

LITERATURE CITED

- CARDOSO, A. J., AND C. F. B. HADDAD. 1982. Nova espécie de *Hyla* da Serra da Canastra (Amphibia, Anura, Hylidae). *Rev. Brasil. Biol.* 42:499-503.
- , AND I. SAZIMA. 1980. Nova espécie de *Hyla* do sudeste Brasileiro (Amphibia, Anura, Hylidae). *Ibid.* 40:57-59.
- DUPELLMAN, W. E. 1970. The hylid frogs of Middle America. *Monogr. Mus. Nat. Hist. Univ. Kansas* 1: 1-753.
- FOUQUETTE, M. J., JR., AND A. J. DELAHOUSAYE. 1977. Sperm morphology in the *Hyla rubra* group (Amphibia, Anura, Hylidae), and its bearing on generic status. *J. Herpetol.* 11:387-396.
- FROST, D. R. EDITOR. 1985. Amphibian species of the world. Association of Systematic Collections, Lawrence, Kansas.
- GONÇALVES DA CRUZ, C. A., AND O. L. PEIXOTO. 1983. Uma nova espécie de *Hyla* do Estado do Espírito Santo, Brasil (Amphibia, Anura, Hylidae). *Rev. Brasil. Biol.* 42:721-724.
- HOOGMOED, M. S., AND S. J. GORZULA. 1979. Checklist of the savanna inhabiting frogs of the El Man-teco region with notes on their ecology and the description of a new species of treefrog (Hylidae, Anura). *Zool. Mededel. Rijksmus. Nat. Hist. Leiden* 54:183-216.
- , AND U. GRUBER. 1983. Spix and Wagler type specimens of reptiles and amphibians in the Natural History Museum in Munich (Germany) and Leiden (The Netherlands). *Spixiana Supple.* 9:319-415.
- LEVITON, A. E., R. H. GIBBS, JR., E. HEAL AND C. E. DAWSON. 1985. Standards in herpetology and ichthyology. Part I. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. *Copeia* 1985:802-832.
- LUTZ, B. 1973. Brazilian species of *Hyla*. University of Texas Press, Austin, Texas.
- PYBURN, W. F., AND M. J. FOUQUETTE, JR. 1971. A new striped treefrog from Central Colombia. *J. Herpetol.* 5:97-101.
- MUSEUM OF NATURAL HISTORY AND DEPARTMENT OF SYSTEMATICS AND ECOLOGY, THE UNIVERSITY OF KANSAS, LAWRENCE, KANSAS 66045. Accepted 2 Dec. 1985.

Copeia, 1986(4), pp. 870-875

Description of a Gold Cichlid (Teleostei: Cichlidae) from Lake Malawi, Africa

KENNETH R. MCKAYE AND JAY R. STAUFFER, JR.

A Lake Malawi cichlid of the *Pseudotropheus zebra* group is described. The males of the species are gold (sensu Barlow 1976). The behavior and ecology of this species which is endemic to the Maleri Islands is discussed in light of previous hypotheses concerning the evolution of cichlid gold coloration.

HAPLOCHROMINE cichlids are particularly well known for their explosive speciation in the rift valley lakes of Africa and their incredible variety of color patterns within these lakes (Greenwood, 1981; Fryer and Iles, 1972; Ribbink et al., 1983). The existence of unique color patterns, among cichlids especially the male's, generally is recognized to be sufficient to delimit valid species (Barel et al., 1977; Barlow, 1974; Greenwood, 1981; Hoogerhoud and Witte, 1981; McKaye et al., 1982, 1984). However, the adaptive significance of these color patterns has been examined seriously only by Barlow's (1983) study of the midas cichlid, *Cichlasoma citrinellum*.

