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DEVELOPMENT OF COLOR PATTERN IN POND-REARED YOUNG OF FIVE *Micropterus* SPECIES OF SOUTHEASTERN U. S.

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ABSTRACT

Six stocks of Southeastern *Micropterus* were spawned in earthen ponds, including wild-caught adults of *M. coosae* (Alabama and Apalachicola races), *M. p. punctulatus*, *M. punctulatus henshalli*, and *M. notius*, and hatchery stock of *M. dolomieu*. Fry were reared in earthen ponds provided with *Pimephales promelas* forage. Periodic samples were preserved to determine pigmentation characteristics at different ages and sizes. An illustrated key to species was prepared based on length and juvenal color pattern. Wild-caught specimens of *M. salmoides* were included for comparison. Color pattern changes progressed at a smaller size in stunted and wild-caught young.

INTRODUCTION

Young basses of the genus *Micropterus* are difficult or impossible to identify using recent taxonomic keys applicable to southeastern U. S. (Cook, 1959; Moore, 1968; Smith-Vaniz, 1968; Eddy, 1969). Most authors employ the natural keying system suggested by Hubbs and Bailey (1949), which is useful for identification of adult basses, but important characters used often are absent, modified, or difficult to discern in young specimens. For example, interrational scales beyond the basal sheath usually do not develop on the soft dorsal and anal fins before 45 to 60 mm standard length, and the upper jaw terminates before or at the level of the hind margin of the eye in *M. salmoides* up to 160 mm standard length (our observations). Coloration of young *Micropterus* is usually mentioned incompletely in more detailed works, and some early postembryonic color phases are described (Fish, 1932; Carr, 1942; Meyer, 1970). Many aquatic biologists have derived personal methods for identifying young basses, but none has published a comparative review of color changes useful in determination of species.

We have studied color development in known-age young of four species of Southeastern stream basses (*Micropterus punctulatus*, *M. notius*, *M. dolomieu*, and *M. coosae*) reared in ponds. Young of wild-caught specimens (including *M. salmoides*) were included in a size-related comparison of species, upon which a key to juvenal color phases is based.

MATERIALS AND METHODS

Rearing experiments were begun in spring, 1969 in earthen ponds of the Auburn University Agricultural Experiment Station, located in the southern Piedmont drainage of the Tallapoosa River basin. Fry were produced from natural spawnings and stocked in separate 0.1-A rearing ponds (0.07-A in the case of *M. notius*) as described by Smitherman and Ramsey (1972). Growth was rapid due to provision of abundant *Pimephales promelas* fry in the rearing ponds. Samples of young in brood

and rearing ponds were seined periodically and preserved in 10% formalin with Ionol C.P.-40 (Shell Chemical Co., N. Y.) color preservative added. Color observations and photographs were made at sampling and in the laboratory. Body lengths are listed as standard length (upper jaw tip to anterior base of caudal rays, following Hubbs and Bailey, 1940), and were taken from preserved specimens using a dial caliper accurate to 0.05 mm. Specimens ultimately were washed and stored in 40% isopropyl alcohol in the Auburn University ichthyological museum (AU).

Details of pigmentation were drawn freehand by Ramsey from specimens preserved in alcohol (Figs. 1-5). Body proportions are constant in the drawing outlines, and do not reflect observed proportional differences between species. Background color on the body and details of dorsal, anal, and pelvic fin color were deleted. The pectoral fin was partly deleted to depict post-cephalic body pigmentation more clearly. Terminology for markings is defined as follows: (1) blotch—irregular marking, usually rounded or squarish in outline, on more than one adjacent scale when developed on the body; (2) bar—dorsoventrally elongate line of pigment, usually straight; (3) stripe—horizontally elongate line; (4) streak—narrow, faint line of pigment along a single scale row; (5) band—continuous, curved line of pigment usually developed on the fins; (6) caudal spot—a blotch, short stripe, or distinct spot developed over the terminus of the hypural plate and anterior part of caudal rays. Juvenal pigmentation is defined as that developed in young phases distinguishable from mature fish on the basis of color pattern. Subadult pigmentation is designated as that developed in immature fish whose coloration is the same as in the youngest mature fish. Ages are given as days after hatching.

