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A new species of *Protomelas* (Teleostei: Cichlidae) from Lake Malawi, Africa

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Protomelas dejunctus, new species, is described from Chinyankwazi and Chinyamwezi islands, located in the southeast arm of Lake Malawi. The new species is morphologically similar to *P. fenestratus* and *P. taeniolatus*, but sheared principal component analysis of the morphometric data and principal component analysis of the meristic data clearly separate these species. The new species can be distinguished from *P. fenestratus* and *P. taeniolatus* by the greater number of gill rakers on the first gill, its greater head depth, the intense blue coloration of breeding males, and the presence of tricuspid teeth in its outer row of the lower jaw.

Introduction

The vast majority of haplochromine cichlids, which inhabit Lake Malawi are endemic; moreover, many of these fishes are found only around particular islands. For example, at least 10 species of haplochromine cichlids are restricted to the waters surrounding Chinyankwazi (35°00'E 13°53'S) and Chinyamwezi (35°00'E 13°56'S) islands, located in the southeast arm of Lake Malawi (Ribbink et al., 1983; Stauffer, 1988; Stauffer, ms.). The purpose of this paper is to describe a new species of *Protomelas* that is endemic to Chinyankwazi and Chinyamwezi islands.

Methods and materials

Fishes were collected by chasing them into a monofilament net (7 m x 1 m x 1.0 cm) while SCUBA diving. Standard length is used throughout. External counts and measurements follow Barel et al. (1977) and Stauffer (1991). Morphometric data were used to create a truss network as described by Humphries et al. (1981). Except for gill-raker counts, which were recorded from the right side, all counts and measurements were made on the left side of the fish. Overlapping scales in the upper and lower lateral lines were not counted. Institutional abbreviations follow Leviton et al. (1985), except where noted.

Fishes collected from Chinyankwazi and Chinyamwezi islands were compared to the lectotype (BMNH 1935.6.14.679) and paralectotypes (BMNH 1935.6.14.680, 681, 685, 686, 688) of *Protomelas fenestratus* (Trewavas) and the lectotype (BMNH 1935.6.14.866) and paralectotypes (BMNH 1935.6.14.865, 867) of *Protomelas taeniolatus* (Trewavas). Differences in body shape were analyzed using sheared principal component analysis (PCA) of the morphometric data (Humphries et al., 1981; Bookstein et al., 1985). This

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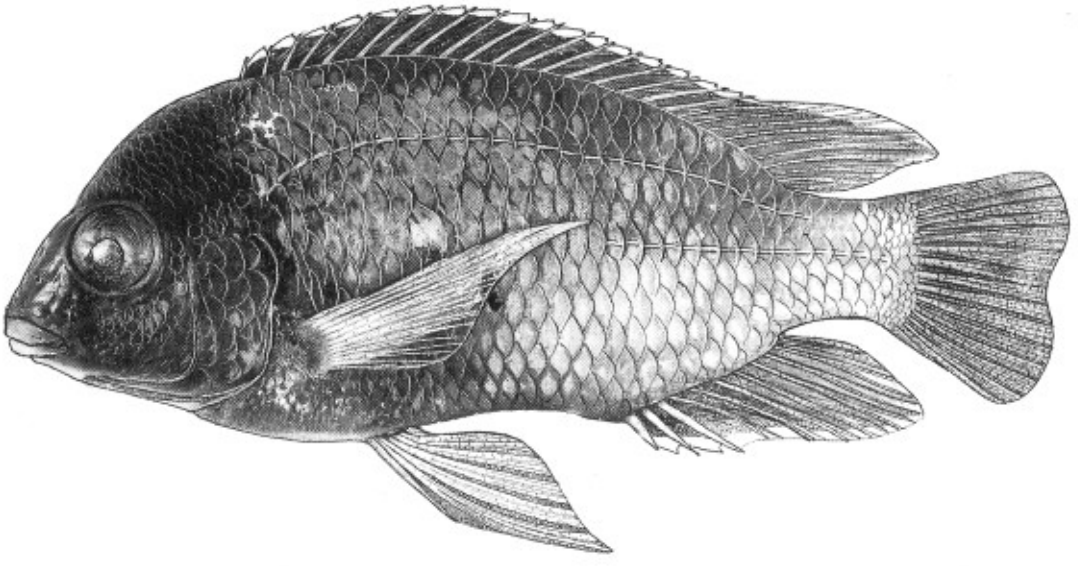

