameter	34.0	1.2	32.6-35.8
Vertical eye diameter	34.3	1.0	33.1-35.3
Snout length	27.1	1.8	24.6-29.4
Postorbital head length	38.3	1.9	35.6-40.6
Preorbital depth	21.1	1.7	19.0-23.5
Lower-jaw length	31.2	1.9	29.4-34.1
Cheek depth	24.8	1.1	23.0-26.3
Head depth	92.5	2.5	89.4-96.3
	Mode	**% Freq.**	**Range**
Counts			
Dorsal spines	17, 18	50.0	17-18
Dorsal rays	9	83.3	9-10
Anal spines	3	100.0	3-3
Anal rays	8	66.7	7-8
Pelvic fin rays	5	100.0	5-5
Pectoral fin rays	14	66.7	14-15
Lateral line scales	30, 31	50.0	30-31
Pored scales posterior to lateral line	1	66.7	0-2
Cheek scales	5	66.7	4-5
Gill rakers on first ceratobranchial	13	50.0	11-13
Gill rakers on first epibranchial	3	66.7	2-3
Teeth in outer row of left lower jaw	22	33.3	19-23
Teeth rows on upper jaw	3	66.7	3-4
Teeth rows on lower jaw	3	100.0	3-3

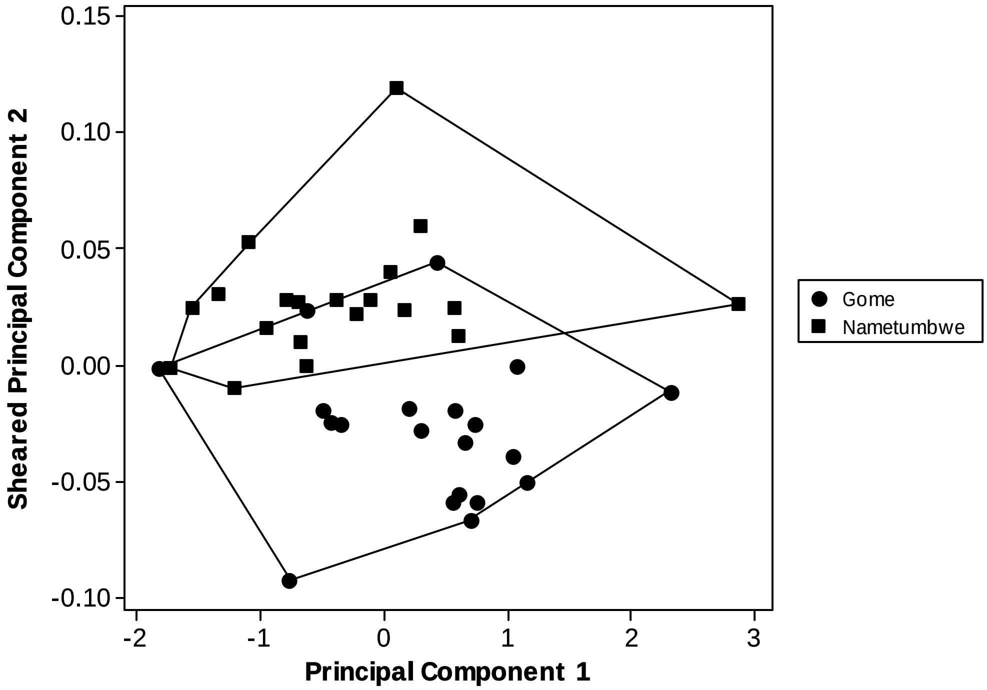

Fig. 6. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima chrysomallos* from Gome and Nametumbwe.

Table 8. Variable loadings on size and the first two sheared principal components (shape factors) for *Metriaclima chrysomallos* from Nametumbwe and Gome.

		Sheared Components	
	Size	PC2	PC3
Standard length	-0.194	*	*
Head length	-0.173	*	0.171
Snout length	-0.252	-0.494	0.343
Postorbital length	-0.162	*	*
Horizontal eye diameter	-0.139	0.358	0.376
Vertical eye diameter	-0.123	0.418	0.317
Preorbital depth	-0.276	-0.403	0.362
Cheek depth	-0.325	-0.296	-0.155
Lower-jaw length	-0.181	*	0.313
Head depth	-0.194	0.181	-0.151
Body depth	-0.199	0.197	*
Snout to dorsal-fin origin	-0.185	*	0.102
Snout to pelvic-fin origin	-0.197	0.106	*
Dorsal-fin base length	-0.212	*	-0.108
Anterior dorsal to anterior anal	-0.199	*	-0.129
Anterior dorsal to posterior anal	-0.210	*	-0.142
Posterior dorsal to anterior anal	-0.213	*	-0.160
Posterior dorsal to posterior anal	-0.190	*	-0.230
Posterior dorsal to ventral caudal	-0.194	*	-0.303
Posterior anal to dorsal caudal	-0.192	*	-0.150
Anterior dorsal to pelvic-fin origin	-0.206	0.209	*
Posterior dorsal to pelvic-fin origin	-0.194	0.123	*
Caudal-peduncle length	-0.190	-0.118	*
Least caudal-peduncle depth	-0.206	*	-0.233

* = Absolute loading values <0.1 for loadings on shape factors.

Table 9. Standardized scoring coefficients for principal component analysis on meristic data for *Metriaclima chrysomallos* from Nametumbwe and Gome.

	Factor 1	Factor 2
Dorsal-fin spines	0.058	0.446
Dorsal-fin rays	-0.091	-0.268
Anal-fin spines	0.000	0.000
Anal-fin rays	0.216	0.190
Pelvic-fin rays	0.000	0.000
Pectoral-fin rays	0.182	0.002
Lateral-line scales	-0.112	0.328
Pored scales posterior to lateral line	0.210	-0.138
Scale rows on cheek	-0.170	0.184
Gill rakers on first ceratobranchial	0.240	-0.164
Gill rakers on first epibranchial	0.112	0.010
Teeth in outer row of left lower jaw	0.228	0.069
Teeth rows on upper jaw	0.269	-0.030
Teeth rows on lower jaw	0.273	0.131

3.3 *Metriaclima glaucos* n. sp.

Holotype.- PSU 4487, 69.2 mm SL, Cobwe, Lake Malaŵi, Mozambique, 7-15 m, 18 Feb. 2002.

Paratypes.- PSU 4488, 16, UMBC 15, 1, AMNH 246003, 2, (53.0-67.4 mm) data as for holotype.

Diagnosis.- The following characters place this new species in the genus *Metriaclima*: moderately sloped head; isognathous jaws; presence of bicuspid teeth in the outer row along the side of the jaws that do not follow the contour of the jaw bone; lower jaw often slightly longer and thicker than upper jaw; large part of upper dental arcade normally exposed when the mouth is closed; tips of teeth in the premaxilla and dentary in a V-shaped line with the anteriormost in upper and lower jaw furthest apart; lateral teeth are rotated so that the plane of their two prolonged tips runs parallel with those in the anterior part of the jaw; feeding at a perpendicular angle to the substrate and has ability to align the teeth of both upper and lower jaws in the same plane by abducting its jaws to a near 180° angle (Konings and Stauffer, 2006)._ The blue body coloration of males in conjunction with the yellow gular and brachiostegals (Fig. 7) and lack of black pigment in the fins distinguishes *M. glaucos* from other *aurora*-group species, with the exception of some populations of *M. chrysomallos*. Males of neighboring populations of *M. aurora* have yellow extending from the gular to the cheeks and lower operculum. There are typically fewer teeth in the outer row of the lower left jaw (mode 16, range 14-19; Table 10) of *M. glaucos* than all other examined members of the *aurora*-group and 2-3 rows of teeth in the upper and lower jaws compared to *M. aurora* and *M. chrysomallos*, which tend to have higher numbers of teeth in the outer row of the lower left jaws (*M. aurora* mode 20, range 12-26; *M chrysomallos* mode 22, range 15-25) and 3-4 rows of teeth in the upper and lower jaws Tables 2, 6, and 7).

Description.- Jaws isognathous; teeth on jaws in 2-3 rows; outer row teeth generally bicuspid anteriorly and unicuspid posteriorly; those in inner rows tricuspid, sometimes inner most row unicuspid; 16 teeth in outer row of left lower jaw of holotype, 14-19 in paratypes. Dorsal fin with 18 spines in holotype and 17-19 in paratypes; dorsal-fin rays 9 in holotype and 8-10 in paratypes. Pectoral fin with 15 rays in holotype and 14-15 in paratypes; anal fin with 3 spines, 8 rays in holotype and 7-8 in paratypes. Lateral scales ctenoid; holotype with 31 lateral line scales and 29-32 in paratypes. First gill arch with 10-11 rakers on ceratobranchial, 3-4 on epibranchial, and 1 between epibranchial and ceratobranchial (Table 10).

Breeding males blue laterally with 7 dark gray bars and white belly. Head blue with preorbital, cheek, and operculum blue; darker blue opercular spot; yellow gular and branchiostegals. Dorsal fin blue with white edge on tip of spines. Caudal-fin rays gray with blue membranes. Anal fin gray with up to 4 yellow ocelli. Pelvic fin with white leading edge, first ray gray and remainder clear. Pectoral fins clear. Female lateral coloration gray dorsally and white ventrally. Head gray with gray cheeks, blue operculum with green highlights, black opercular spot, and white gular. Dorsal fin gray with yellow/orange lappets. Caudal-fin rays gray with clear membranes and faint yellow/orange spots. Anal fin gray proximally and yellow distally with no ocelli. Pelvic fin with white leading edge, rays yellow with black markings except for first clear membrane. Pectoral fins clear.

When the first principal components of the meristic data were plotted against the sheared second principal components of the morphometric data for *Metriaclima glaucos* and *M. aurora*, the minimum polygons formed did not overlap (Fig. 8). Size accounted for 87.4% of the observed variance and the second principal component accounts for 3.5%. The variables with the highest loadings on the sheared second principal component were horizontal eye diameter (0.59), vertical eye diameter (0.55), and snout length (-0.30) (Table 11). The first principal component of the meristic data accounted for 15.4% of the total variance. The variables with the highest loadings on the first principal component based on the standardized scoring coefficients were teeth rows on lower jaw (0.34) and teeth rows on upper jaw (0.31) (Table 12).

Metriaclima glaucos was also compared with the similarly colored *M. chrysomallos*. When the first principal components of the meristic data were plotted against the sheared second principal components of the morphometric data for *Metriaclima glaucos* and *M. chrysomallos*, the minimum polygons formed did not overlap (Fig. 13). Size accounted for 85.3% of the observed variance and the second principal component accounted for 6.4%. The variables with the highest loadings on the sheared second principal component were, vertical eye diameter (0.48), horizontal eye diameter (0.47), and snout length (-0.45) (Table 13). The first principal component of the meristic data accounted for 20.8 % of the total variance. The variables with the highest loadings on the first principal component based on the standardized scoring coefficients were teeth on the outer row of the lower left jaw (0.28) (Table 14).

Distribution.- Metriaclima glaucos was collected only at Cobwe, Mozambique.

Etymology.- The name glaucos is Greek for bluish gray, in reference to the blue-gray body and fin coloration.

Fig. 7. Breeding *Metriaclima glaucos* male.

Table 10. Morphometric and meristic values of the type series of *Metriaclima glaucos*. Mean, standard deviation, and range include the holotype (n = 20).

	Holotype	**Mean**	**Standard Deviation**	**Range**
Standard length, mm	69.2	61.4	5.5	53.0-69.2
Head length, mm	21.0	18.7	1.6	16.1-21.0
Percent standard length				
Head length	30.3	30.5	0.6	29.4-31.9
Snout to dorsal	32.7	33.4	0.7	31.7-34.6
Snout to pelvic	37.4	38.2	1.0	35.9-40.4
Greatest body depth	31.9	32.8	0.6	31.8-34.0
Caudal peduncle length	14.6	14.2	0.8	12.5-15.5
Least caudal peduncle depth	10.9	11.0	0.5	9.9-12.3
Dorsal fin base length	64.4	61.9	1.5	59.8-64.4
ADAA	52.5	53.6	1.2	50.8-55.8
ADPA	66.3	64.4	1.2	62.9-66.5
PDAA	29.6	29.3	0.9	27.1-30.9
PDPA	14.9	15.1	0.6	14.4-16.5
ADP2	36.6	37.2	1.3	35.2-39.5
PDP2	59.1	58.7	1.4	55.6-60.7
Percent head length				
Horizontal eye diameter	30.8	33.7	2.0	30.7-36.6
Vertical eye diameter	32.0	33.7	1.7	31.0-36.9
Snout length	28.1	28.9	1.5	25.4-30.8
Postorbital head length	42.0	41.8	1.1	38.5-43.3
Preorbital depth	21.5	21.9	1.2	19.2-23.6
Lower-jaw length	29.3	30.8	1.2	28.8-32.8
Cheek depth	25.0	23.8	1.4	21.4-26.7
Head depth	92.5	91.0	2.7	86.5-95.9
	Holotype	**Mode**	**% Freq.**	**Range**
Counts				
Dorsal spines	18	18	81.0	17-19
Dorsal rays	8	9	57.1	8-10
Anal spines	3	3	100.0	3-3
Anal rays	8	8	61.9	7-8
Pelvic fin rays	5	5	95.2	4-5
Pectoral fin rays	14	14	57.1	14-15
Lateral line scales	30	30	38.1	29-32
Pored scales posterior to lateral line	1	2	42.9	0-2
Cheek scales	6	6	38.1	4-7
Gill rakers on first ceratobranchial	11	11	61.9	10-11
Gill rakers on first epibranchial	3	3	85.7	2-4
Teeth in outer row of left lower jaw	16	16	28.6	14-19
Teeth rows on upper jaw	3	3	95.2	2-3
Teeth rows on lower jaw	3	3	90.5	2-3

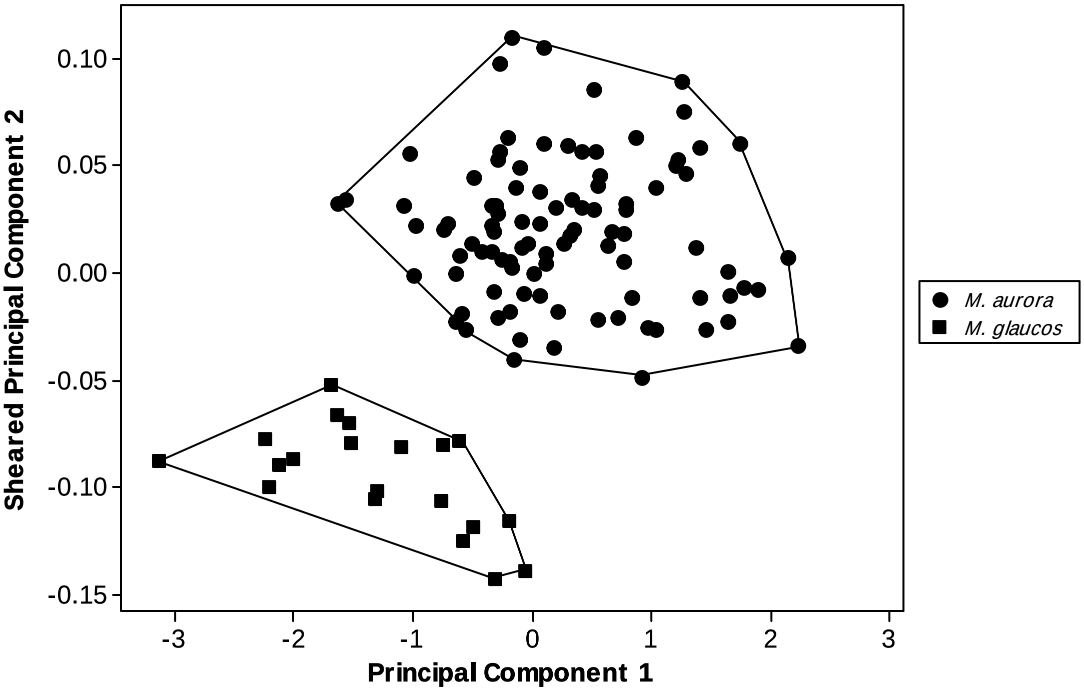

Fig. 8. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima aurora* and *M. glaucos*.

