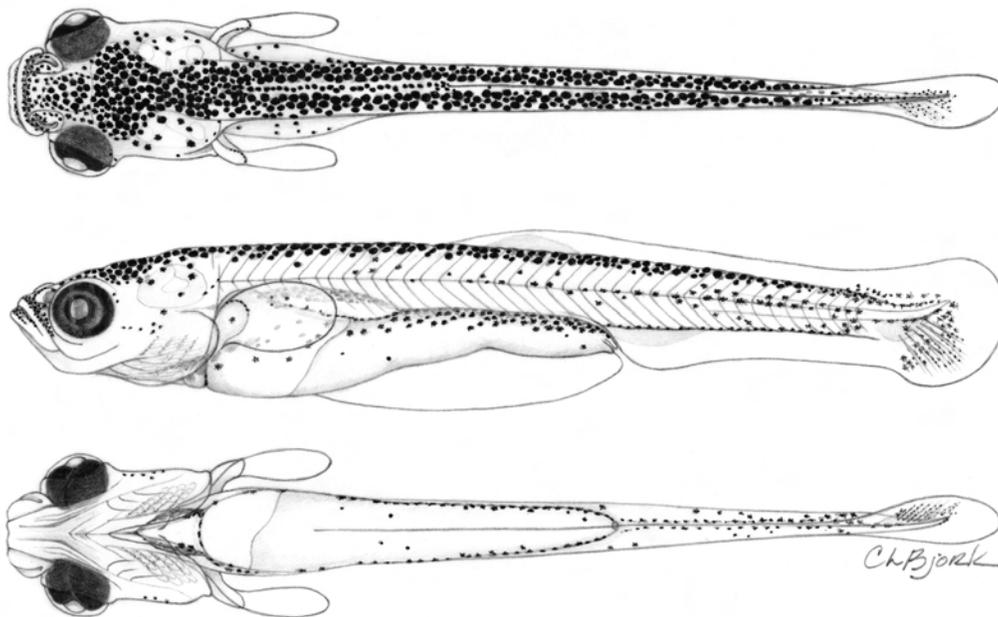


Native Cypriniform Fish Larvae of the Gila River Basin

—
*Morphological Descriptions, Comparisons,
and Computer-Interactive Keys*



by

Darrel E. Snyder, Kevin R. Bestgen, and Sean C. Seal
with larval-fish illustrations by
C. Lynn Bjork

LARVAL FISH LABORATORY
Colorado State University
Fort Collins, Colorado

Laboratory for the Study and Identification of Fishes in North American Fresh Waters

Research
Early Life Stages/Adults
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Aquatic Toxicology/Behavior

Education
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Service
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Descriptions/Keys/Illustrations

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Morphological Descriptions, Comparisons, and Computer-Interactive Keys

Final Report
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by

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C. Bjork prepared all original drawings of larval and early juvenile fishes in this guide, as well as most included in this guide from earlier LFL investigations. Drawings of adult fishes in the species accounts were reproduced with permission from scans of copy-righted drawings by J. Tomelleri. The map of the Gila River Basin was prepared by K. Zelasko using ARCView (ESRI–Environmental Systems Research Institute, Redlands, CA). M. Snyder and LFL work-study students helped enter and proof descriptive data in report tables, species accounts, and data sets for the keys.

Native Cypriniform Fish Larvae of the Gila River Basin

Morphological Descriptions, Comparisons, and Computer-interactive Keys

Darrel E. Snyder, Kevin Bestgen, and Sean C. Seal

ABSTRACT

Use of collections of fish larvae and young-of-the-year juveniles to help document spawning sites and seasons or assess larval production, transport, distribution, nursery habitat, survival, and other aspects of early life history, requires diagnostic criteria to accurately identify target species from morphologically similar taxa. To facilitate identification of the larvae and early juveniles of most native cypriniform fishes in the Gila River Basin, developmental series of reared and collected desert sucker (*Catostomus clarkii*), Sonora sucker ©. *insignis*), longfin dace (*Agosia chrysogaster*), spikedace (*Meda fugida*), and loach minnow (*Rhinichthys cobitis*) were illustrated and described to detail differences in morphology, meristics, pigmentation, and size relative to developmental state. Comparable illustrations and data were extracted from existing descriptions of flannelmouth sucker ©. *latipinnis*), razorback sucker (*Xyrauchen texanus*), bonytail (*Gila elegans*), roundtail chub (*G. robusta*), Colorado pikeminnow (*Ptychocheilus lucius*), speckled dace ®. *osculus*), and non-native cyprinids common carp (*Cyprinus carpio*), red shiner (*Cyprinella lutrensis*), and fathead minnow (*Pimephales promelas*). For the cyprinids, extracted data were supplemented with original observations and, for roundtail chub and speckled dace, illustrations of protolarvae. The results are documented in detailed descriptive species accounts, comparative summary tables, and computer-interactive keys. A computer-interactive key and a pictorial guide to families of Gila River Basin larvae were also prepared using data from previously published keys and descriptions.

INTRODUCTION

Importance of Early Life History Investigations and Identification

(Modified from Snyder and Muth 2004)

For most fishes, larval and early (young-of-the-year) juvenile development includes a few to several life-history phases that are morphologically and ecologically distinct from each other, as well as later juveniles and adults (Snyder 1990; such phases do not necessarily correspond with the morphologically based developmental intervals defined below). Accordingly, knowledge of fish early life history is often essential for better understanding aquatic ecosystems and communities and more effectively monitoring, protecting, or managing fish populations and habitat. Such knowledge is particularly valuable in assessing environmental impacts and recovering endangered species.

The collection and study of fish eggs, larvae, and early juveniles should be an integral part of holistic fish and aquatic ecology investigations. Densities and spatial and temporal distribution of these life stages are indicative of spawning grounds and seasons, larval production, nursery habitat, behavior, and potential year-class strength. A single specimen is proof of at least some reproductive success. Even in baseline surveys to determine presence and relative abundance of fishes, larval-fish collections can sometimes provide information on species that are difficult to collect or observe as adults because of gear selectivity, behavior, habitat, or low abundance.

Research or monitoring based on collections of fish larvae usually requires accurate identification of collected specimens. Inland fishery managers and researchers often exclude potentially critical larval-fish investigations specifically because they haven't done it before or because adequate descriptions of larvae, taxonomic criteria, and keys for identification are not available. Although the inventory of such information is gradually increasing, much descriptive and taxonomic research is piecemeal, uncoordinated, and often "a labor of love."

Of approximately 800 species of freshwater and anadromous fishes in the United States and Canada (Lee et al. 1980, Robins, et al. 1991), less than 25% have been adequately described as larvae for identification purposes (Snyder 1996, extrapolated from 15% reported by Snyder 1976a). In a relatively comprehensive listing of regional larval-fish guides, keys, and comparative descriptions by Simon (1986), only about 80 of 230 citations (35%) pertain to freshwater species. Kelso and Rutherford (1996) listed 18 regionally oriented larval-fish identification manuals for or including North American freshwater species (some for the same regions and all incomplete in coverage at the species level). Not included in the list were guides by Sturm (1988), Snyder and Muth (1988, 1990—probably treated as comparative descriptions rather than regional guides), and most recently, Simon and Wallus (2004) and Snyder and Muth (2004). No guides to North American freshwater fish larvae were published between 1994 and 2004.

This Guide and Prior Descriptions

The purpose of this guide is to document the early morphological development of most native cypriniform fishes in the Gila River Basin (Figure 1) and better facilitate identification of fish larvae collected in the basin. The well-illustrated species accounts, comparative summary tables, and computer-interactive keys provided herein should be particularly beneficial to

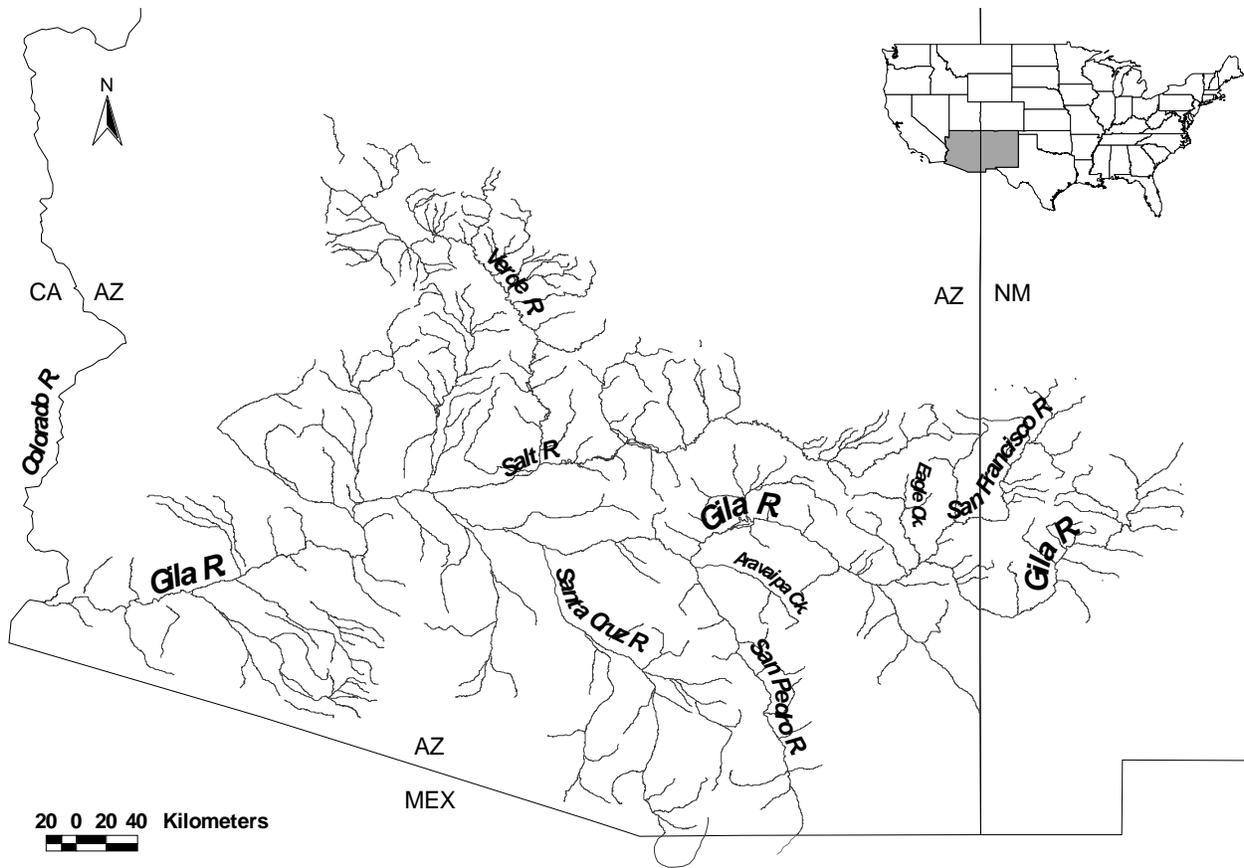


Fig. 1. The Gila River Basin of Arizona, New Mexico, and Mexico.

scientists working in reaches such as Aravaipa Creek and Eagle Creek in Arizona and the upper Gila River Basin in New Mexico, which are known to support mostly intact faunas. In these ways, it contributes to our knowledge of threatened, endangered, and other native fishes in the basin and should help facilitate their conservation or recovery.

Species coverage includes four native catostomids, seven native cyprinids, and, for comparison, three common non-native cyprinids (Table 1). Separate computer-interactive keys were prepared for the covered catostomids and cyprinids. All species in the Gila River Basin are covered at the family level in a third computer-interactive key and in an appended pictorial guide derived mostly from Wallus et al. (1990).