Fig. 1. *Protomelas dejunctus*, holotype, PSU 2642, 122.5 mm SL.

technique, which quantifies shape differences among the populations independent of fish size (Reyment et al., 1984), was used by Stauffer (in press) to distinguish among members of the *Copadichromis eucinostomus* (Regan) complex. Variation in meristic characters were analyzed using PCA. Dissimilarities among populations were illustrated by plotting the sheared second principal component of the morphometric data against the first principal component of the meristic data (Stauffer & Hert, 1992). Cheek depth, expressed as percent head length, was regressed against standard length to compare the type series of the new species with that of the type series of *P. taeniolatus*. The data were treated as though they were from a single taxa, the residuals were calculated and compared using a one-way analysis of variance ($P<0.05$).

Protomelas dejunctus, new species
(Figs. 1, 3-4)

Holotype. PSU 2642, adult male, 122.5 mm, Chinyamwezi Island, Lake Malawi, Africa, 1-3 m, 4 May 1991 (Figs. 1 and 2).

Paratypes. PSU 2639, 11 (100.2-138.1 mm), USNM 326969, 7 (101.1-135.8 mm), MFU 8 (Malawi Fisheries Unit), 3 (106.9-131.6 mm); Chinyankwazi Island, Lake Malawi, Africa, 18 June 1991. - PSU 2640, 4 (97.3-129.5 mm), USNM 326970, 3 (105.2-126.6 mm), MFU 7, 3 (98-116.8 mm); Chinyamwezi Island, Lake Malawi, Africa, 1-3 m, 18 June 1991. - PSU 2641, 4 (100.8-133.3 mm); Chinyankwazi Island, Lake Malawi, Africa, 4 May 1991.

Diagnosis. The vertical bars that overlap with horizontal stripes in females and non-territorial males place this species in the genus *Protomelas*, as it is now defined (Eccles & Trewavas, 1989). The dark blue sides, the white marginal band on the dorsal fin, the brilliant red on the distal portion of the anal fin of breeding males distinguishes *P. dejunctus* from other *Protomelas* species. Cheek depth distinguishes *P. dejunctus* from the type series of *P. taeniolatus*.

Description. Morphometric ratios and meristics are presented in Table 1. Jaws isognathous (Fig. 1); teeth on jaws in 4-5 rows; anterior teeth in outer rows bicuspid, posterior teeth in outer rows tricuspid, those in inner rows tricuspid; 6 teeth in outer row of left lower jaw of holotype, 6-10 in paratypes. Dorsal fin with 18 spines in the holotype and 16-19 in paratypes; dorsal-fin rays 10 in holotype and 9-11 in paratypes. Pectoral fin with 13 rays in holotype and 13-14 in paratypes; anal fin with 3 spines and 8 rays in holotype and 3 spines and 8-9 rays in paratypes; caudal fin emarginate (Fig. 1). Lower pharyn-

geal bone of holotype triangular in outline (Fig. 2). Scales along side ctenoid; holotype with 33 pored lateral-line scales, paratypes with 32-34; pored scales posterior to hypural plate 0-3. Fifteen specimens, including the holotype, with 3 scale rows on cheek, 19 specimens with 2 and one with 4. First gill arch with 11-14 gill rakers on ceratobranchial, 3-4 on epibranchial, and 1 between the epibranchial and ceratobranchial.

Overall body coloration of breeding males dark blue with green highlights; scales on posterior half of body outlined in red/orange; single black horizontal stripe with 4 black vertical bars (Fig. 3). In some territorial males, the intense blue color masks the vertical bars. Head blue with green highlights and yellow gular. Dorsal fin gray with blue and green highlights, white marginal band, and red posterior lappets;

Table 1. Morphometric and meristic characters of *Protomelas dejunctus*. Range and mean include holotype and 35 paratypes.