Wild-caught *M. salmoides* from numerous localities were studied for comparison with the experimental series. Individual series most intensively studied were catalogued as AU 2468 (Alabama, Lowndes-Montgomery Co., Pintlela Creek 9.9 miles west-southwest of Montgomery, Highway 80; Alabama River drainage; April 29, 1969), AU 3138 (Tennessee, Coffee Co., Little Duck River at southern edge of Manchester, Highway 41; Tennessee River drainage; June 14, 1968), and AU 2414 (Alabama, Lee Co., tributary to Halawakee Creek, ca. 5 miles northeast of Opelika, Highway I-85; Apalachicola River system; April 8, 1969).

Data for bass stocks reared in ponds follow: Northern spotted bass, *M. p. punctulatus* (Rafinesque)—brood stock from Halawakee Creek, tributary to Lake Harding (impounded Chattahoochee River) about 10 air miles east-northeast of Opelika, Lee Co., Alabama (Apalachicola River system). Representative Halawakee Creek specimens of this apparently introduced form (Bailey and Hubbs, 1949) were catalogued as AU 1488. The eggs were abandoned by the male parent, but were hatched in vitro on May 9-10, 1969. About 120 were reintroduced to the brood pond as swimup fry on May 16; 55 fry were transferred to the rearing pond when 24 days old, samples of 2 to 4 fish were preserved at ages 32, 41, 52, 66, 82, 95, 110, 137, 169, and 192 days. Although the sample size at each interval was small, the low stocking rate and abundant forage in this particular series yielded a fairly uniform rate of growth.

Southern spotted bass, *M. punctulatus henshalli* Hubbs and Bailey—brood stock from Uphapee Creek, tributary to Tallapoosa River about 5 air miles north of Tuskegee, Macon Co., Alabama (Alabama River drainage). Topotype representatives from Uphapee Creek were catalogued as AU 2671. The eggs hatched on April 7, 1969, and 300 fry were transferred to the rearing pond when 32 days old. Samples of 5 to 20 fish were preserved at ages 45, 59, 74, 85, 100, 129, 144, 171 and 203 days.

Suwannee bass, *M. notius* Bailey and Hubbs—brood stock from Ichetucknee River just east of Hildreth, U. S. Highway 27 crossing, Columbia Co., Florida (Suwannee River system). Representatives from Ichetucknee River were catalogued as AU 4212. The eggs hatched on April 9, 1970, and 12 fry were transferred to the rearing pond when 42 days old. Samples of 1 or 2 fish were preserved at ages 61 and 96 days. The

young apparently succumbed to oxygen depletion sometime before 142 days after hatching.

Smallmouth bass, *M. dolomieu* Lacépède—brood stock from Mammoth Spring National Fish Hatchery near Mammoth Spring, Fulton Co., Arkansas (stock presumably from the White River drainage originally, as a high percentage of young had 13 dorsal soft rays; Hubbs and Bailey, 1940). The eggs hatched on May 6, 1969, and 300 fry were transferred to the rearing pond when 15 days old. Samples of 5 to 20 fish were preserved at ages 29, 37, 46, 57, 72, 101, 116, 143, and 175 days.

Redeye bass, *M. coosae* Hubbs and Bailey—brood stock for one experimental series from Bird and Loblockee creeks, tributaries to Saugahatchee Creek ca. 8 air miles northwest of Auburn, Lee Co., Alabama (Tallapoosa-Alabama River drainage). Representative specimens from Loblockee Creek were catalogued as AU 2641. The eggs hatched on April 16, 1969 and 300 fry were transferred to the rearing pond when 22 days old. Samples of 3 to 20 fish were preserved at ages 35, 49, 64, 75, 90, 119, 134, 161, 193, and 216 days.