Table 11. Variable loadings on size and the first two sheared principal components (shape factors) for *Metriaclima aurora* and *M. glaucos*.

		Sheared Components	
	Size	PC2	PC3
Standard length	-0.196	*	*
Head length	-0.193	0.125	-0.107
Snout length	-0.247	-0.302	-0.401
Postorbital length	-0.181	*	*
Horizontal eye diameter	-0.158	0.591	-0.142
Vertical eye diameter	-0.171	0.548	-0.136
Preorbital depth	-0.249	*	-0.589
Cheek depth	-0.297	-0.222	*
Lower-jaw length	-0.176	0.199	*
Head depth	-0.211	-0.154	*
Body depth	-0.211	*	*
Snout to dorsal-fin origin	-0.195	*	*
Snout to pelvic-fin origin	-0.200	*	-0.132
Dorsal-fin base length	-0.208	*	*
Anterior dorsal to anterior anal	-0.206	*	*
Anterior dorsal to posterior anal	-0.207	*	*
Posterior dorsal to anterior anal	-0.209	*	0.153
Posterior dorsal to posterior anal	-0.184	-0.100	0.345
Posterior dorsal to ventral caudal	-0.186	*	0.223
Posterior anal to dorsal caudal	-0.190	*	0.230
Anterior dorsal to pelvic-fin origin	-0.205	-0.130	*
Posterior dorsal to pelvic-fin origin	-0.190	-0.114	0.104
Caudal-peduncle length	-0.178	*	0.175
Least caudal-peduncle depth	-0.204	0.147	0.334

* = Absolute loading values <0.1 for loadings on shape factors.

Table 12. Standardized scoring coefficients for principal component analysis on meristic data for *Metriaclima aurora* and *M. glaucos*.

	Factor 1	Factor 2
Dorsal-fin spines	0.144	0.300
Dorsal-fin rays	-0.025	-0.304
Anal-fin spines	-0.040	0.292
Anal-fin rays	0.220	-0.140
Pelvic-fin rays	0.136	0.136
Pectoral-fin rays	-0.194	-0.207
Lateral-line scales	0.133	0.151
Pored scales posterior to lateral line	0.088	0.225
Scale rows on cheek	-0.098	-0.066
Gill rakers on first ceratobranchial	0.195	0.087
Gill rakers on first epibranchial	-0.125	0.234
Teeth in outer row of left lower jaw	0.191	-0.104
Teeth rows on upper jaw	0.309	-0.144
Teeth rows on lower jaw	0.341	-0.107

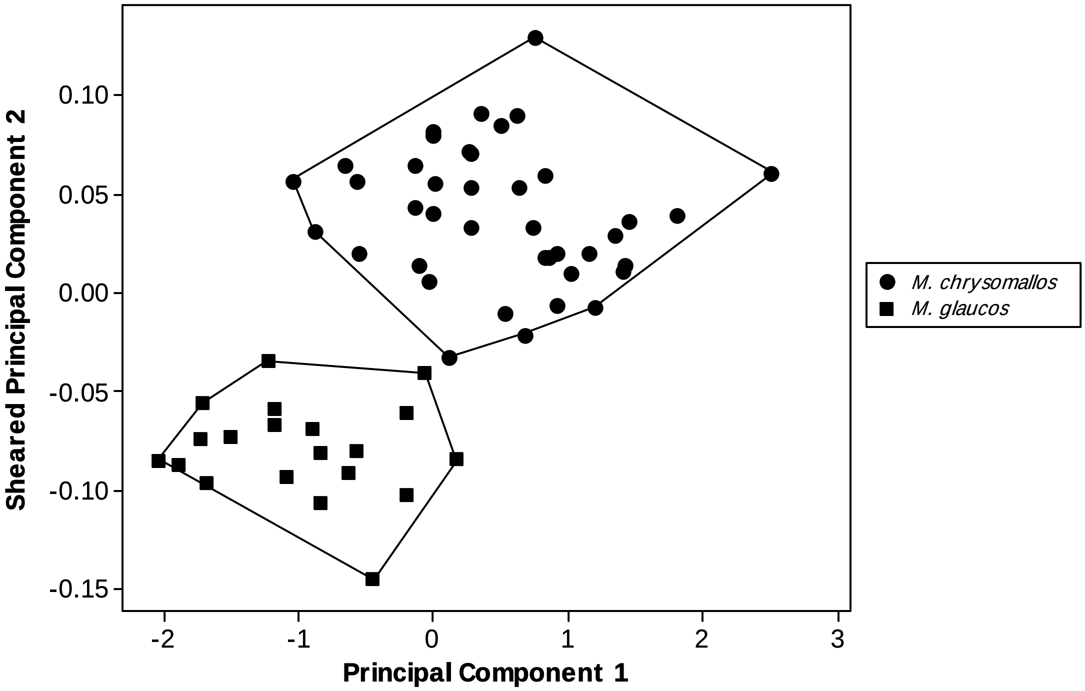

Fig. 9. Plot of the sheared second principal component (morphometric data) and the first factor principal component (meristic data) for *Metriaclima chrysomallos* and *M. glaucos*.

Table 13. Variable loadings on size and the first two sheared principal components (shape factors) for *Metriaclima chrysomallos* and *M. glaucos*.

		Sheared Components	
	Size	PC2	PC3
Standard length	-0.195	*	*
Head length	-0.176	0.144	-0.150
Snout length	-0.264	-0.447	-0.322
Postorbital length	-0.191	*	*
Horizontal eye diameter	-0.101	0.472	-0.291
Vertical eye diameter	-0.103	0.477	-0.192
Preorbital depth	-0.258	-0.318	-0.409
Cheek depth	-0.316	-0.141	-0.264
Lower-jaw length	-0.184	0.257	-0.226
Head depth	-0.203	*	0.142
Body depth	-0.192	*	0.124
Snout to dorsal-fin origin	-0.189	*	-0.126
Snout to pelvic-fin origin	-0.190	*	*
Dorsal-fin base length	-0.215	*	*
Anterior dorsal to anterior anal	-0.203	*	0.105
Anterior dorsal to posterior anal	-0.214	*	0.107
Posterior dorsal to anterior anal	-0.220	*	0.165
Posterior dorsal to posterior anal	-0.209	*	0.235
Posterior dorsal to ventral caudal	-0.200	*	0.198
Posterior anal to dorsal caudal	-0.198	*	0.281
Anterior dorsal to pelvic-fin origin	-0.187	*	0.100
Posterior dorsal to pelvic-fin origin	-0.192	*	*
Caudal-peduncle length	-0.189	-0.119	0.382
Least caudal-peduncle depth	-0.206	0.306	0.112

* = Absolute loading values <0.1 for loadings on shape factors.

Table 14. Standardized scoring coefficients for principal component analysis on meristic data for *Metriaclima chrysomallos* and *M. glaucos*.

	Factor 1	Factor 2
Dorsal-fin spines	0.093	0.506
Dorsal-fin rays	-0.041	-0.185
Anal-fin spines	0.000	0.000
Anal-fin rays	0.188	0.041
Pelvic-fin rays	0.084	0.248
Pectoral-fin rays	0.017	-0.210
Lateral-line scales	0.077	0.313
Pored scales posterior to lateral line	0.146	-0.179
Scale rows on cheek	-0.249	0.134
Gill rakers on first ceratobranchial	0.244	-0.143
Gill rakers on first epibranchial	-0.004	0.137
Teeth in outer row of left lower jaw	0.280	-0.025
Teeth rows on upper jaw	0.155	-0.122
Teeth rows on lower jaw	0.257	0.067

3.4 *Metriaclima sciasma* n. sp.

Holotype.- PSU 4490, 63.8 mm SL, Magunga, Lake Malaŵi, Tanzania, 5-20 m, 11 Feb. 2005.

Paratypes.- PSU 4491, 17, UMBC 16, 1, AMNH 246002, 2, (48.4-71.2 mm) data as for holotype; PSU 4492, 20, (46.9-66.9 mm), Ngwazi, Lake Malaŵi, Tanzania, 3-15 m, 10 Feb. 2005; PSU 4493, 20, (53.6-68.5 mm), Makonde, Lake Malaŵi, Tanzania, 4-20 m, 8 Feb. 2005.

Diagnosis.- The following characters place this new species in the genus *Metriaclima*: moderately sloped head; isognathous jaws; presence of bicuspid teeth in the outer row along the side of the jaws that do not follow the contour of the jaw bone; lower jaw often slightly longer and thicker than upper jaw; large part of upper dental arcade normally exposed when the mouth is closed; tips of teeth in the premaxilla and dentary in a V-shaped line with the anteriormost in upper and lower jaw furthest apart; lateral teeth are rotated so that the plane of their two prolonged tips runs parallel with those in the anterior part of the jaw; feeding at a perpendicular angle to the substrate and has ability to align the teeth of both upper and lower jaws in the same plane by abducting its jaws to a near 180° angle (Konings and Stauffer, 2006). The black pelvic fins and dark blue cheeks and preorbital area of breeding males distinguish *Metriaclima sciasma* from the other members of the *aurora*-group. Fewer dorsal spines (mode 17, range 16-19; Table 15) also distinguish *M. sciasma* from all other *aurora*-group species (mode 18) with the exception of *M. xanthos* n. sp. (mode 17, range 17-18; Table 20). The snout to dorsal fin insertion length, expressed as percent standard length, is typically smaller in *M. sciasma* (mean 31.1, range 29.3-33.6; Table 15) than *M. xanthos* (mean 34.7, range 32.4-36.5; Table 20).

Description.- Jaws isognathous; teeth on jaws in 2-3 rows (one specimen from Ngwazi had 4 rows on upper jaw); outer row teeth typically bicuspid anteriorly and unicuspid posteriorly; those in inner rows tricuspid, sometimes inner most row unicuspid; 19 teeth in outer row of left lower jaw of holotype, 12-23 in paratypes. Dorsal fin with 17 spines in holotype and 16-19 in paratypes; dorsal fin rays 9 in holotype and 8-10 in paratypes. Pectoral fin with 14 rays in holotype and 13-15 in paratypes; anal fin with 3 spines, 8 rays in holotype and 7-9 in paratypes. Lateral scales ctenoid; holotype with 29 lateral-line scales and 28-31 in paratypes. First gill arch with 10-14 rakers on ceratobranchial, 2-4 on epibranchial, and 1 between epibranchial and ceratobranchial (Table 15).

Lateral body coloration of breeding males blue dorsally with 7 gray bars, white ventrally, and gray in caudal peduncle. Preorbital, cheek, and operculum dark blue/gray; blue opercular spot; white gular; premaxillary and maxillary blue/gray; blue/gray interorbital bar. Dorsal fin blue with light blue lappets. Caudal-fin rays gray with blue membranes. Anal fin blue/gray with 3 yellow ocelli. Pelvic fin with white leading edge, first 2 rays black fading into gray posteriorly. Pectoral fins clear (Fig. 10). Female coloration brown dorsally and white ventrally. Head brown with blue highlights on operculum and black opercular spot; white gular. Dorsal and anal fins brown. Proximal third of caudal fin dark brown, distal third light brown, membranes with faint blue spots. Pelvic fins with white leading edge, first 2 rays and membranes brown with remaining clear. Pectoral fins clear.

The minimum polygon clusters formed by plotting the first principal components of the meristic data against the sheared second principal components of the morphometric data for the three populations of *M. sciasma* examined overlap (Fig. 11). The minimum polygon clusters formed by plotting the first principal components of the meristic data against the sheared second principal components of the morphometric data for *M. sciasma* and *M. aurora* were significantly ($p < 0.05$) different (Fig. 12). Size accounted for 90.0% of the observed variance and the second principal component accounted for 3.3%. The variables with the highest loadings on the sheared second principal components were horizontal eye diameter (-0.56), vertical eye diameter (-0.54), and cheek depth (0.38) (Table 16). Eye diameter of *M. sciasma*, expressed as percent head length, is typically smaller (horizontal mean 33.8, range 30.4-37.1; vertical mean 33.7, range 30.9-37.1; Table 15) than the eye diameter of *M. aurora* (horizontal mean 37.0, range 32.3-40.3; vertical mean 36.8, range 33.0-40.3; Table 2). The first principal component of the meristic data accounted for 19.6% of the total variance. The variable with the highest loading on the first principal component was teeth rows on lower jaw (0.31) (Table 17).

Shape analysis was also conducted with *M. sciasma*, *M. glaucos*, and *M. xanthos*. The minimum polygon clusters formed by plotting the first principal components of the meristic data against the sheared second principal components of the morphometric data were significantly ($p < 0.05$) different between *M. sciasma*, *M. glaucos*, and *M. xanthos* (Fig. 13). Size accounted for 91.3% of the observed variance and the second principal component accounted for 2.8%. The variables with the highest loadings on the sheared second principal components were preorbital depth (-0.53) and snout length (-0.51)

(Table 18). The first principal component of the meristic data accounted for 18.1% of the total variance. The variables with the highest loadings on the first principal components were gill rakers on first ceratobranchial (-0.31) and dorsal spines (0.30) (Table 19).

Distribution.- Metriaclima sciasma has an extensive distribution north of the Ruhuhu River in the northeastern part of Lake Malawi. The river and the sandy shores of Mbamba Bay form a geographic barrier between *M. sciasma* and other members of the *aurora*-group to the south (Konings, personal communication).

Etymology.- The name sciasma is Greek for shadow, reflecting the black pelvic fins of the males.

Fig. 10. Breeding *Metriaclima sciasma* male from Magunga, Tanzania.

Table 15. Morphometric and meristic values of the type series of *Metriaclima sciasma*. Mean, standard deviation, and range include the holotype (n = 61).