The purpose of this paper is to describe a species which has been previously mentioned in the literature (Ribbink et al., 1983) and hopefully stimulate future studies to test the generality of Barlow's earlier hypotheses. Ribbink et al. (1983) published a photograph and a brief synopsis of a species repeatedly called *Pseudotropheus zebra* "fusco." The males of this species are gold or yellow (henceforth referred to as gold sensu Barlow, 1976). A brief account of the color of this species was given, but no formal description has appeared in the literature. A number of specimens have now been obtained and the ecology and behavior of this species is now under investigation (McKaye and Stauffer,

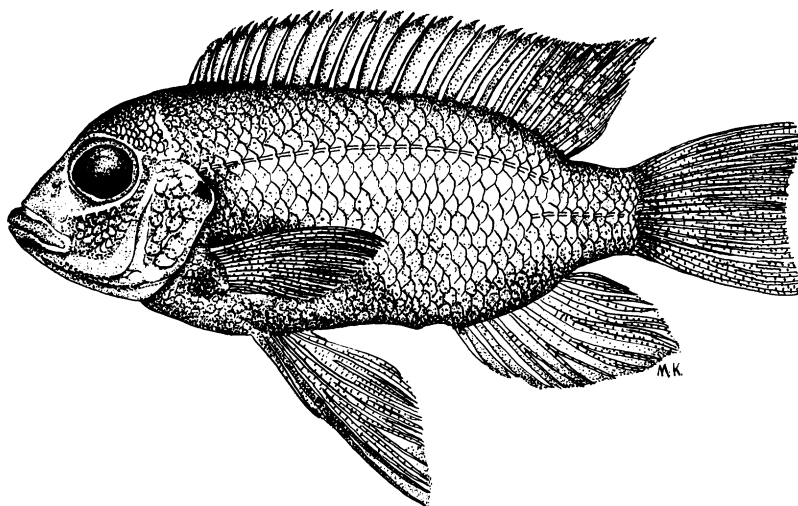


Fig. 1. Holotype of *Pseudotropheus barlowi*.

in prep.). We are, thus, taking the opportunity to describe this species. The counts and measurements employed follow Barel et al. (1977).

Pseudotropheus barlowi, n. sp.

Fig. 1

Holotype.—National Museum of Natural History (USNM) 274782, adult male, 76.9 mm standard length (SL) from Nakantenga Island, Lake Malawi, Malawi (34°39'E, 13°55'S), collected by K. R. McKaye and J. R. Stauffer, Jr., at 12–15 m, Field No. JRS 84-33, 19 April 1984.

Paratypes.—USNM 274783 (4 specimens, 72.6 mm, 81.1 mm, 70.3 mm, 71.4 mm SL) Nakantenga Island, 19 April 1984; 274784 (1 specimen, 77.0 mm SL) Nakantenga Island, 16 April 1984, 10–12 m. British Museum (Natural History) (BMNH) 1985.10.23:1–4 (4 specimens 73.5 mm, 77.8 mm, 64.1 mm, 73.9 mm SL), Nakantenga Island, 19 April 1984 (10–12 m).

Diagnosis.—*P. barlowi* is a member of the *P. zebra* group (Ribbink et al., 1983). D. S. C. Lewis (in prep.), who is currently revising the “mbuna” of Lake Malawi, distinguishes the *P. zebra* group from other “mbuna” by the “straight to concave snout, wide terminal mouth and lower jaw of equal to or longer than upper jaw.” Other described members of the *P. zebra* group include *P. livingstoni*, *P. elegans*, *P. aurora*, *P. lombardoi* and *P. greshakei* Meyer and Foerster 1984.

P. barlowi is distinguished from other sympatric members of this group by the gold coloration of the male and the brown coloration of the female. The male’s distinctive anal fin has blue membranes with a black ventral edge and gold ocelli with a red/orange border. Neither females nor males have any stripes or bars.

Description.—Based on the holotype (Fig. 1) and nine paratypes, six males 64.1–81.1 mm SL and three females 71.4–77.0 mm SL. Principal morphometric ratios given in Table 1.