This guide continues a quarter century of work by the Larval Fish Laboratory (LFL) on early life stages of Southwestern fishes. Its format, including the descriptive species accounts, comparative summary tables, and computer-interactive keys, is modeled after Snyder and Muth (2004) except that new species accounts include as few as five rather than eight three-view illustrations of larvae and early juveniles, and osteological features were not included in any account. All descriptive data and illustrations herein for larvae and early juveniles of desert sucker, Sonora sucker, longfin dace, spikedace, and loach minnow are original, as are one drawing of a protolarval roundtail chub, another of a speckled dace, and a composite photograph

Table 1. List of native and most established non-native fishes in the Gila River Basin. Basin status as native (N), native-extirpated (NE), native-extirpated with recent attempts to reintroduce (NER), or native-formerly extirpated but successfully reintroduced (NR) is indicated parenthetically, as is listing status for the U. S. Department of Interior (USDI, E = endangered, T = threatened), State of Arizona (AZ, special concern = SC), State of New Mexico (NM, E = endangered, T = threatened), and Republic of Mexico (Mex, E = endangered, T = threatened, R = rare).^a Asterisks indicate species covered herein. Current common and scientific names follow Nelson et al. (2004).

tenpounders (Elopidae)

machete – *Elops affinis* (NE)^b

herrings (Clupeidae)

threadfin shad – *Dorosoma petenense*

minnows (Cyprinidae)

* longfin dace – *Agosia chrysogaster* (N, Mex = E)

* bonytail – *Gila elegans* (NE, USDI = E, AZ = SC, Mex = E)

Gila chub – *Gila intermedia* (N, NM = E, AZ = SC, Mex = E)

headwater chub – *Gila nigra* (N, AZ = SC)

* roundtail chub – *Gila robusta* (N, NM = E, AZ = SC, Mex = R)

* spikedace – *Meda fulgida* (N, USDI = T, NM = T, AZ = SC)

woundfin – *Plagopterus argentissimus* (NE, USDI = E, AZ = SC)

* Colorado pikeminnow, formerly Colorado squawfish^c – *Ptychocheilus lucius* (NER, USDI = E (experimental, non-essential), NM = E, AZ = SC, Mex = E)

* loach minnow – *Rhinichthys cobitis*, formerly *Tiaroga cobitis*^c (N, USDI = T, NM = T, AZ = SC, Mex = E)

* speckled dace – *Rhinichthys osculus* (N, Mex = E)

goldfish – *Carassius auratus*

grass carp – *Ctenopharyngodon idella*

* red shiner – *Cyprinella lutrensis*, formerly *Notropis lutrensis*

* common carp – *Cyprinus carpio*

* fathead minnow – *Pimephales promelas*

suckers (Catostomidae)

* desert sucker – *Catostomus clarkii*, formerly *Pantosteus clarki*^c (N)

* Sonora sucker – *Catostomus insignis* (N, Mex = E)

* flannelmouth sucker – *Catostomus latipinnis* (NE)

Rio Grande sucker – *Catostomus plebeius*, formerly *Pantosteus plebeius*^c

* razorback sucker – *Xyrauchen texanus* (NER, USDI = E, AZ = SC, Mex = E)

smallmouth buffalo – *Ictiobus bubalus*

bigmouth buffalo – *Ictiobus cyprinellus*

black buffalo – *Ictiobus niger*

catfishes (Ictaluridae)

black bullhead – *Ameiurus melas*, formerly *Ictalurus melas*

yellow bullhead – *Ameiurus natalis*, formerly *Ictalurus natalis*

channel catfish – *Ictalurus punctatus*

flathead catfish – *Pylodictis olivaris*

(continued)

Table 1. Continued.

trouts (Salmonidae)

Gila trout – *Oncorhynchus gilae*, formerly *Salmo gilae* (N, USDI = E, NM = E, AZ = SC)

Apache trout – *Oncorhynchus gilae apache*, formerly *Oncorhynchus apache* and *Salmo apache* (N, USDI = T, AZ = SC),

rainbow trout – *Oncorhynchus mykiss*, formerly *Salmo gairdneri*

brown trout – *Salmo trutta*

brook trout – *Salvelinus fontinalis*

mulletts (Mugilidae)

striped mullet – *Mugil cephalus* (N)^b

pupfishes (Cyprinodontidae)

Santa Cruz pupfish – *Cyprinodon arcuatus* (NE, species extinct)

desert pupfish – *Cyprinodon macularius* (NR, USDI = E, AZ = SC, Mex = E)

livebearers (Poeciliidae)

Gila topminnow – *Poeciliopsis occidentalis* (N, USDI = E, NM = T, AZ = SC, Mex = T)

western mosquitofish – *Gambusia affinis*

sailfin molly – *Poecilia latipinna*

temperate basses (Moronidae)

white bass – *Morone chrysops*

yellow bass – *Morone mississippiensis*

striped bass – *Morone saxatilis*

sunfishes (Centrarchidae)

rock bass – *Ambloplites rupestris*

green sunfish – *Lepomis cyanellus*

redecor sunfish – *Lepomis microlophus*

bluegill – *Lepomis macrochirus*

smallmouth bass – *Micropterus dolomieu*

largemouth Bass – *Micropterus salmoides*

white crappie – *Pomoxis annularis*

black crappie – *Pomoxis nigromaculatus*

perches (Percidae)

yellow perch – *Perca flavescens*

walleye – *Sander vitreus*, formerly *Stizostedion vitreum*

cichlids (Cichlidae)

blue tilapia – *Oreochromis aureus*, formerly *Tilapia aurea*

Mozambique tilapia – *Oreochromis mossambicus*, formerly *Tilapia mossambica*

redbelly tilapia – *Tilapia zillii*

^a Sources: Arizona Game and Fish Department (2000-2003); Desert Fishes Team 2003, 2004; Minckley 1973; Minckley and DeMarais 2000; Minckley et al. 1991; Minckley et al. 2002; Propst 1999; Secretaria de Desarrollo Social 1994; Voeltz 2002.

^b Euryhaline, estuarine- or marine-spawning species that historically ranged up the Gila River.

^c Change in name not universally accepted—former name still used by some biologists (e.g., Minckley 1973, Simons and Mayden 1999, and Desert Fishes Team 2003 and 2004).

of a juvenile red shiner. However, some of the illustrations and data for the suckers were prepared earlier for descriptions in a report by Bestgen (1989). Species accounts for flannelmouth sucker and razorback sucker were replicated with little modification from Snyder and Muth (1990, 2004), but the illustrations and much of the data in those accounts were first published by Snyder (1981). Most descriptive information and illustrations provided herein for the remaining species were originally published by Snyder et al. (1977), Snyder (1981), or Muth (1990), except all illustrations of common carp and most of Colorado pikeminnow and red shiner, and some of fathead minnow.

Winn and Miller (1954) published the earliest comparisons of and key to larvae for native cyprinid (minnow) and catostomid fishes in the American southwest. Their illustrated descriptions and key for the Lower Colorado River Basin below Lake Mead covered all native species included herein except bonytail and Colorado pikeminnow, but it was limited to mesolarval stages (developmental intervals defined below) with single lateral- and dorsal-view photographs for each species. Although not described or illustrated, Colorado pikeminnow was included in their discussion and key as similar to roundtail chub. The illustrations of roundtail chub were attributed to subspecies *intermedia*, which is now recognized as a separate species, the Gila chub. Tabulated data for the onset of selected developmental events in roundtail chub were noted as being based on both subspecies *robusta* and *intermedia*. Also, *Pantosteus* larvae, some of which were illustrated as desert sucker and some as bluehead sucker (*Catostomus discobolus*), have since been recognized as desert sucker by Smith (1966). Winn and Miller's (1954) data and illustrations generally match well with those herein, but we found some exceptions to their diagnostic criteria. We recommend that biologists working with fish larvae in the Gila River Basin and elsewhere in the Lower Colorado River Basin be familiar with this landmark work and use it as a supplement to this guide.

Few other authors have published descriptive information on the early life stages of native species covered in this guide. Minckley and Gustafson (1982) chronicled early development of razorback sucker, but their illustrations are sketchy and include only lateral views. Douglas (1952) published photographs of a razorback sucker protolarva (or recently transformed mesolarva) without yolk and a 10-cm specimen labeled as a juvenile razorback sucker, but, as noted by Winn and Miller (1954), the subject of the latter photograph is actually an adult speckled dace (*Rhinichthys osculus*). In the process of documenting hybridization among several catostomids, Hubbs et al. (1943) and Hubbs and Hubbs (1947) published descriptive information for young-of-the-year juveniles (and some larvae) of flannelmouth sucker. Seethaler (1978) described and illustrated very well the early development of Colorado pikeminnow.

In contrast to native species, the larvae and early juveniles of the three non-native cyprinids covered herein are all widely distributed elsewhere in the United States (and for common carp and fathead minnow, in Canada) and have been well described by other authors and covered in other guides. In addition to Snyder (1981), and Snyder et al. (1977) for fathead minnow, early life stages of all three species have been included in identification manuals by Wang (1986) and Holland-Bartels et al. (1990); and common carp and fathead minnow by Fish (1932), Hogue et al. (1976), and Heufelder and Fuiman (1982). Common carp have also been described or included in many other publications, including Balon (1958), Bragensky (1960), Mansueti and Hardy (1967), May and Gasaway (1967), Nakamura (1969), Taber (1969), Lippson and Moran (1974), Loos et al. (1979), Jones et al. (1978), Wang and Kernehan (1979), and McGowan (1988). Fathead minnow have also been described by Buynak and Mohr (1979), red

shiner by Saksena (1962) and Taber (1969), and both species by Perry (1979) and Perry and Menzel (1979).

Many cypriniform fishes not covered by this guide have been described. We recommend Fuiman (1982) and Kay et al. (1994) for the buffalo fishes, Snyder (1998) for Rio Grande sucker, Soin and Sukhanova (1972) and Conner et al. (1980) for grass carp, and Jones et al. (1978) and Heufelder and Fuiman (1982) for goldfish. Gila chub (except as combined with roundtail chub in Winn and Miller 1954), headwater chub, and woundfin remain undescribed as larvae.

Systematics, Distribution, and Status of the Fish

Native Catostomidae in the Gila River Basin belong to subfamily Catostominae and tribe Catostomini. *Xyrauchen* is a monotypic genus. Among the *Catostomus* species, desert sucker belongs to subgenus *Pantosteus*, a distinctive group known as "mountain suckers" and treated as a separate genus prior to study by Smith (1966); others belong to subgenus *Catostomus*, the "valley suckers" (Smith 1987).

Native Cyprinidae belong to the subfamily Leuciscinae, and are arranged in tribes Plagopterini and Leuciscini (Hubbs 1955). Genera in the tribe Plagopterini consist of *Lepidomeda*, *Meda*, and *Plagopterus*, all of the Colorado River Basin, and are characterized by spine-like modifications of anterior fin rays in dorsal and pelvic fins (Miller and Hubbs 1960). *Meda* (endemic to the Gila River Basin) and *Plagopterus* are monotypic genera. All other native cyprinids in the Gila River Basin are in tribe Leuciscini; *Agosia* is a monotypic genus. Loach minnow *Rhinichthys cobitis* was formerly placed in the monotypic genus *Tiaroga*, a name that is no longer recognized by Nelson et al. (2004). Among the non-native Cyprinidae considered herein, carp (*Cyprinus carpio*) belongs to subfamily Cyprininae, and the others to Leuciscinae, tribe Leuciscini.