Another experimental series was derived from brood stock from Hala-wakee and Wacoochee creeks, tributaries to Chattahoochee River, respectively 10 air miles east-northeast and 14 air miles east-southeast of Opelika, Lee Co., Alabama (Apalachicola River system). Representative specimens from Wacoochee Creek were catalogued as AU 2108. The eggs hatched ca. May 20, 1969, and 300 fry were transferred to the rearing pond when 21 days old. Samples of 5 to 20 fish were preserved at ages 32, 43, 58, 74, 87, 102, 129, 161, and 183 days.

RESULTS

The chief color difference between juvenal and subadult phases was in melanic pigmentation of the posterior margin of the caudal. In subadults and adults the rays and interradial membranes were dusky to the end of the fin, and no colorless areas were visible along the entire posterior margin. In certain adult and subadult populations the caudal lobes had opaque white on the posterior margins, which persisted in preservative. Juvenal phases were characterized by having a colorless border at the posterior margin of the caudal, especially on the inner edges of the caudal lobes. The unpigmented border sometimes was very narrow but still apparent to the unaided eye. Whitish iridescent guanine deposits were conspicuous on the caudal margin of some young phases in life, but the areas thus pigmented became colorless in preservative.

Major differentiae are discussed generally in the key. Color pattern changes are discussed below for each species. Data from unscaled fry are incomplete, so these are not included in the key. Wild fish of each species were examined for construction of the key, but are not included in the following descriptions (except for *M. salmoides*).

Micropterus salmoides

The lateral stripe was conspicuous, wide, and essentially uninterrupted in unscaled young (Fig. 1a), and persisted under the blotched scale pigment of later stages. The lateral stripe appeared somewhat disrupted in scaled fish, becoming more so at about 35 mm (Fig. 1b). The stripe became fainter in larger juvenal specimens, especially in those from turbid streams.

The caudal spot was continuous with or separated from the lateral stripe in unscaled fry. The spot was distinct and elongated posteriorly in young up to 60 mm. The caudal submarginal band first became readily visible in some specimens at 35 mm, and was always present in those over 40 mm (Fig. 1c). The caudal band never was intensely developed, and usually was indistinct anteriorly (Fig. 1d). Some infrequently had whitish iridescence on the caudal lobes in life. The largest juvenal specimen observed was 95 mm, and the smallest subadult 91 mm. Juvenal fish were most similar to those of *M. punctulatus*, but could be distinguished by character differences in the key proposed below.

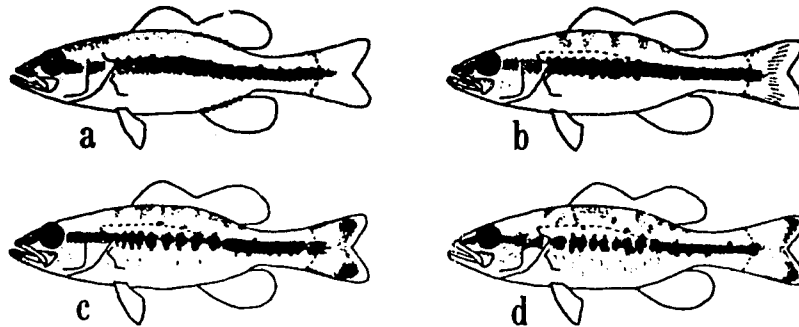


FIGURE 1. *Micropterus salmoides* (wild-caught). (a) AU 2468, 16.8 mm standard length, five scales formed on posterior part of lateral line; (b) AU 3183, 31.6 mm; (c) AU 2414, 45.9 mm; (d) AU 2414, 57.0 mm

Micropterus punctulatus

The lateral stripe was present and distinct in unscaled fry (Fig. 2a), but was somewhat narrower and less heavily pigmented than in *M. salmoides* fry. It persisted as a narrow stripe of deep pigment in early scaled fry (Fig. 2b), but was dominated by the development of bars on the scales overlying the lateral stripe. The bars were dorsoventrally elongate on the anterior half of the body, becoming squarish to horizontally elongate on the caudal peduncle. The lateral stripe persisted distinctly in subadults of 203 days and 120 mm (*M. p. henshalli*) and 192 days and 169 mm (*M. p. punctulatus*).