Head 314–346 thousandths of SL. Interorbital width 267–293 thousandths of head length (HL). Snout length 324–372 thousandths of HL. Posterior margin of maxilla does not extend to vertical through anterior margin of orbit. Lower jaw 318–365 thousandths of HL. Jaws isognathus.

Dorsal-fin base 590–643 thousandths of SL. Caudal peduncle 90–120 thousandths of SL. Caudal peduncle 1.11–1.48 deeper than long. Dorsal fin with 25 (1), 26 (4), 27 (3), 28 (1) and 29 (1) serial elements comprised of 17 (2), 18 (6), 19 (1) and 20 (1) spines and 8 (5), 9 (4), 10 (1) segmented rays. Anal fin with 11 (10) elements, comprised of 3 spines and 8 segmented rays. Pectoral fins 267–318 thousandths of SL, comprised of 13 (8), 14 (2) segmented rays. Pelvic fins 280–416 thousandths of SL. Caudal fin emarginate.

Scales ctenoid. Lateral line with 29–31 pored lateral line scales (mode 31). It should be noted

TABLE 1. MERISTIC AND MORPHOMETRIC CHARACTER VALUES FOR *Pseudotropheus barlowi*. (N = 10 and includes holotype.)

Character	Holotype	Mean	SD	Range
Standard length mm	76.9	73.9	4.7	64.1–81.1
Head length mm	24.9	24.1	1.1	22.2–25.6
Thousandths of SL				
Head length	324	326	10	314–346
Head depth	328	333	12	319–352
Dorsal fin base	602	611	16	590–643
Caudal peduncle length	105	110	10	90–120
Caudal peduncle depth	136	135	4	131–144
Snout to dorsal fin origin	350	348	13	331–374
Snout to pelvic fin origin	424	424	10	417–446
Pectoral fin length	267	296	16	267–318
Pelvic fin length of males (N = 7)	382	377	24.2	339–417
Pelvic fin length of females (N = 3)	—	294	15.8	280–311
Thousandths of HL				
Interorbital width	273	279	8	267–293
Snout length	353	349	14	324–372
Horizontal eye diameter	325	329	8	324–349
Vertical eye diameter	309	318	13	298–345
Preorbital depth	189	198	5	189–204
Cheek depth	217	217	10	202–225
Postorbital head length	361	375	10	361–392
Premaxillary pedicels	287	278	12	254–297
Lower jaw length	349	343	16	318–365
Meristic characters				
Lateral line scales	30	30.4	0.70	29–31
Pored scales posterior to (hypural plate)	1	1.3	0.82	0–3
Dorsal spines	18	18.1	0.88	17–20
Dorsal rays	8	8.6	0.70	8–10
Pectoral rays	13	13.2	0.42	13–14
Scale rows on cheek	5	4.3	0.48	4–5
Gill rakers on ceratobranchial	10	10.5	0.53	10–11
Gill rakers on epibranchial	3	2.7	0.46	2–4

that the lateral line is in two parts which overlap. The scales in the overlap are counted in one part only. Scales which are pored and are located posteriorly to the hypural plate are not counted. Cheek with 4–5 scale rows (mode 4). Minute scales extend onto caudal fin.

Gill rakers on epibranchial 2–4 (mode 3) + 1 (in angle) + 10 (5), 11 (5) on ceratobranchial. Gill rakers with single filaments, not trifid or bifid.

Teeth bicuspid, 9–13 on left side of lower jaw in outer row. Upper jaw teeth in 4 rows. Teeth in the posterior upper rows are sparse. Teeth on lower jaw in 5 rows. Posterior lower rows incomplete.

Lower pharyngeal bone (N = 4) is triangular

in outline and its width is 1.0–1.1 times its length (Fig. 2). Its length is 269–290 thousandths of HL. Suture between two halves almost indistinct. Dentigerous area 1.0–1.2 times broader than long. Teeth in a posterior row weakly bicuspid (Barel et al., 1977, Fig. 53). Teeth in lateral rows unicuspid with flattened and obliquely truncated crowns (Barel et al., 1977, Fig. 54).