Identification of organisms, particularly poorly known larval and early juvenile life stages of fishes, is often aided by knowledge of the species that may occur in the sampling area. Although reporting distribution of native fishes in the Gila River Basin is beyond the scope of this project, general information is available in Minckley (1973). More up-to-date information on status and distribution of native fishes in the Gila River basin is available in reports by the Desert Fishes Team (Desert Fishes Team 2003, 2004) and documented at www.gf.state.az.us/w_c/edits/hdms_abstracts_fish.shtml, the Arizona Game and Fish Department website. The Desert Fishes Team reports summarize efforts to repatriate native fishes in some stream reaches and also report on the general plight of fishes in the Gila River Basin. Chief among the reasons for reduced distribution and abundance of native fishes is negative effects of introduced fishes and over-development of water resources in this arid environment, particularly at lower elevations.

A Combined Developmental Interval Terminology

(Reprinted from Snyder and Muth 2004, modified from Snyder and Muth 1988 and 1990)

It is often convenient and desirable to divide the ontogeny of fish into specifically defined intervals. If the intervals selected are used by many biologists as a frame of reference, such division can facilitate communication and comparison of independent results. The largest intervals, periods (e.g., embryonic, larval, juvenile, and adult), are often subdivided into phases and sometimes into steps (Balon 1975a and 1984); the word "stage," although commonly used as

a synonym for period or phase (e.g., Kendall et al. 1984), should be reserved for instantaneous states of development.

The larval phase terminologies most commonly used in recent years, particularly for descriptive purposes, are those defined by Hardy et al. (1978–yolk-sac larva, larva, prejuvenile; modified from Mansueti and Hardy 1967), Ahlstrom et al. (1976–preflexion, flexion, postflexion; expanded upon by Kendall et al. 1984), and Snyder (1976b and 1981–protolarva, mesolarva, metalarva). Definitions for all three terminologies were presented by Snyder (1983) and Kelso and Rutherford (1996). During a workshop on standardization of such terminologies, held as part of the Seventh Annual Larval Fish Conference (Colorado State University, January 16, 1983), it became obvious that these are not competing terminologies, as they often are treated, but rather complementary options with subdivisions or phases defined for different purposes. As such, it is possible to utilize all three terminologies simultaneously to: (1) facilitate comparative descriptions and preparation of keys based on fish in similar states of development with respect to morphogenesis of finfold and fins; (2) segregate, for fishes with homocercal tails, morphometric data based on standard length measured to the end of the notochord prior to and during notochord flexion from those measured to the posterior margin of the hypural plates following notochord flexion; and (3) approximate transition from at least partially endogenous nutrition (utilization of yolk material) to fully exogenous nutrition (dependence on ingested food) based on presence or absence of yolk material.

The combined terminology presented below and utilized herein effectively integrates principal subdivisions and functions of the three component terminologies. In doing so, Ahlstrom's "preflexion-flexion-postflexion" terminology is treated, for fishes with homocercal tails, as a subset of Snyder's mesolarva phase. Since notochord flexion in the caudal region usually begins when the first caudal-fin rays appear and is essentially complete when all principal caudal-fin rays are well defined, and since presence of fin rays can be more precisely observed than the beginning or end of actual notochord flexion, fin rays are used as transition criteria. As a result, all protolarvae are preflexion larvae, and all metalarvae are postflexion larvae. Although most fish pass sequentially through all phase subdivisions designated, some pass pertinent points of transition prior to hatching or birth and begin the larval period in a later phase or possibly skip the period entirely.

The definition for the end of the larval period is necessarily a compromise deleting all requirements (some taxon-specific, others difficult to determine precisely) except acquisition of the full complement of fin spines and rays in all fins and loss of all finfold (last remnants are usually part of the preanal finfold). Provision for taxon-specific prejuvenile (or transitional) phases are also deleted. In some cases, finfold persists through the endpoint for such special intervals, which are then effectively included in the larval period.

Timing of complete yolk absorption varies from well before notochord flexion and initial fin ray formation, as in most fishes with pelagic larvae, to postflexion stages after all or most of the fin rays are formed, as in many salmonids. Accordingly, the interval during which fish larvae bear yolk should not be represented generally as a separate phase preceding phases based on fin formation as it has been treated by Kendall et al. (1984). The Hardy et al. terminology effectively distinguishes between larvae with and without yolk by modifying the period name with the adjective "yolk-sac" when yolk material is present. Any period or phase name of the combined terminology can be similarly modified to indicate presence or absence of yolk material (e.g., yolk-bearing larva, yolk-sac metalarva, postflexion mesolarva with yolk, protolarva without yolk).

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 the adult complement of principal soft rays in at least one median (dorsal, anal, or caudal) fin or lacking pelvic-fin buds or pelvic 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, subphase 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 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, subphase of mesolarval development characterized by an 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, subphase 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 pelvic 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.

The combined terminology is designed to be relatively simple but comprehensive, precise in its transition criteria, applicable to nearly all teleost fishes, and flexible. It can be utilized in part (essentially as one of its component terminologies) or its entirety depending on purposes of the user. For example, if it is necessary to acknowledge only that the fish is a larva and whether it bears yolk, the terms "yolk-sac larva" and "larva without yolk" are all that is needed.

Biologists who formerly utilized one of its component terminologies should have no difficulty in adapting to the combined terminology—essential features and terms of the original terminologies have been retained.

Characteristics Useful in Identification of Cypriniform Fish Larvae
(Modified from Snyder 1981 and Snyder and Muth 1988, 1990, and 2004)

Fishes of the families Cyprinidae (minnows and carps) and Catostomidae (suckers), order Cypriniformes, are closely related and morphologically similar. Together these two families account for 41% of 56 total and 67% of 21 native species in the Gila River Basin (Table 1). Generalizations in the following discussion with respect to the order Cypriniformes refer specifically to North American species in these families. Figures 2 and 3 identify the more obvious morphological features and structures of catostomid (and cyprinid) eggs and larvae.

Identification of fish larvae is in part a process of elimination. Even before examination of a single specimen, the number of candidate species can be substantially reduced by a list of known or likely species based on adult captures in the study area or connected waters. However, there are cases in which the presence of certain species was first documented by collection and identification of larvae. Incidental transport of eggs or larvae from far upstream or distant tributaries also must be considered. Knowledge of spawning seasons, temperatures, habitats, and behavior coupled with information on egg deposition, larval nursery grounds, and larval behavior are also useful in limiting possibilities.

Berry and Richards (1973) noted that "although species of a genus may vary from one geographical area to another, generally the larval forms of closely related species look alike. At the same time, larvae of distantly related forms may be closely similar in gross appearance." Cypriniform larvae as a group are distinctive and generally easy to distinguish from larvae of other families. Beginning workers should become familiar with the general larval characteristics of each family likely to be encountered. The guides and keys cited in Snyder (1983) and Kelso and Rutherford (1996) are most useful in this respect. Auer (1982) is particularly recommended since it covers most families and many non-native species in the Gila River Basin. The pictorial guides to families by Holland-Bartels et al. (1990) and Wallus et al. (1990; also Kay et al. 1994, and Simon and Wallus 2004) and discussions of taxonomic characters by Berry and Richards (1973) and Kendall et al. (1984) are also recommended.

Generally, cypriniform larvae are readily categorized as cyprinids or catostomids. But in the Gila River Basin and elsewhere, if members of the cyprinid subfamily Cyprininae (carps) and the catostomid subfamily Ictiobinae (carpsuckers and buffalofishes) or tribe Erimyzontini (chubsuckers) are present, identification at the family level can be more difficult.

Within their respective families, and especially at the subfamily level, cypriniform larvae are very homogeneous in gross structure and appearance. Accordingly, they may be especially difficult to discriminate at genus or species levels. This is particularly true of Colorado River Basin catostomids. For the latter, specific identification relies on size at which certain developmental events occur, form of the gut, melanistic (brown or black) pigment patterns, osteological characters, and to a limited extent, morphometrics and meristics (especially dorsal-fin-ray counts for metalarvae and juveniles).

There is often a noticeable amount of intra- as well as inter-regional variability in many of the characters to be discussed. This variability necessitates confirmation of identity based on as many diagnostic characters as possible.

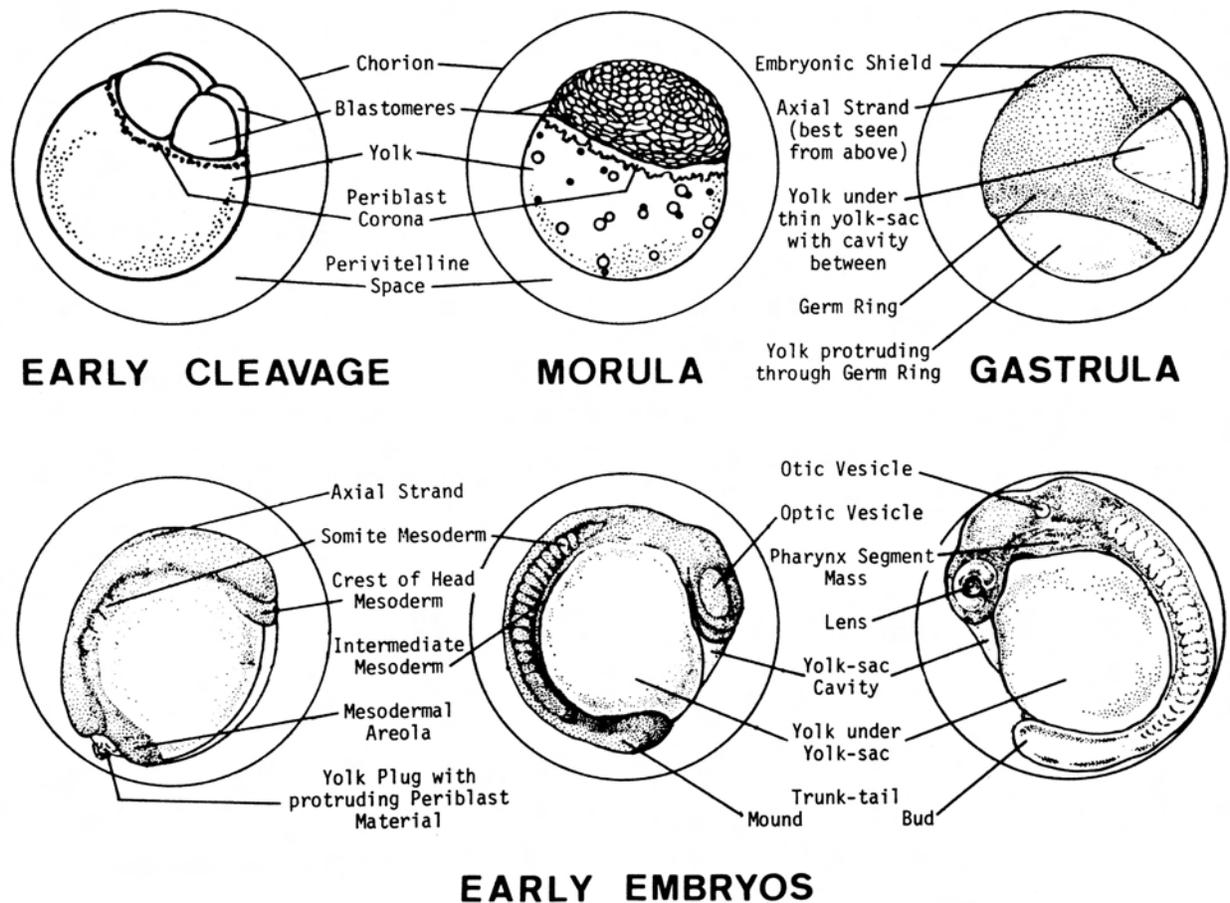


Fig. 2. Selected anatomical features of cypriniform fish eggs and embryos (from Snyder 1981; based on drawings from Long and Ballard 1976).