	Holotype	Mean	St. Dev.	Range
Standard length, mm	122.9	118.0	14.2	97.4-138.1
Head length, mm	40.3	39.6	3.8	32.6- 45.8
Percent standard length				
Head length	32.8	33.7	1.5	31.3- 36.5
Snout to dorsal-fin origin	38.2	38.7	1.7	35.9- 42.6
Snout to pelvic-fin origin	43.2	43.4	1.5	40.5- 46.3
Caudal-peduncle length	13.0	13.4	0.8	12.2- 15.7
Least caudal-peduncle depth	13.7	13.1	0.6	12.0- 14.4
Pectoral-fin length	34.8	35.4	3.1	25.0- 40.7
Pelvic-fin length	36.5	32.0	3.4	26.1- 43.0
Dorsal-fin base length	62.9	60.2	1.8	55.9- 63.2
Anterior dorsal to anterior anal	54.0	56.3	1.9	52.9- 60.1
Posterior dorsal to posterior anal	16.2	16.7	1.0	14.8- 18.7
Anterior dorsal to posterior anal	67.7	65.3	2.2	61.1- 68.5
Posterior dorsal to anterior anal	33.9	34.4	1.4	32.1- 38.5
Posterior dorsal to ventral caudal	18.5	18.0	0.9	16.6- 19.8
Posterior anal to dorsal caudal	18.8	19.8	0.8	17.4- 21.4
Anterior dorsal to pelvic-fin origin	44.4	43.1	1.3	40.1- 46.5
Posterior dorsal to pelvic-fin origin	54.7	56.1	2.0	51.7- 59.3
Percent head length				
Horizontal eye diameter	34.5	35.6	2.7	31.4- 40.7
Vertical eye diameter	34.4	34.5	2.4	30.7- 38.6
Snout length	35.2	33.6	2.7	28.8- 37.5
Postorbital head length	36.8	36.4	1.6	33.5- 39.5
Preorbital depth	20.6	19.5	1.1	17.0- 21.7
Lower-jaw length	34.7	33.9	1.5	30.6- 38.6
Cheek depth	32.1	29.4	2.0	26.3- 32.3
Head depth	104.0	102.0	4.2	95.2-112.7
Counts				
Lateral-line scales	33	33.0	0.6	32-34
Pored scales posterior to lateral line	2	1.5	0.7	0- 3
Scale rows on cheek	3	2.4	0.6	1- 4
Dorsal-fin spines	18	17.4	0.6	16-19
Dorsal-fin rays	10	10.4	0.6	9-11
Anal-fin rays	8	8.4	0.5	8- 9
Pectoral-fin rays	13	13.3	0.5	13-14
Gill rakers on first ceratobranchial	13	13.1	0.8	11-14
Gill rakers on first epibranchial	3	3.6	0.5	3- 4
Teeth in outer row of left lower jaw	6	7.1	1.5	6-10
Teeth rows on upper/lower jaw	4/5	4.8/4.7	.5/.5	4- 5

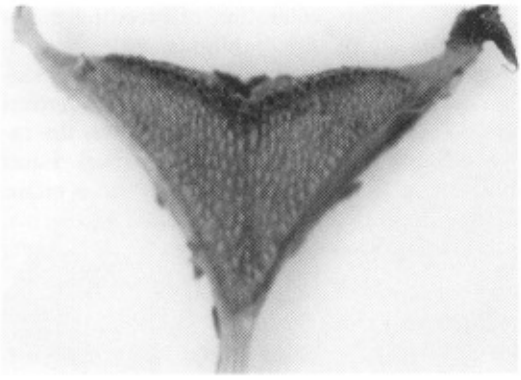

Fig. 2. Lower pharyngeal bone of *Protomelas. dejunctus*, holotype, PSU 2642, 122.5 mm SL; width 12.07 mm.

caudal-fin rays blue with red/orange membranes; anal fin orange/brown with distal one-third red/orange and with 7 yellow ocelli; pectoral fins with gray rays and clear membranes; pelvic fins black with orange leading edge. Coloration of females and non-breeding males similar to that of breeding males but ground color brown instead of dark blue, anal fin brown with faint yellow ocelli, and pelvic fins brown (Fig. 4).

