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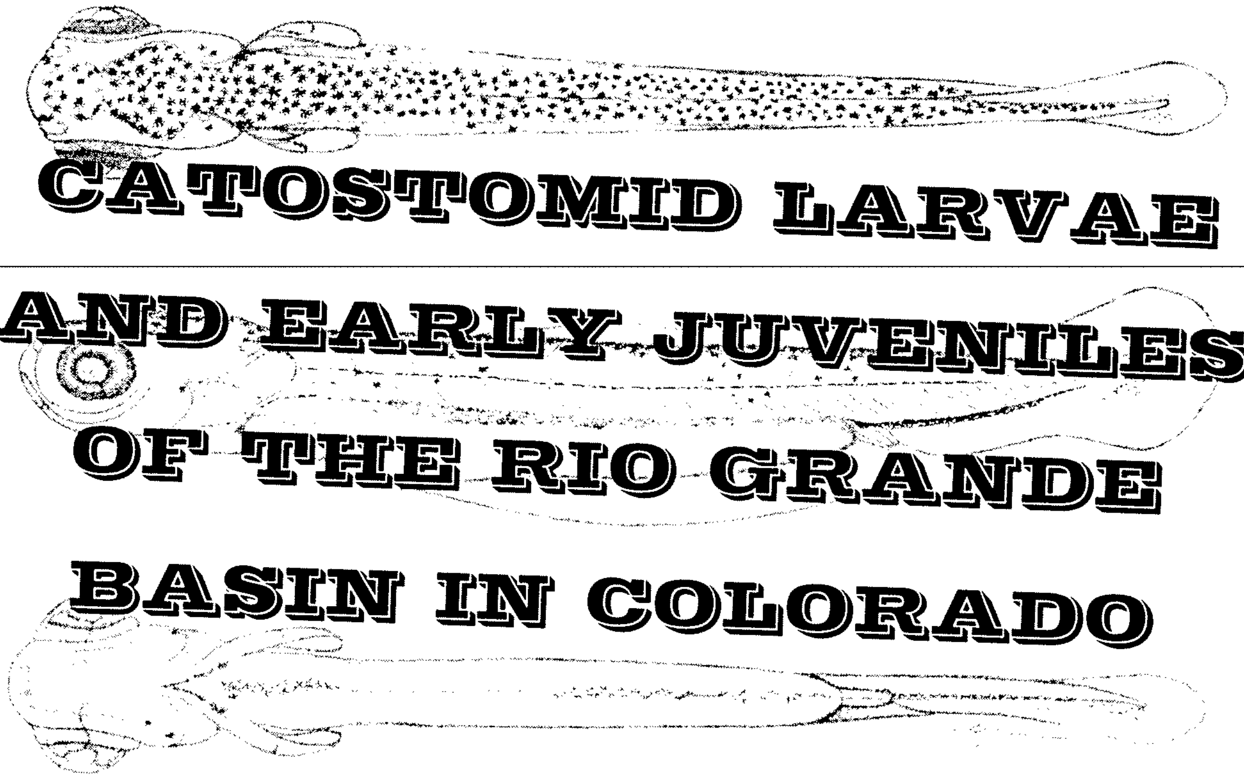

CATOSTOMID LARVAE AND EARLY JUVENILES OF THE RIO GRANDE BASIN IN COLORADO

Final Report

to

Colorado Division of Wildlife
c/o John Alves
722 S. County Road 1E
Monte Vista, Colorado 81144

(Contract 251-98, ENC C104419)

by

Darrel E. Snyder

Larval Fish Laboratory
Colorado State University
Fort Collins, Colorado 80523-1474

29 June 1998
(Revised 10 July 1998)

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Contribution 102 of the Larval Fish Laboratory, Colorado State University

CONTENTS

TABLES

FIGURES

ACKNOWLEDGMENTS

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ABSTRACT

The native Rio Grande sucker, *Catostomus plebeius*, an endangered species in Colorado, and introduced white sucker (*C. Commersoni*) are the only catostomids inhabiting most of the upper Rio Grande Basin in Colorado and northern New Mexico. Their larvae are broadly similar in appearance. To document early morphological development and facilitate identification, developmental series of collected and reared Rio Grande sucker were assembled, studied, illustrated, described, and compared with white sucker for differences in morphology, meristics, pigmentation, and size relative to developmental state.

Principal dorsal-fin-ray counts, lateral-line-scale counts, and various mouth characters are typically reported as criteria for diagnosis of older juveniles and adults and are useful for these early life stages once the pertinent structures are sufficiently developed. However, there is substantial range overlap in dorsal-fin-ray and lateral-line-scale counts if credence is given to extreme range values.

Rio Grande sucker typically progress in development from protolarvae to flexion mesolarvae and especially from flexion mesolarvae to postflexion mesolarvae at a smaller size than white sucker but from metalarvae to juveniles at a notably larger size. These differences in size relative to developmental state can be used as diagnostic criteria. Total myomere and vertebra counts for Rio Grande sucker average 2 or 3 units fewer than for white sucker but may be difficult to use as a diagnostic. Useful morphometrics include: length of the base of the dorsal fin for juveniles, metalarvae and later postflexion mesolarvae; depths behind the eye and vent and length to the origin of the dorsal finfold for flexion mesolarvae and protolarvae; and eye diameter and length to the posterior margin of the eye for protolarvae. Diagnostically useful pigmentation characters include those associated with the ventral midline from heart to vent, dorsal midline from head to tail, the rest of the dorsal surface, and for later larvae and early juveniles, lateral surfaces and the peritoneum. Pigmentation of reared Rio Grande sucker was extremely light relative to that of wild specimens and often required separate criteria for diagnosis.

When possible, it is best to base identities on a combination of characters. For protolarvae and mesolarvae pigmentation characters associated with the ventral midline and dorsal surface are generally quick, easy, and may be sufficient for confident identification of most specimens. When these characters are inadequate or in need of confirmation, try next the pertinent set of size relative to developmental state characters. For metalarvae, begin with a dorsal fin ray count and combine it with applicable size relative to developmental state and pigmentation characters. For early juveniles begin with a dorsal fin ray count, lateral pigmentation if the distinctive patterns are present, and mouth characters when the lower lip lobes are sufficiently developed. Except in the case of hybrids, the criteria and data presented herein should be adequate for accurate identification of most collected specimens.

INTRODUCTION

Three species of catostomid fishes are found in Colorado's portion of the Rio Grande Basin, the native Rio Grande sucker, *Catostomus plebeius*, the introduced white sucker, *Catostomus commersoni*, and most recently, the introduced longnose sucker, *Catostomus catostomus*. As members of the same genus *Catostomus*, all belong to the subfamily Catostominae and tribe Catostomini. Within the genus, the Rio Grande sucker belongs to the subgenus of mountain suckers, *Pantosteus*, whereas the white sucker and longnose sucker belong to the subgenus of valley suckers, *Catostomus* (Smith 1987). *Pantosteus* was revised from full genus to subgenus by Smith (1966) in part because some characteristics of Rio Grande sucker cross-over or are intermediate to the more typical states for most other members of the two groups (e.g., silvery to dusky or speckled peritoneum, rounded lower jaw, small lips, papillae on the anterior face of the upper lip, deep median cleft between lower lip lobes).

The Rio Grande sucker was historically very abundant in the Rio Grande and its tributaries in Colorado, possibly throughout the drainage, but natural populations have declined dramatically and been found recently only in Hot Creek (Hot Creek State Wildlife Area), a tributary of La Jara Creek west of Capulin (Fig. 4; Langlois et al. 1994). Outside Colorado, native populations of Rio Grande sucker inhabit the Rio Grande and Mimbres River Basins in New Mexico and several river systems in northern Mexico (Sublette et al. 1990). Populations in New Mexico's portion of the Rio Grande Basin are limited to the northern half of the state (Lee et al. 1980; Sublette et al 1990), especially in clearer, cooler, upstream reaches (Platania 1991), but are also declining (Langlois et al 1994, Rinne 1995).

In 1993, the Colorado Wildlife Commission designated the Rio Grande sucker as a state endangered species. A recovery program has since been established to ensure its long-term survival in Colorado (Langlois et al. 1994, Kelly 1997), in part through attempts to establish or re-establish new populations (Fig 4). Status and biology of the Rio Grande sucker was most recently reviewed and studied by Swift (1996).

Since their introduction, perhaps as early as 1939 (Sublette et al. 1990), white sucker populations have spread and become abundant throughout much of the Rio Grande Basin in Colorado and northern New Mexico (Fig. 16). Coupled with habitat changes, rough fish control measures, and introductions of predatory game fishes, the white sucker is suspected to have adversely affected Rio Grande sucker populations through competition and perhaps hybridization (Zuckerman and Langlois 1990, Langlois et al. 1994, Rinne 1995, Swift 1996, Kelly 1997).

Two other catostomids in the upper Rio Grande Basin are much less abundant and limited in distribution. The longnose sucker, the third catostomid in Colorado's portion of the basin, was recently discovered only in Placer Creek, a northern tributary of Sangre De Cristo Creek which in turn is tributary to Trinchera Creek (Alves, personal communication). In northern New Mexico, the native river carpsucker, *Carpiodes carpio* (subfamily, Ictiobinae), joins the Rio Grande sucker and white sucker in the lower mainstem reaches of the upper basin (Sublette et al. 1990).

Reproduction and early life history may be the keys to understanding the decline, stabilizing, and recovering Rio Grande sucker populations in Colorado and northern New Mexico. For most fishes, the larvae and early juveniles represent several life-intervals that are ecologically distinct from each other and from their later juvenile and adult counterparts (Snyder 1990).

Unfortunately, the larvae and early life history of the Rio Grande sucker are virtually unknown except for assumed similarities with other mountain suckers. Winn and Miller (1954) included mesolarvae of *Pantosteus* species in their photograph-illustrated key. All *Pantosteus* larvae included in that publication have since been recognized as desert sucker (*Catostomus clarki*) by Smith (1966). Larvae and early juveniles of mountain sucker, *Catostomus platyrhynchus*, were described by Snyder (1981, 1983a) and Snyder and Muth (1988, 1990) and those of bluehead sucker, *Catostomus discobolus*, by Snyder (1981) and Snyder and Muth (1990). Butler (1960) documented development of the Weberian apparatus in Rio Grande sucker, but the larvae and early juveniles themselves were not described.

In contrast, the early life stages of white sucker have been described and illustrated by many authors: Crawford (1923), Stewart (1926), Fish (1929,1932), Long and Ballard (1976), Buynak and Mohr (1978), Loos et al.(1978), Fuiman (1978, 1979), McElman and Balon (1980), and Snyder and Muth (1990). In addition, information and illustrations from these descriptions have been incorporated in several regional larval fish identification manuals: Mansueti and Hardy (1967), Lippson and Moran (1974), Jones et al. (1978), Wang and Kernehan (1979), Snyder (1981), Auer (1982), Holland-Bartels, et al. (1990, unillustrated), and most recently, Kay et al. (1994). The pattern of three large lateral spots or blotches that often develops on juvenile white sucker was recognized as a typical and distinctive character at least as early as Ellis (1914).

The larvae and early juveniles of longnose sucker have been described by Fuiman and Witman (1979) and Sturm (1988) and the former description included in larval fish manuals by Snyder (1981), Auer (1982), and Kay et al. (1994). However, as Kay et al. (1994) emphasized, current descriptive information is inadequate to distinguish most larvae and early juveniles of longnose sucker from white sucker until scales have formed. Like white sucker, juvenile longnose sucker often develop a three-blotch lateral pigmentation pattern.

The larvae of river carpsucker have been photographically illustrated by May and Gasaway (1967) and the larvae and recently transformed juveniles described and illustrated by Yeager (1980). The latter description has been incorporated in larval fish manuals by (Snyder 1981), Auer (1982), Holland-Bartels et al. (1990, unillustrated) and Kay et al. (1994). River carpsucker larvae are readily distinguished from all *Catostomus* by significantly lower preanal and total myomere counts (27-31 and 34-39, respectively) and in later stages by a much larger dorsal fin (23-30 principal rays).

With this report, I document the early morphological development of Rio Grande sucker, supplement prior descriptions of white sucker larvae with two new illustrations, and compare the two species for diagnostic criteria to facilitate identification of collected larvae and early juveniles. In doing so, I've modified and updated the white sucker species account from Snyder and Muth (1990) and produced a comparable species account for Rio Grande sucker. Most criteria for distinguishing Rio Grande sucker larvae and early juveniles from white sucker should also separate Rio Grande sucker from longnose sucker, but confirmation of this assumption must await a comparable detailed analysis of longnose sucker.

SPECIMENS EXAMINED

Both cultured and wild (collected) specimens of Rio Grande sucker were examined and selected specimens were analyzed for morphometric and meristic characters. The cultured series of larvae and early juveniles was reared and preserved by the Colorado Division of Wildlife at it's Bellvue Research Hatchery in spring 1995. Parental stock was collected from Hot Creek, Rio Grande Drainage, Conejos County, Colorado. Wild larvae and juveniles analyzed for morphometrics and meristics were collected from Sapillo Creek, Gila River Drainage, Grant County, New Mexico (T14SR13WS31) on 27 September 1983 (K. R. Bestgen Collection 211; late summer spawn, specimens less than 20 mm TL), 5 November 1983 (K. R. Bestgen Collection 227; 38 and 41 mm

TL), June 1984 (K. R. Bestgen Collection 363; less than 20 mm TL), and July 9 1984 (Collection 384; 23 and 27 mm TL) and from the Mimbres River, Mimbres River Drainage, Grant County, New Mexico (T17SR10WS30-31) between December 1982 and May 1985 (K. R. Bestgen collections; 20-22 mm TL). Additional specimens from these collections were also examined for developmental state and pigmentation characters.

Also examined were Rio Grande sucker juveniles and adults collected from the Mimbres River on 29 January 1986 (New Mexico Department of Fish and Game, provided by K. R. Bestgen), and larvae, juveniles, and adults collected from the Jemez River, Rio Grande Drainage, Sandoval County, New Mexico on 11 July 1991 (Collection MSB 9567 on loan by Museum of Southwestern Biology, University of New Mexico) and from the Rio Bonito, Pecos River Drainage, Lincoln County, New Mexico on 19 June 1993 (Collection MSB 13582 on loan). Two juveniles (45 and 46 mm TL) and one adult (125 mm TL) from the Jemez River collection and two adults (90 and 135 mm TL) from the Rio Bonito collection also were analyzed for morphometrics (juveniles only) and meristics.

Although Metcalf (1966) suggested that there is little rationale for subspecies designations for white sucker (e.g., *C. commersoni suckeyi* for western white sucker), Rio Grande sucker larvae and early juveniles are compared herein mostly with a descriptive information by Snyder and Muth (1990) for reared and wild series from western (Coloradan) populations of white sucker rather than earlier descriptions based on eastern populations. The cultured series was reared by the Larval Fish Laboratory at Colorado State University in spring 1979. Parental stock was collected from a private pond (Louis Swift) southeast of Fort Collins, Larimer County, Colorado. The wild larvae and juveniles were collected in 1977 from the Yampa River, Routt and Moffat Counties, Colorado (Carlson et al. 1979). Some specimens from these holdings were re-examined during this investigation and two (9.6 mm TL reared and 23 mm TL wild) were selected for new drawings to replace lateral-view-only drawings in the original species account.

All specimens, except those borrowed from the Museum of Southwestern Biology, are maintained as part of the Larval Fish Laboratory Collection but have not yet been cataloged. Most specimens were killed and fixed in 10% formalin, then stored in 3% buffered formalin. However, specimens borrowed from by the Museum of Southwestern Biology were stored in 70% ethanol.

METHODS

The methods utilized herein and detailed below generally follow Snyder 1981 and Snyder and Muth (1988 and 1990) except with regard to skeletal characters which were deemed unnecessary for diagnosis of Rio Grande sucker and white sucker metalarvae and early juveniles. These publications also include useful illustrations of the embryonic and larval fish anatomy and discussions of the various characters featured herein for description and identification of cypriniform fish larvae. The combined developmental interval terminology utilized herein was originally alluded to by Snyder (1983b) and presented and discussed by Snyder and Muth (1988 and 1990). The terms and definitions are as follows:

Larva: Period of fish development between hatching or birth and (1) acquisition of adult complement of fin spines and rays (principal and rudimentary) in all fins, and (2) loss beyond recognition of all finfold not retained by the adult.

Protolarva: Phase of larval development characterized by absence of dorsal, anal, and caudal fin spines and rays. (Standard length measured to end of notochord.)