Myomeres

Myomeres, because they are obvious morphological features and relatively consistent in number and position, are one of the most useful characters available for identification of larvae above (and sometimes at) the species level, especially for protolarvae and mesolarvae. They begin as part of the embryonic somites and are usually formed in their full complement prior to hatching. Throughout the protolarval and much of the mesolarval phase, myomeres are chevron-shaped, but by the metalarval phase they evolve to their typical three-angled adult form. Fish (1932) and many subsequent authors observed that there is a nearly direct, one-to-one correlation between total myomeres and total vertebrae (including Weberian ossicles in cypriniforms). Snyder (1979) and Conner et al. (1980) summarized myomere and vertebral counts for many cypriniform fishes.

The most anterior and most posterior myomeres are frequently difficult to distinguish. The most anterior myomeres are apparent only in the epaxial or dorsal half of the body; the first is often deltoid in shape and is located immediately behind the occiput. The most posterior myomere is defined as lying anterior to the most posterior complete myoseptum. Siefert (1969) describes a "false (partial) myoseptum" posterior to the last complete myoseptum which adds to

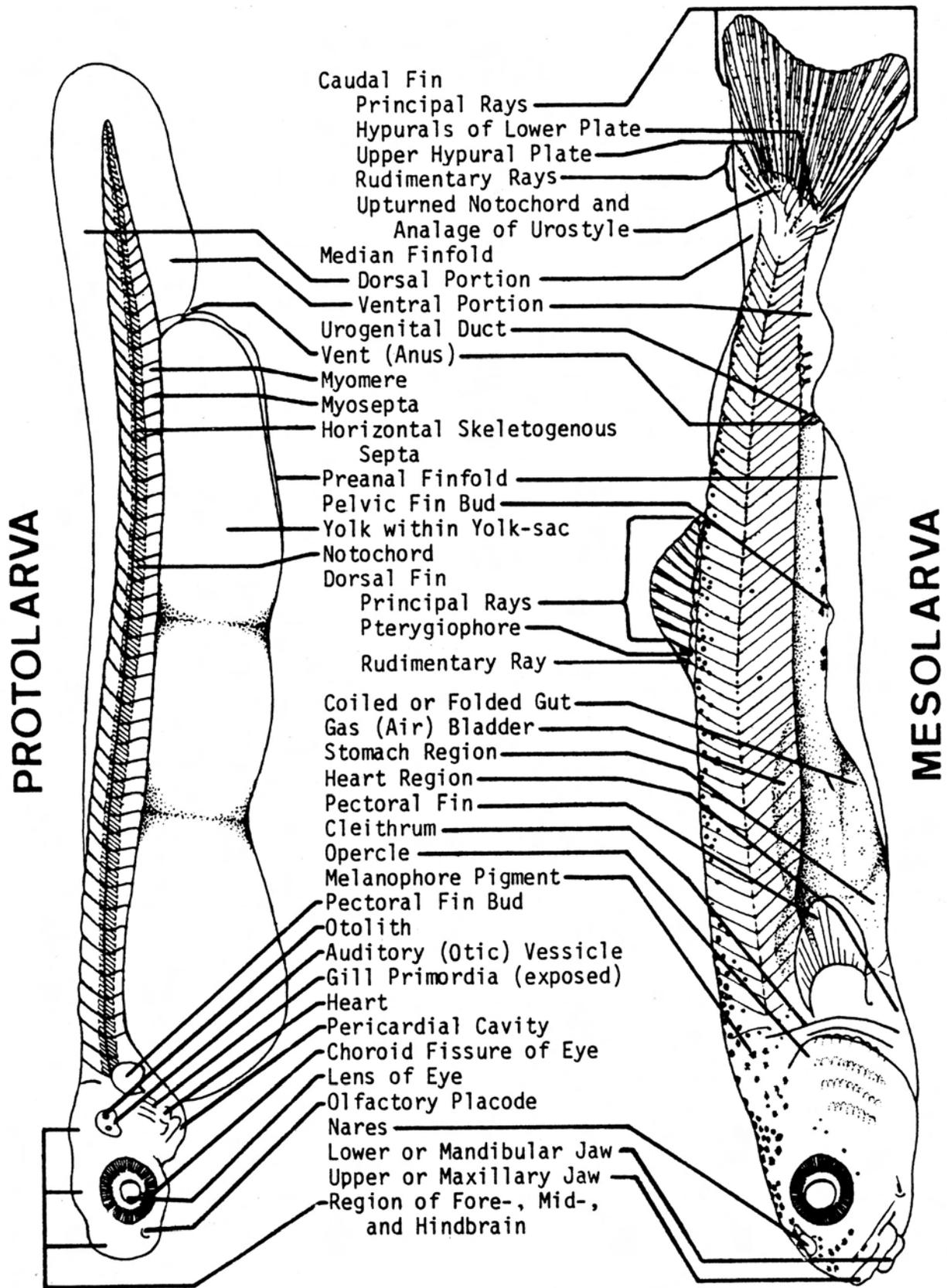


Fig. 3. Selected anatomical features of cypriniform fish larvae (modified from Snyder 1981).

the difficulty of discerning the last myomere. Early in the larval period, myomeres are most readily observed using transmitted light. Polarizing filters, depending on thickness and certain other qualities of the preserved tissues, can dramatically increase contrast between the muscle tissue of myomeres and the myosepta that separate them. Myomeres of some metalarvae and most juveniles are difficult to observe even with polarizing filters; reflected light at a low angle from one side and higher magnification sometimes facilitates observation.

Typical counts used in taxonomic work include total, preanal, and postanal myomeres. Partial counts are frequently used to also reference the location of structures other than the vent or anus. The most generally accepted method of making partial counts was described by Siefert (1969) for distinguishing preanal and postanal myomeres: "postanal myomeres include all [entire] myomeres posterior to an imaginary vertical line drawn through the body at the posterior end of the anus . . . Remaining myomeres, including those bisected by the line, are considered preanal." The technique is equally applicable with other structures or points of reference such as origins of fins or finfolds. The opposite approach was used by Snyder et al. (1977), Snyder and Douglas (1978), Loos and Fuiman (1977) and, according to the last authors, Fish (1932)—only entire myomeres were included in counts anterior to points of reference. Siefert's method is recommended as standard procedure because resulting counts are expected to more nearly approximate the number of vertebrae to the referenced structures.

In the United States and Canada, the range of total myomere (and vertebral) counts for cyprinids, 28 to 52, is slightly larger and nearly includes that for catostomids, 32 to 53. Ranges for preanal and postanal myomere counts also overlap with 19 to 35 and 9 to 22, respectively, for cyprinids and 25 to 42 and 5 (possibly 3) to 14, respectively, for catostomids. Despite the magnitude of overlap in these ranges, proportions of postanal to preanal and preanal to total myomeres will distinguish most cyprinids from catostomids (Snyder 1979). The postanal to preanal myomere proportion is at least $2/5$ (often greater than $1/2$) for cyprinids (exclusive of subfamily Cyprininae, the carps) and less (often less than $1/3$) for catostomids. Also, the proportion of preanal to total myomeres is $5/7$ or less (often less than $2/3$) for cyprinids and greater (often greater than $3/4$) for catostomids. For cypriniform fishes in the Gila River Basin, exclusive of *Ictiobus* species, the degree of overlap in total and preanal myomere counts is less and larvae with fewer than 44 total or 36 preanal myomeres can only be cyprinids.

Fins and finfolds

Fin-ray meristics and fin positions are among the most useful characters for later mesolarvae and metalarvae, especially among the cyprinids. These data can be determined from older juveniles and adults or gleaned from published descriptions of adults. The sequence and timing of fin development, fin lengths, and basal lengths of the dorsal and anal fins are also useful.

The median finfold, one of the most obvious structures in protolarvae and mesolarvae, is a thin, erect, medial fold of tissue that originates on the dorsal surface, usually well behind the head. It extends posteriorly to and around the end of the notochord, then anteriorly along the ventral surface to the posterior margin of the vent. During the mesolarval phase, the soft-rayed portions of the median fins (dorsal, anal, and caudal) differentiate from this finfold. As the median fins develop, the finfold diminishes and recedes before and between the fins until it is no longer apparent during or near the end of the metalarval phase.

The preanal finfold is a second median fold of tissue that extends forward from the vent. In cypriniform and most other fishes, the preanal finfold is completely separated from the ventral portion of the median finfold by the vent. But in burbot (*Lota lota*), and its marine relatives (Gadidae, codfishes), the preanal finfold is initially continuous with the median finfold and only later are the finfolds entirely separated by the vent (vent initially opens through right side of finfold). The preanal finfold may or may not be present upon hatching, depending upon size and shape of the yolk sac. In cypriniform fishes, it is typically absent or barely apparent upon hatching. As yolk is consumed and the yolk sac decreases in size prior to hatching or during the protolarval phase, a small preanal finfold appears just anterior to the vent. As more yolk is consumed and the larva grows, the preanal finfold enlarges and extends anteriorly. Ultimately, its origin lies anterior to that of the dorsal portion of the median finfold. The preanal finfold remains prominent throughout the mesolarval phase, then slowly diminishes and recedes in a posterior direction during the metalarval phase. It is typically the last finfold to be absorbed or lost.

The caudal fin is the first fin to differentiate from the median finfold in cypriniform and most other fishes with homocercal tails. The portion of the finfold involved first thickens along the ventral side of the posterior end of the notochord and begins to differentiate into the hypural elements of the caudal skeleton. Immediately thereafter, the first caudal-fin rays appear (beginning of flexion mesolarval phase) and the posterior portion of the notochord begins to bend or flex upward. Be careful not to confuse striations or folds in the finfold with developing fin rays. As the fin develops and the notochord continues to flex upward, the hypurals and developing caudal-fin rays, all ventral to the notochord, move to a posterior or terminal position. The first principal rays are medial and subsequent principal rays form progressively above and below. Principal caudal-fin rays articulate with hypural bones of the caudal structure and ultimately include all branched rays plus two adjacent unbranched rays, one above and one below the branched rays. Branching and segmentation of rays can be observed as or shortly after the full complement of principal rays becomes evident and notochord flexion is completed (beginning of postflexion mesolarval phase).

The number of principal caudal-fin rays is typically very stable within major groupings of fish. Cyprinids generally have 19 principal rays (ten based on superior hypurals or hypural plate and nine on inferior hypurals or hypural plate), and catostomids usually have 18 principal rays (nine and nine respectively).

Dorsal and ventral rudimentary rays of the caudal fin (shorter unbranched rays anterior to the outermost principal rays which also remain unbranched in later stages) begin forming sequentially in an anterior direction immediately after all or nearly all principal caudal-fin rays are formed. They are often the last group of fin rays among all fins to form their full adult complement. Accordingly, counts of rudimentary caudal-fin rays are usually ignored in larval fish identification, but they may be of taxonomic value for juveniles and adults.

The dorsal and anal fins, which typically form either simultaneously (many cyprinids) or dorsal first (most catostomids), usually begin development prior to attainment of the full complement of principal caudal-fin rays. Tissue first thickens in vicinity of the future fin, and basal structures or pterygiophores soon become evident. The latter structures permit limited use of dorsal and anal fin position and meristics about midway through the mesolarval phase. Anterior principal fin rays develop first and subsequent rays are added in a posterior direction. The first rudimentary fin rays (shorter unbranched rays anterior to the principal rays) are

frequently evident before all the principal fin rays form. Rudimentary fin rays are added in an anterior direction.