Distribution. *Protomelas dejunctus* is restricted to Chinyankwazi and Chinyamwezi islands, in the southeast arm of Lake Malawi. No specimens of this species were observed elsewhere during numerous diving expeditions throughout the southeast arm over the past 10 years.

Life history. *Protomelas dejunctus* has been observed feeding on plankton in the water column and foraging on attached algae. All specimens were collected at water depths of 2-10 m. Males establish breeding territories over rocks. One female captured on 4 May had young in her mouth.

Etymology. The name *dejunctus*, from the Latin meaning separated, was chosen to reflect the restricted distribution of this species.

Discussion

There are currently no known synapomorphic characters that distinguish *Protomelas* from other Lake Malawi fish genera (Eccles & Trewavas, 1989). The rock-dwelling forms (i.e. *P. fenestratus*, *P. taeniolatus*, *P. virgatus* (Trewavas), and *P. dejunctus*) may form a monophyletic group within the genus. *Protomelas virgatus* is described based on a single specimen (BMNH 1935. 6.14.1011) collected from Monkey Bay in the southeast arm of Lake Malawi. It differs from other members of this group by possessing more specialized jaws, in which "the dental arch of the premaxilla narrow anteriorly, but spreading laterally at the posterior ends, with rather long anterior teeth, and in the enlargement of the pharyngeal teeth" (Eccles & Trewavas, 1989: 65). The only specimens of *P. virgatus* recorded since the original description, were from Monkey Bay (Jackson, 1961).

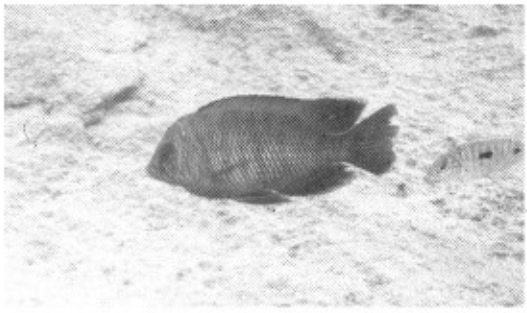

Fig. 3. *Protomelas dejunctus*, male, at Chinyankwazi Island, April 1993.

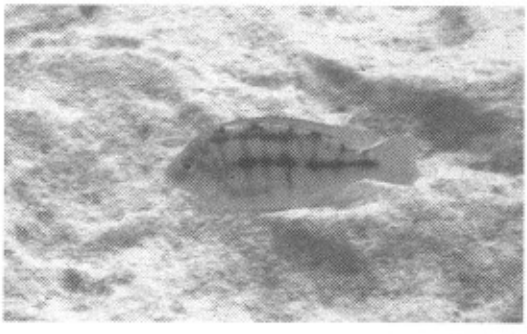

Fig. 4. *Protomelas dejunctus*, female, at Chinyankwazi Island, April 1993.

Both *P. fenestratus* and *P. taeniolatus* are widespread throughout the southwest arm of Lake Malawi, occurring from Chilumba, along the northern shores of Lake Malawi, to the southern portion of Lake Malawi. Both of these species have plesiomorphic vertical stripes that overlap with horizontal bars, typical of *Protomelas* spe-

cies. Additionally, both forms have relatively small mouths (lower jaw length 26.8-31.2 % HL) and large eyes, which are characteristic of the rock-dwelling *Protomelas* species (Table 2).

Historically, *P. dejunctus*, was considered to be a race of *P. taeniolatus* (Konings, 1992); however, cheek depth, expressed as percent head length (Tables 1 & 2) clearly distinguishes these two taxa. Because the type series of *P. dejunctus* is larger (SL 97.4-138.1 mm) than the type series of *P. taeniolatus* (SL 73.2-89.6 mm), it was postulated that the differences in cheek depth may be a function of allometric growth. When cheek depth was regressed against standard length the residuals of the two species were significantly different ($p<0.05$) (Fig. 5); thus, indicat-

Table 2. Morphometric and meristic characters of the type series of *P. fenestratus* (n = 6) and *P. taeniolatus* (n = 3).