Mesolarva: Phase of larval development characterized by presence of at least one dorsal, anal, or caudal fin spine or ray but either lacking adult complement of principal soft rays in all median (dorsal, anal, and caudal) fins or lacking pelvic fin buds or fins (if present in adult). (Standard length measured to end of notochord or, when sufficiently developed, axial skeleton.)

Preflexion Mesolarva: Among fishes with homocercal tails, phase of mesolarval development characterized by absence of caudal fin rays. (Posterior portion of notochord remains essentially straight and standard length measured to end of notochord. When the first median fin ray is a caudal ray, as in most fishes, larva progresses directly from protolarva to flexion mesolarva.)

Flexion Mesolarva: Among fishes with homocercal tails, phase of mesolarval development characterized by incomplete adult complement of principal caudal fin rays. (Posterior portion of notochord flexes upward and standard length measured to end of notochord.)

Postflexion Mesolarva: Among fishes with homocercal tails, phase of mesolarval development characterized by adult complement of principal caudal fin rays. (Notochord flexion essentially complete and standard length measured to posterior-most margin of hypural elements or plates.)

Metalarva: Phase of larval development characterized by presence of (1) adult complement of principal soft rays in all median fins and (2) pelvic fin buds or fins (if present in adult). (Standard length measured to posterior end of axial skeleton, hypural elements or plates in fishes with homocercal tails.)

Yolk-sac, Yolk-bearing, With Yolk, Without Yolk: Examples of modifiers used with any of the above period or phase designations to indicate presence or absence of yolk material, including oil globules.

Specimens were analyzed for counts, measures, developmental state, structural differences, and pigment distribution. Figure 1 illustrates the various measurements, fin ray counts, and myomere counts that were made on at least two specimens, if available, in each 1-mm TL (total length) interval throughout the larval period of each species. Thereafter, to a length of about 50 mm TL, one or more specimens were similarly processed for each 5-mm interval, if available. Specimens were studied under low-power stereo-zoom microscopes with measuring eyepiece reticles and various combinations of reflected, transmitted, and polarized light. Magnification was adjusted before each series of measurements to calibrate the scale in the eyepiece against a stage micrometer for direct measurement. Measurements under scopes were made to the nearest 0.1 mm and occasionally to half that unit. Some Rio Grande sucker specimens were measured using computer captured images and a computer image analysis program (Optimas). Re-measurement of selected specimens by a second observer or between manual and computer-aided procedures indicated that most measurements are repeatable to within 0.1 mm. Most partial body measurements are reported herein as a percentage of standard length (% SL) but are readily converted to percent total length by dividing the length of interest (as % SL) by total length (AS to PC, as % SL), and multiplying by 100. Some meristic data were obtained from specimens cleared and stained for skeletal study and from available adults.

Size at apparent onset of selected developmental events was documented for fully analyzed and additional specimens. Selected events were hatching, attainment of eye pigment, formation of

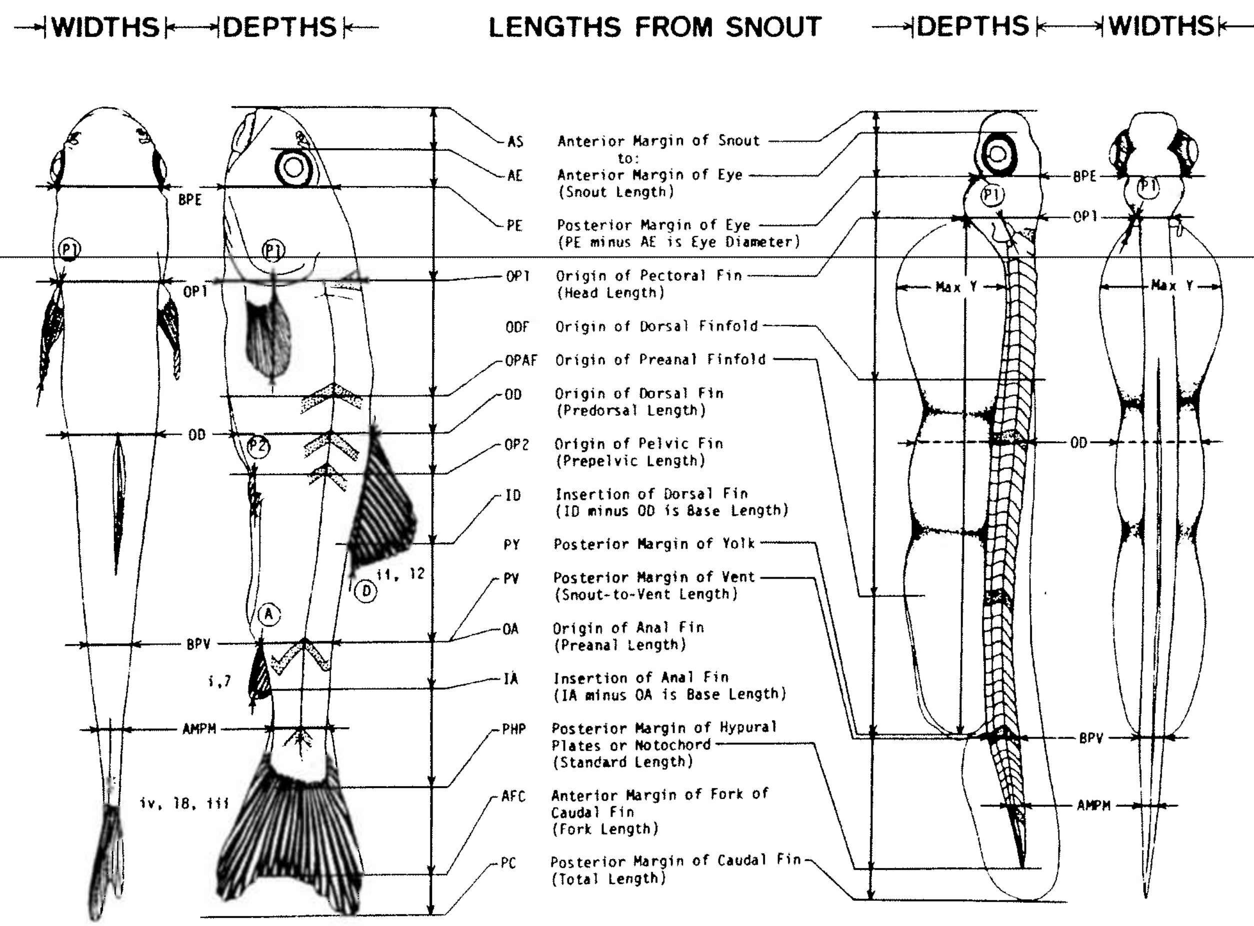


Fig. 1. Measures and counts for larval and early juvenile fishes. Yolk-sac and pterygiophores are included in width and depth measures but fins and finfolds are not. "B" in BPE and BPV means immediately behind. AMPM is anterior margin of most posterior myomere. Location of width and depth measures at OD prior to D formation is approximated to that of later larvae. PHP is measured to end of notochord until adult complement of principal caudal fin rays are observed. Fin lengths (D, A, P1, and P2, encircled) are measured along plane of fin from origin to most distal margin. When reported together, rudimentary median fin rays (outlined above) are given in lower case Roman numerals, while principal median fin rays (darkened above) are given in arabic numerals); rudimentary rays are not distinguished in paired fins. Most anterior, most posterior and last myomeres in counts to specific points of reference are shaded above. (From Snyder 1981.)

pectoral and pelvic fin buds, loss of yolk and preanal finfold, formation of first and last principal fin rays in each of the median fins, formation of first and last fin rays in the paired fins, formation of first and last rudimentary rays of the caudal fin, and initial and complete formation of lateral scales on the body. For each specimen, developmental phase (e.g., Protolarva) and extent of gut folding were also determined. The latter was classified as one of five gut phases (Fig. 2). Changes in other structures were noted. Variation in pigmentation patterns was studied by sketching observed patterns and noting their frequency.

Drawings, including dorsal, lateral, and ventral views, were prepared for the beginning and middle of each larval phase (flexion and postflexion mesolarvae treated respectively as beginning

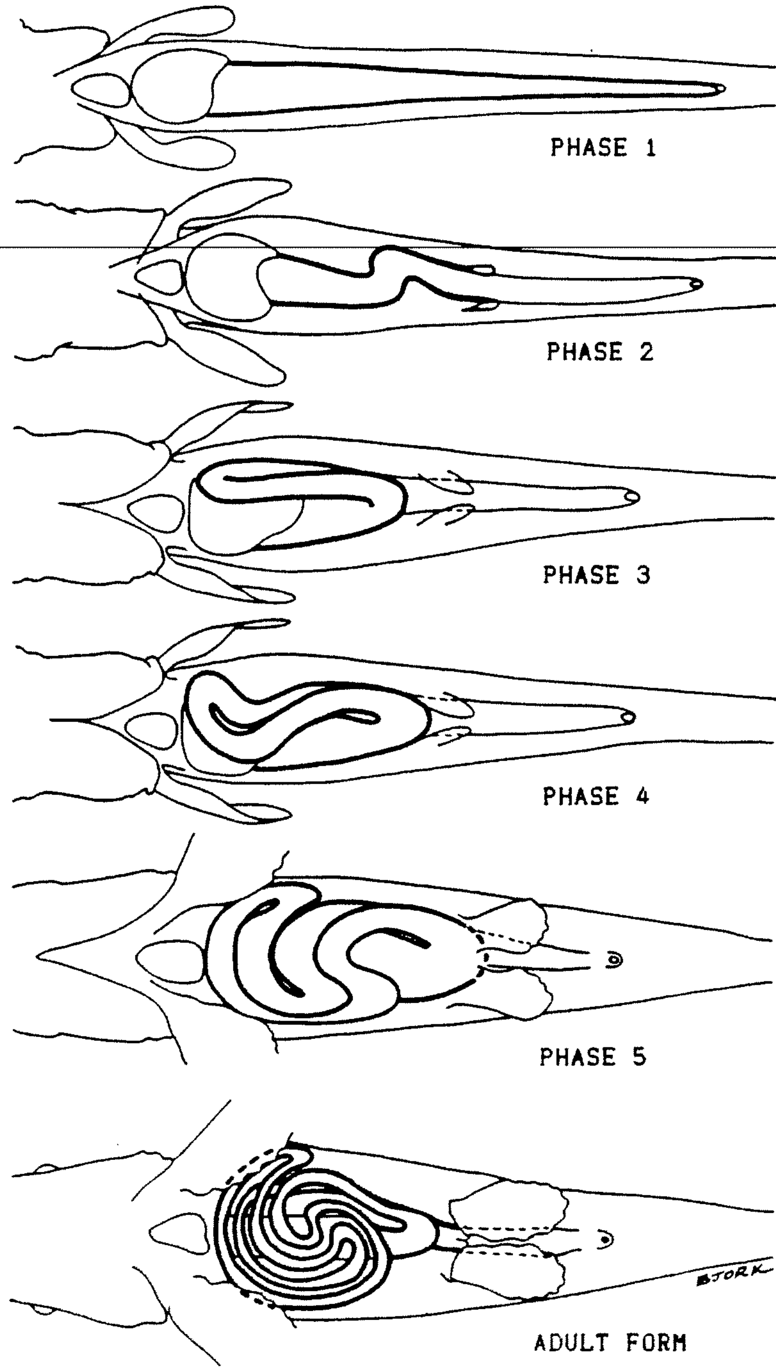


Fig. 2. Phases of gut coil development in catostomid fish larvae and early juveniles with comparison to adult form in *Catostomus commersoni* (latter modified from Stewart 1926). Phase 1 -- essentially straight gut. Phase 2 -- initial loop formation (usually on left side), begins with 90° bend. Phase 3 -- full loop, begins with straight loop extending to near anterior end of visceral cavity. Phase 4 -- partial fold and crossover, begins with crossing of first limb over ventral midline. Phase 5 -- full fold and crossover, begins with both limbs of loop extending fully to opposite (usually right) side, four segments of gut cross nearly perpendicular to the body axis. Later in Phase 5 and in adult form, outer portions of gut folds or coils extend well up both sides of visceral cavity.

and middle of the mesolarval phase) and the early or young-of-the-year portion of the juvenile period to document typical body form and pigmentation of Rio Grande sucker. Specimens were not available for a drawing of recently hatched protolarvae. Instead, three supplemental drawings of Rio Grande sucker were prepared to illustrate extremes in pigmentation. In addition, two new drawings of white sucker were prepared to replace lateral-view-only drawings previously used in the white sucker species account. For each of these drawings, enlarged photographs or prints from computer-captured images of typical specimens were traced to assure accurate body proportions. Various structures were checked and additional detail was added to drawings while specimens were examined under a microscope. Final drawings were idealized (e.g., closed or frayed fins opened and smoothed and curved bodies straightened). If necessary, melanophore distribution was modified using additional reference specimens to represent a more typical pattern. The base map for species distributions was selectively traced from U.S. Soil Conservation Service (1970) Map 47.

RESULTS AND CONCLUSIONS

Species Accounts

Results are compiled in the following species accounts for Rio Grande sucker and white sucker and subsequent comparative tables and discussion. Each species account opens with illustrations of the adult form (Figs. 3, 15), summaries of selected information on adult diagnosis, reproduction, and the young, and a map of regional distribution (Figs. 4, 16). Next is a table of selected juvenile and adult meristics summarized from original observations and literature (Tables 1, 5). The remaining tables detail size at apparent onset of selected developmental events (Tables 2, 6), document size at developmental interval and gut phase transitions (Tables 3, 7), and summarize morphometrics and myomere counts by developmental interval (Tables 4, 8). With a few exceptions, probably attributable to culture, morphometrics and meristics for reared and wild specimens were quite similar and combined for the latter species account tables. Each species account then continues with a series of eight three-view drawings representing the morphology and pigmentation of specimens at the beginning and middle of the protolarval, mesolarval, metalarval and early juvenile phases (Figs. 5-12, 17-24). In the case of the Rio Grande sucker species account, recently hatched protolarvae were not available and a modification of the middle protolarva drawing was substituted to illustrate the extremely sparse pigmentation of reared specimens (Fig. 5). Likewise, the base drawings for the postflexion mesolarva (Fig. 8) and recently transformed juvenile (Fig. 11) were used to illustrate the lighter pigmentation of similar-size reared specimens. These supplementary drawings are appended to the end of the species account (Figs. 14, 13, respectively). Except for a modified adult diagnosis, new regional distribution map, and new drawings representing recently hatched protolarvae and middle metalarvae (Figs. 17, 22), the white sucker species account and other white sucker data used for comparison are essentially identical to those published by Snyder and Muth (1990). Subsequent tables abstract diagnostically useful data from the species accounts and document additional changes in mouth position, lower-lip-lobe development, and pigmentation.

In the species account briefs on reproduction, both suckers are classified according to Balon's (1975a, 1981) reproductive guilds as non-guarding, open-substrate, lithophils. Lithophils prefer to spawn over predominately rock or gravel substrates. Their recently hatched larvae are photophobic and usually hide or remain in the substrate for at least a few days before emerging and drifting with the current.

Species Account – *Catostomus plebeius*

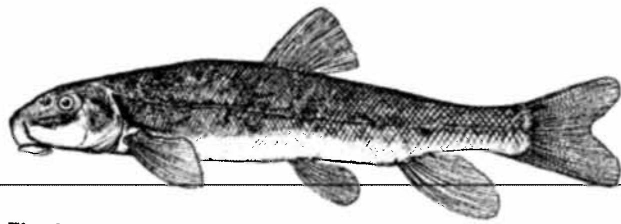


Fig. 3. *Catostomus plebeius* (from Miller 1952).

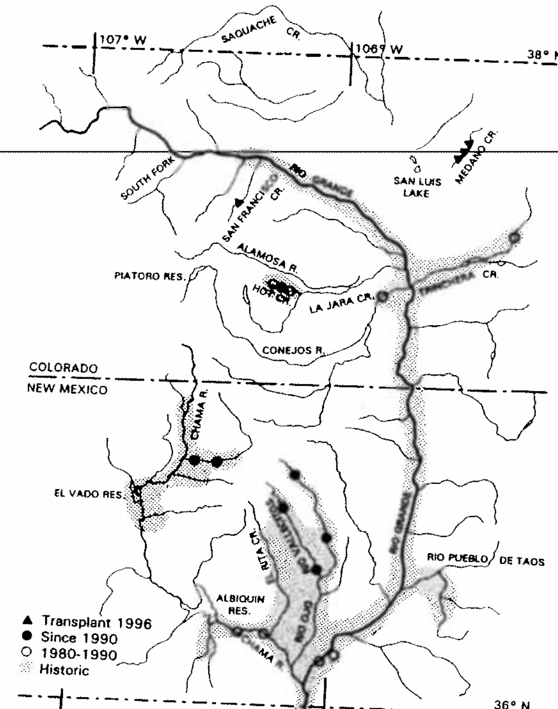


Fig. 4. Regional distribution of native *Catostomus plebeius*, based mostly on documented collections since 1850; historic distribution includes recent collections. Endangered in CO.