	Holotype	**Mean**	**Standard Deviation**	**Range**
Standard length, mm	63.8	60.9	6.6	46.9-71.2
Head length, mm	18.7	18.3	1.8	14.4-21.1
Percent standard length				
Head length	29.4	30.1	0.8	28.7-31.9
Snout to dorsal-fin origin	30.4	31.1	0.9	29.3-33.6
Snout to pelvic-fin origin	38.6	37.8	1.3	34.6-43.4
Greatest body depth	31.4	31.8	1.2	29.1-34.3
Caudal peduncle length	15.2	14.5	0.8	12.4-16.5
Least caudal peduncle depth	12.4	11.8	0.5	10.7-13.1
Dorsal fin base length	63.5	61.7	1.4	58.9-65.5
ADAA	51.6	51.1	1.4	47.7-54.3
ADPA	65.3	64.2	1.4	60.6-66.9
PDAA	31.0	29.7	1.2	26.9-32.3
PDPA	15.6	14.8	0.5	13.4-15.9
ADP2	35.6	35.3	1.5	31.0-38.3
PDP2	56.8	57.3	1.3	53.3-60.7
Percent of head length				
Horizontal eye diameter	33.9	33.8	1.4	30.4-37.1
Vertical eye diameter	32.7	33.7	1.3	30.9-37.1
Snout length	26.9	26.3	1.5	22.8-31.5
Postorbital head length	41.5	41.0	1.1	38.7-43.3
Preorbital depth	23.7	21.4	2.2	16.7-28.9
Lower-jaw length	33.2	34.3	1.1	30.7-36.9
Cheek depth	26.4	24.5	2.3	18.6-28.8
Head depth	93.5	90.8	4.3	80.8-101.6
	Holotype	**Mode**	**% Freq.**	**Range**
Counts				
Dorsal spines	17	17	73.8	16-19
Dorsal rays	9	9	70.5	8-10
Anal spines	3	3	100.0	3-3
Anal rays	8	8	77.0	7-9
Pelvic fin rays	5	5	100.0	5-5
Pectoral fin rays	14	14	75.4	13-15
Lateral line scales	29	30	52.5	28-31
Pored scales posterior to lateral line	2	2	59.0	0-3
Scale rows on cheek	5	5	50.8	3-6
Gill rakers on first ceratobranchial	12	12	72.1	10-14
Gill rakers on first epibranchial	3	3	70.5	2-4
Teeth in outer row of left lower jaw	19	17	29.5	12-23
Teeth rows on upper jaw	3	3	80.3	2-4
Teeth rows on lower jaw	3	3	60.7	2-3

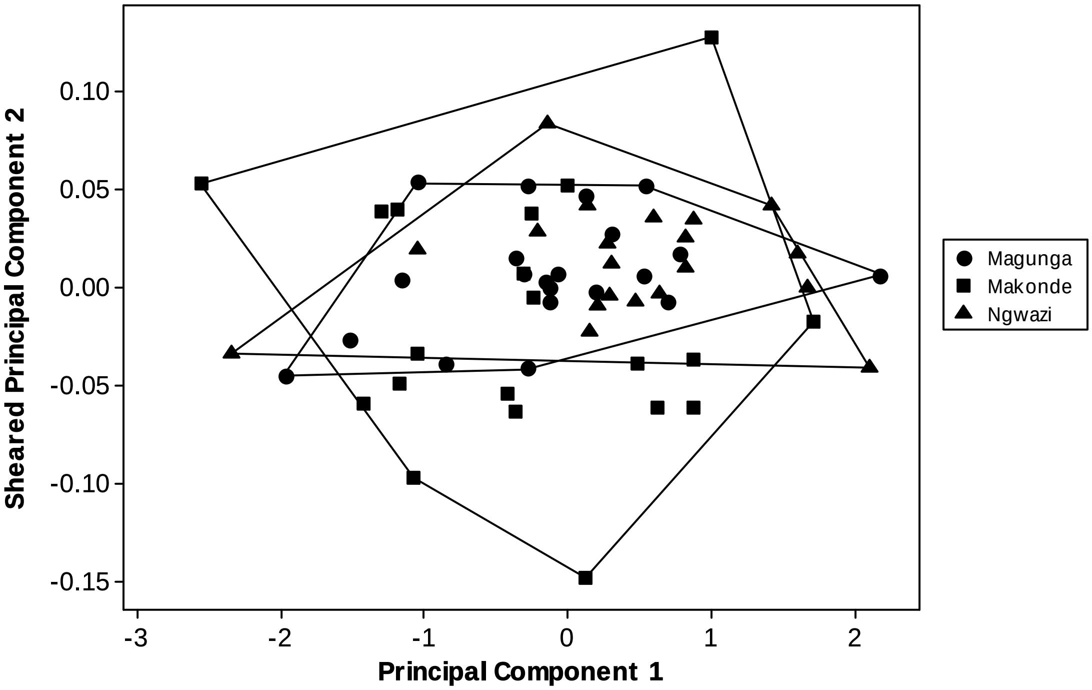

Fig. 11. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima sciasma* from Magunga, Makonde, and Ngwazi, Tanzania.

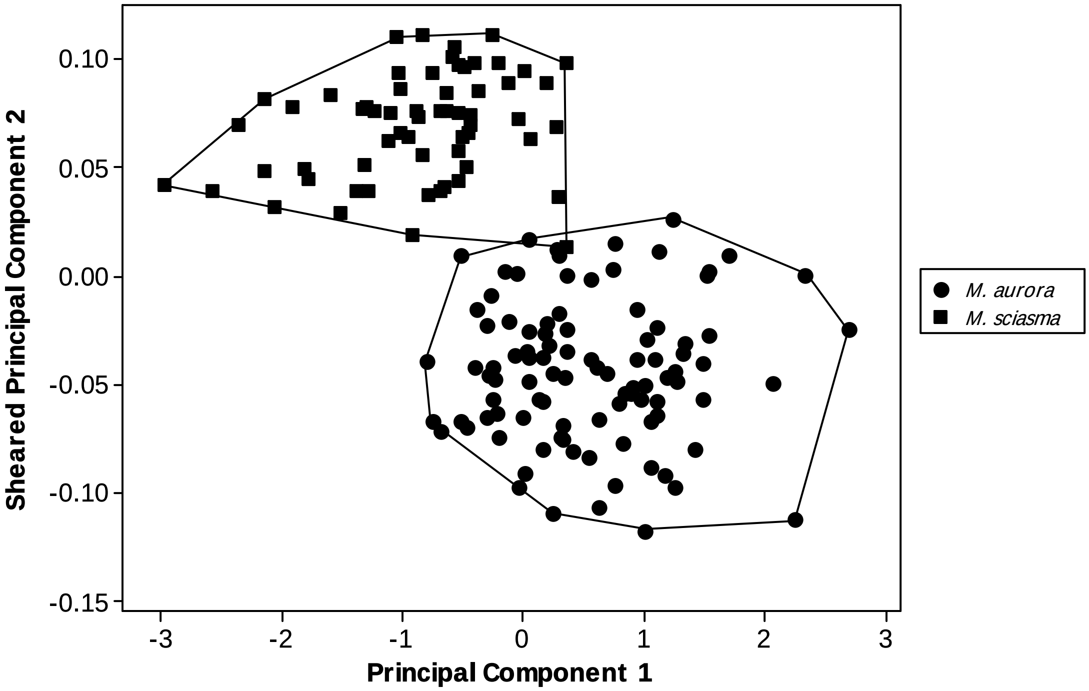

Fig. 12. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima aurora* and *M. sciasma*.

Table 16. Variable loadings on size and the first two sheared principal components (shape factors) for *Metriaclima aurora* and *M. sciasma*.

		Sheared Components	
	Size	PC2	PC3
Standard length	-0.191	*	*
Head length	-0.182	-0.158	*
Snout length	-0.233	-0.102	-0.385
Postorbital length	-0.175	*	*
Horizontal eye diameter	-0.147	-0.561	0.143
Vertical eye diameter	-0.156	-0.544	0.141
Preorbital depth	-0.263	*	-0.817
Cheek depth	-0.297	0.379	*
Lower-jaw length	-0.170	*	*
Head depth	-0.219	0.137	*
Body depth	-0.220	*	*
Snout to dorsal-fin origin	-0.184	-0.300	0.122
Snout to pelvic-fin origin	-0.196	*	*
Dorsal-fin base length	-0.206	0.125	*
Anterior dorsal to anterior anal	-0.209	*	0.114
Anterior dorsal to posterior anal	-0.208	*	*
Posterior dorsal to anterior anal	-0.216	0.130	*
Posterior dorsal to posterior anal	-0.198	*	0.156
Posterior dorsal to ventral caudal	-0.181	*	0.105
Posterior anal to dorsal caudal	-0.190	*	*
Anterior dorsal to pelvic-fin origin	-0.220	*	*
Posterior dorsal to pelvic-fin origin	-0.194	*	*
Caudal-peduncle length	-0.171	*	0.105
Least caudal-peduncle depth	-0.212	0.130	0.162

* = Absolute loading values <0.1 for loadings on shape factors.

Table 17. Standardized scoring coefficients for principal component analysis on meristic data for *Metriaclima aurora* and *M. sciasma*.

	Factor 1	Factor 2
Dorsal-fin spines	0.275	0.227
Dorsal-fin rays	-0.078	-0.380
Anal-fin spines	0.018	0.306
Anal-fin rays	0.069	-0.225
Pelvic-fin rays	0.000	0.000
Pectoral-fin rays	-0.066	-0.252
Lateral-line scales	0.249	0.086
Pored scales posterior to lateral line	-0.017	0.263
Scale rows on cheek	0.016	0.008
Gill rakers on first ceratobranchial	-0.101	0.155
Gill rakers on first epibranchial	-0.094	0.148
Teeth in outer row of left lower jaw	0.212	-0.097
Teeth rows on upper jaw	0.274	-0.120
Teeth rows on lower jaw	0.314	-0.104

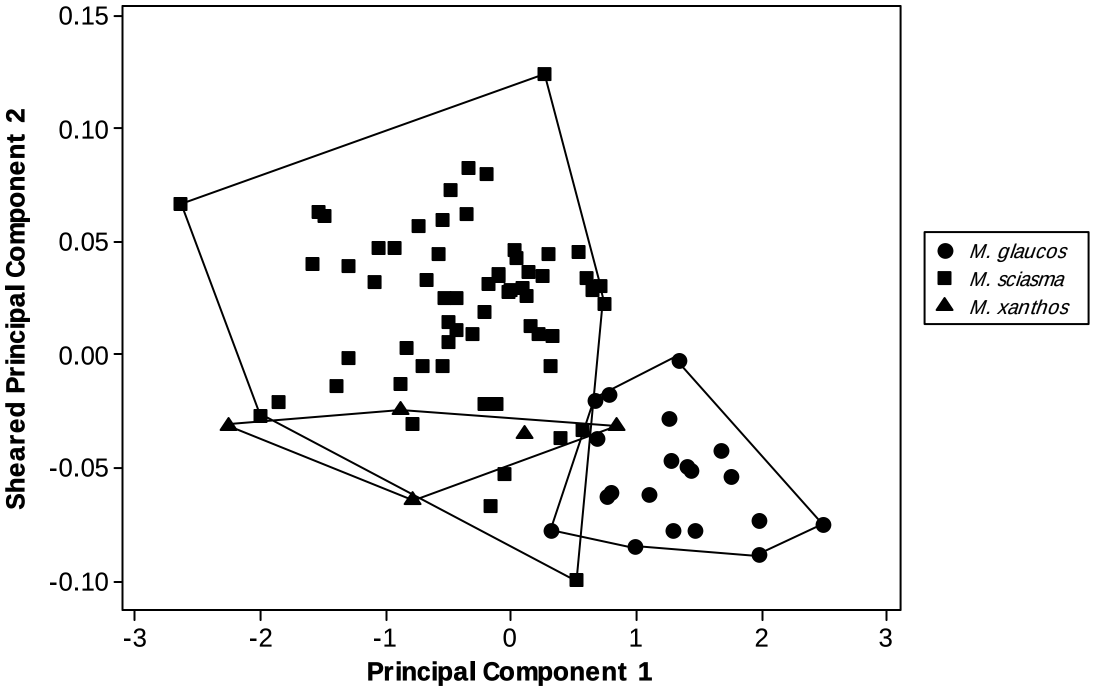

Fig. 13. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima glaucos, M. sciasma,* and *M. xanthos*.

Table 18. Variable loadings on size and the first two sheared principal components (shape factors) for *Metriaclima glaucos*, *M. sciasma*, and *M. xanthos*.

		Sheared Components	
	Size	PC2	PC3
Standard length	-0.188	*	*
Head length	-0.174	*	*
Snout length	-0.219	-0.514	0.104
Postorbital length	-0.181	*	*
Horizontal eye diameter	-0.120	*	*
Vertical eye diameter	-0.135	*	0.119
Preorbital depth	-0.261	-0.530	-0.619
Cheek depth	-0.287	0.208	-0.169
Lower-jaw length	-0.173	0.288	-0.475
Head depth	-0.232	*	*
Body depth	-0.225	*	0.130
Snout to dorsal-fin origin	-0.178	-0.185	0.241
Snout to pelvic-fin origin	-0.188	*	*
Dorsal-fin base length	-0.211	0.102	*
Anterior dorsal to anterior anal	-0.213	*	0.203
Anterior dorsal to posterior anal	-0.214	*	*
Posterior dorsal to anterior anal	-0.229	0.165	*
Posterior dorsal to posterior anal	-0.217	*	0.161
Posterior dorsal to ventral caudal	-0.181	0.210	*
Posterior anal to dorsal caudal	-0.192	*	*
Anterior dorsal to pelvic-fin origin	-0.225	-0.134	0.187
Posterior dorsal to pelvic-fin origin	-0.204	*	0.124
Caudal-peduncle length	-0.168	0.267	0.185
Least caudal-peduncle depth	-0.211	0.281	-0.287

* = Absolute loading values <0.1 for loadings on shape factors.

Table 19. Standardized scoring coefficients for principal component analysis on meristic data for *Metriaclima glaucos*, *M. sciasma*, and *M. xanthos*.

	Factor 1	Factor 2
Dorsal-fin spines	0.303	0.143
Dorsal-fin rays	-0.153	-0.279
Anal-fin spines	0.000	0.000
Anal-fin rays	-0.116	-0.003
Pelvic-fin rays	-0.065	0.238
Pectoral-fin rays	0.099	-0.297
Lateral-line scales	0.211	0.037
Pored scales posterior to lateral line	-0.149	0.188
Scale rows on cheek	0.182	-0.044
Gill rakers on first ceratobranchial	-0.306	0.217
Gill rakers on first epibranchial	-0.035	0.220
Teeth in outer row of left lower jaw	0.026	0.392
Teeth rows on upper jaw	0.174	0.252
Teeth rows on lower jaw	0.238	0.028

3.5 *Metriaclima xanthos* n. sp.

Holotype.- PSU 4494, 44.3 mm SL, Lumbaulo, Lake Malaŵi, Mozambique, 19 Feb. 2002.

Paratypes.- PSU 4495, 4, (44.6-49.3 mm), data as for holotype.

Diagnosis.- The following characters place this new species in the genus *Metriaclima*: moderately sloped head; isognathous jaws; presence of bicuspid teeth in the outer row along the side of the jaws that do not follow the contour of the jaw bone; lower jaw often slightly longer and thicker than upper jaw; large part of upper dental arcade normally exposed when the mouth is closed; tips of teeth in the premaxilla and dentary in a V-shaped line with the anteriormost in upper and lower jaw furthest apart; lateral teeth are rotated so that the plane of their two prolonged tips runs parallel with those in the anterior part of the jaw; feeding at a perpendicular angle to the substrate and has ability to align the teeth of both upper and lower jaws in the same plane by abducting its jaws to a near 180° angle (Konings and Stauffer, 2006). This fish is unique among the examined members of the *aurora*-group in the brown and blue/gray alternating lateral bars in conjunction with the gray and yellow head of breeding males. The lower jaw length, as percent head length, of *M. xanthos* is generally larger (mean 35.4, range 34.6-36.7; Table 20) than *M. aurora* (mean 31.2, range 28.4-33.5; Table 2) and *M. glaucos* (mean 30.8, range 28.8-32.8; Table 10), both neighboring populations, as well as *M. chrysomallos* (mean 32.1, range 29.6-34.2; Tables 6 and 7), in two non-neighboring populations. The snout to dorsal fin insertion length, expressed as percent standard length, is typically larger in *M. xanthos* (mean 34.7, range 32.4-36.5; Table 20) than *M. sciasma* (mean 31.1, range 29.3-33.6; Table 15).