Radiographs were taken of the holotype and eight paratypes. Five specimens (including the holotype) have 14 abdominal vertebrae and four had 15. Seven specimens (including the holotype) had 16 caudal vertebrae and two had 15.

Live coloration.—Male. Head gold with green

opercular spot; anterior with faint blue flecks on gold ground coloration. Lateral side and pectoral fins are gold. Pelvic fin gold with black anterior margin. Anal fin membranes blue with black ventral edge; bright gold ocelli with red/orange border. Caudal fin gold with middle membranes blue. Dorsal-fin spines and rays gold; membranes pale blue with gold lappets.

Female.—Head brown, lateral surface with blue and gold flecks on brown ground coloration. Pectoral fin clear. Pelvic fin clear with brown leading edge. Anal fin gold distally, brown in proximal portion of membranes; distal membranes clear, spines with black micromelanophores.

Larvae.—Two females were captured with young in their mouths. The larvae were all bright gold with orange yolk sacs.

Preserved coloration.—Males. Head and lateral side pale yellow. Dark dorsally, fading to almost white ventrally. Paired fins clear. Anal fin clear with pale yellow ocelli. Dark brown opercular spot.

Female.—Head and lateral sides brown. Fins clear.

Distribution.—This species is common to the three Maleri Islands. Ribbink et al. (1983) report similar looking individuals at Nkudzi, Mbenji Island, Thumbi Island West and Mazinzi Reef. The allopatric males have slightly different coloration, whereas the females appear identical to those at the Maleri Islands. Further research is required to determine whether or not those allopatric entities are the same species as described here.

Relationships.—This species belongs to a group of species closely related to *P. zebra* (Fryer, 1959; Ribbink et al., 1983). Most of the species in this group are presently undescribed and at this time it would be premature to speculate on the phylogenetic relationship of *P. barlowi* to any of these species. Revisions of the genus *Pseudotropheus* are presently in preparation (Lewis, in prep.; Stauffer, in prep.).

Etymology.—Named after George W. Barlow in recognition of his behavioral studies on the benefits of being a gold cichlid.

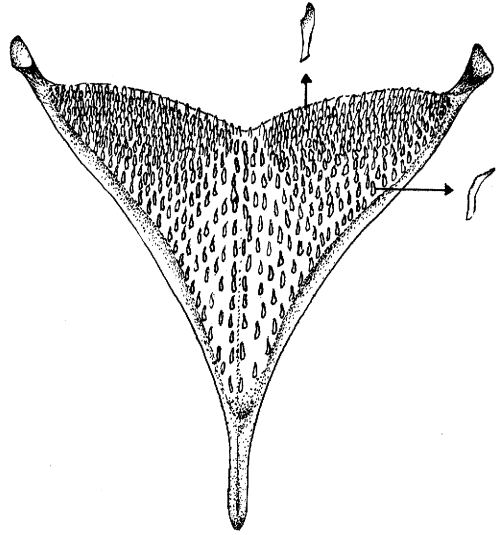


Fig. 2. Lower pharyngeal bone of *Pseudotropheus barlowi*.

Ecology.—*P. barlowi* is a rock dwelling cichlid which feeds primarily upon zooplankton, insect larvae, phytoplankton and algae. This generalized feeding behavior is typical of most members of the *P. zebra* group (Fryer, 1959; McKaye and Marsh, 1983; Ribbink et al., 1983). The males are territorial and remain close to the rocks, whereas the females tend to occur higher in the water column feeding upon zooplankton. They occur primarily at depths between 10 and 20 m.

DISCUSSION

Convergent evolution results when similar environmental conditions evoke similar phenotypic responses among unrelated organisms (Mayr, 1963). Although hypotheses of convergent vertebrate evolution are difficult to test experimentally, comparisons of different species under similar environmental conditions can give important insight into the processes of natural selection (Endler, 1982). Cichlids (Teleostei) are one of the best vertebrate groups on which to examine hypotheses of convergent evolution and the corresponding role of natural selection (McKaye, 1984).