Adult Diagnosis: Mouth inferior, slightly overhung by broad snout. Lips small, uniformly papillose including external surface of upper lip. Deep median cleft with two to three rows of papillae spanning lobes; well-developed notches at corners of mouth. Mandible with narrow rounded cartilaginous ridge. Isthmus relatively narrow. Fontanelle closed in adults (nearly closed in young). Dorsal fin triangular; pelvic axillary process present, absent, or variously developed. Peritoneum dusky or silvery with densely scattered melanophores. TL usually 10-16 cm, up to 30 cm. (Also, Table 1.)

Reproduction: Non-guarding, open-substrate lithophil. Mature about 6-9 cm TL; display brilliant breeding colors and tuberculation. Spawns in spring to early summer and sometimes in fall over gravel. Spawns on waning side of peak flows Fecundity about 700-4,700, 2000 mean

Young: Unknown–assume like many other suckers hatch in 1-2 weeks, remain in gravel another 1-2 weeks, drift as late protolarvae and mesolarvae, usually at night, and subsequently occupy low velocity shoreline areas, often over sand and gravel or in aquatic vegetation.

Table 1. Selected juvenile and adult meristics for *Catostomus plebeius*. P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Gill rakers for exterior row of first arch, specimens >70 mm SL. Mean or modal values underlined if known and noteworthy; rare or questionable extremes in parentheses.

Character	Original	Literature
Dorsal Fin Rays - P:	8-9-10	8-9-10(11)
Anal Fin Rays - P:	(6)7(-9)	7(8)
Caudal Fin Rays - P:	18(19)	
Pectoral Fin Rays:	14-15-16	14-15
Pelvic Fin Rays:	8-9	8-9-10(11)
Vertebrae:		42-43-44-45(46)

Character	Original	Literature
Dorsal Fin Rays - R:	3-4	
Anal Fin Rays - R:	2-3	
Caudal Fin Rays - RD:	11-12-14	
Caudal Fin Rays - RV:	8-9-12	
Lateral Scales:	~73-75,[a] 85-91[b]	(70-)74-75-95-99(-103)
Gill Rakers:		19-20-23-27

[a] Hot Creek, CO, reared; n = 3, 33-38 mm TL (tentative counts). [b] Rio Bonito and Jemez River, NM, wild; n = 5, 45 & 90-135 mm TL

Table 2. Size at apparent onset of selected developmental events for *Catostomus plebeius*, as observed under low power magnification. P = principal rays; R = rudimentary rays; Scales are lateral series. Rare or questionable extremes in parentheses.

Event or Structure	Onset or Formation mm SL	mm TL
Hatched:	8(?)[a]	8[a]
Eyes Pigmented:	<10	<10
Yolk Assimilated:	10-11	10-12
Finfold Absorbed:	23-25	27-30
Pectoral Fin Buds:	<10	<10
Pelvic Fin Buds:	12-14	(13)14-15(16)

Fin Rays or Scales	First Formed mm SL	mm TL	Last Formed mm SL	mm TL
Dorsal - P:	12	(13)14	13-15	15-17
Anal - P:	14	(15)16	15-17	18-19
Caudal - P:	10	10-11	11	12
Caudal - R:	12	(13)14	22-23	26-27(28)
Pectoral:	14	(15)16	19-20	23-24
Pelvic:	15-17	18-20	19-20	23-24
Scales:	23-25	27-30	27-29	33-35

[a] Butler (1960).

References: Alves (1998 personal communication), Beckman 1952, Butler 1960, Ellis 1914, Hubbs et al. 1943, Jordan and Evermann 1896, Koster 1957, Langlois et al. 1994, Lee et al. 1980, McAllister 1968, Miller 1952, Minckley 1973, Moore 1968, Platania 1994, Rinne 1995, Smith 1966, Smith et al. 1983, Sublette et al. 1990, Swift 1996, Woodling 1985, Zuckerman 1984, Zuckerman and Langlois 1990.

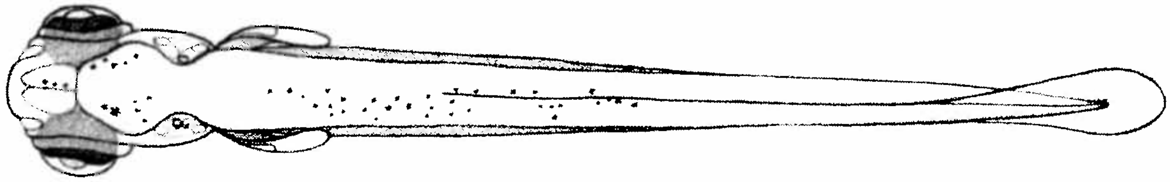
Table 3. Size at developmental interval (left) and gut phase (right) transitions for *Catostomus plebeius*. See Figure 2 for phases of gut folding. Rare or questionable extremes in parentheses.

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion Mesolarva:	10	10-11	2 - 90° bend:	14-15	(15)16-17
Postflexion Mesolarva:	11	12	3 - Full loop:	16-18	18-20(21)
Metalarva:	15-17	18-19	4 - Partial crossover:	18-19	21-22
Juvenile:	23-25	27-30	5 - Full cross over:	22-23	26-27(28)

Table 4. Summary of morphometrics and myomere counts by developmental phase for *Catostomus plebeius*. See Figure 1 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded.

	Protolarvae (N=7)				Flexion Mesolarvae (N=10)				Postflexion Mesolarvae (N=31)				Metalarvae (N=19)				Juveniles (N=8)			
	$\bar{x}$	±SD	Range		$\bar{x}$	±SD	Range		$\bar{x}$	±SD	Range		$\bar{x}$	±SD	Range		$\bar{x}$	±SD	Range	
SL,mm:	10	0	10	10	11	1	10	11	14	1	11	17	18	2	15	25	31	5	23	37
TL,mm:	11	0	10	11	11	1	10	12	15	2	12	19	22	3	18	30	37	7	27	46
Lengths %SL:																				
AS to AE	2	0	2	3	3	1	2	4	4	1	3	7	6	1	5	8	8	1	7	10
PE	10	0	10	11	10	1	8	11	12	1	10	15	14	1	12	15	15	1	13	17
OP1	19	1	17	20	19	1	18	22	23	2	20	27	25	1	23	27	26	2	23	29
OP2									53	1[c]	51	55	55	2	52	59	57	2	56	60
PY	73	1	72	75	71	1[b]	70	72												
OPAF	27	4	23	34	26	1	23	28	31	3	26	38	40	10	29	64				
ODF	41	2	40	45	41	1	39	44	44	2[d]	40	49								
OD									50	1[d]	47	52	50	1	48	52	50	1	49	51
ID									60	2[e]	57	63	61	1	59	64	62	1	61	62
PV	78	1	77	79	78	2	76	81	79	1	76	83	76	2	74	81	74	1	72	77
OA									79	1[f]	77	81	77	2	75	80	75	2	72	77
IA									84	2[g]	81	87	83	1	82	87	83	1	82	85
AFC									111	1	108	115	114	1	113	117	115	1	113	117
PC	106	0	105	106	107	1	105	109	113	2	108	117	117	2	115	121	120	2	118	122
Y	48	3	43	51	14	23	0	49												
P1	10	1	9	11	11	1	10	13	14	1	12	17	17	1	15	21	19	2	16	22
P2									3	2	0	7	8	3	4	13	14	2	11	16
D									14	2[e]	10	18	18	1	15	19	20	2	18	23
A									8	1[h]	6	9	10	2	8	14	16	2	13	20
Depths %SL:																				
at BPE	12	1	11	13	12	1	11	14	15	1	13	17	17	1	16	19	17	1	15	19
OP1	12	1	11	13	13	1	11	15	17	1	14	20	20	1	18	21	21	2	18	23
OD	10	2	8	12	10	1	8	12	14	2	10	19	19	2	14	21	22	2	19	25
BPV	7	1	6	8	7	1	6	8	8	1	6	9	10	1	8	13	13	1	11	14
AMPM	3	0	3	4	4	1	3	4	6	1	4	9	7	1	6	9	8	1	8	9
Max Yolk	5	3	1	12	1	2	0	5												
Widths %SL:																				
at BPE	11	1	10	12	12	1	10	13	14	1	13	17	16	1	15	17	16	1	15	18
OP1	7	0	7	8	9	1	7	10	11	1	9	13	15	1	12	17	17	2	14	20
OD	6	1	5	7	6	0	5	7	8	1	5	11	12	2	9	15	16	3	13	20
BPV	4	0	3	4	4	0	4	5	5	1	4	6	7	1	6	9	8	2	7	11
AMPM	2	1	1	3	2	0	2	3	3	0	2	4	4	1	3	5	5	1	3	6
Max Yolk	7	2	2	8	1	2	0	5												
Myomeres:																				
to PY	31	1	30	32	31	1[b]	30	32												
OPAF	6	2[a]	4	10	6	1	5	7	7	1	6	10	11	6	6	26				
OP2									20	1[c]	19	21	20	1	19	22				
ODF	14	1	12	16	14	1	13	17	15	1[d]	12	16								
OD									18	1[d]	16	19	17	1	15	19				
PV	34	1	34	35	35	1	34	36	34	1	33	36	33	1	31	37				
Total	43	0	42	43	43	1	42	45	43	1	41	45	43	1	42	45				
After PV	8	1	7	9	8	1	7	9	8	1	7	10	10	1	8	11				

[a]N = 6; [b]N = 3; [c]N = 22; [d]N = 25; [e]N = 24; [f]N = 13; [g]N = 7; [h]N = 8



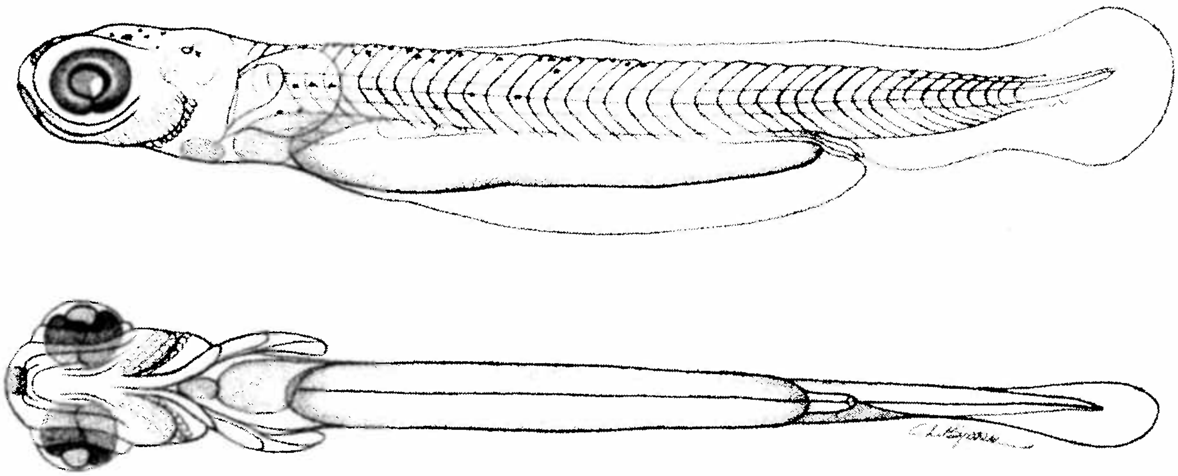


Fig. 5. *Catostomus plebeius* protolarva, pigment only using base drawing from Fig. 6. 9 mm SL, 10.5 mm TL. Cultured in 1995 with stock from Hot Creek, Rio Grande Drainage, Colorado (CDOW).

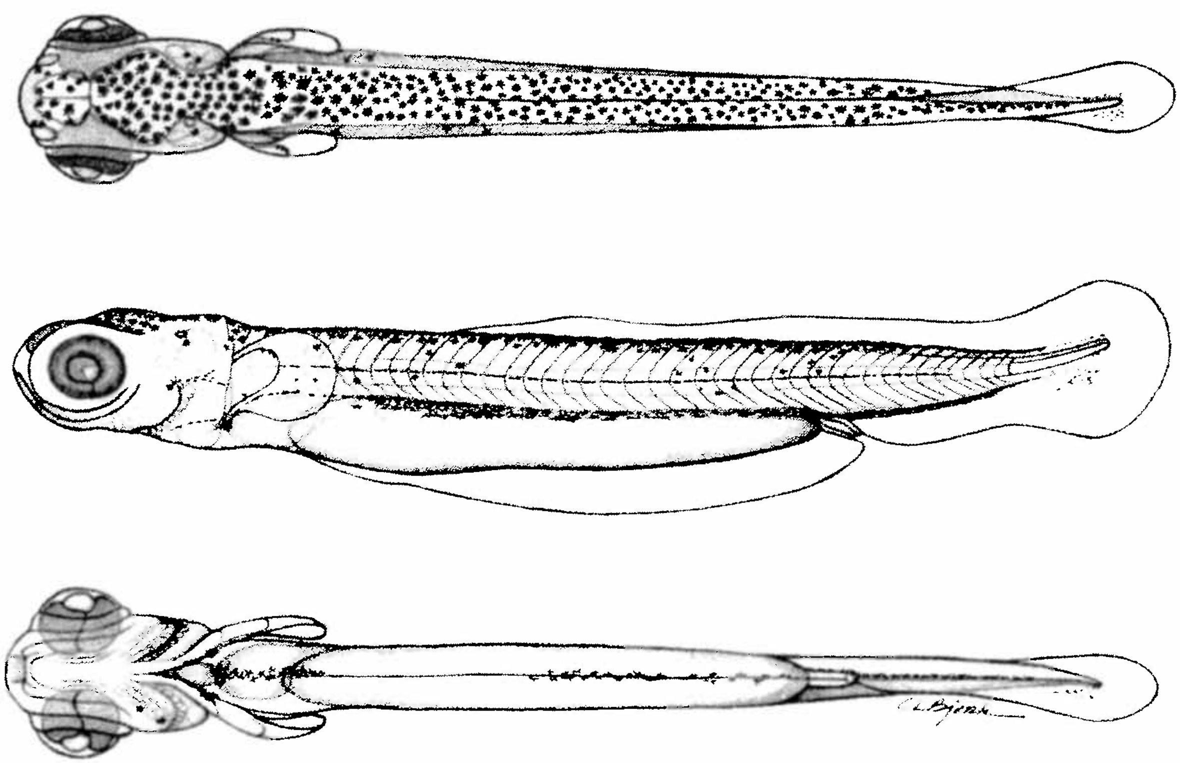


Fig. 6. *Catostomus plebeius* protolarva, 9.9 mm SL, 10.4 mm TL . Collected in 1983 from Sapillo Creek, Gila River Drainage, New Mexico (K. R. Bestgen Collection 211).

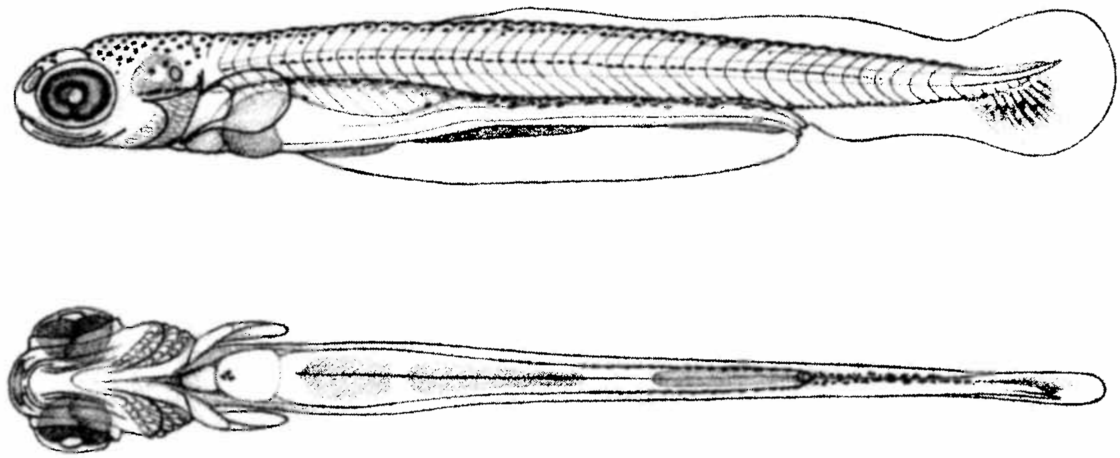


Fig. 7. *Catostomus plebeius* flexion mesolarva, recently transformed, 11.9 mm SL, 11.3 mm TL . Collected in 1983 from Sapillo Creek, Gila River Drainage, New Mexico (K. R. Bestgen Coll. 211).