	Protomelas fenestratus			*Protomelas taeniolatus*		
	Mean	St. Dev.	Range	Mean	St. Dev.	Range
Standard length, mm	81.7	14.9	55.3-97.0	82.9	8.6	73.2-89.6
Head length, mm	26.0	4.9	18.0-31.1	27.5	1.7	25.6-28.7
Percent standard length						
Head length	31.9	1.7	29.1-34.0	33.3	1.7	31.6-35.0
Snout to dorsal-fin origin	35.3	0.7	34.5-36.4	37.6	3.1	34.0-39.7
Snout to pelvic-fin origin	43.1	2.8	39.8-46.7	43.1	2.2	41.6-45.6
Caudal-peduncle length	16.0	0.7	15.4-17.1	13.7	1.0	12.6-14.6
Least caudal-peduncle depth	11.6	0.6	10.8-12.3	10.9	0.3	10.6-11.2
Pectoral-fin length	29.6	1.9	26.5-31.8	30.0	1.2	28.8-31.2
Pelvic-fin length	26.0	1.8	24.4-29.3	29.6	1.3	28.6-31.1
Dorsal-fin base length	56.3	1.5	54.3-59.0	57.5	2.5	55.6-60.3
Anterior dorsal to anterior anal	50.9	1.4	48.8-52.7	52.7	1.5	51.0-53.7
Posterior dorsal to posterior anal	15.6	0.5	15.0-16.4	14.9	0.5	14.6-15.5
Anterior dorsal to posterior anal	61.3	1.5	59.9-63.2	60.7	1.9	58.6-62.3
Posterior dorsal to anterior anal	31.2	1.6	29.8-33.8	29.4	0.5	29.0-29.9
Posterior dorsal to ventral caudal	18.8	1.3	16.5-20.3	17.0	0.9	16.0-17.7
Posterior anal to dorsal caudal	20.9	1.1	19.4-22.4	19.4	0.8	18.7-20.2
Anterior dorsal to pelvic-fin origin	36.1	0.9	35.1-37.4	36.4	1.9	34.8-38.5
Posterior dorsal to pelvic-fin origin	51.0	1.7	49.2-52.7	51.8	0.8	51.0-52.4
Percent head length						
Horizontal eye diameter	34.6	2.9	31.5-39.4	37.3	1.5	35.9-38.9
Vertical eye diameter	34.5	3.2	30.8-39.9	37.8	2.1	35.4-39.2
Snout length	32.3	2.1	29.2-35.1	32.5	1.6	30.9-34.1
Postorbital head length	38.0	2.3	34.7-41.2	35.6	1.4	34.1-36.9
Preorbital depth	18.5	1.5	16.5-20.2	17.1	1.4	16.3-18.8
Lower-jaw length	29.4	1.4	26.8-31.0	29.9	1.1	29.0-31.2
Cheek depth	20.9	1.9	18.1-23.9	18.9	0.6	18.2-19.3
Head depth	91.4	4.1	86.1-96.3	93.2	1.2	91.9-94.0
Counts						
Lateral-line scales	31.3	1.2	30-33	32.3	0.6	32-33
Pored scales posterior to lateral line	1.2	0.8	0- 2	0.7	0.6	0- 1
Scale rows on cheek	2.7	0.5	2- 3	2.7	0.6	2- 3
Dorsal-fin spines	16.0	0	–	17.0	0	–
Dorsal-fin rays	9.8	0.4	9-10	10.7	0.6	10-11
Anal-fin rays	8.3	0.5	8- 9	8.0	0	–
Pectoral-fin rays	13.2	0.4	13-14	12.6	0.6	12-13
Gill rakers on first ceratobranchial	10.3	0.8	9-11	9.3	0.6	9-10
Gill rakers on first epibranchial	2.8	0.4	2- 3	3.0	0	–
Teeth in outer row of left lower jaw	11.2	1.0	10-12	10	0	–
Teeth rows on upper/lower jaw	4/4	0/0	–	4/4	0/0	–