Description.- Jaws isognathous; teeth on jaws in 2-3 rows; outer row teeth typically bicuspid anteriorly and unicuspid posteriorly; 21 teeth in outer row of left lower jaw of holotype, 15-23 in paratypes. Dorsal fin with 17 spines in holotype and 17-18 in paratypes; dorsal fin rays 9 in holotype and 8-10 in paratypes. Pectoral fin with 13 rays in holotype and 13-14 in paratypes; anal fin with 3 spines, 9 rays in holotype and 8-9 in paratypes. Lateral scales ctenoid; holotype with 29 lateral line scales and 29-32 in paratypes. First gill arch with 11-13 rakers on ceratobranchial, 2-3 on epibranchial, and 1 between epibranchial and ceratobranchial (Table 20).

Lateral body coloration of breeding male blue/gray with 6 brown bars, yellow ventrally, yellow caudal peduncle with flecks of blue. Head gray with 2 blue/gray interorbital bars; ventral third of operculum yellow with gray opercular spot; gular yellow. Dorsal fin yellow with blue lappets. Caudal-fin rays yellow with blue membranes. Anal fin brown with light blue distal edge and 4 orange ocelli. Leading edge of pelvic fins white, first ray brown, remainder yellow. Pectoral fins clear (Fig. 14). Female brown laterally with 5 faint brown bars, yellow breast, and white belly. Head orange/brown; gular yellow; black opercular spot. Dorsal fin brown with orange lappets. Caudal-fin rays orange with brown membrane. Anal fin orange with 1 small yellow ocellus. Pelvic fins orange. Pectoral fins clear.

The minimum polygon clusters formed by plotting the first principal components of the meristic data against the sheared second principal components of the morphometric data for *M. xanthos* and *M. aurora* were significantly ($p < 0.05$) different (Fig. 15). Size accounted for 91.5% of the observed variance and the second principal component accounted for 1.9%. The variables that had the highest loadings on the sheared second principal components were distance between the PDPA (-0.41), horizontal eye diameter (0.38), vertical eye diameter (0.38), and preorbital depth (0.36) (Table 21). The first principal component of the meristic data accounted for 11.6% of the total variance. The variables with the highest loadings on the first principal component were teeth rows on lower jaw (0.33), dorsal spines (0.33), and teeth rows on upper jaw (0.31) (Table 22).

When compared with *M. glaucos* from Cobwe, an *aurora*-group species to the south and the most geographically proximal population other than *M. aurora*, the minimum polygon clusters formed by plotting the first principal components of the meristic data against the sheared second principal components of the morphometric data do not overlap (Fig. 16). Size accounted for 94.9% of the observed variance and the second principal component accounted for 1.1%. The variables that had the highest loadings on the sheared second principal components were caudal-peduncle length (0.58), lower-jaw length (0.31), PADC (0.31), and vertical eye diameter (0.31) (Table 23). The first principal component of the meristic data accounted for 26.7% of the total variance. The variable with the highest loading on the first principal component was gill rakers on the epibranchial (-0.23) (Table 24).

Metriaclima xanthos is morphologically similar to *M. sciasma* as the minimum polygons clusters formed by plotting the first principal components of the meristic data against the sheared second principal components of the morphometric data overlap (Fig. 17). The Ruhuhu River and the sandy shore of Mbamba Bay further to the south serve as powerful barriers between these two populations preventing any genetic exchange between them, and should thus be considered separate species (Konings, personal communication). A closer observation of the principal component plot suggests that *M.*

xanthos is different from the majority of *M. sciasma* along the sheared second principal component axis with the exception of two *M. sciasma* outliers. The two clusters were significantly ($p < 0.05$) different along the sheared second principal component axis of the morphometric data, but not significantly different in regards to the first principal component axis of the meristics. Additionally, male breeding colors between the two species are drastically different as well as that of the females. Size accounted for 93.1% of the observed variance and the second principal component accounted for 2.2%. The variables that had the highest loadings on the sheared second principal components were preorbital depth (-0.77) and snout length (-0.39) (Table 25). The first principal component of the meristic data accounts for 17.3% of the total variance. The variables with the highest loadings on the first principal component were dorsal spines (0.35) and dorsal rays (-0.34) (Table 26).

Distribution.- *Metriaclima xanthos* was only collected at Lumbaulo, Mozambique, and is not known to occur at other places.

Etymology.- The name xanthos is Greek for yellow, in reference to the yellow belly and dorsal fin of breeding males.

Fig. 14. Breeding *Metriaclima xanthos* male.

Table 20. Morphometric and meristic values of the type series of *Metriaclima xanthos*. Mean, standard deviation, and range include the holotype (n = 5).

	Holotype	**Mean**	**Standard Deviation**	**Range**
Standard length, mm	44.3	45.7	2.0	44.3-49.3
Head length, mm	13.9	14.7	0.6	13.9-15.6
Percent standard length				
Head length	31.4	32.2	0.6	31.4-32.8
Snout to dorsal	35.4	34.7	1.5	32.4-36.5
Snout to pelvic	36.4	36.9	0.6	36.1-37.4
Greatest body depth	33.9	33.0	1.8	30.8-35.1
Caudal peduncle length	13.2	14.2	1.1	12.8-15.3
Least caudal peduncle depth	11.4	11.9	0.4	11.4-12.4
Dorsal fin base length	62.8	61.6	2.2	58.6-63.9
ADAA	52.6	51.3	1.5	49.6-53.1
ADPA	65.6	64.1	1.5	62.2-65.6
PDAA	30.3	29.8	1.1	28.3-31.1
PDPA	15.9	15.4	0.8	14.8-16.7
ADP2	37.2	35.9	1.6	33.3-37.4
PDP2	60.7	57.8	2.1	55.3-60.7
Percent head length				
Horizontal eye diameter	36.8	37.1	0.5	36.7-37.6
Vertical eye diameter	33.7	35.9	1.3	33.7-37.1
Snout length	27.5	26.2	1.3	24.1-27.5
Postorbital head length	43.7	40.0	2.2	38.4-43.7
Preorbital depth	21.4	20.9	1.0	19.2-21.7
Lower-jaw length	34.6	35.4	0.8	34.6-36.7
Cheek depth	20.1	20.8	1.5	18.7-22.6
Head depth	92.2	87.8	4.6	80.8-92.2
	Holotype	**Mode**	**% Freq.**	**Range**
Counts				
Dorsal spines	17	17	60.0	17-18
Dorsal rays	9	8, 9	40.0	8-10
Anal spines	3	3	100.0	3-3
Anal rays	9	8	60.0	8-9
Pelvic fin rays	5	5	100.0	5-5
Pectoral fin rays	13	14	80.0	13-14
Lateral line scales	29	29, 31	40.0	29-32
Pored scales posterior to lateral line	0	1, 2	40.0	0-2
Cheek scales	4	4	60.0	3-5
Gill rakers on first ceratobranchial	12	11, 12	40.0	11-13
Gill rakers on first epibranchial	3	3	80.0	2-3
Teeth in outer row of left lower jaw	21	21	40.0	15-23
Teeth rows on upper jaw	3	3	60.0	2-3
Teeth rows on lower jaw	3	2	80.0	2-3

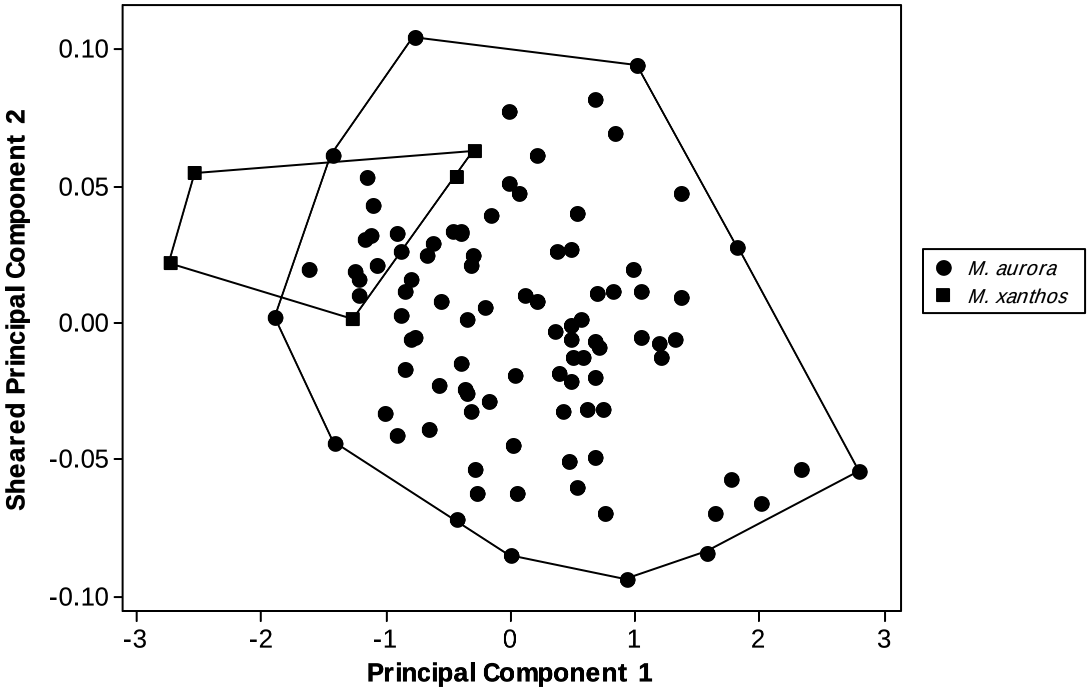

Fig.15. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima aurora* and *M. xanthos*.

Table 21. Variable loadings on size and the first two sheared principal components (shape factors) for *Metriaclima aurora* and *M. xanthos*.

		Sheared Components	
	Size	PC2	PC3
Standard length	-0.195	*	*
Head length	-0.193	0.184	0.135
Snout length	-0.248	0.189	-0.315
Postorbital length	-0.173	*	0.250
Horizontal eye diameter	-0.169	0.382	0.199
Vertical eye diameter	-0.177	0.376	0.188
Preorbital depth	-0.256	0.355	-0.714
Cheek depth	-0.304	*	0.179
Lower-jaw length	-0.173	0.194	0.173
Head depth	-0.207	*	*
Body depth	-0.211	*	*
Snout to dorsal-fin origin	-0.195	0.102	0.130
Snout to pelvic-fin origin	-0.204	0.177	0.203
Dorsal-fin base length	-0.202	*	*
Anterior dorsal to anterior anal	-0.205	-0.109	0.130
Anterior dorsal to posterior anal	-0.203	-0.101	*
Posterior dorsal to anterior anal	-0.204	-0.167	*
Posterior dorsal to posterior anal	-0.178	-0.406	-0.116
Posterior dorsal to ventral caudal	-0.184	-0.241	*
Posterior anal to dorsal caudal	-0.191	-0.209	*
Anterior dorsal to pelvic-fin origin	-0.205	-0.131	*
Posterior dorsal to pelvic-fin origin	-0.184	-0.188	-0.111
Caudal-peduncle length	-0.180	-0.114	-0.135
Least caudal-peduncle depth	-0.206	-0.196	0.184

* = Absolute loading values <0.1 for loadings on shape factors.

Table 22. Standardized scoring coefficients for principal component analysis on meristic data for *Metriaclima aurora* and *M. xanthos*.

	Factor 1	Factor 2
Dorsal-fin spines	0.325	-0.188
Dorsal-fin rays	-0.253	0.266
Anal-fin spines	0.048	-0.297
Anal-fin rays	-0.037	0.198
Pelvic-fin rays	0.000	0.000
Pectoral-fin rays	-0.108	0.145
Lateral-line scales	0.103	-0.104
Pored scales posterior to lateral line	0.127	-0.191
Scale rows on cheek	0.233	0.110
Gill rakers on first ceratobranchial	0.002	-0.122
Gill rakers on first epibranchial	-0.120	-0.266
Teeth in outer row of left lower jaw	0.030	0.117
Teeth rows on upper jaw	0.311	0.222
Teeth rows on lower jaw	0.332	0.212

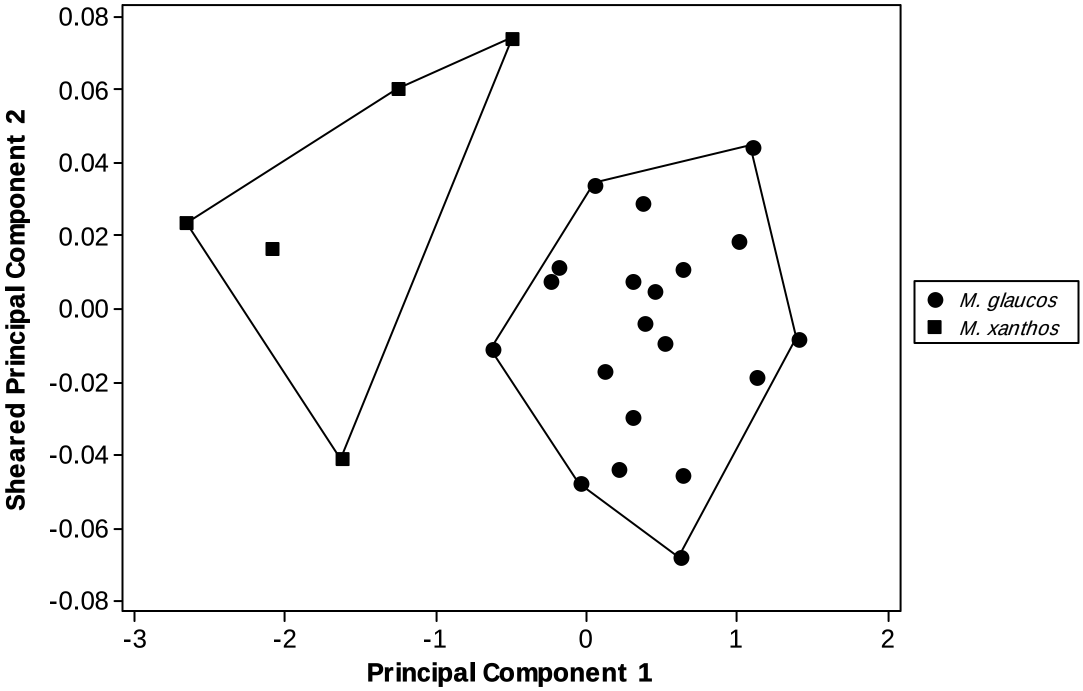

Fig. 16. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima glaucos* and *M. xanthos*.

Table 23. Variable loadings on size and the first two sheared principal components (shape factors) for *Metriaclima glaucos* and *M. xanthos*.