The caudal spot was triangular and distinct on unscaled and scaled fry at 32 days, and was not produced extensively onto the caudal rays (Fig. 2a). It became somewhat elongate by 59 days and 50 mm, and persisted in subadults, but the spot remained smaller than eye diameter. The caudal submarginal band was barely defined to the unaided eye in some at 43 days and 33 mm (from brood pond), but was best developed (Fig. 2c) in those between 59 days (50 mm) and 85 days (65 mm). At about 70 mm the caudal band began to expand posteriad and disappear anteriorly, and general appearance was much as in *M. salmoides* of the same size (Fig. 2d). Juvenal *M. punctulatus* in life always had white iridescent caudal margins after about 45 mm. Some subadults retained unpigmented areas on the outer margins of the caudal lobes, but this feature disappeared in the largest subadults. The largest juve-

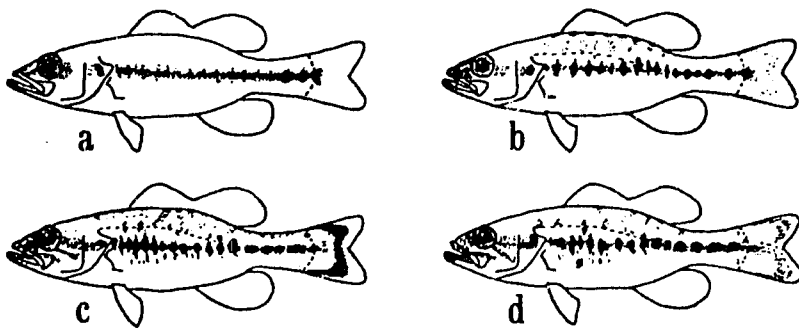


FIGURE 2. *Micropterus punctulatus henshalli*. (a) unscaled fry from brood pond, 32 days, 20.7 mm standard length; (b) 27.8 mm, nape and belly unscaled, from brood pond, 43 days; (c) 50.4 mm, from rearing pond, 59 days; (d) 75.7 mm, from rearing pond, 100 days

nal specimen observed was 105 mm at 203 days, the smallest subadult was 111 mm, also at 203 days. The two subspecies had essentially the same pattern of color development, but the somewhat larger scales of *M. p. punctulatus* (Hubbs and Bailey, 1940) provided some modification of intensity.

Micropterus notius

Only five specimens were preserved before the stock of young succumbed. Coloration of all samples in preservative is depicted in Fig 3 and compared in the key. In life the dorsum and sides below the vague lateral stripe were washed with yellow (lighter in those at 42 days and 20-23 mm). The caudal before the submarginal band was pale orange, and the posterior margin was highlighted with iridescent white. The caudal spot in the youngest fish was distinctly formed and conspicuous against a field of yellow-orange color.

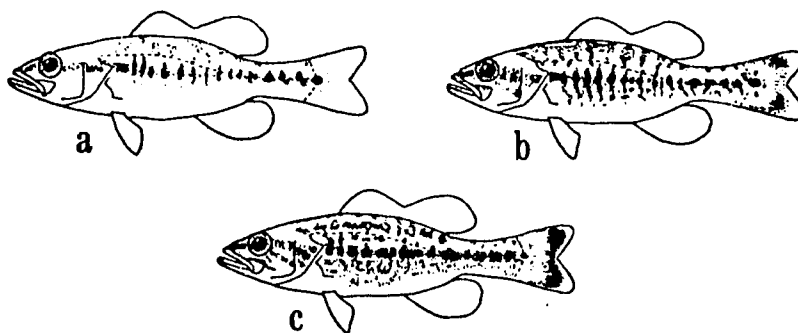


FIGURE 3. *Micropterus notius*. (a) 23.0 mm standard length, fully scaled fry from brood pond, 42 days; (b) 43.9 mm, from rearing pond, 61 days; (c) 68.7 mm, from rearing pond, 90 days

Micropterus dolomieu

A faint, narrow lateral stripe was developed along the horizontal intermuscular septum in unscaled fry (Fig. 4a), but the most conspicuous feature of pigmentation was the persistence of large melanophores on the entire body (also reported by Fish, 1932 and Meyer, 1970). The lateral stripe essentially disappeared with scale formation, but the large melanophores were conspicuous until 29 days and 49 mm.