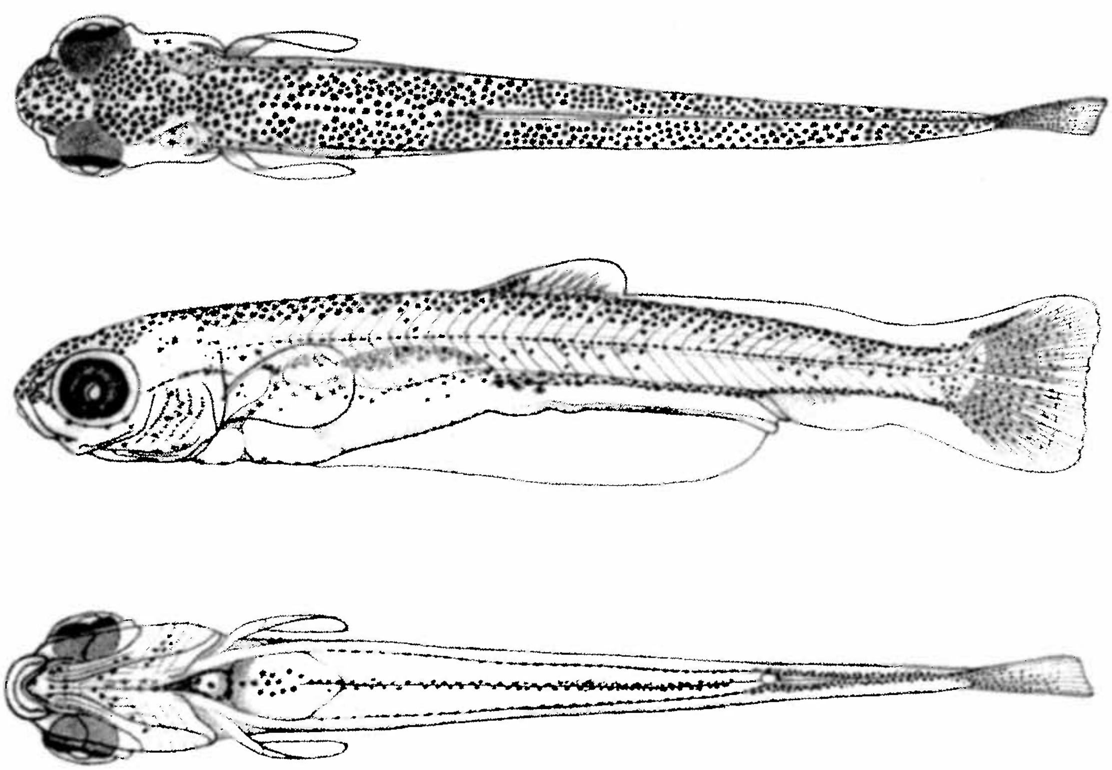


Fig. 8. *Catostomus plebeius* postflexion mesolarva, 14.3 mm SL, 15.7 mm TL. Collected in 1983 from Sapillo Creek, Gila River Drainage, New Mexico (K. R. Bestgen Collection 211).

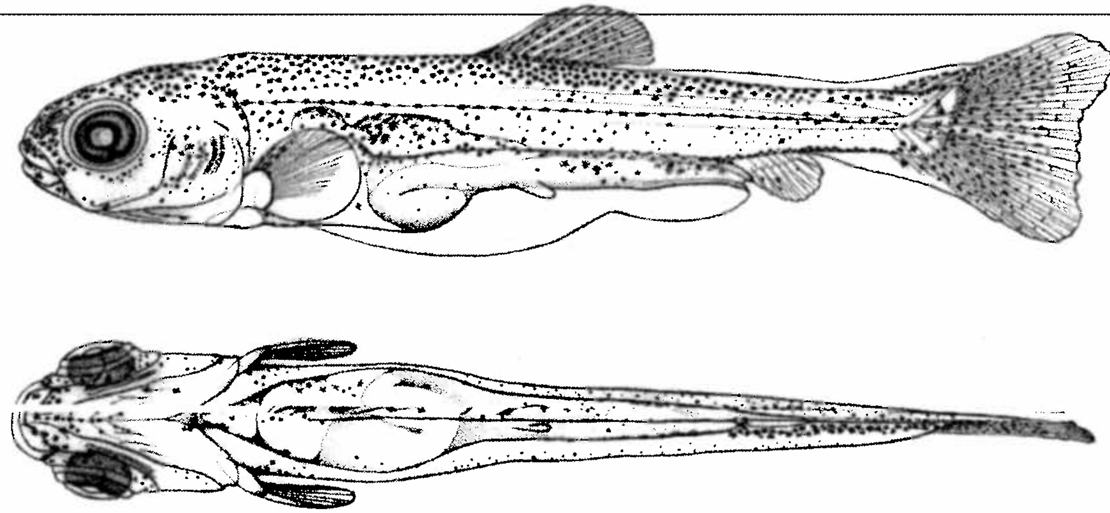


Fig. 9. *Catostomus plebeius* metalarva, recently transformed, 16.9 mm SL, 19.6 mm TL . Collected in 1983 from Sapillo Creek, Gila River Drainage, New Mexico (K. R. Bestgen Collection 211).

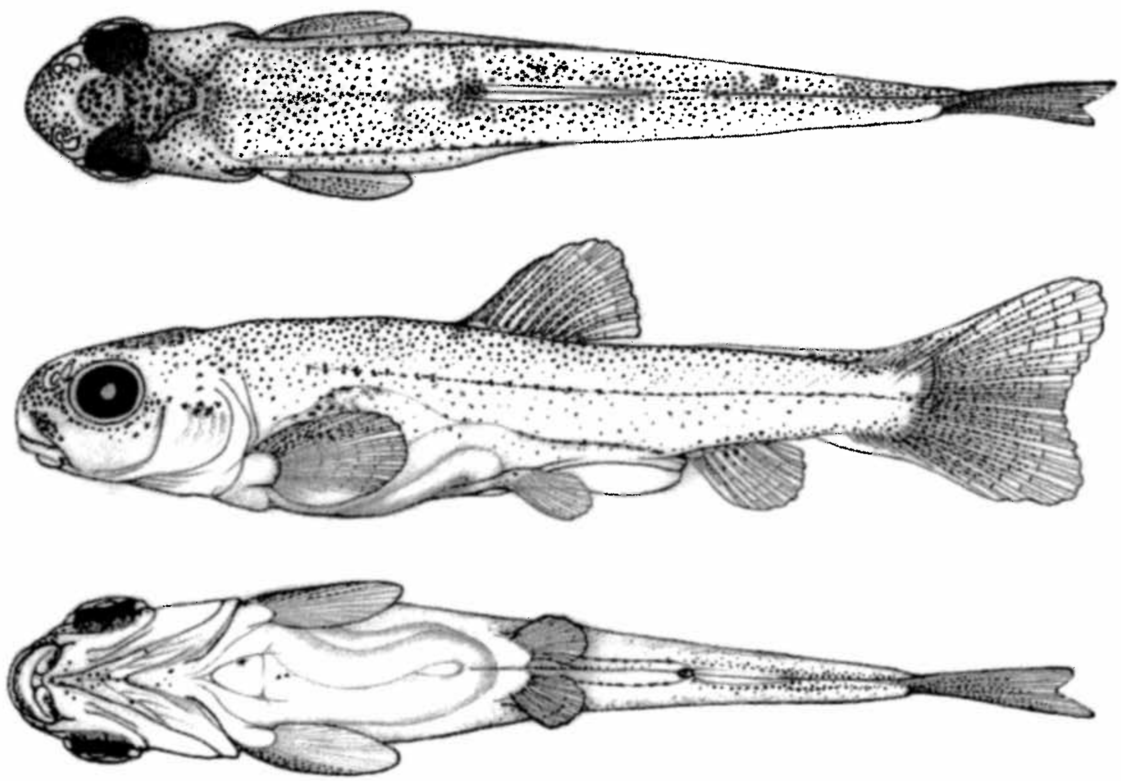


Fig. 10. *Catostomus plebeius* metalarva, 19.9 mm SL, 23.5 mm TL. Cultured in 1995 with stock from Hot Creek, Rio Grande Drainage, Colorado (CDOW).

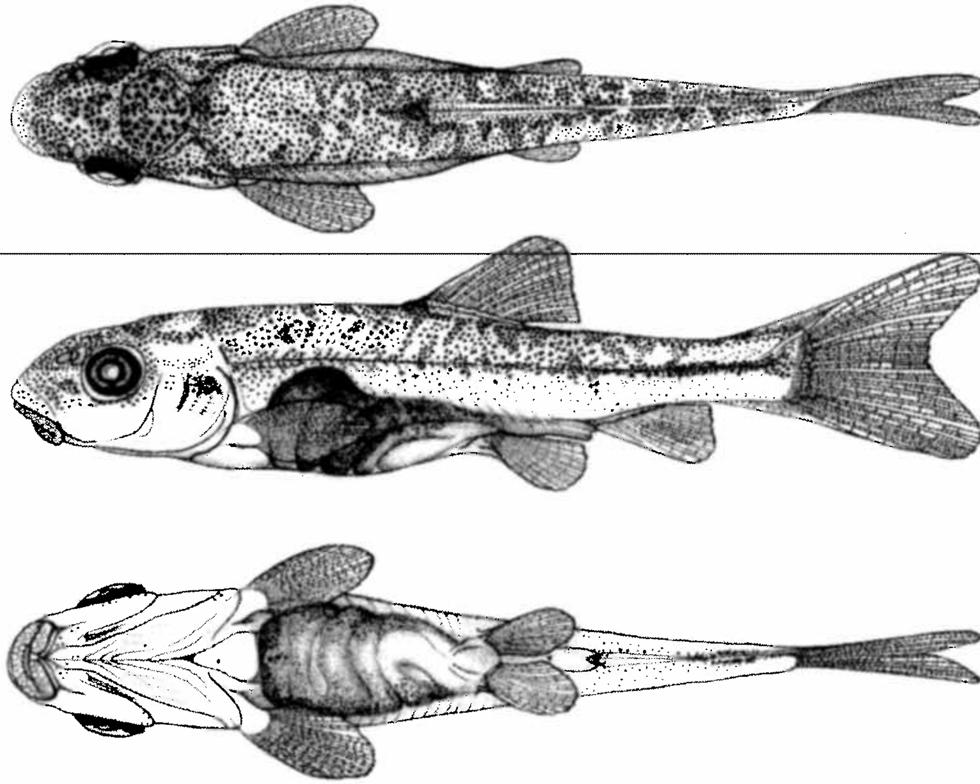


Fig. 11. *Catostomus plebeius* juvenile, recently transformed, 23.1 mm SL, 27.4 mm TL . Collected in 1984 from Sapillo Creek, Gila River Drainage, New Mexico (K. R. Bestgen Collection 384).

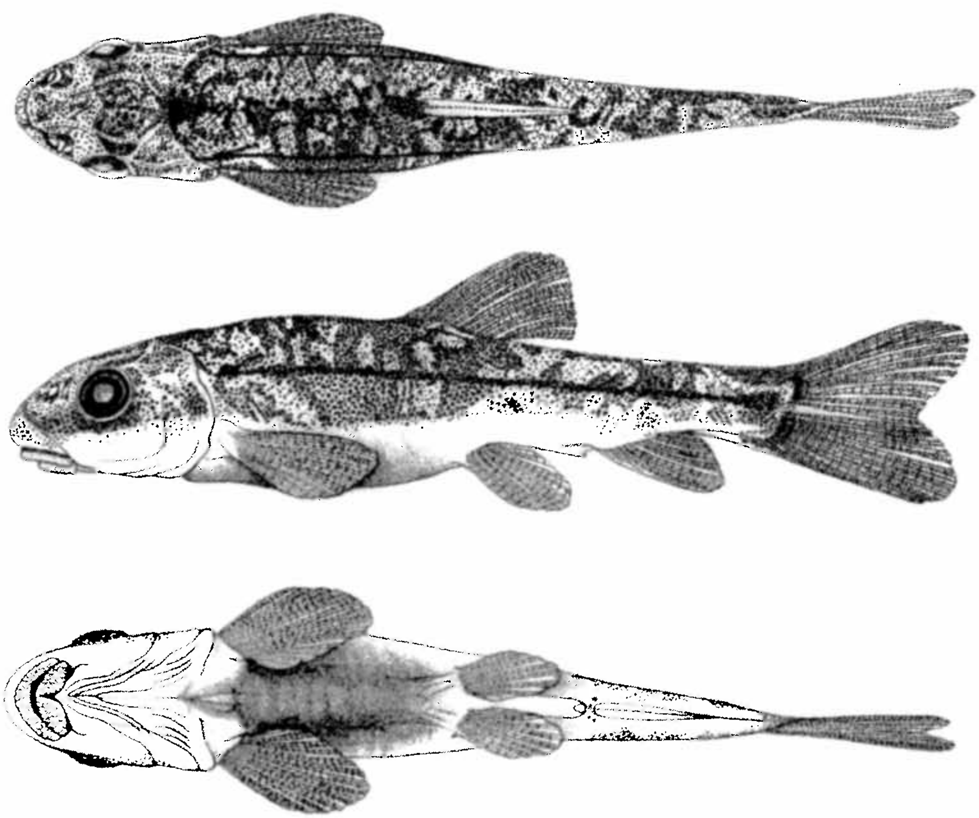


Fig. 12. *Catostomus plebeius* juvenile, 31.4 mm SL, 37.8 mm TL .Collected in 1983 from Sapillo Creek, Gila River Drainage, New Mexico (K. R. Bestgen Collection 227).

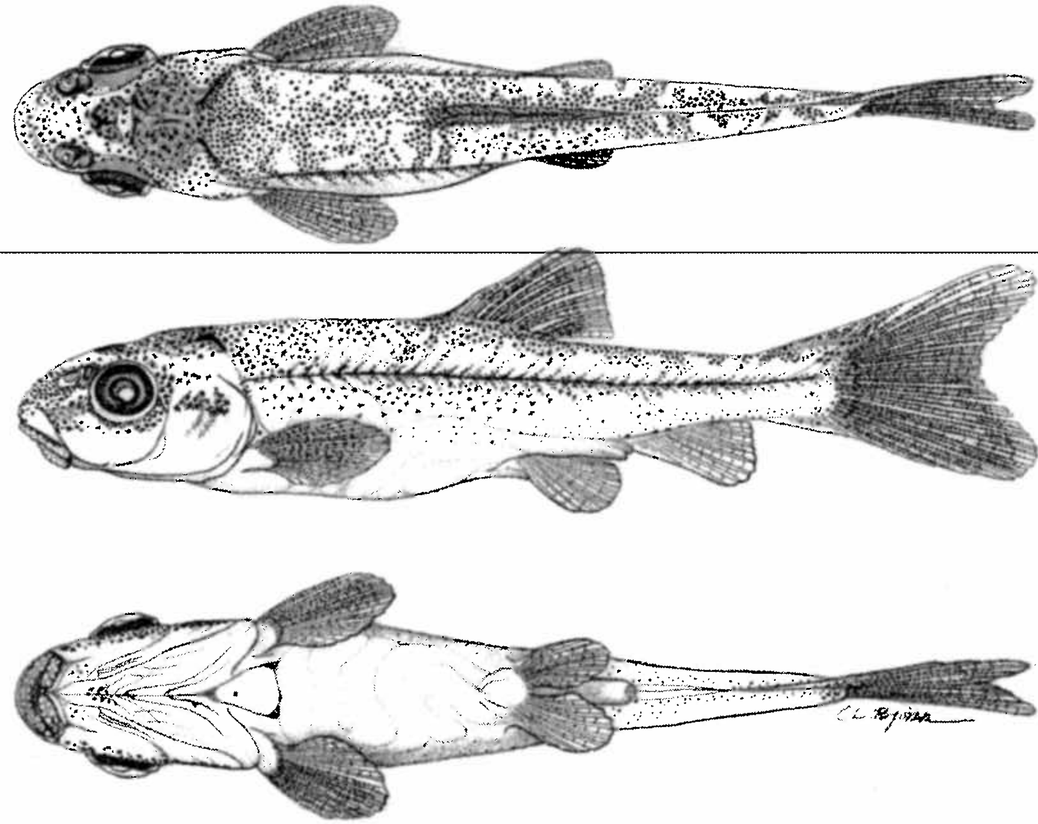


Fig. 13. *Catostomus plebeius* juvenile, pigment only using base drawing from Fig. 11, 24.6 mm SL, 29.6 mm TL. Cultured in 1995; stock from Hot Creek, Rio Grande Drainage, Colorado (CDOW).