		Sheared Components	
	Size	PC2	PC3
Standard length	-0.200	*	*
Head length	-0.188	*	*
Snout length	-0.235	-0.236	*
Postorbital length	-0.209	-0.214	*
Horizontal eye diameter	-0.099	0.276	*
Vertical eye diameter	-0.140	0.306	*
Preorbital depth	-0.214	-0.109	-0.177
Cheek depth	-0.271	-0.135	*
Lower-jaw length	-0.199	0.312	0.662
Head depth	-0.230	*	*
Body depth	-0.206	*	*
Snout to dorsal-fin origin	-0.207	*	*
Snout to pelvic-fin origin	-0.184	*	-0.205
Dorsal-fin base length	-0.225	-0.111	*
Anterior dorsal to anterior anal	-0.210	-0.139	*
Anterior dorsal to posterior anal	-0.224	-0.117	*
Posterior dorsal to anterior anal	-0.230	*	0.225
Posterior dorsal to posterior anal	-0.210	0.106	*
Posterior dorsal to ventral caudal	-0.196	-0.126	*
Posterior anal to dorsal caudal	-0.199	0.307	-0.133
Anterior dorsal to pelvic-fin origin	-0.184	-0.186	-0.332
Posterior dorsal to pelvic-fin origin	-0.207	-0.141	*
Caudal-peduncle length	-0.190	0.583	-0.454
Least caudal-peduncle depth	-0.182	0.163	0.183

* = Absolute loading values <0.1 for loadings on shape factors.

Table 24. Standardized scoring coefficients for principal component analysis on meristic data for *Metriaclima glaucos* and *M. xanthos*.

	Factor 1	Factor 2
Dorsal-fin spines	0.184	0.191
Dorsal-fin rays	-0.067	-0.338
Anal-fin spines	0.000	0.000
Anal-fin rays	-0.187	-0.098
Pelvic-fin rays	-0.022	0.215
Pectoral-fin rays	0.127	-0.163
Lateral-line scales	0.017	-0.146
Pored scales posterior to lateral line	-0.058	0.160
Scale rows on cheek	0.173	-0.134
Gill rakers on first ceratobranchial	-0.233	0.129
Gill rakers on first epibranchial	0.141	0.213
Teeth in outer row of left lower jaw	-0.152	0.325
Teeth rows on upper jaw	0.178	0.197
Teeth rows on lower jaw	0.188	-0.009

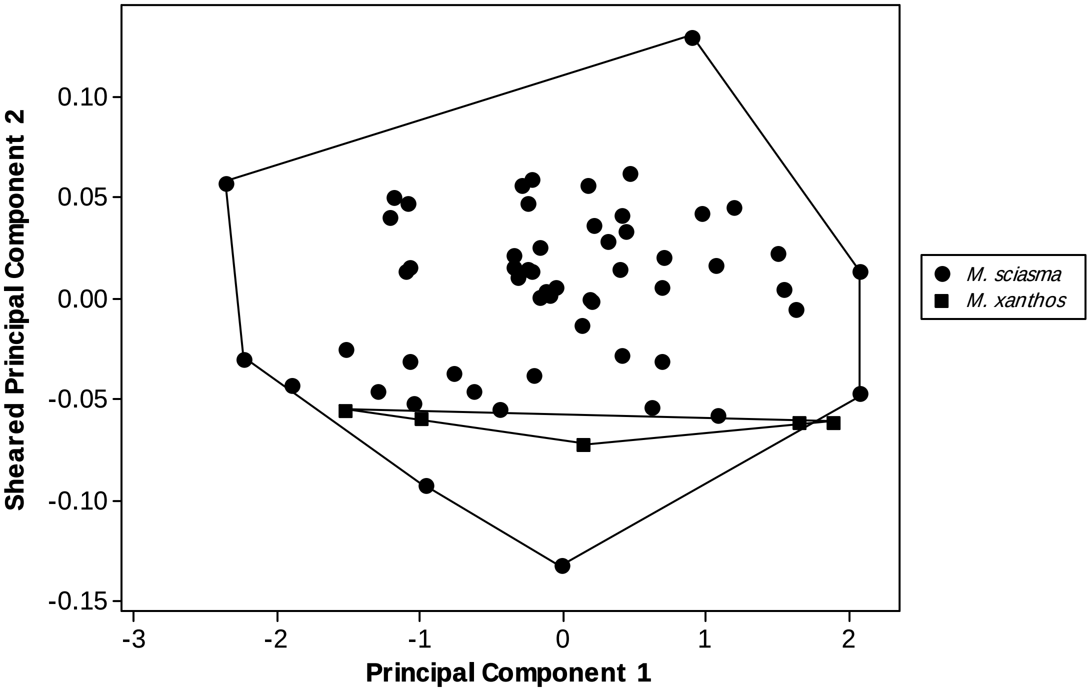

Fig. 17. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima sciasma* and *M. xanthos*.

Table 25. Variable loadings on size and the first two sheared principal components (shape factors) for *Metriaclima xanthos* and *M. sciasma*.

		Sheared Components	
	Size	PC2	PC3
Standard length	-0.185	*	*
Head length	-0.170	*	*
Snout length	-0.216	-0.394	*
Postorbital length	-0.174	*	*
Horizontal eye diameter	-0.124	*	0.125
Vertical eye diameter	-0.134	*	0.150
Preorbital depth	-0.271	-0.765	-0.268
Cheek depth	-0.291	0.192	0.227
Lower-jaw length	-0.168	*	0.164
Head depth	-0.232	*	*
Body depth	-0.228	*	0.114
Snout to dorsal-fin origin	-0.174	*	0.135
Snout to pelvic-fin origin	-0.189	*	*
Dorsal-fin base length	-0.207	0.137	*
Anterior dorsal to anterior anal	-0.213	*	*
Anterior dorsal to posterior anal	-0.211	0.103	*
Posterior dorsal to anterior anal	-0.227	0.139	0.108
Posterior dorsal to posterior anal	-0.218	0.118	*
Posterior dorsal to ventral caudal	-0.178	0.180	-0.321
Posterior anal to dorsal caudal	-0.192	*	-0.334
Anterior dorsal to pelvic-fin origin	-0.231	*	0.167
Posterior dorsal to pelvic-fin origin	-0.202	0.107	*
Caudal-peduncle length	-0.166	0.289	-0.684
Least caudal-peduncle depth	-0.216	*	0.168

* = Absolute loading values <0.1 for loadings on shape factors.

Table 26. Standardized scoring coefficients for principal component analysis on meristic data for *Metriaclima xanthos* and *M. sciasma*.

	Factor 1	Factor 2
Dorsal-fin spines	0.351	-0.270
Dorsal-fin rays	-0.341	0.174
Anal-fin spines	0.000	0.000
Anal-fin rays	-0.036	0.095
Pelvic-fin rays	0.000	0.000
Pectoral-fin rays	-0.120	0.068
Lateral-line scales	0.232	-0.242
Pored scales posterior to lateral line	0.021	-0.045
Scale rows on cheek	0.078	0.285
Gill rakers on first ceratobranchial	-0.027	0.092
Gill rakers on first epibranchial	0.077	0.325
Teeth in outer row of left lower jaw	0.283	0.186
Teeth rows on upper jaw	0.240	0.359
Teeth rows on lower jaw	0.142	0.276

3.6 *Metriaclima mossambiquensis* n. sp.

Holotype.- PSU 4497, 79.7 mm SL, Chiloelo, Lake Malaŵi, Mozambique, 6-10 m, 13 Feb. 2002.

Paratypes.- PSU 4498, 16, UMBC 17, 1, AMNH 246001, 2, (54.9-77.0 mm), data as for holotype; PSU 4601, 19, (47.8-76.5 mm), Chinuni, Lake Malaŵi, Mozambique, 10 m, 14 Feb. 2001; PSU 4602, 18, (54.5-79.1 mm), Lumessi, Lake Malaŵi, Mozambique, 7-25 m, 14 Feb. 2002.

Diagnosis.- The following characters place this new species in the genus *Metriaclima*: moderately sloped head; isognathous jaws; presence of bicuspid teeth in the outer row along the side of the jaws that do not follow the contour of the jaw bone; lower jaw often slightly longer and thicker than upper jaw; large part of upper dental arcade normally exposed when the mouth is closed; tips of teeth in the premaxilla and dentary in a V-shaped line with the anteriormost in upper and lower jaw furthest apart; lateral teeth are rotated so that the plane of their two prolonged tips runs parallel with those in the anterior part of the jaw; feeding at a perpendicular angle to the substrate and has ability to align the teeth of both upper and lower jaws in the same plane by abducting its jaws to a near 180° angle (Konings and Stauffer, 2006). In some populations, the caudal and posterior portions of the dorsal fins are streaked with black, distinguishing these individuals from all other *aurora*-group species. When the black is absent in the dorsal and caudal fins, an extension of gold from the belly dorsally occurs, distinguishing it from all other *aurora*-group species. Other populations show a range of these two extremes, all of which are unique from other species of the group. Head depth, expressed as percent head length, is generally larger in *M. mossambiquensis* (mean 96.0, range 83.3-111.8; Table 27) compared to *M. aurora* (mean 86.8, range 75.8-95.4; Table 2), *M. xanthos* (mean 87.8, range 80.8-92.2; Table 20), and *M. chrysomallos* (mean 86.4, range 79.9-93.3; Tables 6 and 7). Additionally, in *M. mossambiquensis* there are typically more dorsal spines (mode 18, range 16-18; Table 27) than *M. sciasma* (mode 17, range 17-19; 15); more teeth in the outer row of the lower left jaw (mode 21, range 15-26; Table 27) than *M. glaucos* (mode 16, range 14-19; Table 10); and a longer postorbital head length, expressed as percent head length (mean 41.7, range 39.3-44.8; Table 27) than *M. nkhungu* n. sp. (mean 38.3, range 35.6-40.6; Table 34).

Description.- Jaws isognathous; teeth on jaw in 2-4 rows; outer row teeth generally bicuspid anteriorly and unicuspid posteriorly; those in inner rows tricuspid, sometimes inner most row unicuspid; 15 teeth in outer row of lower left jaw in holotype, 15-26 in paratypes. Dorsal fin with 18 spines in holotype, 16-18 in paratypes; dorsal-fin rays 9 in the holotype, 8-10 in paratypes. Pectoral fin with 14 rays in holotype and 14-15 in paratypes; anal fin with 3 spines, 8 rays in holotype and 7-9 in paratypes. Lateral scales ctenoid; holotype with 31 lateral-line scales and 29-32 in paratypes. First gill arch with 10-13 rakers on ceratobranchial, 2-4 on epibranchial, and 1 between epibranchial and ceratobranchial (Table 27).

Breeding males at Lumessi typically with gray/blue ground color with posterior edge of scales gold in dorsal two-thirds and no lateral barring; ventral third gold. Ventral third of head gold; cheeks yellow, gular orange, interorbital gray with green interorbital bar, and black opercular spot. Proximal two-thirds of dorsal fin gold, remainder blue/gray. Caudal-fin rays gold with blue/gray membranes. Proximal third of anal fin orange, distal two-thirds blue/gray. Pelvic fins orange. Pectoral-fin rays orange with clear membranes (Fig. 18).

Breeding males from Chinuni typically with blue ground color and 7 gray bars, caudal peduncle blue/gray. Head blue dorsally with 1 dark interorbital bar, purple cheek and operculum, pale yellow gular, and gray opercular spot. Dorsal fin blue with orange tips. Caudal-fin rays pale orange with blue membranes. Anal fins gray with a black marginal band and 3 yellow ocelli. Pelvic fins with white leading edge, spine black and first two membranes black, remainder clear. Pectoral fins clear (Fig. 18).

Breeding males from Chiloelo with blue ground color and 7 dark blue bars; belly white with area between pelvic fins orange. Head blue with one gray interorbital bar, interorbital light blue, gular orange. Dorsal fin blue with white marginal bar, distal third of rays black. Caudal-fin rays black with blue membranes. Anal fins blue/gray with 5 orange ocelli and black band near distal edge. Pelvic fins clear, except for white spine and first black ray. Pectoral-fin rays black with clear membranes (Fig. 18).

Females of *M. mossambiquensis* more similar in color than males from different localities; females indistinguishable under water (Konings, 2001). At Chiloelo and Lumessi, females gray/brown laterally with scales outlined in blue; belly white. Head brown, cheek with green highlights, gular white. Dorsal fin gray with green spots and orange lappets; orange tips on rays. Caudal fin clear with orange/yellow tips on dorsal and ventral rays and blue spots throughout. Anal fin clear in proximal half, orange/brown in distal half. Pelvic fins clear except for first two orange/brown membranes. Pectoral fins clear. At Chinuni, females brown/green laterally with 6 brown bars, caudal peduncle brown; belly white. Head brown with 1 dark brown interorbital bar, cheek brown with green highlights; gular white. Dorsal fin brown. Caudal fin rays brown with clear membranes. Anal fin gray proximally and brown/orange distally. Pelvic fins with white leading edge, first two rays and first membrane black, remainder clear. Pectoral-fin rays gray with clear membranes.

The minimum polygon clusters formed by plotting the first principal components of the meristic data against the sheared second principal components of the morphometric data overlap for the populations from Chiloelo, Chinuni, and Lumessi (Fig. 19). In *M. mossambiquensis*, there is a clinal change in coloration among the three examined populations. This change in color in not accompanied by a change in morphological traits, however. The yellow coloration of the *M. mossambiquensis* population at Lumessi and a bay north of Chinuni changes to blue, and black pigment develops on the pelvic, anal, posterior dorsal, and/or caudal fins. At each location, color may vary in the extent of yellow or black pigment. Due to the lack of evidence of assortative mating, these morphologically similar populations of *M. mossambiquensis* are considered conspecific. Intra-population variance in color among males, as observed in *M. mossambiquensis* and in another mbuna species *Labeotropheus fuelleborni* (Arnegard *et al.*, 1999), suggests specific mate recognition systems have not diverged sufficiently for reproductive isolation. The neighboring populations may have begun to diverge into separate species (*sensu* semispecies (Mayr, 1963)), but different evolution trajectories cannot be diagnosed at this time. Between the rocky shores directly south of Meponda and those directly north of the Chiloelo River (28 km), no other *aurora*-group species have been observed (Konings, personal communication).

Metriaclima mossambiquensis was compared with *M. aurora*, *M. chrysomallos* and *M. nkhungu* (Figs. 20 and 21). In *M. mossambiquensis,* preorbital depth, expressed as percent head length, is generally larger (mean 23.6, range 18.9-29.0; Table 27) than the preorbital depths recorded for *M. aurora* (mean 21.8, range 18.6-26.4; Table 2), *M. chrysomallos* (mean 20.3, range 16.5-24.2; Tables 6 and 7) and *M. nkhungu* (mean 21.1, range 19.0-23.5; Table 34). Head depth, expressed as percent head length, is also generally larger in *M. mossambiquensis* (mean 96.0, range 83.3-111.8; Table 27) than *M. aurora* (mean 86.8, range 75.8-95.4; Table 2), *M. chrysomallos* (mean 86.4, range 79.9-93.3; Tables 6 and 7), and *M. nkhungu* (mean 92.5, range 89.4-96.3; Table 34). The minimum polygon clusters formed by plotting the first principal components of the meristic data against the sheared second principal components of the morphometric data for *M. mossambiquensis* and *M. aurora* are significantly ($p < 0.05$) different (Fig. 20). Size accounted for 85.6% of the observed variance and the second principal component accounted for 4.9%. The variables that had the highest loadings on the sheared second principal component were vertical eye diameter (0.52) and horizontal eye diameter (0.52) (Table 28). The first principal component of the meristic data accounted for 14.2% of the total variance. The variables with the highest loadings on the first principal component of the meristic data were teeth rows on the lower jaw (0.44) and teeth rows on the upper jaw (0.39) (Table 29). The minimum polygon clusters formed by plotting the first principal components of the meristic data against the sheared second principal components of the morphometric data for *M. mossambiquensis* and *M. chrysomallos* were significantly ($p < 0.05$) different and thus the two are considered separate species (Fig. 22). Size accounted for 87.1% of the observed variance and the second principal component accounted for 4.4%. The variables that had the highest loadings on the sheared second principal component were preorbital depth (-0.57), vertical eye diameter (0.42), horizontal eye diameter (0.39), and snout length (-0.31) (Table 30). The first principal component of the meristic data accounted for 16.1% of the total variance. The variables with the highest loadings on the first principal component based on the standardized scoring coefficients were teeth rows on lower jaw (0.40) and teeth on lower left jaw (0.31) (Table 31).