The first or most anterior principal ray in both dorsal and anal fins remains unbranched while all other principal fin rays branch distally as or after ray segmentation becomes evident. The last or most posterior principal ray in each fin is considered to be divided at the base and therefore usually consists of two elements that, except for their close proximity and association with the same pterygiophore, might otherwise be considered as separate fin rays.

Principal dorsal- and anal-fin-ray counts between and within certain genera often vary sufficiently to be of use in identification at the species level, especially anal-fin rays of cyprinids and dorsal-fin rays of catostomids. Positions of dorsal-fin origin (anterior attachment) and insertion (posterior attachment) relative to origin of pelvic fins or fin buds and the vent vary considerably among cyprinids and are useful in identification of genera or species. These position characters are more consistent among catostomids (e.g., dorsal-fin origin is always well in advance of the pelvic fins), especially at subfamily level, and therefore, are of less value in identification.

The pelvic fins begin as buds before or upon transition to the metalarval phase. In cypriniform fishes, they originate in an abdominal position along each side of the preanal finfold. They may erupt shortly after dorsal-and anal-fin development begins or be delayed until just before or shortly after all principal rays are present in the median fins. Pelvic rays begin to form shortly after the buds appear and the adult complement of rays quickly ensues. Among cypriniform fishes, pelvic-ray counts are seldom used diagnostically. However, position of the pelvic fins or fin buds, relative to other structures, and their formation in the sequence of developmental events can be useful in identification, especially among cyprinids.

The pectoral fins typically begin as buds immediately behind the head in the late embryo. However, pectoral buds are not evident in some cypriniform fishes until shortly after hatching. Though strongly striated and occasionally with membranous folds and breaks, they typically remain rayless in cypriniforms until late in the mesolarval phase when most of the principal median-fin rays are present. With the exception of rudimentary caudal-fin rays, the rays of pectoral fins are often the last to establish their full complement. For this reason and because the number of pectoral rays is usually relatively large and difficult to count without excision (especially the smaller ventral rays), pectoral-fin-ray counts are generally of little value in larval fish identification.

Other countable structures

Other structures that may be treated meristically (and in some cases morphologically) include branchiostegals, gill rakers, pharyngeal teeth, and scales. Branchiostegals form early in larval development, but counts are usually constant within major taxon groups. Within the order Cypriniformes, all members of superfamily Cyprinoidea, which includes Cyprinidae and Catostomidae, have three branchiostegals (McAllister 1968). Due to later development, small size or internal location, the other characters are seldom used to diagnose fish larvae. Gill rakers form gradually in postflexion mesolarvae or metalarvae with numbers increasing throughout much of the early portion of the juvenile period. The adult complement of gill rakers on the first gill arch is not achieved in many Catostominae until they reach about 70 mm standard length (Smith 1966). Pharyngeal teeth form relatively early but may not be sufficiently well developed to be readily removed and observed until late in the larval period or early in the juvenile period.

Detailed study of gill rakers and pharyngeal teeth might reveal some useful diagnostic qualities, including size, shape, and number. However, most specimens are more easily identified using external characters. Scales typically become apparent late in the larval period or early in the juvenile period. First scales on cypriniforms typically appear midlaterally on the posterior half of the body and from there spread anteriorly, dorsally, and ventrally toward adult coverage. Scales of large-scaled species are sometimes sufficiently obvious by late in the metalarval phase to distinguish certain species or genera.

Morphology

The shape or form of larvae and specific anatomical structures (e.g., gut, air bladder, yolk sac, and mouth) changes as fish grow and provides some of the most obvious characters for identification, particularly at family and subfamily levels. Within genera, morphological differences among species are usually much more subtle, but may still be of diagnostic value. Much shape or form-related information can be quantified via proportional measurements or morphometrics.

Morphometric data emphasize the relative position and relative size of various body components and dimensions and may be critical to species identification. Such measurements may be allometric, changing in proportion as the fish grow; thus morphometric data should be related to size, at least for protolarvae and mesolarvae. Some morphometric data, particularly body depths and widths, may be directly affected by the condition of individual specimens and volume and form of food items in their digestive tracts. The source of specimens and the preservative in which they are stored also may affect morphometric data. Some measures in wild fish may differ from those of laboratory-reared specimens (e.g., fin lengths). Shrinkage and deformation are notably greater in alcohol than in formalin preservatives.

Morphometric data in this guide are reported as percentages of standard length (% SL). Use of standard length (SL) avoids the allometric influence of caudal fin growth included in percentages based on total length (TL). As explained later (Methods), data can be easily converted to percent TL (% TL) for comparison with other works. Prior to hypural plate formation and completion of notochord flexion (protolarvae and flexion mesolarvae), SL is the length from snout to posterior end of the notochord (notochord length). Thereafter, SL is measured from the anterior margin of the snout to the most posterior margin of the hypural plates (usually the superior plate or hypurals). Use of notochord length for protolarvae and early mesolarvae gives the appearance of greater allometric growth differences than may really exist, at least in comparison with subsequent measures based on the posterior margin of the hypural plates. This undesirable effect is a result of upward bending or flexing of the notochord and the switch from use of end of the notochord to posterior margin of the hypurals as the basis for length measurement. These factors must be taken into account when reviewing morphometric data herein.

In contrast to procedures recommended by Hubbs and Lagler (1958) for larger juveniles and adults, measurements of body length and various parts thereof for fish larvae are generally taken along lines parallel to the horizontal axis of the fish. Exceptions are fin lengths which, in studies conducted for this manual, were measured from origin of the fin base to most distal margin of the fin rays. Typical measures include total, standard, head, snout, eye, and fin lengths, as well as snout-to-vent and snout-to-origin-of-fin (dorsal, anal, and pelvic) lengths.

Snout-to-vent length is measured to the posterior margin of the vent or anus. It is a primary diagnostic character for many species, especially at the family and sometimes subfamily level. In the Gila River Basin, most cyprinid larvae are readily differentiated from catostomid larvae by snout-to-vent lengths less than 72% SL. Exceptions are most larvae of common carp (*Cyprinus carpio*) and occasionally mesolarvae of Colorado pikeminnow (*Ptychocheilus lucius*). The term "preanal length" is often applied to this measure but might be misinterpreted as length to origin of the anal fin. For many fishes, including cypriniforms, the latter measure is approximately the same as snout-to-vent length since the anal fin begins at or near the posterior margin of the vent.

Head length is typically measured to the posterior margin of the operculum in juveniles and adults, but the operculum may be absent or incomplete throughout much of the larval period. Accordingly, many biologists have redefined head length for larvae to be measured to the posterior end of the auditory vesicle or the anterior or posterior margin of the cleithrum, one of the first bones to ossify in fish larvae (Berry and Richards 1973). Unfortunately, the auditory vesicle and cleithrum are not always easy to observe, especially in postflexion mesolarvae and metalarvae. Also, resultant measures to the auditory vesicle are considerably anterior to the eventual posterior margin of the operculum. Snyder et al. (1977) and Snyder and Douglas (1978) measured larval head length to origin (anterior insertion) of the pectoral fin. This measure has distinct advantages over the alternatives—the base of the pectoral fin is readily observed throughout the larval period (except in the few species that hatch prior to pectoral bud formation), it somewhat approximates the position of the cleithrum (part of its supporting structure), and it more nearly approximates the posterior margin of the operculum than does the posterior margin of the auditory vesicle. Accordingly, we recommend this definition of head length (Snyder 1983) and have used it in all our descriptive work. For purposes of consistency, we apply it to juveniles as well as larvae. The measure is most precisely determined while examining the specimen from above or below and, if necessary, holding the fin away from the body.

Body depths and widths are measured in planes perpendicular to the horizontal axis of the fish. Many biologists report these as maximum or minimum measures (e.g., greatest-head depth, greatest-body depth, and least-caudal-peduncle depth). However, for comparative purposes, it seems more logical to specify standard reference points for such measures as was done by Moser and Ahlstrom (1970), Fuiman (1979), and Snyder and Douglas (1978). Five specific locations, four corresponding to specific length measurements, are used herein: (1) immediately posterior to eyes, (2) origin of pectoral fin, (3) origin of dorsal fin, (4) immediately posterior to vent, and (5) at anterior margin of most posterior myomere (along the horizontal myosepta). It is often desirable to approximate position of reference points in larvae prior to formation of the referenced structure (e.g., origin of dorsal fin in protolarvae and flexion mesolarvae based on position in later stages). Neither fins nor finfolds are included in depth measurements herein. As mentioned earlier, care must be used in evaluation of depth and width measures affected by body condition and gut contents (e.g., measures at the origin of the dorsal fin).

Other morphological characters such as position, size, and form of the mouth and gut, and related changes, can be among the more useful characters for identification to the species level. Size of the mouth, as well as its position, its angle of inclination, and the form of specific mouth structures are diagnostic for some cypriniforms, especially in metalarvae. Timing of mouth migration from terminal to inferior position can be especially useful for catostomid metalarvae. Gut-loop length, timing of loop formation, and eventual degree and form of gut

loops, folds, or coils can be diagnostic for the larvae of many fishes. Such characters are especially useful in distinguishing postflexion mesolarvae, metalarvae, and early juveniles of certain catostomids.

Pigmentation

Basic patterns of chromatophore distribution, and changes in these patterns as fish grow are often characteristic at the species level. Used with caution, preferably in combination with other characters, and with an awareness of both intra- and interregional variation, chromatophore distribution and patterns for many fishes are among the most useful characters available for identification. However, in some instances, differences are so subtle or variation so great that use of pigmentation is impractical and may be misleading.

In cypriniform and most other fishes, chromatophores other than melanophores have not been sufficiently studied for identification purposes. Such chromatophores are typically neither as numerous nor as obvious as melanophores and their pigments are difficult to preserve. In contrast, melanin, the amino acid breakdown product responsible for the dark, typically black, appearance of melanophores (Lagler et al. 1977), remains relatively stable in preserved specimens. However, melanin is subject to fading and bleaching if specimens are stored or studied extensively in bright light for long periods of time, stored in highly alkaline preservatives, or subjected to changing concentrations of preservative fluids. To minimize the latter effects, as well as shrinkage and deformation, dilute formalin solutions (3-5%, unbuffered or buffered to near neutral) are strongly recommended over alcohol solutions as storage media. Most of the following discussion refers to chromatophores in general, but in this manual and others for freshwater species in North America, pigmentation typically refers to that of melanophores.

According to Orton (1953), pigment cells originate in the neural crest region (dorsal portion of body and tail) and migrate in amoeboid fashion in waves to their eventual position. The first wave of chromatophores occurs late in the embryonic period or early in the larval period and establishes a relatively fixed basic or primary pattern of chromatophore distribution. In a few species (mostly marine), such cells acquire pigment prior to chromatophore migration and the actual migration can be observed and documented. But in cypriniform and most other freshwater fishes, pigment is not present in chromatophores until after the cells reach their ultimate destination.

For a specific species and developmental stage, pigmental variation in general or specific areas is largely a function of the number of chromatophores exhibiting pigment rather than differences in chromatophore distribution. Chromatophores without pigment cannot contribute to the visible pigmentation pattern. In addition, pigment in chromatophores can be variously displayed from tight, contracted spots, resulting in a relatively light appearance, to widely expanded, reticular networks, resulting in a dark or more strongly pigmented appearance. Differences in environmental conditions and food can significantly affect the presence and displayed form of pigmentation. Accordingly, researchers must be aware that pigmentation of cultured specimens can appear quite different from that of field-collected material.