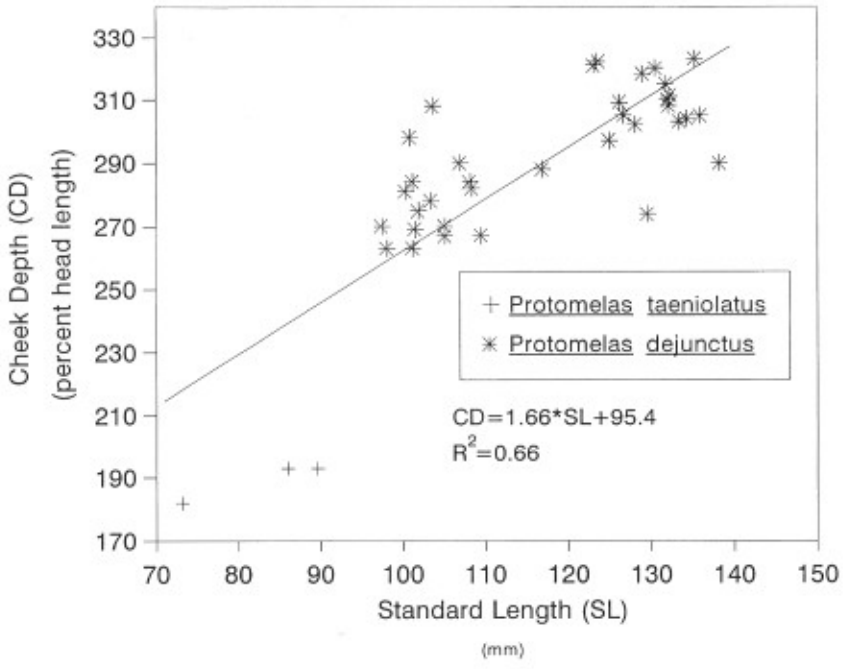

Fig. 5. Plot of cheek depth, expressed as percent head length versus standard length of *Protomelas dejunctus* and *P. taeniolatus*.

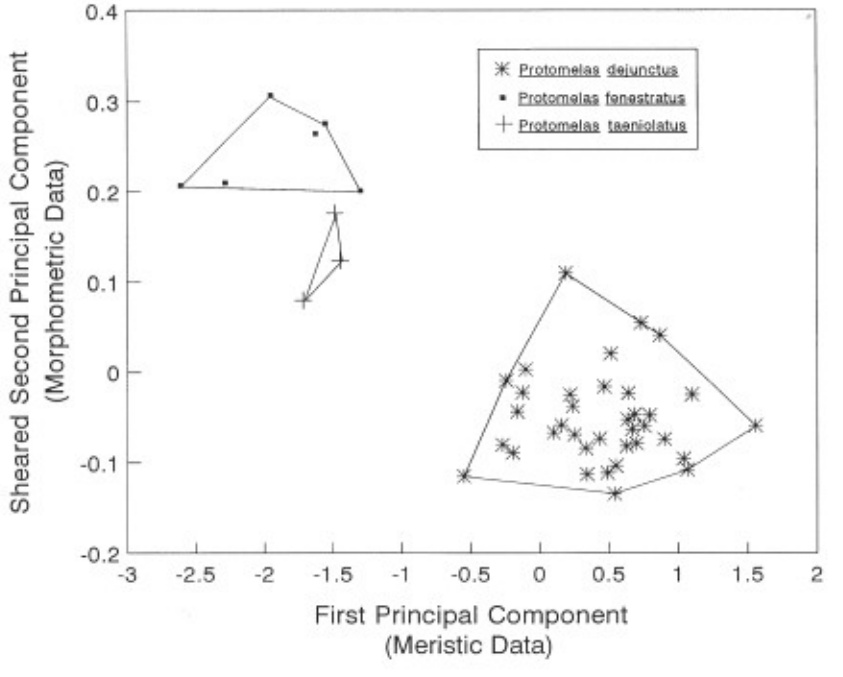

Fig. 6. Plot of individual first and second principal component scores (morphometric data) and first principal component scores (meristic data) of *Protomelas dejunctus*, *P. fenestratus*, and *P. taeniolatus*.

ing that the observed difference in this morphometric was not a result of allometry.