The minimum polygon clusters formed by plotting the first principal components of the meristic data against the sheared second principal components of the morphometric data show that the polygons formed by *M. mossambiquensis* and *M. nkhungu* are overlapping (Fig. 23). A MANOVA showed, however, that the polygon clusters for the two populations were significantly ($p < 0.05$) different. Size accounted for 90.5% of the observed variance and the second principal component accounted for 2.5%. The variables that had the highest loadings on the sheared second principal component were preorbital depth (-0.69) and least caudal peduncle depth (0.28) (Table 32). The first principal component of the meristic data accounted for 16.6% of the total variance. The variables with the highest loadings on the first principal component based on the standardized scoring coefficients were teeth rows on lower jaw (0.31) and number of gill rakers on the first epibranchial (0.29) (Table 33). The brown/green coloration of the *M. mossambiquensis* females and the bright blue coloration of *M. nkhungu* females separate these two species. The nearest populations of these two species are separated by a distance of approximately 11 km and another species of *Metriaclima* occurs in the intermediate (rock/sand interface) habitat, preferred by *aurora*-group species that lies in between. It is therefore thought unlikely that genetic exchange would take place between *M. nkhungu* and *M. mossambiquensis.*

Distribution.- Metriaclima mossambiquensis is found north of the Chiloelo River to a bay north of Chinuni.

Etymology.- The name mossambiquensis, Latin for Mozambique, where the species is native.

Fig. 18. Range of male breeding colors of *Metriaclima mossambiquensis*.

Table 27. Morphometric and meristic values of the type series of *Metriaclima mossambiquensis*. Mean, standard deviation, and range include the holotype (n = 57).

	Holotype	**Mean**	**Standard Deviation**	**Range**
Standard length, mm	79.7	67.4	7.5	47.8-79.7
Head length, mm	23.7	20.8	2.2	14.5-24.2
Percent standard length				
Head length	29.8	30.9	0.7	29.3-32.7
Snout to dorsal	31.3	33.8	1.0	31.3-37.0
Snout to pelvic	39.4	39.3	0.9	37.3-41.3
Greatest body depth	33.8	34.1	1.4	31.2-37.4
Caudal peduncle length	13.2	13.9	0.8	12.3-15.6
Least caudal peduncle depth	12.4	11.9	0.5	10.7-13.3
Dorsal fin base length	62.4	61.0	1.1	59.0-63.8
ADAA	56.6	54.3	1.5	51.6-58.4
ADPA	66.7	64.8	1.2	61.8-67.3
PDAA	30.8	29.6	1.1	27.4-32.1
PDPA	16.5	15.7	0.7	13.5-17.4
ADP2	38.8	37.8	1.6	33.1-41.8
PDP2	58.9	58.1	1.5	55.6-61.7
Percent head length				
Horizontal eye diameter	31.4	33.8	1.3	31.1-37.5
Vertical eye diameter	31.0	33.6	1.3	31.1-36.5
Snout length	28.9	28.2	1.2	26.0-31.3
Postorbital head length	42.1	41.7	1.3	39.3-44.8
Preorbital depth	23.4	23.6	2.1	18.9-29.0
Lower-jaw length	31.0	31.4	1.2	27.9-33.8
Cheek depth	31.8	24.9	2.4	19.0-31.8
Head depth	96.9	96.0	4.7	83.3-111.8
	Holotype	**Mode**	**% Freq.**	**Range**
Counts				
Dorsal spines	18	18	71.9	16-18
Dorsal rays	9	9	77.2	8-10
Anal spines	3	3	100.0	3-3
Anal rays	8	8	82.5	7-9
Pelvic fin rays	5	5	100.0	5-5
Pectoral fin rays	14	14	71.9	14-15
Lateral line scales	31	30	57.9	29-32
Pored scales posterior to lateral line	2	2	50.9	0-3
Cheek scales	4	5	47.4	3-6
Gill rakers on first ceratobranchial	12	12	57.9	10-13
Gill rakers on first epibranchial	3	3	82.5	2-4
Teeth in outer row of left lower jaw	15	21	26.3	15-26
Teeth rows on upper jaw	3	3	87.7	2-4
Teeth rows on lower jaw	3	3	89.5	2-4

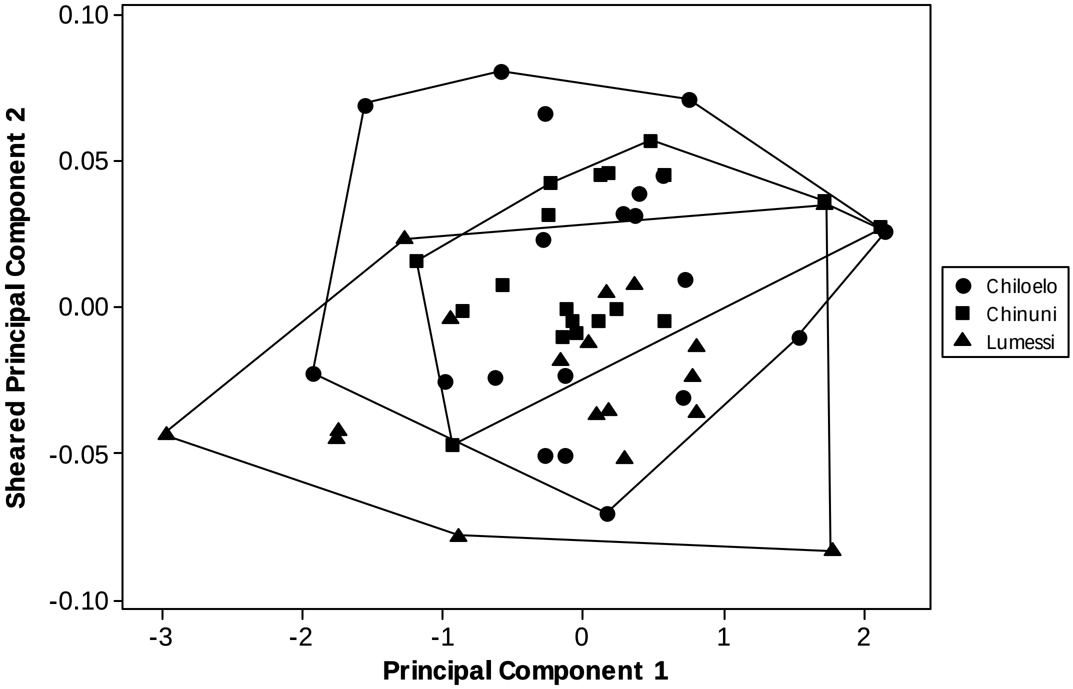

Fig. 19. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima mossambiquensis* from Chiloelo, Chinuni, and Lumessi.

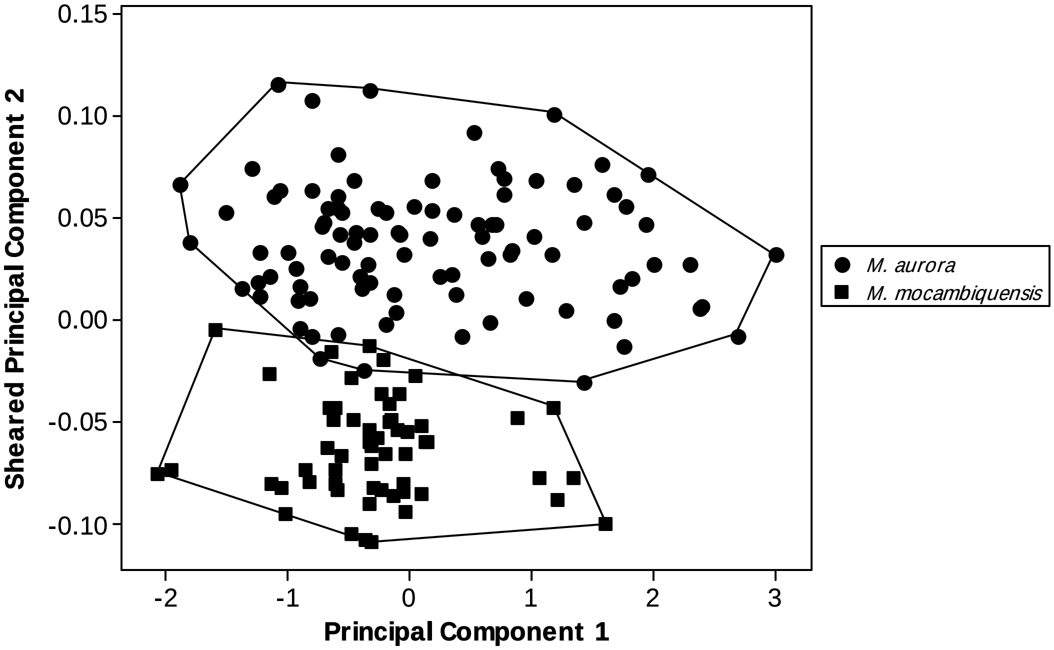

Figure 20. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima aurora* and *M. mossambiquensis*.

Table 28. Variable loadings on size and the first two sheared principal components (shape factors) for *Metriaclima mossambiquensis* and *M. aurora*.

		Sheared Components	
	Size	PC2	PC3
Standard length	-0.193	*	*
Head length	-0.189	0.120	-0.113
Snout length	-0.232	-0.125	-0.245
Postorbital length	-0.182	-0.118	*
Horizontal eye diameter	-0.164	0.516	-0.208
Vertical eye diameter	-0.167	0.523	-0.189
Preorbital depth	-0.261	-0.256	-0.652
Cheek depth	-0.295	-0.262	*
Lower-jaw length	-0.187	0.122	*
Head depth	-0.213	-0.318	*
Body depth	-0.218	-0.122	*
Snout to dorsal-fin origin	-0.194	0.111	*
Snout to pelvic-fin origin	-0.203	*	-0.115
Dorsal-fin base length	-0.201	*	*
Anterior dorsal to anterior anal	-0.205	*	0.133
Anterior dorsal to posterior anal	-0.200	*	0.113
Posterior dorsal to anterior anal	-0.201	*	0.191
Posterior dorsal to posterior anal	-0.186	-0.136	0.303
Posterior dorsal to ventral caudal	-0.182	0.123	0.224
Posterior anal to dorsal caudal	-0.186	0.111	0.225
Anterior dorsal to pelvic-fin origin	-0.217	-0.137	0.101
Posterior dorsal to pelvic-fin origin	-0.194	*	0.143
Caudal-peduncle length	-0.171	0.244	0.135
Least caudal-peduncle depth	-0.211	*	0.264

* = Absolute loading values <0.1 for loadings on shape factors.

Table 29. Standardized scoring coefficients for principal component analysis on meristic data for *Metriaclima mossambiquensis* and *M. aurora*.

	Factor 1	Factor 2
Dorsal-fin spines	0.228	0.335
Dorsal-fin rays	-0.116	-0.350
Anal-fin spines	-0.116	0.287
Anal-fin rays	0.159	-0.104
Pelvic-fin rays	0.000	0.000
Pectoral-fin rays	-0.024	-0.254
Lateral-line scales	0.092	0.185
Pored scales posterior to lateral line	0.028	0.224
Scale rows on cheek	0.174	-0.105
Gill rakers on first ceratobranchial	-0.041	0.127
Gill rakers on first epibranchial	-0.215	0.146
Teeth in outer row of left lower jaw	0.063	-0.155
Teeth rows on upper jaw	0.393	-0.085
Teeth rows on lower jaw	0.438	0.003

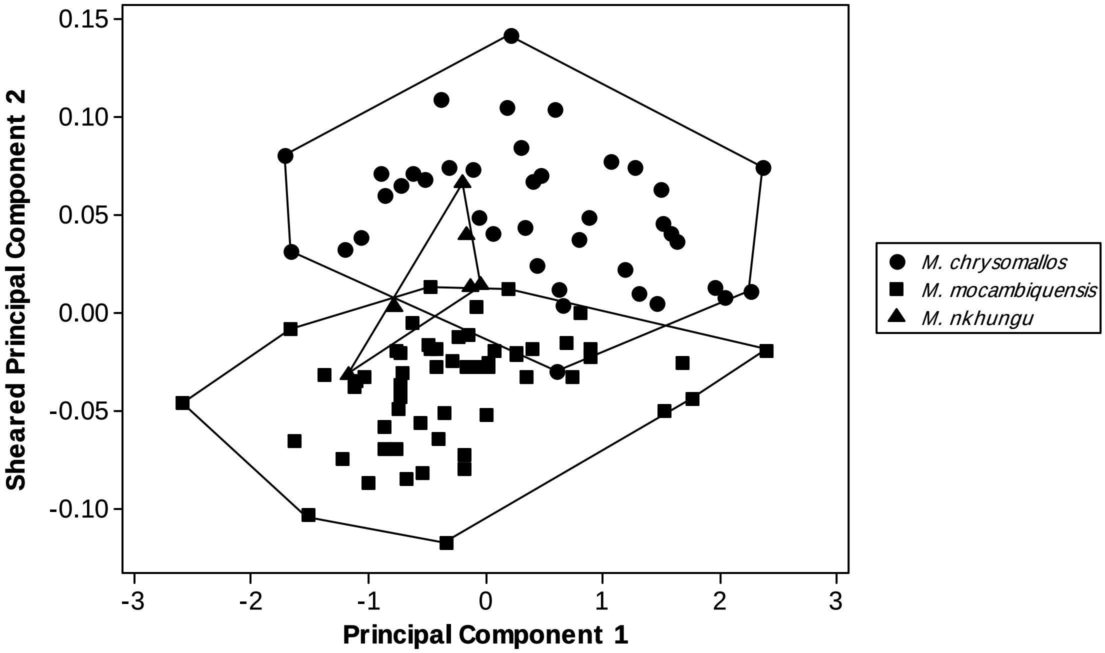

Fig. 21. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima chrysomallos*, *M. mossambiquensis*, and *M. nkhungu*.