The lateral bars developed and were most prominent with scale imbrication (Fig. 4b). The bars still were prominent, but light-centered at 29 days (43 to 50 mm), subsequently becoming vague or absent after 37 days (61 mm), when faint parallel streaks developed along the horizontal scale rows became the dominant feature of body color. While the lateral bars disappeared in the preserved specimens, our aquarium observations showed that live specimens often developed the barred pattern instantly when frightened or attacked by another fish.

The caudal spot was faint in unscaled fry (Fig. 4a). It was larger and fairly distinct in early scaled young (Fig. 4b), but faded centrally to two faint, horizontally zig-zag lines (Fig. 4c, d) on the caudal base by 37 days (60 mm). These lines persisted sporadically into the subadult phase, but generally the caudal base was unmarked in specimens preserved after 57 days (smallest 79 mm).

The caudal submarginal band developed boldly soon after scale formation (Fig. 4b), and the caudal appeared tricolor (opaque pale yellow to yellow-orange before the band, iridescent white behind). The tricolor caudal pattern persisted into smaller fish preserved at 72 days (65 mm), but tended to disrupt as the submarginal band developed further posteriorly in fish larger than 82 mm after 57 days (Fig. 4d). The largest

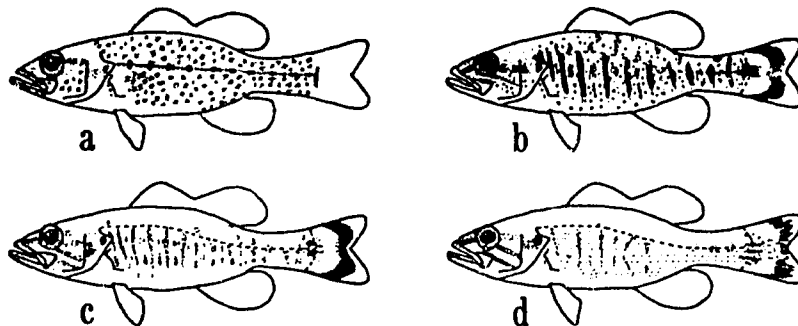


FIGURE 4. *Micropterus dolomieu*. (a) unscaled fry from brood pond, 16.1 mm standard length, 15 days; (b) 28.8 mm, nape and breast unscaled, from brood pond, 29 days; (c) 60.1 mm, from rearing pond, 37 days; (d) 79.1 mm, from rearing pond, 72 days.

juvenal specimen (150 mm) was preserved at 116 days. Subadults first appeared in the sample preserved at 101 days (129 mm). All but a few specimens were subadults by 143 days, including the smallest subadult observed (99 mm).

Micropterus coosae

The following remarks pertain to the Alabama River drainage population. Unscaled fry were not detected, but the pigmentation of early scaled young at 19 mm (Fig. 5a) suggested that a vague, narrow lateral stripe was present before scale imbrication. The lateral stripe was still evident in brood-pond young at 33 days (24 to 28 mm), but had disappeared in faster-growing young at the same age from the rearing pond (31 to 40 mm). The lateral bars became lightly pronounced upon scale imbrication (Fig. 5a), became darker and more contrasting (some with light centers) at 33 days (in brood and rearing ponds), but became vague on the anterior half of the body and light-centered on the posterior half of the body by 49 days (48 mm). The bars became almost indiscernable by 64 days (61 mm), and horizontal streaking on the ventrolateral scale rows became more pronounced as the lateral bars faded (Fig. 5c). Like *M. dolomieu*, *M. coosae* subadults and adults could flash the lateral bars rapidly in fright or appeasement coloration (our aquarium observations). The bars were somewhat darker in life than in preserved specimens in most cases observed.