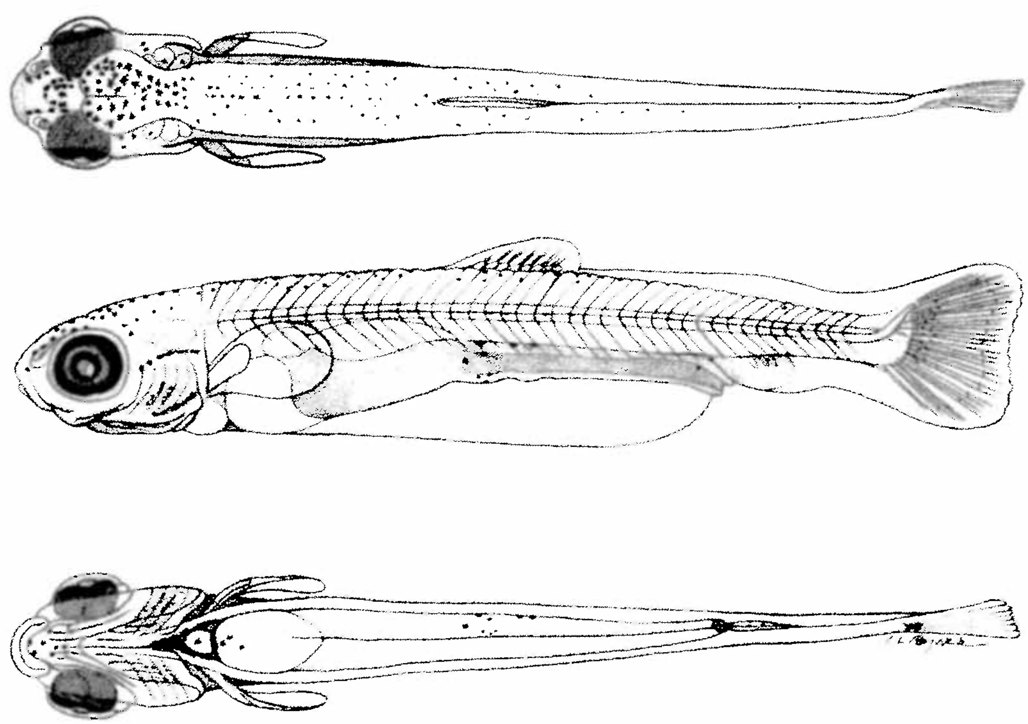


Fig. 14. *Catostomus plebeius* postflexion mesolarva, pigment only using base drawing from Fig 8, 3.6 mm SL, 15.5 mm TL. Cultured in 1995; stock from Hot Creek, Rio Grande Drainage, Colorado.

Species Account – *Catostomus commersoni*

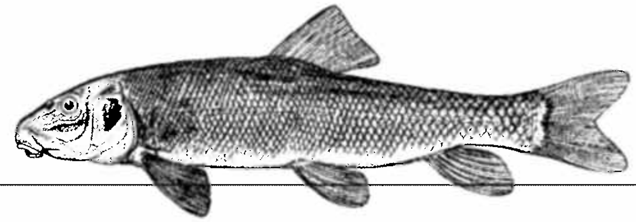


Fig. 15. *Catostomus commersoni* (from Miller 1952).

Adult Diagnosis: Robust. Inferior, slightly overhung mouth; no hard, prominent, cartilaginous ridges along inside of jaws. Lips relatively small, papillose, without notches at corners; lower lip wider than long with a deep median cleft, zero to two rows of papillae spanning the two lobes. Distal margin of dorsal fin straight. Scales large. Gill rakers relatively few, somewhat knobbed. Peritoneum pale or lightly speckled. TL usually 30-50 cm, up to 64 cm. (Also, Table 6.)

Reproduction: Non-guarding, open-substrate lithophil. April or May to August, 7-19°C, usually >10°C; mostly June to mid-July in the Upper Colorado River Basin. Frequently in large aggregations migrate to streams or lake shores to spawn in shallow water, usually <0.3 m, and moderate currents, mostly 30-49 cm/sec, over sand or gravel; often over riffles in streams. Water-hardened eggs 2.6-3.3 mm diameter, demersal, initially adhesive.

Young: Hatch in 5-11 days at 18-10°C, remain in gravel 1-2 weeks, drift as late protolarvae and mesolarvae, usually at night, and subsequently occupy low velocity shoreline areas, often over sand and gravel or in aquatic vegetation.

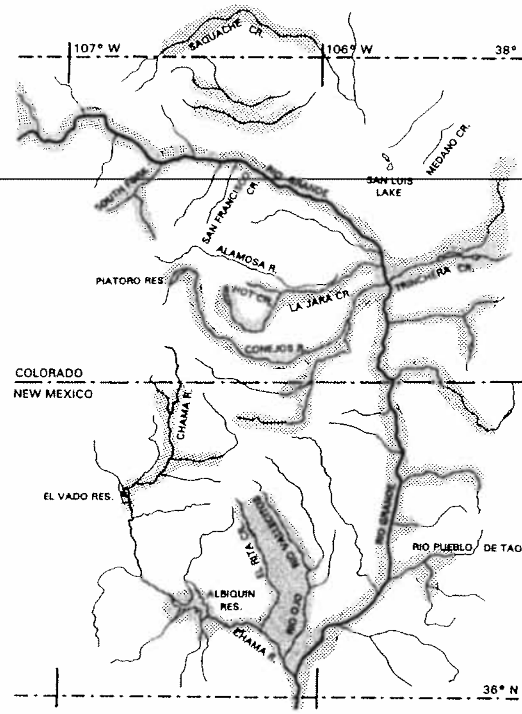


Fig. 16. Regional distribution of non-native *Catostomus commersoni*, based mostly on documented collections since 1971.

Table 6. Selected juvenile and adult meristics for *Catostomus commersoni*. P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Gill rakers for exterior row of first arch, specimens >70 mm SL. Mean or modal values underlined if known and noteworthy; rare or questionable extremes in parentheses.

Character	Original	Literature	Character	Original	Literature
Dorsal Fin Rays - P:	10-11-12(13)	(9)10-13(-15)	Dorsal Fin Rays - R:	2-3-4(5)	
Anal Fin Rays - P:	(5-)7(8)	(6)7-8	Anal Fin Rays - R:	2-3	
Caudal Fin Rays - P:	18	18	Caudal Fin Rays - RD:	10-11-13	
Pectoral Fin Rays:	13-15-16(17)	13-19	Caudal Fin Rays - RV:	8-10	
Pelvic Fin Rays:	8-10	9-11	Lateral Scales:	56-59-68-72	53-56-70-76(-85)
Vertebrae:	45-46-48	44-48	Gill Rakers:		20-27

Table 7. Size at apparent onset of selected developmental events for *Catostomus commersoni*, as observed under low power magnification. P = principal rays; R = rudimentary rays; Scales are lateral series. Rare or questionable extremes in parentheses.

Event or Structure	Onset or Formation mm SL	Onset or Formation mm TL	Fin Rays or Scales	First Formed mm SL	First Formed mm TL	Last Formed mm SL	Last Formed mm TL
Hatched:	(7)8-10	8-10	Dorsal - P:	12-13	14	14-16	16-17
Eyes Pigmented:	(7)8 or *	8 or *	Anal - P:	14-16	16-17	15-16(17)	18-19(20)
Yolk Assimilated:	10-12(-14)	(10)11-13(-15)	Caudal - P:	10-12	10-13	(12)13-15	(13)14-16
Finfold Absorbed:	(17-)19-20	(21-)23-24	Caudal - R:	13-15	14-16	(17)18	(21)22-23
Pectoral Fin Buds:	(7)8 or *	8 or *	Pectoral:	14-16	16-17	16(-20)	19(-24)
Pelvic Fin Buds:	13-15	(14)15-16	Pelvic:	15-16	18-19	16-18	19-22
* before hatching			Scales:	22(23)	27	29-31	36-37

References: Alves (1998 personal communication), Auer 1982, Baxter and Simon 1970, Beckman 1952, Carlander 1969, Carlson et al. 1979, Ellis 1914, Fuiman 1979, Fuiman and Trojnar 1980, Geen et al. 1966, Hubbs et al. 1943, Jones et al. 1978, Jordan and Evermann 1896, Langlois et al. 1994, Lee et al. 1980, Lippson and Moran 1974, Miller 1952, Minckley 1973, Platania 1991, Prewitt 1977, Reighard 1920, Scott and Crossman 1973, Smith 1985, Snyder and Muth 1990, Stewart 1927, Sublette et al. 1990, Swift 1996, Twomey et al. 1984, Woodling 1985, Zuckerman 1984, Zuckerman and Langlois 1990.

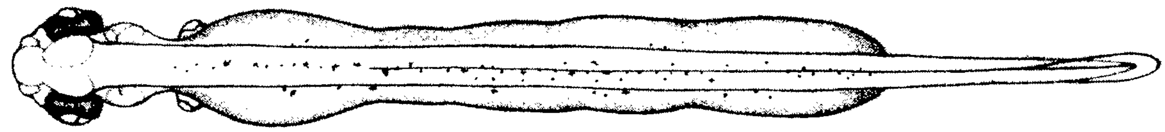
Table 7. Size at developmental interval (left) and gut phase (right) transitions for *Catostomus commersoni*. See Figure 2 for phases of gut folding. Rare or questionable extremes in parentheses.

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion Mesolarva:	10-12	10-13	2 - 90° bend:	14-15(16)	(16)17(18)
Postflexion Mesolarva:	(12)13-15	(13)14-16	3 - Full loop:	(16)17-18	(19)20-21(22)
Metalarva:	15-16(17)	18-19(20)	4 - Partial crossover:	19-20(21)	(22)23-24(-26)
Juvenile:	(17-)19-20	(21-)23-24	5 - Full cross over:	(20)21-25	(24)25-30(31)

Table 8. Summary of morphometrics and myomere counts by developmental phase for *Catostomus commersoni*. See Figure 1 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded.

	Protolarvae (N=11)				Flexion Mesolarvae (N=16)				Postflexion Mesolarvae (N=9)				Metalarvae (N=18)				Juveniles (N=25)			
	$\bar{x}$	±SD	Range		$\bar{x}$	±SD	Range		$\bar{x}$	±SD	Range		$\bar{x}$	±SD	Range		$\bar{x}$	±SD	Range	
SL, mm:	10	1	8	12	12	2	10	15	14	1	12	16	17	1	15	20	25	6	19	39
TL, mm:	10	1	9	12	13	2	10	16	16	2	14	19	21	2	18	24	30	7	23	48
Lengths %SL:																				
AS to AE	2	0	2	3	2	1	2	3	4	1	2	6	6	1	4	8	8	1	6	10
PE	8	1	8	9	8	1	7	10	11	1	9	14	14	1	12	15	15	1	13	16
OP1	16	1	13	19	18	1	16	20	22	2	19	25	26	2	20	30	28	1	24	29
OP2									53	1[b]	52	54	56	2	54	59	57	2	52	59
PY	70	12	47	80	63	10[a]	50	75												
OPAF	31	15	22	73	25	1	23	27	30	2	25	33	48	10	32	68				
ODF	37	2	34	42	38	2	35	43	44	3[c]	38	48								
OD									50	1[b]	49	51	51	1	48	53	51	1	48	53
ID									63	1[d]	61	64	65	2	61	67	65	1	61	68
PV	78	2	76	82	79	1	76	81	80	1	78	81	77	1	75	79	76	1	72	78
OA									80	1[d]	79	80	78	1	76	79	77	1	73	79
IA									85	1[d]	84	86	85	1	83	86	84	1	79	86
AFC									110	2	108	113	113	2	110	119	115	1	113	117
PC	104	1	101	106	106	1	104	109	114	4	109	120	121	2	116	126	122	1	119	124
Y	51	13	26	63	18	21	0	50												
P1	7	4	2	12	11	1	10	12	12	1	11	14	15	2[e]	12	19	17	1	15	20
P2									2	2	0	6	9	3	4	16	12	1	10	15
D									17	1[d]	16	17	19	2	15	22	20	1	18	24
A									7	0[d]	7	7	11	2	7	14	13	2	10	16
Depths %SL:																				
at BPE	9	1	7	11	10	1	9	11	13	1	11	15	16	1	14	19	17	1	16	19
OP1	11	1	9	12	11	1	10	13	16	2	14	18	18	1	16	20	20	1	18	22
OD	10	2	8	13	9	1	8	10	12	2	9	16	16	2	13	20	19	1	17	22
BPV	5	1	3	6	5	0	5	6	7	1	6	9	9	1	7	11	11	1	10	14
AMPM	3	1	2	3	4	0	3	4	5	1	4	7	7	1	5	8	8	1	7	9
Max. Yolk	6	3	1	11	1	1	0	3												
Widths %SL:																				
at BPE	9	2	7	11	10	1	9	12	13	1	11	15	15	1	13	17	16	1	14	18
OP1	6	1	5	7	7	1	6	8	10	1	8	12	13	1	11	14	16	2	13	20
OD	6	1	5	9	5	0	5	6	7	1	5	9	10	2	8	14	13	2	10	16
BPV	4	0	3	4	4	0	3	4	5	1	4	6	6	1	4	8	8	1	7	10
AMPM	2	0	2	2	2	0	2	2	3	0	2	3	3	1	2	4	4	0	4	5
Max. Yolk	6	3	1	10	1	2	0	4												
Myomeres:																				
to PY	33	7	18	38	28	6[a]	21	35												
OPAF	9	7	4	30	6	1	5	8	6	1	5	8	16	6	7	28				
OP2									21	1[b]	19	22	21	1	20	23	21	1[f]	20	22
ODF	13	1	12	14	14	1	12	17	15	2[d]	12	17	14	2[a]	11	17				
OD									19	1[b]	17	20	17	1[c]	16	19	17	1[f]	16	18
PV	38	2	35	40	37	2	34	40	38	1	36	40	35	1	34	37	35	1[f]	33	36
Total	47	1	44	48	46	1	43	48	46	1	45	49	45	1	44	47	45	1[f]	43	47
After PV	9	1	8	10	9	1	7	11	9	1	8	9	10	1	8	12	10	1[f]	9	12

[a]N = 8; [b]N = 7; [c]N = 8; [d]N = 3; [e]N = 17; [f]N = 20



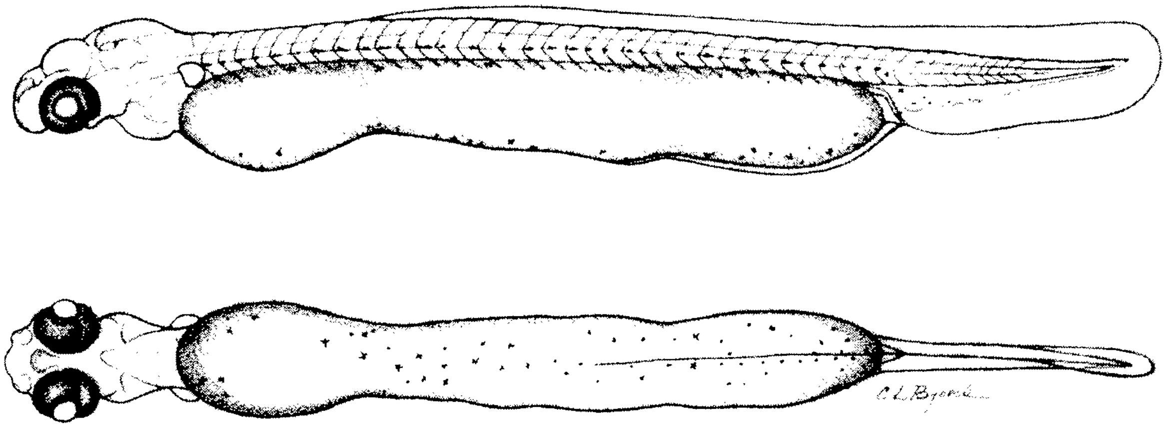


Fig. 17. *Catostomus commersoni* protolarva, recently hatched (day 1), 9.3 mm SL, 9.6 mm TL. Cultured in 1979 with stock from a private pond (Louis Swift), Fort Collins, Colorado.