Pigmentation often changes considerably as larvae and early juveniles grow. Most of the change is due to increased numbers and distribution of chromatophores. Observable pigmentation might also be lost from certain areas through loss of pigment in chromatophores, loss of chromatophores themselves, or, in the case of subsurface or internal chromatophores, by

growth and increased opacity of overlying tissues. Peritoneal melanophore pigmentation is an obvious character for later stages of some larvae, but in late metalarvae and especially juveniles, dark peritoneal pigmentation can be obscured by overlying muscle or membranes with silvery iridophores (this silvery pigment often dissipates over time in formalin preservative, but is usually retained in alcohol). If internal melanophore pigmentation is obscured by overlying tissues, it can be observed by selective dissection or careful clearing of specimens.

Osteology

When externally visible characters fail to segregate species conclusively, osteological characters may come to the rescue. Although whole-specimen clearing and cartilage- and bone-staining techniques are relatively simple (see Methods in Snyder and Muth 1988, 1990, or 2004), they require much time (a few days, mostly waiting) and a fair amount of attention (monitoring progress and changing fluids). Soft (longwave) X-ray techniques (Tucker and Laroche 1984) may be faster and easier, especially when examining many specimens, but they require appropriate X-ray equipment and a darkroom.

Dunn (1983, 1984) reviewed use of skeletal structures and the utility of developmental osteology in taxonomic studies. Among the first bones to ossify are those associated with feeding, respiration, and orientation (e.g., jaws, bones of the branchial region, cleithrum, and otoliths). The axial skeleton follows with formation of vertebrae and associated bones. Once the axial skeleton is sufficiently established, median- and pelvic-fin supports form, and fins develop. Presence, number, position, and shape of certain bones in many parts of the skeleton can have diagnostic value, even for closely related species. Use of osteological characters for identification of fish larvae has received little attention, but its potential value is great, particularly for confirmation of questionable identities and for species in which external characters are diagnostically inadequate.

METHODS

Specimens Examined

Study specimens for description of desert sucker, Sonora sucker, longfin dace, spikedace, and loach minnow were selected from more than 53,000 as-yet uncatalogued specimens in the LFL Collection that were collected or reared in 1982 through 1984 from the Gila River drainage of southwestern New Mexico. Many of these specimens were identified and all were inventoried for consideration as part of this investigation.

The remaining study specimens for these descriptions were selected from among specimens loaned or contributed by outside sources. These included 16 metalarval and juvenile loach minnow collected from the Gila River Basin in New Mexico (MSB 2544,4692, 4801, 4817), 150 specimens from a recently reared developmental series of longfin dace (MSB 49871), and 72 specimens from a recently reared series of spikedace (MSB 43810) loaned by the Museum of Southwestern Biology (Albuquerque, New Mexico); and 82 specimens from a recently reared series of loach minnow contributed by Michael Childs of the Arizona Game and Fish Department.

Specimens for supplemental study of all previously described cyprinids were selected mostly from reference or study series in the LFL collection. Most of these specimens were either

collected in or reared from stock in the Upper Colorado River Basin during the late 1970s to early 1980s. A few speckled dace were selected from among 72 specimens contributed by Michael Childs from a developmental series he reared in Arizona in 1998.

Whenever possible, formalin-preserved specimens (usually 3% buffered) were used for analysis to avoid confounding data with the greater shrinkage and deformation effects typical of many alcohol-preserved specimens. However, some data for larger metalarvae and juveniles of loach minnow were from specimens preserved in 70% ethanol.

Specimen Data, Observations, and Illustrations

Developmental series of desert sucker, Sonora sucker, longfin dace, spikedace, and loach minnow were analyzed in detail (124 specimens longfin dace and 79-85 specimens for each of the others, 532 total) for differences in morphology, morphometrics, meristics, pigmentation, and size relative to developmental state. Additional specimens (35 desert sucker, 52 Sonora sucker) were analyzed only to supplement data on pigmentation and selected developmental-state characters.

Most summarized data for bonytail, roundtail chub, Colorado pikeminnow, speckled dace, common carp, red shiner, and fathead minnow species accounts were extracted from Snyder et al. (1977), Snyder (1981), and Muth (1990). Original raw data for the source descriptions were available for all species except bonytail, roundtail chub, and fathead minnow and were re-analyzed for mesolarvae to divide results for flexion and postflexion subdivisions. Morphometric data for fathead minnow were published as percentages of total length and had to be converted by approximate calculation to percentages of standard length.

To supplement existing descriptive data for the seven previously described cyprinids, 17 to 29 specimens each (total of 153) were analyzed for pigmentation patterns and selected developmental-state characters. Of these, three roundtail chub and four speckled dace were fully analyzed to supplement limited existing data for the protolarval phase.

For each newly described species, various measurements, fin-ray counts, and myomere counts (Figure 4) were made on at least two specimens, if available, in each 1-mm-TL interval throughout the larval period of each species. Thereafter, to a length of about 50 mm TL, two 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. Most measurements were made using multiple digital images of the specimens captured through the microscope and a computer image-analysis and measurement program (Optimas 5.1, Optimas Corp., Seattle, Washington; now owned by Media Cybernetics, Silver Spring, Maryland). 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 cursorily examined specimens. Selected events were hatching, attainment of eye pigment, formation of 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.

Among other characters considered, developmental phase and extent of gut folding were determined for all analyzed and many other specimens. Gut folding was classified as one of five gut phases (Figure 5). Changes in mouth position and size, lower-lip-lobe separation in the

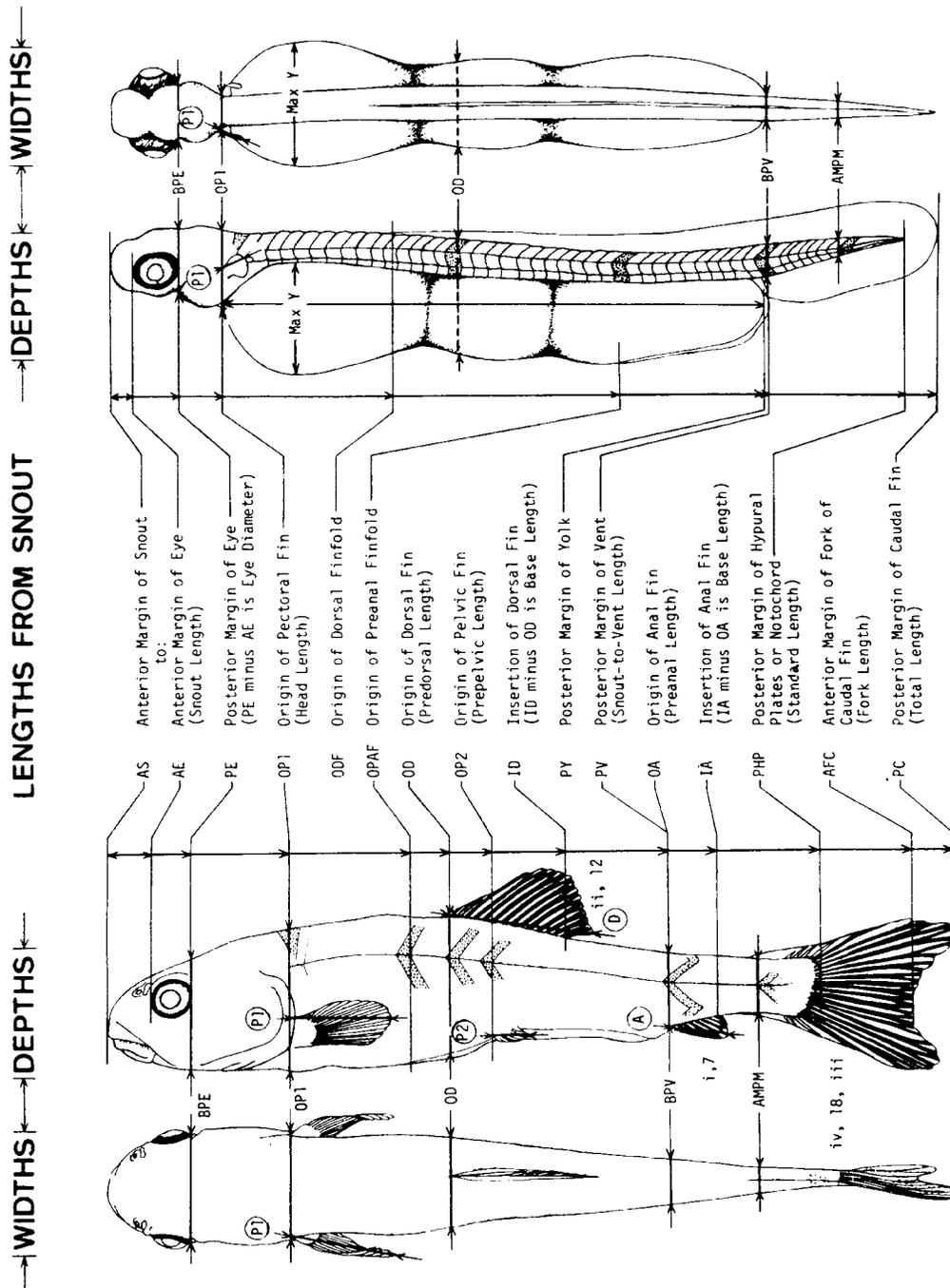


Fig. 4. Measures and counts for larval and early juvenile fishes. Yolk sac and pterygiophores are included in width and depth measures but fins and finfolds are not. "B" in BPE and BPV means immediately behind. AMPM is anterior margin of most posterior myomere. Location of width and depth measures at 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.)