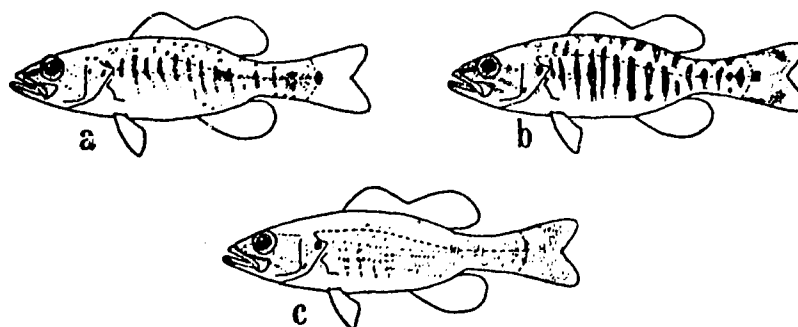


FIGURE 5. *Micropterus coosae*. Alabama River stock. (a) 19.0 mm standard length, scales developed to the opercular flap, from brood pond, 22 days; (b) 36.9 mm, from rearing pond, 35 days; (c) 60.4 mm, from rearing pond, 64 days

Very young fish had a small, distinctly rounded or wedge-shaped caudal spot, usually disjunct from and darker than the lateral stripe and bars (Fig. 5a, b). The spot was vague in about half of those preserved at 64 days and entirely absent (Fig. 5c) by 90 days (61 to 89 mm). The caudal submarginal band was never very dark or distinct, and was truly banded only in two series (35- and 49-day rearing pond young; Fig. 5b). Larger young had progressively more diffuse and broader development of the caudal band (Fig. 5c) until the subadult color phase was attained. Juvenal specimens usually had white iridescent color at the posterior caudal margin, and the soft dorsal, anal, and caudal all were washed with pale red-orange or orange in life.

The first and smallest subadult was encountered at 134 days (87 mm). The largest juvenal specimen (106 mm) also was collected on this day. All had reached subadulthood by 193 days, except for one juvenal specimen obtained on day 216.

In the series from the Apalachicola River stock, coloration of the smallest scaled young was about as in young of the Alabama River stock. The lateral bars persisted vaguely into the late juvenal phase, however, and were somewhat broader and more widely spaced. A more lengthy, detailed comparison of the two populations is reserved for later analysis.

DISCUSSION

Color pattern development followed a characteristic sequence in each of the populations tested. Development of the caudal submarginal band was common to all, major differences being in intensity of pigmentation and extent anteriorly at various ages or sizes. Lateral stripe or bar development, especially on the caudal peduncle, suggested two basic color groupings: (1) the *M. salmoides* and *M. punctulatus* species groups and (2) the *M. dolomieu* species group, including the other forms examined. Differentiae for the species within each of the two groups are less well defined, often a matter of degree, but are distinct at the species level at differing sizes.

The similarity of pigmentation of *M. salmoides* and *M. punctulatus*, even at the unscaled young stage, may represent a relationship closer even than has been proposed previously (Hubbs and Bailey, 1940; Bailey and Hubbs, 1949). *M. notius*, whose tendency toward intermediacy or generalization was pointed out by Bailey and Hubbs (1949), may be positioned phylogenetically between the *M. punctulatus* group and another part of the *M. dolomieu* group.

Basses in natural populations rarely have access to the abundance of forage available in the pond experiments. Viosca (1952) described rapid growth in *M. salmoides* and *M. punctulatus* under accidentally similar circumstances, but offered no remarks on color development. Most young basses in streams grow much more slowly than as observed in our study, and it is anticipated that exceptions to our observations will be common among wild fishes. Examination of museum specimens of indeterminate age indicated that the progression of the sequences reported occurs also in wild fishes, but probably at a somewhat smaller size. This is supported by limited observation of color pattern in some known-age fishes purposely stunted in other experiments. Meyer (1970) indicated that pigmentation of young centrarchids is more dependent on size than on age. This may hold true for embryos and fry up to the free-swimming stage, but apparently it is not that simple in young, actively foraging fishes in natural populations.