While invoking natural selection to explain the patterns observed, one must be careful of simply making post hoc explanations of the system under consideration. Ideally, hypotheses

should be drawn from earlier studies and then applied to the system under consideration. We are fortunate that a series of a priori hypotheses concerning the benefits and disadvantages of being gold are available to test with African cichlids (Barlow, 1976, 1983; Barlow and Rogers, 1978).

Barlow (1983) summarizes his work on the midas cichlid *C. citrinellum* and we will refer the reader to this paper for a detailed justification of the hypotheses presented here. The following hypotheses have been proposed based on studies of the midas cichlid: 1) the gold-yellow coloration conveys an advantage in aggressive encounters; 2) this effect of gold is facilitated if gold fish are rare ("in nature slightly less than one in ten." Barlow, 1983); 3) gold color forms occur deeper in clear water than other forms perhaps to avoid predation by birds (McKaye, 1980), caimans and otters (Barlow, 1983); and 4) color forms mate assortively which can theoretically lead to rapid cichlid speciation (Lande, 1981; McKaye, 1980).

Although the similarities between the African and Central American species are striking, the differences between any given species should be noted. For example, only the *P. barlowi* males are gold and territorial. However, both males and females of *C. citrinellum* are gold and territorial.

Nevertheless, several undescribed cichlid species in Lake Malawi may conform to patterns observed in Central America and are worthy of further investigation to test Barlow's theories. For example, the gold males of *P. barlowi* are "aggressively territorial" as are most mbuna males (Ribbink et al., 1983), but they appear to be attacked less often by the cichlids than are "non-gold" sympatric *Pseudotropheus* spp. (McKaye and Stauffer, in prep.). This situation is analogous to the field observations of *C. citrinellum* by McKaye and Barlow (1976) in which individuals of the gold morph were attacked significantly less than the gray morph. Also both species occur primarily at depths below 10 m (Ribbink et al., 1983, pers. obs.). Furthermore, the occurrence of this deep dwelling species in Lake Malawi is consistent with the suggestion of McKaye (1980) that distinct non-interbreeding species, occupying deep- and shallow-water habitats, respectively, could arise from ancestral color morphs of one species.

Data on the relative aggression directed against gold and non-gold *Pseudotropheus* spp. are still required before we can determine the

generality of Barlow's hypotheses concerning the advantage of being gold. The cichlid species flocks of Lake Tanganyika and Lake Malawi provide the ideal conditions to test the generality of these hypotheses. Clearly, further comparative field observations and experimental manipulations are required.

ACKNOWLEDGMENTS

We thank L. Knapp of the Smithsonian Institution for his continued support and encouragement. We especially thank the government of Malawi for providing the facilities to make this research possible and in particular we would like to thank the personnel of both the Parks and Fisheries Departments for their continued help in our research program. Financial support was from the National Science Foundation grant number BSR 82-14603, Smithsonian Oceanographic Sorting Center and the International Program, University of Maryland. This is contribution No. 1657-AEL of the Center for Environmental and Estuarine Studies, University of Maryland, Appalachian Environmental Laboratory.