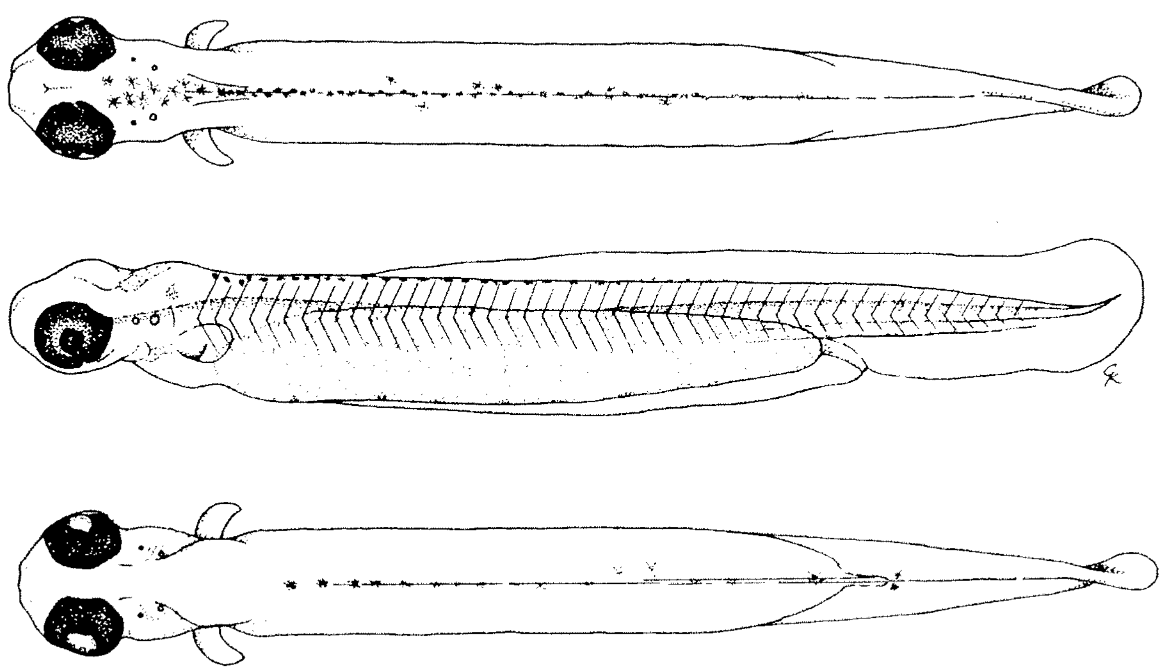
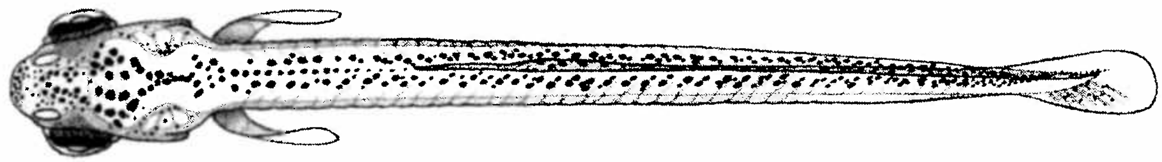


Fig. 18. *Catostomus commersoni* protolarva, 10.5 mm SL, 10.7 mm TL (from Fuiman 1979).



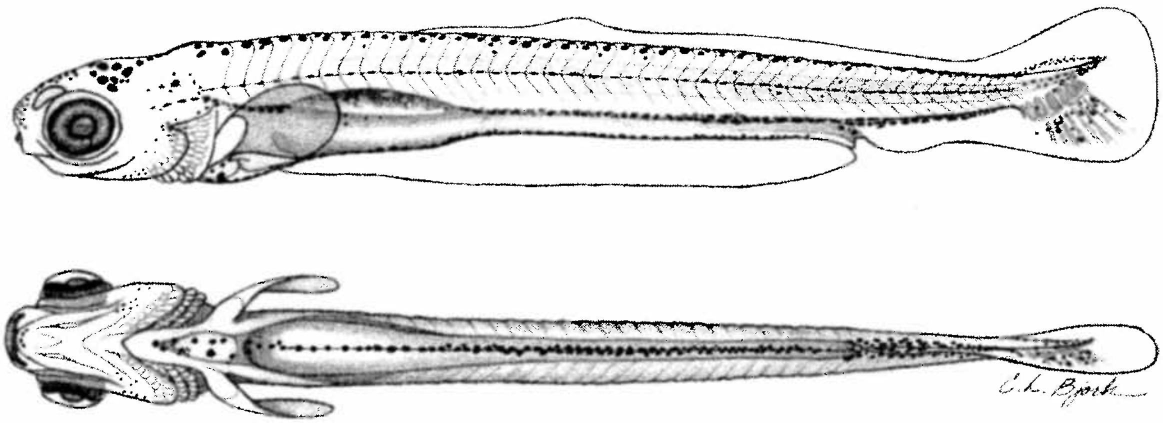


Fig. 19. *Catostomus commersoni* flexion mesolarva, recently transformed, 12.8 mm SL, 13.4 mm TL. Collected in 1977 from the Yampa River, Colorado.

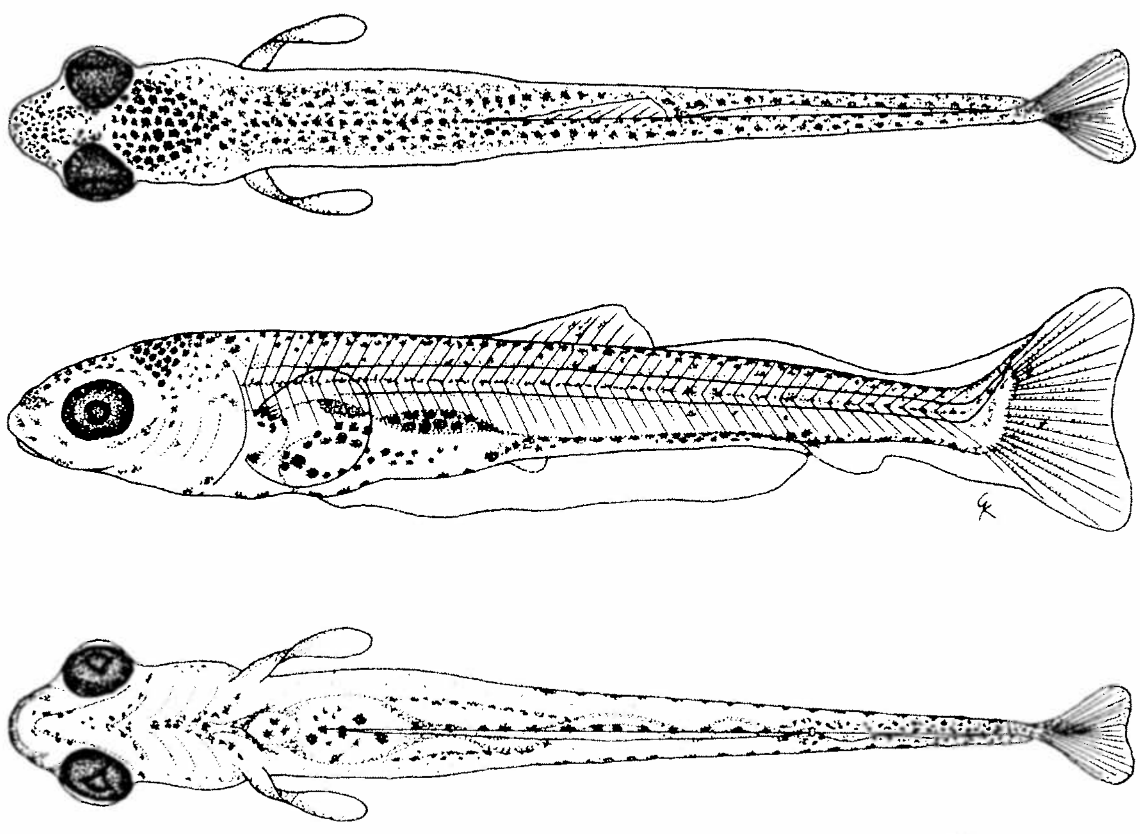


Fig. 20. *Catostomus commersoni* postflexion mesolarva, 16.3 mm SL, 18.2 mm TL (from Fuiman 1979).

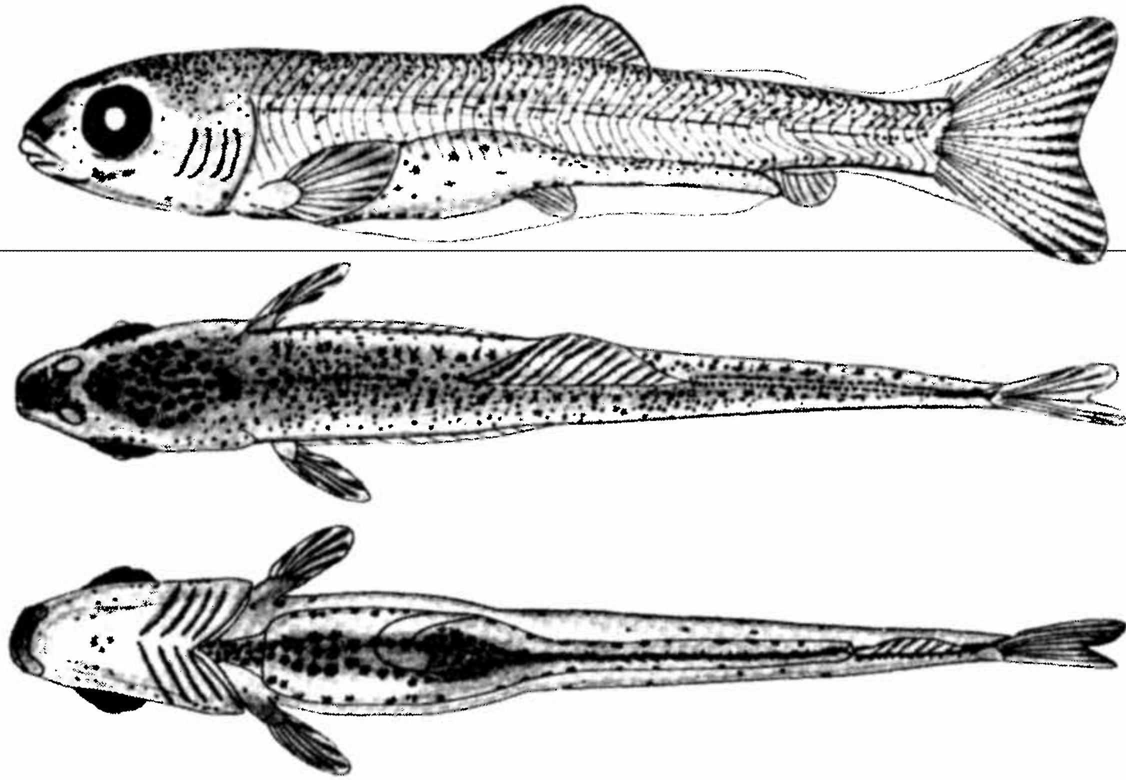


Fig. 21. *Catostomus commersoni* metalarva, recently transformed, 17.8 mm SL, 20.4 mm TL (from Buynak and Mohr 1978).

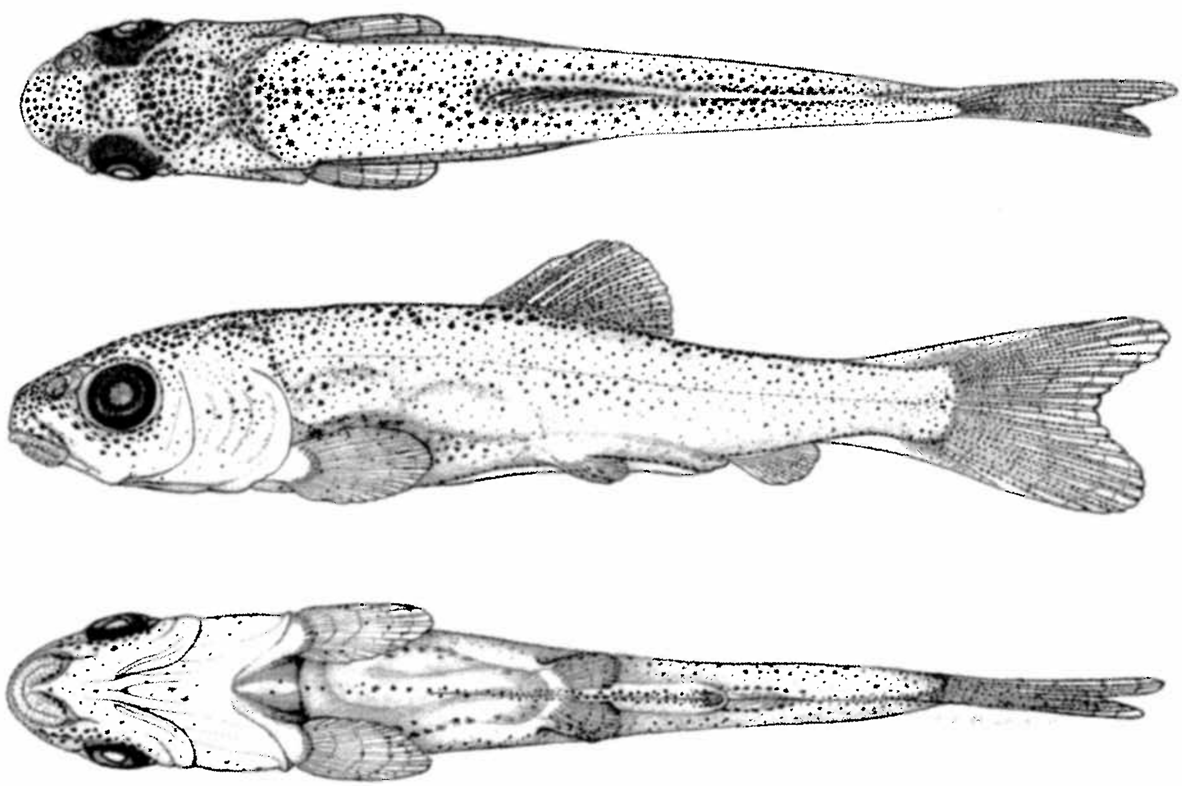


Fig. 22. *Catostomus commersoni* metalarva, 19.2 mm SL, 23.1 mm TL. Collected in 1977 from the Yampa River, Colorado.

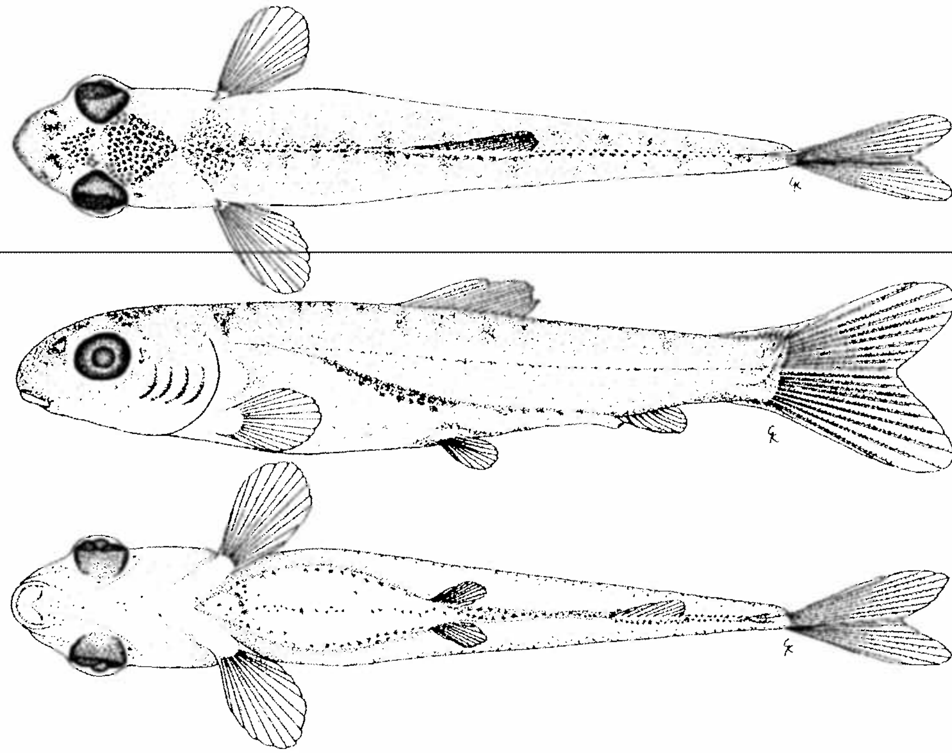


Fig. 23. *Catostomus commersoni* juvenile, recently transformed, 21.3 mm SL, 25.8 mm TL (from Fuiman 1979).