KEY TO JUVENAL COLOR PHASES OF SOUTHEASTERN MICROPTERUS (EXCLUSIVE OF UNSCALED FRY)

- 1a. Caudal dusky to posterior margin, including inner edges of caudal lobes (opaque white outer edges on upper and lower lobe margins in some populations) . . . Subadult and adult pigmentation: see other published keys.
- 1b. Caudal without dusky pigmentation on posterior margin (colorless or whitish area may be very narrow, but still visible to the

- unaided eye, at least along the inner edges of caudal lobes (Figs. 1-5) 2
- 2a. Caudal peduncle stripe or series of blotches extending ventrally only 1 to 1.5 scale row below lateral-line scale row, about as high as wide, contrasting sharply with light-colored lower surface of caudal peduncle 3
- 2b. Caudal peduncle bars (if present) extending 2 to 7 scale rows below lateral-line scale row, higher than wide; lateral stripe absent or inconspicuous, or if present contrasting poorly with extensive dark mottling on lower surface of caudal peduncle 7
- 3a. Less than 40 mm standard length (upper jaw tip to base of middle caudal rays), submarginal caudal band not developed 4
- 3b. More than 40 mm standard length, submarginal caudal band more or less conspicuous 6
- 4a. Lateral blotches more confluent, extending little above broad lateral stripe; caudal spot dark posteriorly, horizontally elongated onto anterior part of middle caudal rays, twice as long as wide, length equal to or greater than eye diameter (Fig. 1b) *M. salmoides*
- 4b. Lateral blotches less confluent, extending well above narrow lateral stripe; caudal spot about as long as wide, not defined on anterior part of caudal rays, length less than eye diameter 5
- 5a. Caudal spot diffuse (Fig. 2b); body slender, depth at dorsal origin more than 3.5 times in standard length *M. punctulatus*
- 5b. Caudal spot dark and discrete (Fig. 3a); body stout, depth at dorsal origin less than 3.5 times in standard length *M. notius* (very small young may key here)
- 6a. Highest expansions on anterior half of lateral stripe developed on 2 to 4 horizontal scale rows; submarginal caudal band usually vaguely defined, weakly decurved anteriorly, midpoint of upper extent falls on distal half of upper margin of fin (Fig. 1c); depigmentation of the caudal posterior margin equal to or slightly more at lobes than at fork (Fig. 1d); suborbital stripe usually absent or represented as blotches on cheek; small scales never formed on soft dorsal and anal interradial membranes of specimens over 70 mm; pyloric caeca branched near bases, 18 or more tips *M. salmoides*
- 6b. Highest expansions on anterior half of lateral stripe developed on 4 to 7 horizontal scale rows; submarginal caudal band either strongly defined and decurved, midpoint of upper extent falling on center or proximal half of upper margin of fin (Fig. 2c), or somewhat vague anteriorly, depigmentation of caudal posterior margin much greater at lobes than at fork (Fig. 2d); suborbital stripe usually well-defined and continuous on cheek; in specimens over 70 mm, 4 to 7 rows of small scales easily visible on anterior interradial membranes of soft dorsal and anal fins when wetted and dried slightly; pyloric caeca simple, 9 to 13 tips *M. punctulatus*
- 7a. Caudal peduncle irregularly mottled below wide, more or less confluent lateral bars (Fig. 3b, c); predorsal stripe usually distinct from dorsal origin to occiput; limited to Suwannee River system in Florida *M. notius* (larger young key here)
- 7b. Lateral bars absent or extended regularly onto lower side of caudal peduncle; predorsal stripe absent or very ill-defined; not in Suwannee River system 8
- 8a. Dorsum almost as dark as preorbital stripe, supralateral markings not readily visible; submarginal caudal band strongly developed except in late juvenal phase (Fig. 4); soft dorsal, anal, and caudal yellow, yellow-orange, or dusky in life; dorsal soft rays 12 to 15 (usually 14, sometimes 13) *M. dolomieu*
- 8b. Dorsum much lighter than preorbital stripe, supralateral markings readily visible; submarginal caudal band usually indis-

tinct or absent (Fig. 5); soft dorsal, anal, and caudal pale orange or red-orange in life; dorsal soft rays 11 to 14 (usually 12) *M. coosae*

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