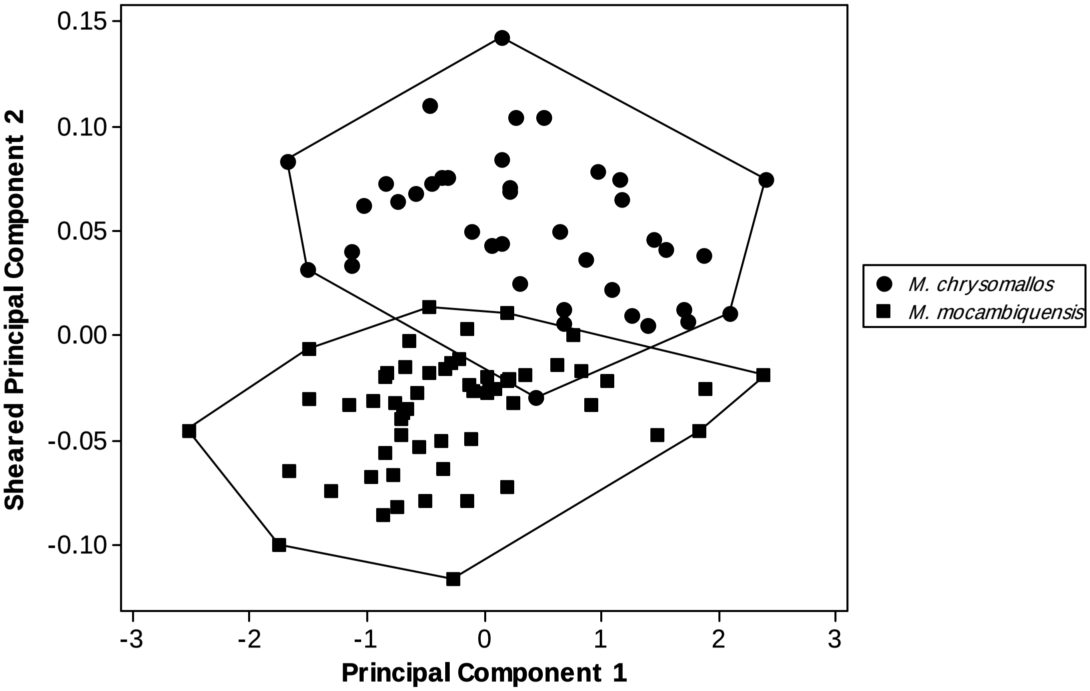

Fig. 22. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *M. chrysomallos* and *M. mossambiquensis*.

Table 30. Variable loadings on size and the first two sheared principal components (shape factors) for *Metriaclima mossambiquensis* and *M. chrysomallos*.

		Sheared Components	
	Size	PC2	PC3
Standard length	-0.191	*	*
Head length	-0.180	0.158	0.144
Snout length	-0.231	-0.305	0.104
Postorbital length	-0.186	*	*
Horizontal eye diameter	-0.144	0.386	0.368
Vertical eye diameter	-0.137	0.416	0.326
Preorbital depth	-0.271	-0.566	0.520
Cheek depth	-0.303	-0.110	*
Lower-jaw length	-0.196	0.279	0.252
Head depth	-0.212	-0.195	*
Body depth	-0.215	*	*
Snout to dorsal-fin origin	-0.190	*	0.174
Snout to pelvic-fin origin	-0.201	*	*
Dorsal-fin base length	-0.201	0.116	*
Anterior dorsal to anterior anal	-0.203	*	-0.147
Anterior dorsal to posterior anal	-0.199	*	-0.116
Posterior dorsal to anterior anal	-0.201	*	-0.233
Posterior dorsal to posterior anal	-0.198	-0.126	-0.272
Posterior dorsal to ventral caudal	-0.186	*	-0.218
Posterior anal to dorsal caudal	-0.187	*	-0.183
Anterior dorsal to pelvic-fin origin	-0.217	*	*
Posterior dorsal to pelvic-fin origin	-0.198	*	*
Caudal-peduncle length	-0.172	*	-0.104
Least caudal-peduncle depth	-0.217	0.197	-0.236

* = Absolute loading values <0.1 for loadings on shape factors.

Table 31. Standardized scoring coefficients for principal component analysis on meristic data for *Metriaclima mossambiquensis* and *M. chrysomallos*.

	Factor 1	Factor 2
Dorsal-fin spines	0.225	-0.407
Dorsal-fin rays	-0.102	0.415
Anal-fin spines	0.000	0.000
Anal-fin rays	0.213	0.046
Pelvic-fin rays	0.000	0.000
Pectoral-fin rays	0.187	-0.048
Lateral-line scales	0.224	-0.139
Pored scales posterior to lateral line	0.027	0.194
Scale rows on cheek	0.051	-0.032
Gill rakers on first ceratobranchial	0.091	0.335
Gill rakers on first epibranchial	0.174	0.296
Teeth in outer row of left lower jaw	0.305	0.130
Teeth rows on upper jaw	0.177	0.109
Teeth rows on lower jaw	0.401	0.050

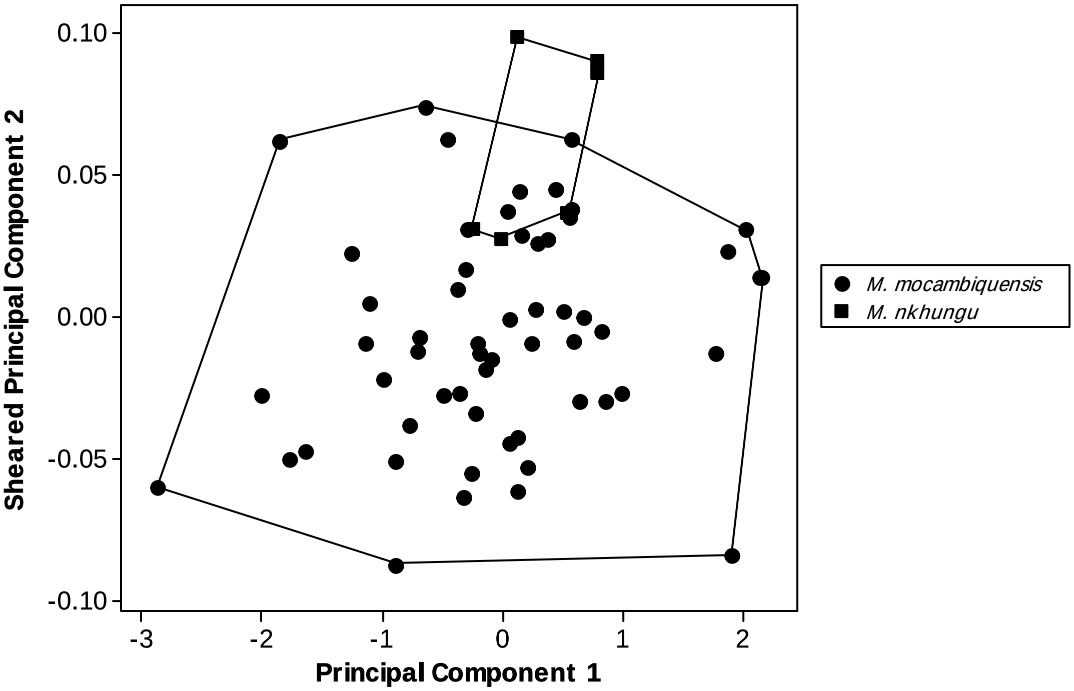

Fig. 23. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima mossambiquensis* and *M. nkhungu*.

Table 32. Variable loadings on size and the first two sheared principal components (shape factors) for *Metriaclima mossambiquensis* and *M. nkhungu*.

		Sheared Components	
	Size	PC2	PC3
Standard length	-0.189	*	0.141
Head length	-0.183	*	0.184
Snout length	-0.215	-0.117	*
Postorbital length	-0.188	-0.231	*
Horizontal eye diameter	-0.157	-0.175	0.220
Vertical eye diameter	-0.154	-0.104	0.240
Preorbital depth	-0.269	-0.689	-0.238
Cheek depth	-0.286	*	-0.509
Lower-jaw length	-0.200	-0.102	0.310
Head depth	-0.219	*	*
Body depth	-0.224	0.102	0.125
Snout to dorsal-fin origin	-0.190	-0.185	0.229
Snout to pelvic-fin origin	-0.202	*	0.185
Dorsal-fin base length	-0.199	0.158	*
Anterior dorsal to anterior anal	-0.204	0.146	*
Anterior dorsal to posterior anal	-0.196	0.122	*
Posterior dorsal to anterior anal	-0.198	0.227	-0.122
Posterior dorsal to posterior anal	-0.196	0.157	-0.325
Posterior dorsal to ventral caudal	-0.182	0.114	-0.238
Posterior anal to dorsal caudal	-0.183	0.183	*
Anterior dorsal to pelvic-fin origin	-0.228	0.118	*
Posterior dorsal to pelvic-fin origin	-0.203	0.223	0.115
Caudal-peduncle length	-0.164	0.115	-0.309
Least caudal-peduncle depth	-0.216	0.277	*

* = Absolute loading values <0.1 for loadings on shape factors.

Table 33. Standardized scoring coefficients for principal component analysis on meristic data for *Metriaclima mossambiquensis* and *M. nkhungu*.

	Factor 1	Factor 2
Dorsal-fin spines	-0.110	-0.025
Dorsal-fin rays	0.219	-0.134
Anal-fin spines	0.000	0.000
Anal-fin rays	0.137	-0.126
Pelvic-fin rays	0.000	0.000
Pectoral-fin rays	0.060	0.403
Lateral-line scales	0.278	-0.150
Pored scales posterior to lateral line	-0.044	-0.235
Scale rows on cheek	0.085	0.345
Gill rakers on first ceratobranchial	0.224	-0.332
Gill rakers on first epibranchial	0.286	0.048
Teeth in outer row of left lower jaw	0.272	-0.037
Teeth rows on upper jaw	0.181	0.316
Teeth rows on lower jaw	0.307	0.115

3.7 *Metriaclima nkhungu* n. sp.

Holotype.- PSU 4603, 72.8 mm SL, Nkhungu Reef, 1 Mar. 2006.

Paratypes.- PSU 4604, 5, (65.3-73.3 mm), data as for holotype.

Diagnosis.- The following characters place this new species in the genus *Metriaclima*: moderately sloped head; isognathous jaws; presence of bicuspid teeth in the outer row along the side of the jaws that do not follow the contour of the jaw bone; lower jaw often slightly longer and thicker than upper jaw; large part of upper dental arcade normally exposed when the mouth is closed; tips of teeth in the premaxilla and dentary in a V-shaped line with the anteriormost in upper and lower jaw furthest apart; lateral teeth are rotated so that the plane of their two prolonged tips runs parallel with those in the anterior part of the jaw; feeding at a perpendicular angle to the substrate and has ability to align the teeth of both upper and lower jaws in the same plane by abducting its jaws to a near 180° angle (Konings and Stauffer, 2006). The species is unique among all examined species here in that the females are blue, rather than brown or gray-yellow in coloration. Morphological differences with the geographically closest populations include a smaller post-orbital head length, expressed as percent head length (mean 38.3, range 35.6-40.6; Table 34) than *M. mossambiquensis* (mean 41.7, range 39.3-44.8; Table 27), and a larger head depth, expressed as percent head length (mean 92.5, range 89.4-96.3; Table 34) than *M. chrysomallos* (mean 86.4, range 79.9-93.3; Tables 6 and 7).

Description.- Jaws isognathous; teeth on jaw in 3-4 rows; outer row teeth generally bicuspid anteriorly and unicuspid posteriorly; those in inner rows tricuspid, sometimes inner most row unicuspid; 22 teeth in outer row of lower left jaw in holotype, 19-23 in paratypes. Dorsal fin with 17 spines in holotype, 17-18 in paratypes; dorsal-fin rays 10 in the holotype, 9-10 in paratypes. Pectoral fin with 15 rays in holotype and 14-15 in paratypes; anal fin with 3 spines, 7 rays in holotype and 7-8 in paratypes. Lateral scales ctenoid; holotype with 31 lateral-line scales and 30-31 in paratypes. First gill arch with 11-13 rakers on ceratobranchial, 2-3 on epibranchial, and 1 between epibranchial and ceratobranchial (Table 34).

Breeding males blue laterally fading to white-blue ventrally. Head entirely blue with white gular. Dorsal fin blue with light blue marginal band. Caudal fin blue. Anal fin blue with orange ocelli. Pelvic fins blue with white leading edge. Pectoral fins clear. Females also blue fading to white ventrally. Head blue, white gular. Dorsal fin blue with orange lappets distally. Caudal fin blue. Anal fin blue with 4 orange ocelli. Pelvic fins blue with white leading edge. Pectoral fins clear (Fig. 24).

The minimum polygon clusters formed by plotting the first principal components of the meristic data with the sheared second principal components of the morphometric data for *M. nkhungu* and, *M. chrysomallos* overlap, but are significantly ($p < 0.05$) different (Fig. 25). Size accounted for 85.0% of the observed variance and the second principal component accounted for 3.7%. The variables with the highest loadings were horizontal eye diameter (0.49), vertical eye diameter (0.46), and lower jaw length (0.32) (Table 35). The first principal component of the meristic data accounted for 17.4% of the total variance. The variable with the highest loadings were dorsal spines (0.39) and dorsal rays (-0.31) (Table 36).

The blue coloration of *Metriaclima nkhungu* females is an unusual trait among members of the genus. At Minos Reef and Nkhungu Reef, the species *M. estherae* is found in the rocky habitat and the males are of very similar coloration to *M. nkhungu* of the intermediate habitat. *Metriaclima estherae* is not a member of the *aurora*-group however because it occupies the rocky rather than the intermediate habitats. Females of *M. estherae* at these two localities are red or orange-blotched in contrast to the blue *M. nkhungu* females. Color differences between the sympatric females of *M. estherae* and *M. nkhungu* may play a role in the mate-recognition systems of males, in that female color may serve as a cue for which individuals males will display to prior to reproduction. Conspicuous color of females is rare in Lake Malaŵi cichlids though, raising the question of the importance of female coloration in mate recognition for the species flock as a whole. Females of most *Metriaclima* species (including all other *aurora*-group species discussed throughout here, as well as *M. estherae* populations outside of Minos Reef and Nkhungu Reef) are generally brown or beige in coloration. Only a few species have blue females, including *M. nkhungu*, *M. callainos*, and *M. lombardoi* (Konings, 2001). Regardless, the blue coloration of *M. nkhungu* females remains a useful character for diagnosing this species from other *aurora*-group species.

Distribution.- Metriaclima nkhungu is endemic to Nkhungu Reef and Minos Reef in Mozambique.

Etymology.- The name refers to one of the reefs at which the species is endemic.

Fig. 24. Blue male (top) and blue female *M. nkhungu*.

Table 34. Morphometric and meristic values of the type series of *Metriaclima nkhungu*. Mean, standard deviation, and range include the holotype (n = 6).