A plot of the sheared second principal component of the morphometric data versus the first principal component of the meristic data demonstrated that there was no overlap between the clusters formed by *P. dejunctus*, *P. fenestratus*, and *P. taeniolatus* (Fig. 6). The first principal component of the morphometric data is interpreted as a size component and the sheared components as shape, independent of size (Humphries et al., 1981; Bookstein et al., 1985). Size accounts for 94.2 % of the observed variance and the second principal component accounts for 2.6 %. The variables that have the highest loadings on the sheared second principal component are eye diameter, cheek depth, and lower jaw length (Table 3). The first principal component of the meristic data explains 53 % of the total variance. The variables with the highest loadings on the first principal component are the number of gill rakers on the first ceratobranchial, number of gill rakers on the first epibranchial, number of teeth in the outer row of the left lower jaw, and the number of teeth rows on the upper and lower jaws (Table 4).

Table 3. Variable loadings on size and the second sheared principal components (shape factors) for *Protomelas dejunctus*, *P. fenestratus*, and *P. taeniolatus*.

Characters	Size	Sheared PC2
Standard length	0.195	0.08
Head length	0.157	-0.138
Snout length	0.235	0.068
Postorbital head length	0.183	-0.024
Horizontal eye diameter	0.073	-0.423
Vertical eye diameter	0.066	-0.387
Preorbital depth	0.210	-0.084
Cheek depth	0.238	-0.283
Lower jaw length	0.157	-0.357
Head depth	0.192	-0.163
Snout to dorsal-fin origin	0.165	-0.158
Snout to pelvic-fin origin	0.166	-0.041
Least caudal-peduncle depth	0.234	0.091
Caudal-peduncle length	0.188	0.198
Anterior dorsal to anterior anal	0.22	0.086
Anterior dorsal to posterior anal	0.221	0.121
Posterior dorsal to anterior anal	0.232	0.1
Posterior dorsal to posterior anal	0.236	0.224
Posterior dorsal to ventral caudal	0.235	0.252
Posterior anal to dorsal caudal	0.221	0.24
Posterior dorsal to pelvic-fin origin	0.216	0.081
Anterior dorsal to pelvic-fin origin	0.213	-0.065
Pectoral-fin length	0.158	-0.261
Pelvic-fin length	0.237	-0.083

Protomelas fenestratus and *P. taeniolatus* are morphologically distinct from each other (Fig. 6). Historically, it was thought that the distinct vertical and horizontal lateral markings of *P. fenestratus*, named from the Latin meaning "window", distinguished it from *P. taeniolatus*, which has predominantly transverse stripes (Eccles & Trewavas, 1989). Ribbink et al. (1983) delimited these two species based on the fact that *P. fenestratus* blows sand and dislodges aquatic insects when feeding, whereas *P. taeniolatus* feeds principally on algae and plankton. Observations by Konings (1992) and myself have indicated that individuals representing both melanin patterns blow sand; thus, this entire group needs extensive study.

Protomelas dejunctus is morphologically distinct from all previously described species. It differs principally by having a larger cheek depth and a greater head depth. All of the *P. dejunctus* examined had at least one tricuspid tooth in the posterior portion of the outer row on the lower jaw, which further distinguishes it from *P. fenestratus* and *P. taeniolatus*. The only other species in this genus with tricuspid teeth in the outer row of the lower jaw is *P. triaenodon* (Trewavas), which is found at depths of 10-18 m in both the southeast and southwest arms of Lake Malawi. The intense dark blue color of the breeding males of *P. dejunctus* further distinguishes it from other *Protomelas* species.

Table 4. Standarized scoring coefficients on meristic data for *Protomelas dejunctus*, *P. fenestratus*, and *P. taeniolatus*.

	Factor 1
Dorsal-fin spines	0.153
Dorsal-fin rays	0.063
Anal-fin rays	0.096
Pectoral-fin rays	0.074
Lateral-line scales	0.173
Pored scales posterior to lateral line	0.061
Scale rows on cheek	-0.003
Gill rakers on first ceratobranchial	0.236
Gill rakers on first epibranchial	0.184
Teeth in outer row of left lower jaw	-0.193
Teeth rows on upper jaw	0.2
Teeth rows on lower jaw	0.186

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