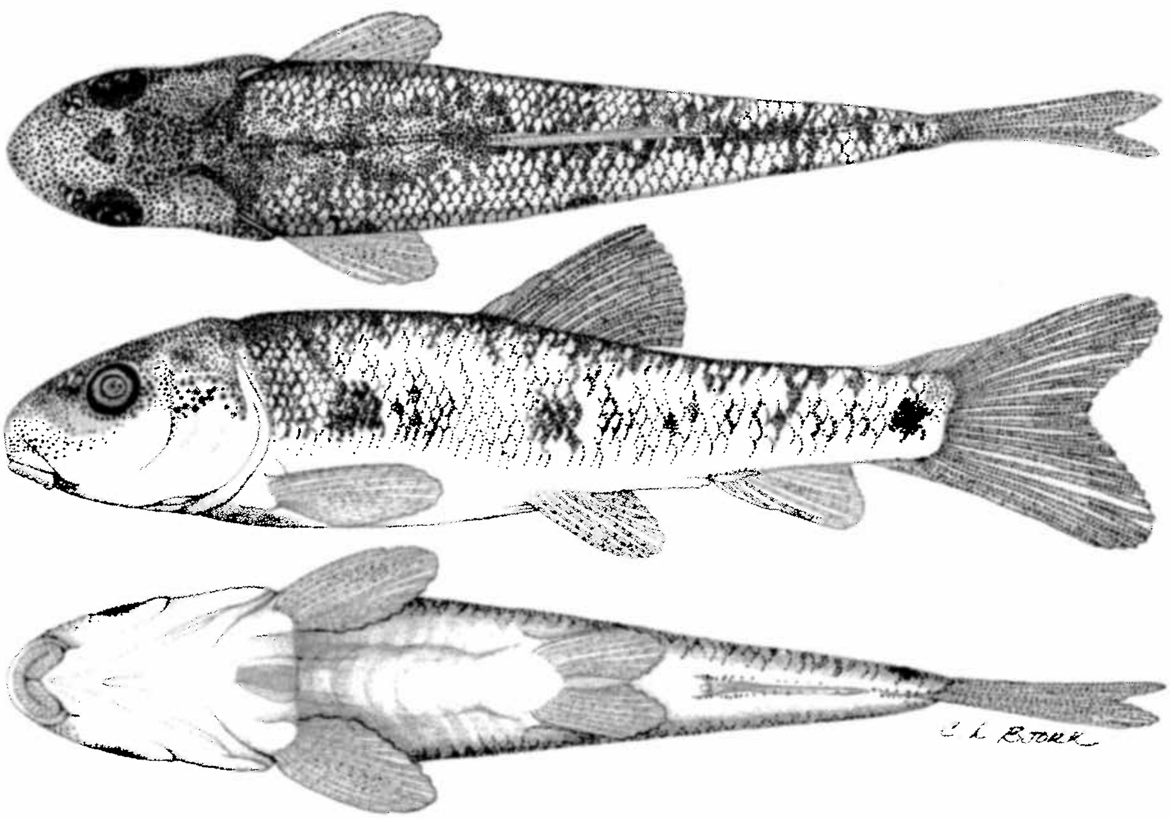


Fig. 24. *Catostomus commersoni* juvenile, 30.8 mm SL, 37.9 mm TL. Collected in 1977 from the Yampa River, Colorado.

Limitations of Data

Except for recently hatched specimens and possible hybrids, most catostomid larvae and early juveniles collected from the Rio Grande Basin of Colorado and northern New Mexico (or wherever else these species co-exist) can be readily distinguished as either Rio Grande sucker or white sucker using the species accounts and additional descriptive data and diagnostic criteria that follow. About 75 Rio Grande sucker and 79 white sucker larvae and juveniles were fully analyzed for morphometrics and meristics and many more reared and wild specimens were examined for additional data. However, the states or values reported for most characters overlap and there are undoubtedly rare specimens with character extremes beyond those observed and documented herein. To help assure correct identifications, diagnoses should be based on multiple characters whenever possible.

Hybridization between Rio Grande sucker and white sucker has been documented by Zuckerman and Langlois (1990) and Swift (1996) with observations of character intermediacy. Hubbs et al. (1943) reported on the intermediacy of morphological characters for hybrids of white sucker and bluehead sucker, *Catostomus discobolus,* as small as 25 mm SL. Using the diagnostic characters and descriptive data that follow, hybrid metalarvae and early juveniles might be at least tentatively identified as hybrids. Because of greater similarity and limited diagnostic characters, hybrid protolarvae and mesolarvae will likely be identified as the parental species they most closely resemble or remain questionable. Tentative or uncertain identities should always be recorded as such, either by leaving identities at the generic level or appending question marks or footnotes to the names of the species they most closely resemble.

Size Relative to State of Development

Water-hardened white sucker eggs typically measure about 2.6 to 3.3 mm in diameter (species account). Preserved Rio Grande sucker eggs were not available for examination or measurement but based on the smaller size of Rio Grande sucker at maturation and the larvae at transition to the flexion mesolarva phase and absorption of yolk, egg diameter is likely to be similar to but slightly smaller than for white sucker, perhaps not exceeding 3.0 mm in diameter. Egg diameters for subgenus *Pantosteus* species range from 2.3 to 2.7 mm for mountain sucker, which also mature at a relatively small size, and 3.3 to 3.6 mm for bluehead sucker which mature at a much larger size.

Table 9 abstracts from the species accounts and compares size relative to developmental state data considered of diagnostic value. Transition events and developmental state boundary criteria considered most useful and reliable for identification are emphasized in bold type; use the remaining transition events and criteria with discretion. Rio Grande sucker typically progress from protolarvae to mesolarvae (based on acquisition of first caudal fin rays) and especially from flexion mesolarvae to postflexion mesolarvae (based on acquisition of the full complement of principal caudal fin rays) at a smaller size than white sucker but from metalarvae to juveniles (upon loss of the preanal finfold) at a notably larger size. Hence a flexion mesolarva larger than 11 mm SL (>12 mm SL to be more confident) is most likely white sucker whereas a fish still bearing preanal finfold at a standard length greater than 20 mm (or preferably 21 mm for greater confidence) is most likely Rio Grande sucker. Acquisition of a full complement of pelvic fin rays also occurs at a greater size in Rio Grande sucker.

Table 9. Size relative to developmental state characters to aid diagnosis of *Catostomus plebeius* and *C. commersoni* larvae and early juveniles. Bold type highlights characters considered most useful and reliable for identification (i.e., those more easily observed with little or overlap in criteria). Data are standard lengths in millimeters at developmental interval transition or onset of other developmental events. Rare or questionable data are enclosed by parentheses.

Character	*Catostomus plebeius*	*Catostomus commersoni*
Phase/period transitions		
Proto- to mesolarva:	10	10-12
Flexion to postflexion mesolarva:	**11**	**(12)13-15**
Larva to juvenile:	**23-25**	**(17-)19-20**
Onset of selected events		
Yolk Assimilated:	10-11	10-12(-14)
Finfold Absorbed:	**23-25**	**(17-)19-20**
Fin rays first observed		
Anal, principal:	14	14-16
Caudal, principal:	10	10-12
Caudal, rudimentary:	12	13-15
Pectoral:	14	14-16
Full fin ray counts first observed		
Caudal, principal:	**11**	**(12)13-15**
Caudal, rudimentary:	22-23	(17)18
Pectoral:	19-20	16(-20)
Pelvic:	**19-20**	**16-18**
Scales, lateral series		
First observed:	23-25	22(23)
Full series first observed:	27-29	29-31

Mouth characters are important in the diagnosis of adult catostomids. Unfortunately the mouths are insufficiently developed in all but the latest metalarvae and certain characters such as the median cleft are not sufficiently developed in the earliest juveniles. The presence of notches at the corners of the mouth is diagnostic for all but the earliest juveniles of Rio Grande sucker (Fig. 12). For juvenile white sucker, the upper and lower lips are smoothly joined (Fig. 24). For mountain sucker the notch is preceded by a deep crease where the upper and lower lips join but the crease is not always distinct.

Table 10. Comparison of mouth position and lower lip lobe separation relative to developmental interval and size (mm SL) for metalarvae (M) and juveniles (J) of upper Rio Grande Basin catostomids less than 40 mm SL. Size is preceded by initials for the applicable developmental intervals. Bold type indicates diagnostically useful characters.

Character	*Catostomus plebeius*	*Catostomus commersoni*
Mouth position		
Terminal, above bottom of eye	M, ≤19	M, ≤18
Low terminal, at or below bottom of eye	**M&J, ≤26**	**M&J, all**
Subterminal, low and not most anterior portion of snout	**M&J, all**	**J, ≥19**
Lower lip lobes, median separation		
Indistinct	M, ≤17	M, ≤18
Well separated	**M&J, ≤25**	**M&J, ≤31**
Slightly separated	M&J, ≥19-25	M&J, 17-31
None, adjacent	**J, ≥25**	**M&J, ≥17**

Mouth position and median separation of the lower lip lobes are documented in Table 10 relative to developmental interval and size. Some of these differences may be diagnostically useful. For example, subterminal mouths may be observed in some metalarvae of Rio Grande sucker but not in metalarvae of white sucker. Also, lower lip lobes remain at least slightly separated in Rio Grande sucker until juveniles reach a standard length of at least 25 mm, whereas adjacent lip lobes may be observed in white sucker metalarvae and juveniles as small as 17 mm SL.

Meristics and Morphometrics

Some character differences determined by comparison of species account meristics and morphometrics are not included in Tables 11 and 12 because corresponding data for an adjacent phase indicates that the differences might not hold up if additional specimens in the size range of concern are analyzed. When comparing morphometric characters, also be aware that some characters (e.g., depths and widths at OD and OP2) are affected by the amount of yolk in early larvae and by gut fullness or condition in later larvae and juveniles. The more diagnostically useful and reliable characters and criteria extracted from the species accounts for Tables 11 and 12 are emphasized with bold print.

Table 11. Meristic characters of diagnostic value for larvae and early juveniles of upper Rio Grande Basin catostomids. Bold type indicates characters considered most useful and reliable for identification (e.g., those easily observed with little or no typical range overlap). See Fig. 1 for methods of counting myomeres and fin rays. Mean or modal data are underlined; rare or questionable data are enclosed by parentheses.

Character	*Catostomus plebeius*	*Catostomus commersoni*
Myomeres		
to posterior margin of the vent:	(31)32-33-35-36(37)	34-35-38-40
total:	**(41)42-43-45**	**(43)44-45-47-48(49)**
Vertebrae (with four Weberian units):	42-43-44-45(46)	44-46-48
Principal dorsal fin rays:	**8-9-10(11)**	**(9)10-12-13(-15)**
Lateral line or series scales:	**(70-)73-75-95-99(-103)**	**53-56-70-76(-85)**

Total myomeres, which correspond closely with total vertebrae (including the four Weberian apparatus vertebrae), are only moderately diagnostic but are emphasized here as the only meristic character for identification of protolarvae and mesolarvae, at least until dorsal fin pterygiophores are sufficiently formed to count in postflexion mesolarvae. Unfortunately, the mean difference between the two species is only two or three myomeres fewer for Rio Grande sucker and the ranges for total myomeres overlap and include some mean values (Table 11). If used, accurate counts are imperative and should be made in combination with other diagnostic characters.

Principal dorsal fin ray counts and lateral line scale counts are typically reported as criteria for diagnosis of juveniles and adults. However, in both cases there is substantial range overlap if credence is given to extreme (rare or questionable) range values (Table 11). In the species account for Rio Grande sucker, I included rather low original lateral series scale counts about 73 to 75 for early juveniles reared from Hot Creek. Scales were difficult to count on these very early juveniles and some scales may have been missed. If genuine, these low counts may be an artifact of culture since the eggs were incubated and larvae reared at temperatures of 18 to 21 °C (A. Martinez, personal communication), somewhat higher than might be expected naturally (Zuckerman and Langlois 1990). For phenotypically good Hot Creek specimens collected in the early 1980's, Zuckerman and Langlois (1990) reported a range of 81 to 95 lateral line scales.

Considering the extensive number of morphometric characters documented for comparative description, very few were found diagnostically useful except those for protolarvae (Table 12). Length of the dorsal fin base and, to a lesser degree, horizontal length from snout to dorsal fin insertion (posterior most juncture with the body) are the only diagnostically useful morphometric characters for early juveniles, metalarvae, and postflexion mesolarvae for which dorsal fin pterygiophores or fin rays are sufficiently developed. Both characters reflect the smaller number of dorsal fin rays or pterygiophores (skeletal supports for the rays) typically found in Rio Grande sucker. Since early protolarvae were not available for description of Rio Grande sucker, species account morphometric data for white sucker extracted for Table 12 were modified for better

Table 12. Morphometric characters of diagnostic value for larvae and juveniles (≤40 mm SL) of upper Rio Grande Basin catostomids. Bold type indicates characters considered most useful and reliable for identification (e.g., those easily observed with little or no typical range overlap). See Fig. 1 for abbreviations and methods of measurement. Except as otherwise noted, all data are given as a percentage of standard length; head length (HL) is measured to the origin of the pectoral fin (AS to OP1). Mean or modal data are underlined; rare or questionable data are enclosed by parentheses.

Character	*Catostomus plebeius*	*Catostomus commersoni*
Protolarvae (wild only)[a]		
Eye diameter:[b]	**7-<u>8</u>-9**	**5-<u>6</u>-7**
AS to PE length:	**<u>10</u>-11**	**8-<u>9</u>**
AS to ODF length:	**40-<u>41</u>-45**	**34-<u>36</u>-38**
Depth at BPE:	**11-<u>12</u>-13**	**<u>9</u>-11**
Depth at BPV:	**6-<u>7</u>-8**	**<u>5</u>-6**
Width at BPE:	10-<u>11</u>-12	8-<u>9</u>-11
Flexion mesolarvae		
AS to ODF	39-<u>41</u>-44	35-<u>38</u>-43
Depth at BPE:	**11-<u>12</u>-14**	**9-<u>10</u>-11**
Depth at BPV:	**6-<u>7</u>-8**	**<u>5</u>-6**
Postflexion mesolarvae		
AS to ID length:[c]	57-<u>60</u>-63	61-<u>63</u>-64
Dorsal fin base length:[c,d]	**9-<u>10</u>-12**	**12-<u>13</u>-14**
Metalarvae		
AS to ID length:	59-<u>61</u>-64	61-<u>65</u>-67
Dorsal fin base length:[d]	**10-<u>11</u>-12**	**12-<u>14</u>-15**
Juveniles <40 mm SL		
AS to ID length:	61-<u>62</u>	61-<u>65</u>-68
Dorsal fin base length:[d]	**11-<u>12</u>-13**	**13-<u>14</u>-16**

[a] Since early protolarvae were not available for *C. plebeius*, these comparisons are restricted to the later protolarvae (reared specimens 5 days or older and wild specimens which are assumed to be at least as old); n = 7 for both species.
[b] Eye diameter = (AS to PE)-(AS to AE).
[c] Applicable only to specimens with a full complement of dorsal fin pterygiophores or principal rays.
[d] Dorsal fin base = (AS to ID)-(AS to OD).

comparison by excluding reared specimens less than 5 days old (all wild fish were assumed to be older). Head depth just behind the eyes and body depth immediately beyond the vent are notably greater for protolarvae and flexion mesolarvae of Rio Grande sucker than white sucker. Also, the origin of the dorsal finfold is consistently a bit further back on the body of Rio Grande sucker protolarvae than on white sucker, but less so for flexion mesolarvae. Finally eye diameter and length from snout to posterior margin of the eye are typically greater for Rio Grande sucker protolarvae than for white sucker. Among catostomid protolarvae described for the Upper Colorado River Basin, Snyder and Muth (1990) reported that mountain sucker have the greatest eye diameters and head lengths (although both are a bit less than Rio Grande sucker) and bluehead sucker among the least (even a bit less than white sucker).