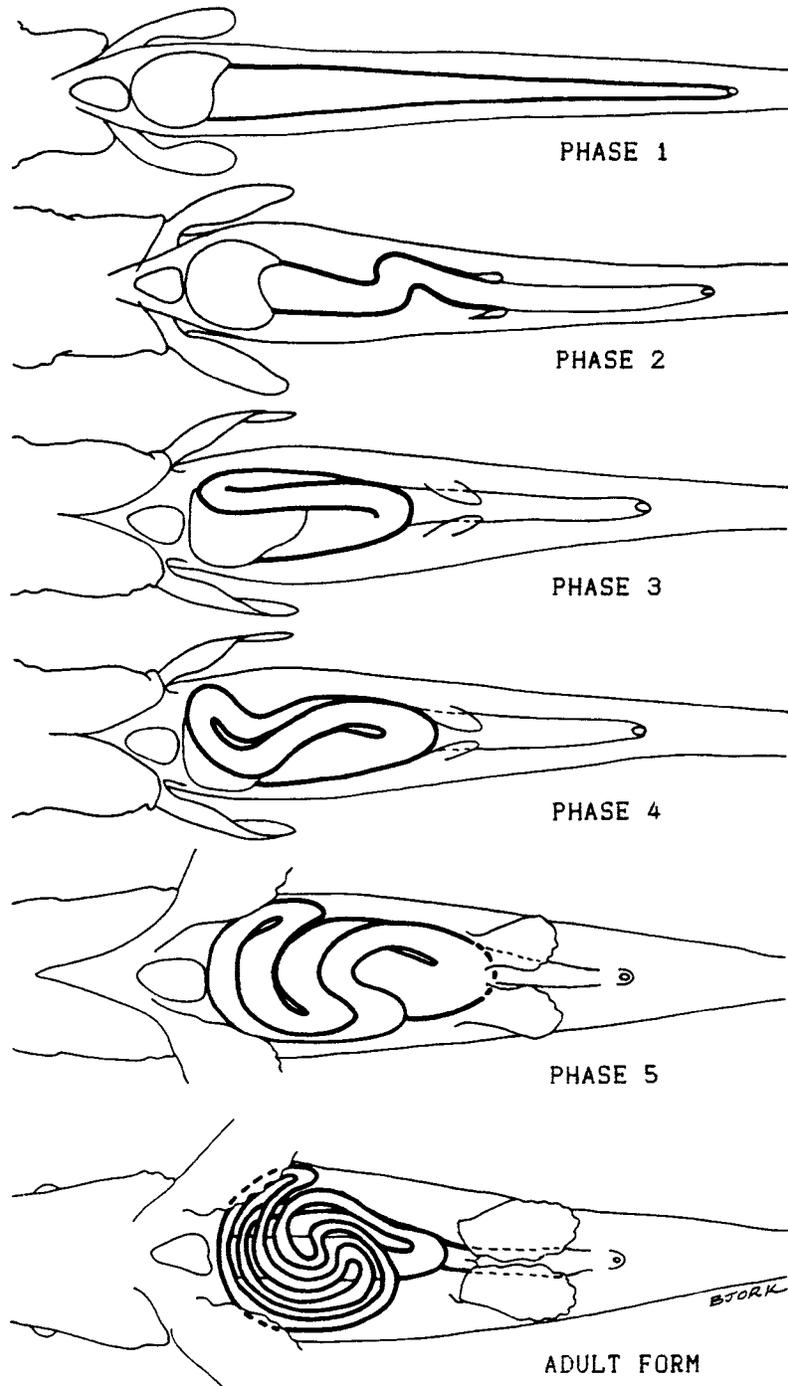


Fig. 5. Phases of gut coil development in catostomid fish larvae and early juveniles with comparison to adult form in *Catostomus commersonii* (latter modified from Stewart 1926). Phase 1 – essentially straight gut. Phase 2 – initial loop formation (usually on left side), begins with 90° bend. Phase 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.

catostomids, fin position in the cyprinids, and development of other special structures (e.g., mouth barbels in certain cyprinids) were noted when appropriate. Variation in pigmentation patterns was studied by categorizing observed patterns and character-coding their frequency (see keys to pigment characters at the ends of summary Tables 62 (catostomids) and 69 (cyprinids).

Nineteen new continuous-tone graphite and black-ink drawings were prepared—five each for longfin dace, spikedace, and loach minnow (mid-phase protolarvae, early flexion mesolarvae, and mid-phase postflexion mesolarvae, metalarvae and juveniles), and, to supplement existing illustrations, one stage each for desert sucker (flexion mesolarva), Sonora sucker (flexion mesolarva), roundtail chub (protolarva), and speckled dace (protolarva). Black ink was used only for surface or near-surface pigmentation to distinguish it from deeper pigmentation, other structure, and shading. Each drawing consists of dorsal, lateral, and ventral views. Enlarged digital prints of primary drawing specimens were traced to assure accurate body proportions. Various structures were checked and detail added while drawing specimens were examined under a microscope. If necessary, drawings were idealized (e.g., closed or frayed fins opened and smoothed and curved bodies straightened), and melanophore distribution and other structures were modified to represent a more typical pattern or condition based on secondary drawing specimens.

All morphometric, meristic, and size at onset of selected developmental event data are summarized in species accounts with associated illustrations, maps of recent distribution, and brief descriptions of the adult, reproduction, and early life history (young). The more diagnostically useful of those data are also compared among species in sets of summary tables, along with all pigmentation and special character data. All data, except those in terms of TL, are also used by, and accessible in, the computer-interactive keys.

Computer-Interactive Key

For complex sets of organisms, computer-interactive keys are easier to prepare, update, and expand than traditional printed keys, and much more flexible for the user. Most computer-interactive keys are data sets designed to be used with specific commercial, public-domain, or proprietary host programs (Dallwitz et al. 2000 et seq.). The features and flexibility of several alternative computer-interactive key programs were compared (in part via Dallwitz 2000 et seq.) during preparation of early versions of the key included in Snyder and Muth (2004). Based on this comparison, our prior experience with the DELTA (DEscriptive Language for TAXonomy) suite of programs for taxon description and keys (Dallwitz 1974, 1980, 1993; Dallwitz and Paine 1986), including *Intkey* (Dallwitz et al. 1993 et seq., 1995 et seq.), and successful production of the key for Snyder and Muth (2004), we decided to continue developing our keys for use by the *Intkey* program. The latest versions of *Intkey*, *DELTA Editor* (Dallwitz et al. 1999 et seq.), and associated programs and files can be freely downloaded from the Internet (<http://delta-intkey.com/>).

DELTA Editor was used to add character data for desert sucker and Sonora sucker to the catostomid data set prepared for Snyder and Muth (2004). Characters were encoded using the DELTA format, a powerful, flexible, and widely accepted method for recording descriptive taxonomic data for computer processing. Output from *DELTA Editor* to the derived files required by *Intkey* was then limited to just the Gila River Basin catostomids. A series of similar data sets and derived files were prepared and progressively refined for the cyprinids, including the three non-native species, and for identification of the larvae of all Gila River Basin fishes at

the family level. Because developmental state changes dramatically as fish grow and to better facilitate use of character dependencies (e.g., if yolk is absent, characters such as length of yolk are removed from consideration), it was necessary in the catostomid and cyprinid keys to treat each developmental phase and size interval for a species as separate taxa (e.g., *Catostomus insignis* protolarva, 13 mm SL). Rich-text files of background information, beginning instructions, and other information to be accessed when using *Intkey* were prepared or modified with a word processor. Character lists and natural-language, taxon descriptions were also generated as rich-text files for reference when using the key.

The computer-interactive key to families of Gila River Basin fish larvae is based on characters and character states utilized in previously published family keys by Drewry (1979), Auer (1982), Holland-Bartels, et al. (1990), and Wallus et al. (1990; also Kay et al. 1994 and Simon and Wallus 2004). Those data were then modified or supplemented as necessary with descriptive data and observations from other publications, particularly for the family Cichlidae (Mironova 1969, Fryer and Iles 1972, Trewavas 1983, McGowan 1988, Morrison et al. 2003; also FishBase at <http://www.fishbase.org/home.htm>). Mostly to illustrate representative larvae for use with the key, but also as an alternative to it, a pictorial guide to the families of Gila River Basin fish larvae was prepared as an appendix. It consists of pertinent portions of the pictorial family guide with brief lists of distinguishing characteristics published by Wallus et al. (1990) for the Ohio River drainage, but is supplemented with an original section on Cichlidae with drawings of larvae from Fryer and Iles (1972) and McGowan (1988).

Although *Intkey* can make extensive use of taxon and character-state-selection images, preparation and inclusion of such were neither critical for operation of the key nor logistically and budgetarily feasible for this guide (if there is enough interest and support, they could be prepared and incorporated in future versions of the key). Also, such images can require a considerable amount of storage memory and at times a strictly text key may be preferable, especially for the experienced user or when using a slower computer with limited memory. Instead, the user is expected to extensively reference the illustrations and descriptive information provided in the species accounts. However, as examples of how character-state-selection images function, such illustrations were prepared and included in the key for developmental phase and phases of gut development. Images used by *Intkey* were created or modified from scanned files using computer drawing and presentation programs.

Interim and near-final versions of the three keys were subjected to in-house testing. However, based on reviews and feedback from use in routine collection processing, future refinements of the key will likely be implemented and made available for download over the Internet.

RESULTS AND DISCUSSION

Results are divided into three complementary sections—Species Accounts, Comparative Summary Tables, and Computer-Interactive Keys. For identification purposes, users should become familiar with and use all three taxonomic tools. Although all descriptive data in the species accounts and comparative summary tables (except those replicated in terms of total length in the species accounts) comprise the data sets for the keys, results from the keys can be confirmed using the well-illustrated species accounts and comparative summary tables.

Whenever possible, specimen identification should be based on multiple characters.

More than 1,480 specimens (539 for this investigation and 842 for prior studies) were analyzed in detail for morphometrics, meristics, and morphological developmental state relative to size, and several hundred of these and additional specimens for pigmentation and special morphological characters. Still, there are undoubtedly rare specimens with character extremes beyond the ranges recorded herein. Data for fathead minnow are particularly weak (just 15 specimens analyzed for a partial set of counts and measures—Snyder et al., 1977).

Because of the similarity among larvae of some Gila River Basin catostomids and cyprinids, the specific identity of some larvae will remain inconclusive or questionable after application of the key and diagnostic criteria provided herein. The identity of such specimens must be considered tentative and should be designated as such by appending a question mark ("?",) to the most probable taxon name (e.g., "*Gila robusta* ?", preferably with a footnote on other possibilities), or by leaving the identity at family level (e.g., "unidentified Cyprinidae"), or genus (i.e., *Gila* sp.) if other genera can be eliminated. Some inconclusive specimens may be hybrids.

Hybridization among Colorado River System catostomids is particularly well documented (e.g., Hubbs et al. 1943, Hubbs and Hubbs 1947, Hubbs and Miller 1953, Smith 1966, Holden and Stalnaker 1975, McAda 1977, Prewitt 1977, McAda and Wydoski 1980, and Clarkson and Minckley 1988). Based on the key or diagnostic criteria summarized herein, some hybrid metalarvae and early juveniles may be at least tentatively identified as such by more experienced users, but because of fewer characters, hybrid protolarvae and mesolarvae, will likely be identified as the parental species they most closely resemble or remain questionable.

Although skeletal characters were not studied as part of this investigation (except for vertebra counts), Snyder and Muth (2004) found that certain osteological features can be diagnostic for late metalarvae and juveniles of razorback sucker, subgenus *Pantosteus*, and subgenus *Catostomus*. Those data (size and shape of the frontoparietal fontanelle, first interneural bone, and anterior-dorsal maxillary projection; angle at which the postcleithrum extends from the cleithrum; and position of the mandibles relative to the maxillae) are included in the catostomid key for flannelmouth sucker and razorback sucker, but unlike Snyder and Muth (2004), have not been included in the species accounts for those species. The subgeneric differences probably extend to desert sucker and Sonora sucker but such have not been verified except for frontoparietal fontanelle dimensions in Sonora sucker based on data from an earlier unpublished investigation. The fontanelle narrows somewhat later in Sonora sucker than in flannelmouth sucker, after which its width becomes diagnostic for distinguishing Sonora sucker from razorback sucker (Table 64 and catostomid key). Unfortunately these skeletal characters, as well as vertebra counts, require that specimens be cleared and preferably stained for bone (or that the structures of interest be otherwise exposed). They are therefore best used to confirm or refine identities based on characters for which special preparation is not required.

Although prepared for use by Gila River Basin biologists, the species accounts, comparative summary tables, and keys that follow, as well as introductory information at the beginning of this guide, may also be useful to early life history investigators working elsewhere. Allowing for potential population differences in developmental morphology, these descriptions and the keys can be used for identification of covered species wherever they may occur. For example, roundtail chub, speckled dace, red shiner, fathead minnow, and carp are common in many reaches of the Colorado River Basin, and the latter four species in many other North American river systems. Where two or more of these species occur together and any other closely related sympatric species can be eliminated otherwise as possibilities, the computer-interactive key has the flexibility of being limited to just those species and effectively becoming a

key for that region, site, or circumstance. The family key might be particularly useful elsewhere, although several families of freshwater-spawning fishes in North America are not included.