	Holotype	**Mean**	**Standard Deviation**	**Range**
Standard length, mm	72.8	69.6	3.1	65.3-73.3
Head length, mm	22.3	20.9	0.9	19.8-22.3
Percent standard length				
Head length	30.6	30.1	0.8	29.1-31.0
Snout to dorsal	29.8	31.1	1.4	29.8-33.1
Snout to pelvic	38.1	37.5	0.6	36.5-38.1
Greatest body depth	31.9	32.9	1.1	31.6-34.1
Caudal peduncle length	14.3	14.0	0.8	12.9-15.3
Least caudal peduncle depth	12.3	12.2	0.3	11.7-12.7
Dorsal fin base length	62.5	61.4	1.6	58.5-62.6
ADAA	53.7	52.6	0.9	51.5-53.7
ADPA	64.9	63.7	0.9	62.1-64.9
PDAA	29.5	29.6	1.4	28.0-32.0
PDPA	15.9	15.2	0.9	14.1-16.4
ADP2	36.2	36.1	1.0	34.6-37.5
PDP2	59.8	59.5	0.7	58.3-60.2
Percent head length				
Horizontal eye diameter	32.6	34.0	1.2	32.6-35.8
Vertical eye diameter	33.1	34.3	1.0	33.1-35.3
Snout length	29.4	27.1	1.8	24.6-29.4
Postorbital head length	39.4	38.3	1.9	35.6-40.6
Preorbital depth	23.5	21.1	1.7	19.0-23.5
Lower-jaw length	29.7	31.2	1.9	29.4-34.1
Cheek depth	24.5	24.8	1.1	23.0-26.3
Head depth	91.6	92.5	2.5	89.4-96.3
	Holotype	**Mode**	**% Freq.**	**Range**
Counts				
Dorsal spines	17	17, 18	50.0	17-18
Dorsal rays	10	9	83.3	9-10
Anal spines	3	3	100.0	3-3
Anal rays	7	8	66.7	7-8
Pelvic fin rays	5	5	100.0	5-5
Pectoral fin rays	15	14	66.7	14-15
Lateral line scales	31	30, 31	50.0	30-31
Pored scales posterior to lateral line	1	1	66.7	0-2
Cheek scales	4	5	66.7	4-5
Gill rakers on first ceratobranchial	13	13	50.0	11-13
Gill rakers on first epibranchial	2	3	66.7	2-3
Teeth in outer row of left lower jaw	22	22	33.3	19-23
Teeth rows on upper jaw	3	3	66.7	3-4
Teeth rows on lower jaw	3	3	100.0	3-3

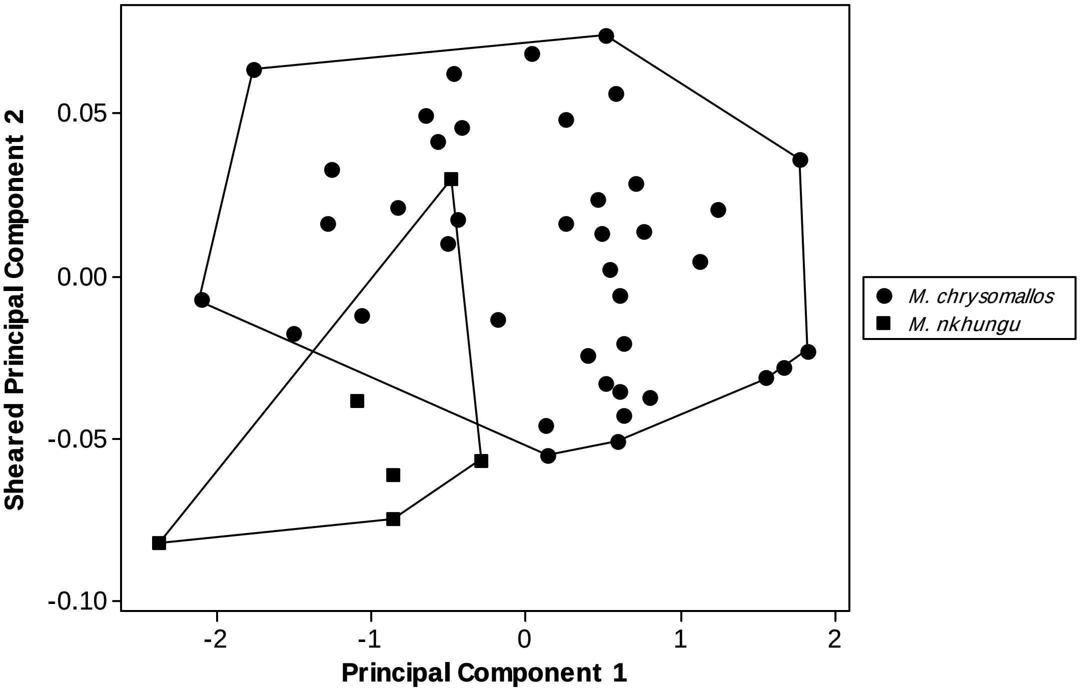

Fig. 25. Plot of the sheared second principal component (morphometric data) and the first principal component (meristic data) for *Metriaclima chrysomallos* and *M. nkhungu*.

Table 35. Variable loadings on size and the first two sheared principal components (shape factors) for *Metriaclima chrysomallos*, and *M. nkhungu*.

		Sheared Components	
	Size	PC2	PC3
Standard length	-0.192	*	*
Head length	-0.170	0.183	-0.129
Snout length	-0.258	-0.293	-0.502
Postorbital length	-0.158	0.159	-0.125
Horizontal eye diameter	-0.134	0.482	*
Vertical eye diameter	-0.119	0.464	*
Preorbital depth	-0.284	-0.212	-0.483
Cheek depth	-0.319	-0.121	-0.198
Lower-jaw length	-0.173	0.317	-0.222
Head depth	-0.193	*	0.216
Body depth	-0.195	0.110	0.183
Snout to dorsal-fin origin	-0.177	0.234	-0.151
Snout to pelvic-fin origin	-0.197	0.101	*
Dorsal-fin base length	-0.213	*	0.146
Anterior dorsal to anterior anal	-0.200	*	0.131
Anterior dorsal to posterior anal	-0.209	*	0.146
Posterior dorsal to anterior anal	-0.217	*	0.179
Posterior dorsal to posterior anal	-0.198	-0.202	0.145
Posterior dorsal to ventral caudal	-0.197	-0.111	0.198
Posterior anal to dorsal caudal	-0.197	-0.150	0.154
Anterior dorsal to pelvic-fin origin	-0.206	0.109	0.181
Posterior dorsal to pelvic-fin origin	-0.193	*	0.149
Caudal-peduncle length	-0.193	-0.268	0.156
Least caudal-peduncle depth	-0.207	*	0.161

* = Absolute loading values <0.1 for loadings on shape factors.

Table 36. Standardized scoring coefficients for principal component analysis on meristic data for *Metriaclima chrysomallos* and *M. nkhungu*.

	Factor 1	Factor 2
Dorsal-fin spines	0.385	-0.165
Dorsal-fin rays	-0.308	0.048
Anal-fin spines	0.000	0.000
Anal-fin rays	0.259	0.100
Pelvic-fin rays	0.000	0.000
Pectoral-fin rays	-0.002	0.155
Lateral-line scales	0.161	-0.259
Pored scales posterior to lateral line	0.057	0.255
Scale rows on cheek	0.037	-0.264
Gill rakers on first ceratobranchial	-0.066	0.293
Gill rakers on first epibranchial	0.166	0.095
Teeth in outer row of left lower jaw	0.192	0.226
Teeth rows on upper jaw	-0.008	0.251
Teeth rows on lower jaw	0.265	0.196

4. DISCUSSION

Based on differences in shape, meristics, and color, five previously undescribed cichlid species in the genus *Metriaclima* were diagnosed. In *M. glaucos*, there are fewer teeth in the outer row of the lower jaw compared to all other species discussed here and fewer teeth rows than most other *aurora*-group species (with the exception of *M. xanthos*), in addition to the blue lateral and yellow gular colorations of the males. *Metriaclima sciasma* males are the only *aurora*-group species with dark blue cheeks and black pelvic fins and individuals generally have fewer dorsal spines than all *aurora*-group species with the exception of *M. xanthos*. In *M. xanthos* there is a larger lower jaw length (expressed as percent head length) compared to *M. aurora*, *M. chrysomallos*, and *M. glaucos*, a larger snout to dorsal fin insertion length (expressed as percent standard length) than *M. sciasma*, and the males are brown with blue/gray alternating lateral bars and gray and yellow heads, a unique color pattern among the *aurora*-group species. There is a larger head depth (expressed as percent head length) in *M. mossambiquensis* compared to *M. aurora, M. chrysomallos*, and *M. xanthos*, and unique male colorations compared to all of the species discussed throughout, with differing amounts of yellow and blue lateral coloration and various degrees of black pigment on the dorsal, caudal, and anal fins. In *M. nkhungu*, there is a larger head depth than *M. aurora*, *M. chrysomallos*, and *M. xanthos*, a smaller post-orbital head length (expressed as percent head length) than *M. mossambiquensis*, and it is the only *aurora*-group species with blue females. All species described here inhabit the transition areas between the rocks and sand, known as the intermediate habitats (Konings, 2001). These species, in addition to *Metriaclima aurora* and *M. chrysomallos,* are distinguished from most similar cichlid species in the intermediate habitat by the absence of a black band in the dorsal fin. Each has a distinct body coloration pattern and differs morphologically from the other and from the previously described *M. aurora* and *M. chrysomallos*. Similarities in ecology, dorsal fin coloration, and morphology between the populations examined here suggest the *aurora*-group is monophyletic; however more *Metriaclima* species in the intermediate habitats need to be examined and compared to the new species described here before a new subgenus is designated. An artificial key to the species described here, as well as *M. aurora* and *M. chrysomallos*, is presented at the end of the discussion. Although not necessarily reflecting phylogenetic relationships, dichotomous keys based on morphological features are useful.

The Evolutionary Species Concept was the species definition used as a theoretical framework. As it is not operational, the biological and morphological species concepts were used as surrogate definitions where species were delineated based on differences in male coloration and comparisons of shape and meristics. The combination of color and morphological differences has been used to describe other species of Lake Malaŵi cichlids across a number of genera (Stauffer and Hert, 1992; Bowers and Stauffer, 1993; Stauffer, 1994; Stauffer and van Snik, 1996; Stauffer and Kellogg, 2002). Early delineations of several mbuna cichlids were made based solely on color, where color differences were considered the limiting factor in mate recognition (Paterson, 1985). Some of those species would later receive formal descriptions based on differences in shapes and meristics that reflected the original color delineations (Bowers and Stauffer, 1993). Among sympatric populations, differences in color and morphological characters suggest different species, whether the populations are reproductively isolated or possess different mate-recognition systems (Stauffer *et al.,* 1997). Delineating allopatric populations as separate species can be problematic however, particularly if significant morphological differences are absent. Gradual morphological variation among a range of allopatric populations for example suggests the populations are conspecific (Stauffer *et al.*, 1997). This was observed in *M. aurora*. Although the minimum polygon clusters overlapped, there was some slight morphological divergence, particularly between the populations with brown-barred males and the populations with blue males. Overall similarities in morphology, ecology, and behavior of the five *M. aurora* populations maintained them as conspecific however. Depending on a shape analysis of a population between Nametumbwe and Gome, this may also be the case in *M. chrysomallos*.

Taxonomy has and will continue to be a cornerstone of biological research (Wheeler, 2004). Studies of evolution, ecology, and conservation science, in addition to the wide variety of documented and perhaps even larger number of unknown benefits of biodiversity would all be impossible without adequate descriptive taxonomy (Wilson, 2004). The small portion of formally described species (approximately 1.7 million described species to the potentially 100+ million total) and the grave threat to global biodiversity from a continuously growing human population should serve as a strong impetus for taxonomy and systematics (Mace, 2004; Wilson, 2004). This is especially the case with fishes. Even as specious and well-studied fishes are as a group, there is much more taxonomic and phylogenetic work to be completed. Threats to fishes, including habitat degradation/destruction, over-harvesting, and the introductions of exotics, may greatly hinder taxonomic studies and in turn limit the potential evolutionary and ecological research as well as management of commercially and recreationally important fisheries (Stauffer and Kocovsky, 2007).

Lake Malaŵi supports a large number of diverse species, many of which have yet to be described. The cichlids of Lake Malaŵi are immensely important as a food source, a disease control, and a source of revenue through tourism to the surrounding countries of the lake, in addition to their major role in scientific research (Stauffer et al., 2007). Proper species delineations are necessary to conserve and manage these species for the above purposes, and thus the species descriptions presented in this thesis are vital pieces of information in that regard. Additionally, traditional morphological approaches to species descriptions, as was used here, are becoming rarer in the scientific literature with the advancement of DNA-based methods. Although molecular genetics are an extremely useful tool in taxonomy, older morphological techniques are just as functional in diagnosing new species and should not be laid to rest (Wheeler, 2004). Descriptions based on color and morphology allow for other taxonomists to potentially identify species in the field with artificial keys and without the use of DNA technologies. More taxonomic work as was conducted here needs to be completed before the cichlids of Lake Malaŵi are fully chronicled and they can be readily identified to be utilized for human benefits and scientific advances in understanding the natural world.

Artificial Key to the *Aurora*-group Species

1 (a) Both male and female bright blue dorsally and laterally fading to white ventrally in body coloration …………………………………………………..*Metriaclima nkhungu*
1 (b) Female brown or yellow in coloration, male has some blue to blue/gray pigment ………………………………………………………………………………………..2

2 (a) Black pigment present in caudal-fin membranes of male; head depth greater than 89% of head length ………………………………..*Metriaclima mossambiquensis* (in part)
2 (b) Black pigment absent in caudal-fin membranes of male; head depth to head length ratio variable ……………………………………………………………………...3

3 (a) Black pigment present in the pelvic-fin membranes of male ………………………4
3 (b) Black pigment absent in pelvic-fin membranes of male …………………………...5

4 (a) Male with dark blue cheeks, black pigment in first two pelvic-fin rays fading to gray in remaining rays giving fins an overall dark appearance, and no black pigment in the anal fin; dorsal spines typically 17, occasionally 18, rarely 16 or 19 ………………… …………………………………………………………….………*Metriaclima sciasma*
4 (b) Male with purple cheeks, black pigment in first two pelvic-fin rays and remaining clear, and a black marginal band in the anal fin; dorsal spines typically 18, occasionally 17, rarely 16 ………………………………………*Metriaclima mossambiquensis* (in part)

5 (a) Lower-jaw length greater or equal to34.6% of head length; lateral coloration of male blue/gray with brown bars ….……………………………………*Metriaclima xanthos*
5 (b) Lower-jaw length less than 34.6% of head length; male lateral coloration variable, but if brown bars present, on bright blue background and lower-jaw length less than 33.5% of head length ……………………………………………………………………..6

6 (a) Breast and ventral half to ventral third of cheeks and opercula of male yellow or orange …..7
6 (b) Breast and lower portions of cheeks and opercula of male blue, gular region may be yellow …..……………………………...9

7 (a) Dorsal fin of male pale blue with posterior membranes orange distally, breast orange ………………………………………………*Metriaclima chrysomallos* (in part)
7 (b) Dorsal fin of male yellow with blue pigment throughout, breast yellow …………..8

8 (a) Lateral coloration of male blue dorsally with anterior portions of scales dark blue, faint blue or brown bars present; head depth, expressed as percent head length, generally smaller (mean 86.8) …………………………………………………...*Metriaclima aurora*
8 (b) Lateral coloration of male gray/blue with posterior edge of scales gold in dorsal two-thirds of body, lateral barring absent; head depth, expressed as percent head length,

generally larger (mean 96.0) …………….............*Metriaclima mossambiquensis* (in part)

9 (a) Gular of male always yellow; generally fewer teeth in the outer row of the lower left jaw (mode 16, range 14-19); 2-3 teeth rows in upper and lower jaws; head depth, expressed as percent head length, generally larger (mean 91.0, range 86.5-95.9); found only at Cobwe, Mozambique ……………………...………………*Metriaclima glaucos*

9 (b) Gular of male may be yellow depending on locality; generally more teeth in the outer row of lower left jaw (mode 22, range 15-25); 3-4 teeth rows in upper and lower jaws; head depth, expressed as percent head length, generally smaller (mean 86.4, range 79.9-93.3) ……………………………………………..*Metriaclima chrysomallos* (in part)

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