Pigmentation

Capture of these catostomids prior to initial eye and body pigmentation is unlikely since the larvae of white sucker and presumably Rio Grande sucker typically remain in the gravel of the spawning grounds for at least several days and possibly up to two weeks (Geen et al. 1966, Scott and Crossman (1973). If not pigmented at hatching, at least eye and some body pigmentation are likely to be developed by emergence from the spawning substrate. White sucker usually hatch with eyes at least moderately pigmented and often with some body pigmentation (Fig. 17); they are usually well pigmented by 10 mm SL. Rio Grande sucker specimens were not available to document pigmentation, or lack thereof, as late embryos or recently hatched larvae. Among 10 mm SL Rio Grande sucker larvae, the eyes are well pigmented but head and body pigmentation can vary from barely more than a dozen or so melanophores aggregated in one or more patches on the anterior dorsal surface (Fig. 5) to very well pigmented with densely scattered melanophores over most of the dorsal surface of the body and discrete horizontal myosepta and mid-ventral lines (Fig. 6). Most wild specimens examined for this study were well-pigmented (Figs. 6-9, 11, 12) whereas most specimens in the reared series were very lightly pigmented (Figs. 5, 10, 13, 14), probably due to culture conditions.

Once melanophore pigmentation is sufficiently established, one of the more useful surface pigment characters for distinguishing Rio Grande and white sucker is the extent of pigmentation on the ventral midline between the heart region and the vent (Table 13, Character 1). White sucker typically have a continuous line or narrow band of midventral pigment with well over 20 melanophores at least through the larval period (Figs. 19-23). Occasionally, this character is shared by Rio Grande sucker (Fig. 8), nullifying it's value as a stand-alone diagnostic character for white sucker. Extension of the pigment line into the branchial region anterior to the heart is common in white sucker but can also occur in Rio Grande sucker. The line in white sucker sometimes begins to break up or dissipate late in the metalarval phase. Unlike white sucker, ventral midline pigmentation between the heart and vent of Rio Grande sucker larvae is highly variable from the continuous full-length line or band discussed above (Fig. 8) to discontinuous, shorter, or multiple, widely spaced lines (Figs. 6, 9, 10), to one, two or a few clustered or widely spaced melanophores (Figs. 7, 14). Although rare, ventral midline pigmentation in larvae can be totally absent (Fig. 5). Any of these conditions with 20 or fewer melanophores for larvae is normally diagnostic for Rio Grande sucker through the mesolarval phase. Relatively short or multiple widely spaced lines even with many more than 20 melanophores are also highly suggestive of Rio Grande sucker.

Table 13 Comparison of selected melanophore pigmentation patterns by developmental phase for larvae and juveniles of upper Rio Grande Basin catostomids less than 40 mm SL. Key to characters and character states given below. Bold type indicates diagnostically useful characters. Rare or questionable data are enclosed by parentheses. NA = not applicable.

	Character States	
Character	*Catostomus plebeius*	*Catostomus commersoni*
Protolarvae (after pigment is well established)		
1.	**(1)[a],2-5**	**1-2**
2.	1,3	1,(2),3
7.	**3**	**1-2**
8.	**3**	**1-2**
Flexion Mesolarvae		
1.	**(1),2-5**	**1-2**
2.	1-3	1-3
3.	**1-2**	**2**
4.	1-2	1-2
5.	**1-2**	**2**
7.	**(2),3**	**1-3**
8.	**3**	**1-3**
9.	**NA**	**1-2**
10.	2	2
11.	**1-3**	**1-2**
12.	**1-3**	**1-2**
13.	1-3	2-3
Postflexion Mesolarvae		
1.	**(1),2-5**	**1,(2)**
2.	1-3	(1),2-3
3.	**1-2**	**2**
8.	3	(1-2),3
9.	**NA**	**(1-2)**
12.	1-3	1-3
13.	**1-3**	**3**
18.	**1-2**	**2**
23.	**1-2**	**1**
Metalarvae		
1.	**(1),2-5**	**1-2**
2.	1-3	1-3
3.	**1-2**	**2**

Table 13 Continued.

Character	Character States *Catostomus plebeius*	*Catostomus commersoni*
6.	**1-2**	**1**
11.	3	3
12.	3	(1-2),3
19.	1	1,(2)
20.	(1),2-3	1-2,(3)
21.	1-3	1-2,(3)
23.	**1-2**	**1**
Juveniles		
1.	(1-2)[b],3-5	1-3,(4-5)
2.	1,(2)[b],3	1,(2),3
14.	3	(2),3
15.	1-3	1-2,(3)
16.	**1-2**	**1,(2),4**
17.	1-2	1-2
19.	**1**	**1-2**
20.	**3**	**1-2,(3)**
22.	1-2	1,(3)
23.	**(1),2**	**1**

[a] Based on presence in some flexion and postflexion mesolarvae.
[b] Based on presence in larvae.

<u>Key to pigment characters and states</u>:

1. Ventral midline from shortly behind heart region to near vent
    1. with ≥21 melanophores in a continuous or nearly continuous line or narrow band.
    2. with ≥21 melanophores in a shorter or a distinctly discontinuous line.
    3. with 7-20 melanophores.
    4. with 1-6 melanophores.
    5. without pigment.
2. Pigment over ventral to ventro-lateral surfaces of gill covers (opercula)
    1. absent.
    2. present in a distinct oblique row of 3 or more melanophores near or along ventral margin of one or both preopercles.
    3. present but not in distinct oblique rows.
3. Pigment on ventral surface of heart region
    1. absent.
    2. present.
4. Pigment under chin (anterior ventral surface of lower jaw)

1. absent.
2. present.

5. Dorsal body pigmentation between head and last myomere
   1. scattered with no distinct lines of melanophores on or lateral (and parallel) to dorsal midline.
   2. including at least a partial distinct line of melanophores on or lateral (and parallel) to dorsal midline.
6. ~~Dorsal body pigmentation between head and last myomere~~
   1. scattered more or less evenly (with or without emphasis on distinct lines of melanophores on or lateral and parallel to dorsal midline).
   2. scattered but in a blotchy pattern (with or without emphasis on distinct lines of melanophores on or lateral and parallel to dorsal midline).
7. Dorsal midline from shortly behind head to near last myomeres
   1. with ≥25 melanophores in a distinct continuous or nearly continuous line.
   2. with ≥25 melanophores but in one or more shorter segments or a distinctly discontinuous line .
   3. with ≤24 melanophores in one or more short lines, a discontinuous, well-spaced line, or (rarely) with no distinct line of melanophores.
8. Dorsal surface lateral to midline from shortly behind head to about 2/3 distance to last myomeres
   1. with distinct continuous or nearly continuous lines of melanophores along (parallel to) each side of dorsal midline.
   2. with distinctly shorter or discontinuous lines of melanophores along one or both sides of dorsal midline.
   3. without distinct lines of melanophores along either side of dorsal midline.
9. Melanophores in lines lateral (and parallel) to dorsal midline between head and 2/3 distance to last myomeres mostly
   1. in single file.
   2. in obliquely oriented pairs or groups resulting in a "herring bone" or "tractor tread" pattern.
10. Dorsal surface of head pigmented
    1. only over hindbrain (posterior to middle of eyes).
    2. over both mid- and hindbrain (anterior and posterior to middle of eyes).
11. Lateral surface of body above horizontal myosepta (or lateral midline), exclusive of melanophores associated with horizontal myosepta, air bladder, visceral cavity (peritoneum), or gut,
    1. unpigmented.
    2. with 1-5 melanophores.
    3. with ≥6 melanophores.
12. Lateral surface of body below horizontal myosepta (or lateral midline), exclusive of melanophores associated with horizontal myosepta, air bladder, visceral cavity (peritoneum), or gut,
    1. unpigmented.
    2. with 1-5 melanophores.
    3. with ≥6 melanophores.
13. Lateral surface of head posterior to eyes
    1. unpigmented.
    2. with 1-5 melanophores.
    3. pigmented with ≥6 melanophores.

14. Pigmentation on lateral surfaces of body above bottom-of-eye level and anterior to vent, exclusive of melanophores associated with horizontal myosepta, air bladder, visceral cavity (peritoneum), or gut,
   1. scattered only partially down to the horizontal myoseptum (lateral midline).
   2. scattered fully and evenly down to the horizontal myoseptum with few if any melanophores below the myoseptum.
   3. scattered evenly or in blotchy pattern (continuous with dorsal and dorso-lateral surface pattern) down to horizontal myoseptum and at least partially to bottom- of-eye level below.
15. Pigmentation on lateral to ventro-lateral surfaces of body below bottom-of-eye level, exclusive of melanophores associated with horizontal myosepta, air bladder, visceral cavity (peritoneum), or gut,
   1. absent including caudal peduncle.
   2. absent except on caudal peduncle.
   3. present.
16. Lateral surface of body
   1. with no large, distinct, mid-lateral body spots.
   2. with 1 large, distinct mid-lateral spot on caudal peduncle near base of caudal fin.
   3. with 2 large, distinct mid-lateral body spots, one between head and dorsal fin and the other between pelvic and anal fins.
   4. with 3 large, distinct mid-lateral body spots, one between head and dorsal fin, the second between pelvic and anal fins, and the last on caudal peduncle near base of caudal fin.
17. Pigment outlining scales
   1. absent or light.
   2. bold.
18. Developing dorsal fin
   1. with few (≤ 5) or no melanophores.
   2. with many (≥ 6) melanophores.
19. Pigment in dorsal fin
   1. along fin rays with very few, if any, melanophores on membrane between rays.
   2. abundant both along and between rays.
20. Pigment in anal fin
   1. absent.
   2. present but very light with only a few (≤ 5) melanophores.
   3. present but more prominent with many (≥ 6) melanophores.
21. Pigment in pectoral fin
   1. absent.
   2. present but very light with only a few (≤ 5) melanophores.
   3. present but more prominent with many (≥ 6) melanophores.
22. Pigment in caudal fin
   1. along fin rays with very few, if any, melanophores on membrane between rays.
   2. proximally abundant both along and between rays but distally along fin rays with very few, if any, melanophores between rays.
   3. abundant both along and between rays for most of the length of the rays.
23. Pigment along and in horizontal myosepta
   1. not notably more intense than other lateral pigmentation.
   2. notably more intense than other lateral pigmentation.

Another very obvious set of diagnostic characters for late protolarvae and mesolarvae define the melanophore pattern of the dorsal surface from behind the head to about two-thirds the distance to the last myomeres (Table 13, characters 5, 7, 8, 9). For nearly all wild Rio Grande sucker examined and illustrated (Figs. 6-9), dorsal pigmentation is heavily and evenly scattered over the entire surface with no distinct longitudinal lines or just a anterior dorsal midline, often with fewer than 25 melanophores,. Such pigmentation without longitudinal lines is diagnostic through the mesolarval phase. With a dorsal midline, it is diagnostic for protolarvae and highly probable for mesolarvae, especially flexion mesolarvae. The very lightly pigmented dorsum of most reared Rio Grande sucker protolarvae and mesolarvae is probably not common in the wild. However, with its lack of a notable dorsal midline and absence of pigmentation over much of the dorsal surface (Figs. 5, 14), the pattern is not shared by white sucker except as early protolarvae. White sucker protolarvae are typically characterized by a strong but sometimes discontinuous dorsal midline with more than 25 melanophores from head to caudal peduncle (Figs. 17, 18); the line tends to disappear under the developing dorsal fin in mesolarvae (Figs. 19, 20). Pigmentation lateral to the midline of white sucker late protolarvae and mesolarvae is often emphasized as a single, sometimes discontinuous, line parallel to each side of the midline, but it can also be randomly or evenly scattered, although seldom as broadly or densely as in Rio Grande sucker and other mountain suckers. In some white sucker mesolarvae the lines of melanophores lateral to the dorsal midline consist of melanophores obliquely oriented in pairs or groups resulting in a distinctive "herring bone" or "tractor tread" pattern (Fig. 19).

Lateral pigmentation can sometimes be diagnostic (Table 13, Characters 11-13, 16, 23). As juveniles, only white sucker frequently display three large mid-lateral spots (Fig. 24). Sometimes as postflexion mesolarvae, often as metalarvae, and especially as early juveniles only Rio Grande sucker display a particularly intense line of pigment in and along the horizontal myosepta (Figs. 9-13).

Of all pigment characters, the most diagnostic for the later larvae and early juveniles of most mountain suckers is the development of dark peritoneal pigmentation (Snyder and Muth 1990). However the peritoneum of the Rio Grande sucker is variously described as silvery to dusky with scattered melanophores or some speckles (Smith 1966, Woodling 1985, Sublette et al. 1990). I found the inner surface of the peritoneum of an alcohol-preserved 58-mm TL juvenile from the Mimbres River to be silvery with a moderately heavy, even covering of melanophore pigmentation. For comparison, the peritoneum of white sucker is described as pale or speckled (Scott and Crossman 1973).

Table 14 documents the state of peritoneal pigmentation relative to size and developmental interval for postflexion mesolarvae, metalarvae, and early juveniles less than 40 mm SL. For Rio Grande sucker, peritoneal pigmentation was entirely lacking in reared specimens, which included juveniles up to 31 mm SL. Among wild fish, it was absent from ventro-lateral and ventral surfaces in juveniles as large as 27 and 31 mm respectively. Sparse or patchy peritoneal pigmentation was present ventro-laterally in postflexion mesolarvae as small as 15 mm and ventrally in metalarvae as small as 17 mm . Uniformly light pigmentation was present ventro-laterally in metalarvae as small as 17 mm but observed ventrally only in one 37 mm juvenile. Uniformly dark pigmentation was observed ventro-laterally only in a 21 mm metalarva and a 34 mm juvenile and ventrally only in a 37 mm SL juvenile. Among specimens illustrated in the Rio Grande sucker species account, the peritoneum of the 23 mm SL, recently transformed juvenile in Fig. 11 is uniformly dark laterally, uniformly light ventro-laterally, and sparse ventrally. The peritoneum of the 31 mm SL juvenile in Fig. 12 is uniformly light ventro-laterally and unpigmented ventrally (lateral aspect is obscured by muscle). Among white sucker documented in Table 14, ventro-lateral and ventral surfaces were never observed to be uniformly dark and rarely observed to be uniformly light (35-37 mm SL juveniles), but pigmentation was sparse or patchy on the ventral surface for juveniles as small as 22 mm and on the ventro-lateral surface for postflexion mesolarvae as small as 16 mm.

Table 14 Comparison of peritoneal pigmentation[a] relative to developmental interval and size (mm SL) for postflexion mesolarvae (P), metalarvae (M), and early juveniles (J) of upper Rio Grande Basin catostomids less than 40 mm SL. Size is preceded by initials for the applicable developmental intervals. Bold type indicates diagnostically useful characters. Rare or questionable data are enclosed by parentheses.

Character	*Catostomus plebeius*	*Catostomus commersoni*
Lateral surface, P and M only[b]		
Absent	**P&M, all**	**P&M, ≤18**
Sparse or patchy	P&M, ≥14	P&M, ≥14
Uniformly light	**M, ≥14**	-
Uniformly dark	**M, ≥20(17)**	-
Ventro-lateral surface		
Absent (or obscured in J)	P,M,&J, all	P,M,&J, all
Sparse or patchy	P,M,&J, ≥15	P,M,&J, ≥16
Uniformly light	**M&J, ≥17**	**(J, ≥35)**
Uniformly dark	**(M&J, ≥21)**	-
Ventral surface		
Absent	P,M,&J, all	P,M,&J, all
Sparse or patchy	**M&J, ≥17**	**J, ≥22**
Uniformly light	(J, ≥37)	(J, ≥35)
Uniformly dark	**(J, ≥37)**	-

[a] Peritoneal pigmentation as it appears through the lateral, ventro-lateral, and ventral walls of the visceral cavity. This pigmentation is subsurface (inner lining of the cavity) and should not be confused with surface or cutaneous pigmentation. Also, pigment might be apparent in the dorsal and dorso-lateral portions of the peritoneum of smaller larvae but should not be interpreted as pigment in the lateral region.

[b] In juveniles, lateral pigmentation of the peritoneum usually is obscured by muscle.

CONCLUSIONS

When possible, it is best use a combination of characters to distinguish between the larvae and early juveniles of Rio Grande sucker and white sucker. For protolarvae and mesolarvae, pigmentation characters associated with the ventral midline and dorsal surface are generally quick, easy, and may be sufficient for confident identification of most specimens. When these characters are inadequate or in need of confirmation, try next the pertinent set of size relative to developmental state characters. For metalarvae, begin with a dorsal fin ray count and combine it with applicable size relative to developmental state and pigmentation characters. For early juveniles begin with a dorsal fin ray count, lateral pigmentation if the distinctive patterns are present, and mouth characters when the lower lip lobes are sufficiently developed. Except in the case of hybrids, the criteria and data presented herein should be adequate for accurate identification of most collected specimens.

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