LITERATURE CITED

- BAREL, C. D. N., M. J. O. VAN OIJEN, F. WITTE AND E. L. M. WITTE-MAAS. 1977. An introduction to the taxonomy and morphology of the haplochromine Cichlidae from Lake Victoria. Part A. Text. *Neth. J. Zool.* 27:333-389.
- BARLOW, G. W. 1974. Contrasts in social behavior between Central American cichlid fishes and coral reef surgeon fishes. *Amer. Zool.* 14:9-34.
- . 1976. The midas cichlid in Nicaragua, p. 333-358. *In: Investigations of the ichthyofauna of Nicaraguan lakes.* T. B. Thorson (ed.). University of Nebraska, School of Life Sciences, Lincoln, Nebraska.
- . 1983. The benefits of being gold: behavioral consequences of polychromatism in the midas cichlid, *Cichlasoma citrinellum*. *Env. Biol. Fish.* 8:235-247.
- , AND W. ROGERS. 1978. Female midas cichlids' choice of mate in relation to parents' and to own color. *Biol. Behav.* 3:137-145.
- ENDLER, J. A. 1982. Convergent and divergent effects of natural selection on color patterns in two fish faunas. *Evolution* 36:178-188.
- FRYER, G. 1959. The tropic interrelationships and ecology of some littoral communities of Lake Nyasa with especial reference to the fishes, and a discussion of the evolution of a group of rock-frequenting Cichlidae. *Proc. Zool. Soc. Lond.* 132:153-281.
- , AND T. D. ILES. 1972. The cichlid fishes of

- the Great Lakes of Africa: their biology and evolution. Oliver and Boyd, Edinburgh, Scotland.
- GREENWOOD, P. H. 1981. The haplochromine fishes of East African lakes. Cornell University Press, Ithaca, New York.
- HOOGERHOUD, R. J. C., AND F. WITTE. 1981. Revision of species from the "Haplochromis" empodisma group. Revision of the haplochromine species (Teleostei, Cichlidae), from Lake Victoria, Part II. Neth. J. Zool. 31:232-274.
- LANDE, R. 1981. Models of reproduction by sexual selection of polygenic traits. Proc. Nat. Acad. Sci. 78:3721-3725.
- MAYR, E. 1963. Animal species and evolution. Harvard University Press, Cambridge, Massachusetts.
- MCKAYE, K. R. 1980. Seasonality in habitat selection by the gold color morph of *Cichlasoma citrinellum* and its relevance to sympatric speciation in the family Cichlidae. Env. Biol. Fish. 5:75-78.
- . 1984. Behavioural aspects of cichlid reproductive strategies: patterns of territoriality and brood defense in Central American substratum spawners versus African mouth brooders, p. 245-275. In: Fish reproduction: strategies and tactics. R. J. Wootton and G. W. Potts (eds.). Academic Press, London, England.
- , AND G. W. BARLOW. 1976. Competition between color morphs of the midas cichlid, *Cichlasoma citrinellum*, in Lake Jiloa, Nicaragua, p. 465-475. In: Investigations of the ichthyofauna of Nicaraguan lakes. T. B. Thorson (ed.). University of Nebraska, School of Life Sciences, Lincoln, Nebraska.
- , AND A. MARSH. 1983. Food switching by two algae-scraping cichlid fishes in Lake Malawi, Africa. Oecologia 56:245-248.
- , T. KOCHER, P. REINTHAL AND I. KORNFELD. 1982. Genetic analyses of a sympatric species complex of *Petrotilapia* Trewavas (Cichlidae, Lake Malawi). J. Linn. Soc. 76:91-96.
- , ———, ———, R. HARRISON AND I. KORNFELD. 1984. Genetic variation among color morphs of a Lake Malawi cichlid fish. Evolution 31:215-219.
- RIBBINK, A. J., B. A. MARSH, A. C. MARSH, A. C. RIBBINK AND B. J. SHARP. 1983. A preliminary survey of the cichlid fishes of the rocky habitats in Lake Malawi. S. Afr. J. Sci. 18:149-310.
- TREWAVAS, E. 1947. Speciation in cichlid fishes of East African lakes. Nature 160:96-97.
- UNIVERSITY OF MARYLAND, CENTER FOR ENVIRONMENTAL AND ESTUARINE STUDIES, APPALACHIAN ENVIRONMENTAL LABORATORY, FROSTBURG STATE COLLEGE CAMPUS, FROSTBURG, MARYLAND 21532 and SCHOOL OF FOREST RESOURCES, FERGUSON BUILDING, THE PENNSYLVANIA STATE UNIVERSITY, UNIVERSITY PARK, PENNSYLVANIA 16802. Accepted 22 Nov. 1985.