Species Accounts

The following accounts serve as concise, but detailed and well-illustrated descriptions of the larvae and early juveniles of the subject species. Together with the comparative summary tables, they are provided to help confirm identities determined through the keys or for use as an alternative to the keys.

Species accounts herein for desert sucker, Sonora sucker, longfin dace, spikédace, and loach minnow comprise the only descriptive information published for the larvae of those species since Winn and Miller (1954) described their mesolarvae. The remaining accounts are either slight modifications of existing accounts in Snyder and Muth (1990, 2004—flannelmouth sucker and razorback sucker) or reformatted accounts from Snyder et al. (1977), Snyder (1981), and Muth (1990), supplemented with new or recalculated data and, for roundtail chub and speckled dace, new illustrations of protolarvae.

Each 6-page account begins with an illustration of the adult fish; map of its distribution in the Colorado River Basin; brief summaries of adult descriptions, reproduction (including reproductive guides as defined by Balon 1975b and 1981), and early life history; and a table of adult meristics. Much of this information was extracted from literature cited at the bottom of the first page. Each account continues with description of the larvae and early juveniles. Page one concludes with a table of size at apparent onset of selected developmental events. Page two consists of a table of size at developmental-interval and gut-phase transitions and a table of morphometrics and meristics summarized by developmental phase. The next four pages illustrate five to eight stages of development from just hatched protolarvae through early juveniles up to about 30 mm SL.

Species Account – *Catostomus clarkii*

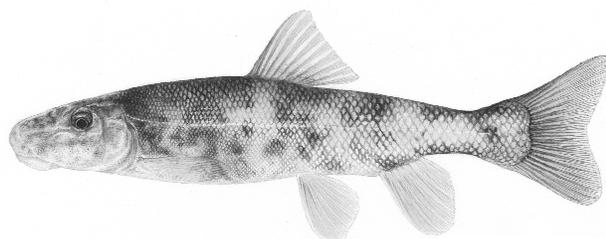


Fig. 6. *Catostomus clarkii* adult (© Joseph R. Tomelleri).

Adult Description: About 16-40 cm TL, heavy-bodied, and fusiform with ventral mouth and no dorsal keel. Head somewhat flattened, large, about 25% of SL. Mouth with shallow median cleft between broadly connected, moderately large lower lip lobes, distinct notches at corners of lips, and strong, truncate, cartilaginous scraping ridge on anterior margin of lower jaw. Small, evenly-spaced papillae over lips except on anterior face of upper lip. Dorsal fin moderate in size with truncate posterior margin. Scales moderately large. Caudal peduncle relatively thick, usually 8.5-10% of SL. Typically tan to green above and yellow or dirty white below. (Also, Table 2.)

Reproduction: Non-guarding, open-substrate lithophil. Spawn February-July, usually March-May, when day-time water temperatures reach 11-19°C. Breeding males sometimes have red lateral stripe. Usually spawn over gravel-cobble riffles, where demersal, adhesive eggs develop in interstitial spaces. Water-hardened eggs are 3.0-3.4 mm diameter.

Young: Hatch in 7-8 d when incubated 3 d at 15-16°C and 4-5 d at 20-22°C, 12-15 d at 15°C. Late protolarvae and mesolarvae are transported in considerable numbers downstream after emergence from spawning substrate. Later larvae occupy near-shore, low-velocity channel margins, backwaters, eddies, and pools. Mesolarvae consume early instars of chironomids and other small invertebrates.

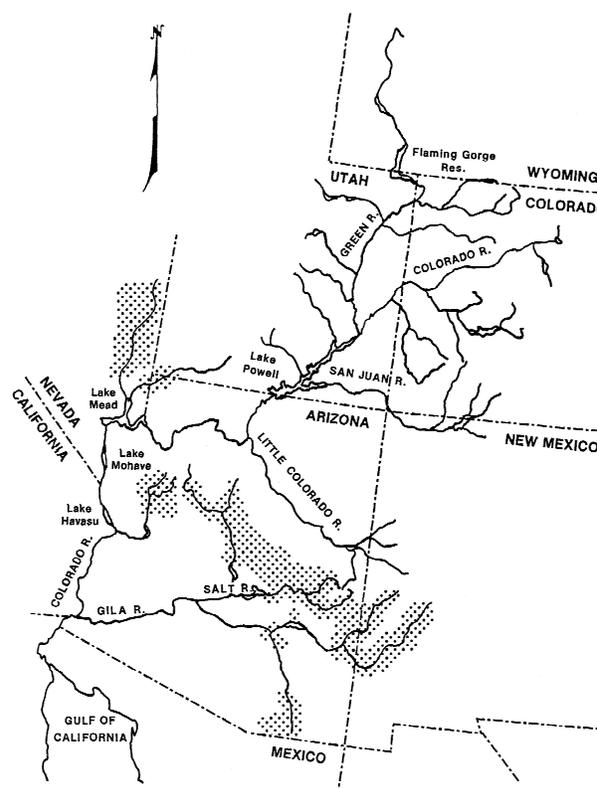


Fig. 7. Recent distribution of *Catostomus clarkii* in the Colorado River Basin.

Table 2. Selected juvenile and adult meristics for *Catostomus clarkii*. (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 values in parentheses.)

Character	Observed	Literature	Character	Observed	Literature
Dorsal-fin rays - P	10-11(12)	(8-) <u>10-11-12</u>	Dorsal-fin rays - R	3-4(5)	(2)
Anal-fin rays - P	7	7	Anal-fin rays - R	2-3	2
Caudal-fin rays - P	18	18	Caudal-fin rays - RD	<u>11-12-13</u>	(5)
Pectoral-fin rays	15-17	15-17	Caudal-fin rays - RV	9-11	(4)
Pelvic-fin rays	(9)10-11	8- <u>9-10-12</u>	Lateral scales	70-75	61-67-95(-104)*
Vertebrae	46-48	45- <u>46-49-51</u>	Gill rakers	-	(27) <u>28-30-40-43</u>

*Usually 65-80, always <85 in Gila River Basin populations.

Table 3. Size at onset of selected developmental events for *Catostomus clarkii*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	(8)9-10	9-10	Dorsal - P	13-14	14-15(16)	(14)15-16	(16)17-18
Eyes pigmented	10	10(11)	Anal - P	15-16	17-18	(15)16(-18)	(18)19(-21)
Yolk assimilated	12-14	(12)13-15	Caudal - P	(10)11-12	11-13	(13)14(15)	15-16
Finfold absorbed	(22)23-24(25)	27-29	Caudal - R	13-14	14-15(16)	21-23(-25)	23-26(-29)
Pectoral-fin buds	*	*	Pectoral	(13)14-15	(14)15-16(17)	18	21-22
Pelvic-fin buds	13-14	14-15(16)	Pelvic	15-16	17-18	(18)19-20	22-24
* before hatching			Scales	28-29	32-34	29-34	34-37

References: Baird and Girard 1854b, Bestgen unpublished data, Bestgen 1989, Bestgen et al. 1987a & b, Clarkson and Minckley 1988, Hubbs et al. 1943, LaRivers 1962, Miller 1952, Minckley 1973, Moore 1968, Sigler and Sigler 1987 & 1996, Smith 1966, Sublette et al. 1990, Winn and Miller 1954.

Table 4. Size at developmental interval (left) and gut phase (right) transitions for *Catostomus clarkii*. (See Figure 5 for phases of gut folding. Rare values in parentheses.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	(10)11-12	11-13	2 - 90° bend	(13)14-15(16)	(15)16-17
Postflexion mesolarva	(13)14(15)	15-16	3 - Full loop	(15)16-17	(17)18-19(20)
Metalarva	(15)16(-18)	(18)19(-21)	4 - Partial crossover	(16)17(18)	(19)20(21)
Juvenile	(22)23-24(25)	27-29	5 - Full crossover	18-19	21-22

Table 5. Summary of morphometrics and myomere counts by developmental phase for *Catostomus clarkii*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. SD value of 0 actually between 0.0 and 0.5.)

	Protolarvae (N=11)			Flexion mesolarvae (N=15)			Postflexion mesolarvae (N=14)			Metalarvae (N=27)			Juveniles (N=11)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	11	1	10 - 12	12	1	10 - 13	15	1	13 - 16	20	3	15 - 25	28	4	23 - 34
TL, mm	12	1	10 - 13	13	1	11 - 14	17	1	15 - 19	23	3	18 - 29	33	5	27 - 40
<u>Lengths %SL</u>															
AS to AE	2	0	1 - 2	3	1	2 - 4	5	1	4 - 6	7	1	5 - 9	9	1	7 - 11
PE	8	1	8 - 9	9	1	8 - 11	12	1	11 - 13	14	1	12 - 15	15	1	14 - 17
OP1	16	1	15 - 17	18	1	16 - 20	23	1	22 - 25	25	1	23 - 27	26	1	24 - 27
OP2							56	1	54 - 57	58	2	54 - 61	58	1	57 - 60
PY	78	2	76 - 81	72	4 ^a	60 - 77									
OPAF	35	21 ^b	21 - 67	23	2	19 - 26	33	2	29 - 37	50	10	36 - 69			
ODF	39	2	34 - 42	39	2	36 - 42	45	1 ^c	43 - 47						
OD							49	1	47 - 50	48	1	46 - 50	49	1	47 - 50
ID							63	2 ^d	59 - 66	64	1	63 - 66	65	1	64 - 66
PV	80	1	78 - 82	78	1	76 - 80	81	1	79 - 82	77	2	75 - 81	75	1	74 - 76
OA							79	1 ^e	78 - 79	76	1	75 - 79	75	1	74 - 76
IA							85	0 ^f	85 - 85	84	1	82 - 86	83	1	82 - 84
AFC							110	1	109 - 113	112	1	110 - 115	114	1 ^c	112 - 115
PC	104	1	102 - 105	106	1	104 - 107	114	2	111 - 118	118	2	114 - 121	117	2	115 - 121
Y	61	2 ^g	58 - 63	48	15	0 - 59									
P1	6	2	3 - 8	11	1	8 - 12	13	1	11 - 16	16	1	13 - 18	18	1	16 - 20
P2							4	1	2 - 6	10	3	6 - 14	14	2	10 - 16
D							17	3 ^h	12 - 21	22	1	20 - 23	23	1	22 - 25
A							9	1 ^e	8 - 9	12	2	9 - 15	15	1	12 - 16
<u>Depths %SL</u>															
at BPE	10	1	9 - 11	11	0	10 - 12	15	1	14 - 17	17	1	15 - 18	17	1	17 - 18
OP1	12	1 ^d	10 - 15	12	1	11 - 13	17	2	15 - 20	21	1	18 - 22	21	1	19 - 23
OD	15	2	11 - 19	11	2	9 - 14	14	3	10 - 19	20	2	16 - 23	21	1	18 - 22
BPV	6	0	5 - 6	6	0	6 - 7	7	1	6 - 8	10	1	8 - 11	11	1	10 - 12
AMPM	3	0	3 - 4	4	0	4 - 5	6	1	5 - 7	7	1	6 - 8	8	0	7 - 9
Max. yolk	12	3	9 - 18	5	2	0 - 8									
<u>Widths %SL</u>															
at BPE	9	0	8 - 10	11	1	10 - 11	14	1	13 - 16	16	1	15 - 18	17	1	16 - 18
OP1	9	3	6 - 15	8	1	7 - 9	12	1	10 - 14	16	2	12 - 19	18	1	17 - 20
OD	12	2 ^c	9 - 16	7	1	5 - 9	9	2	7 - 13	15	2	11 - 19	17	1	15 - 18
BPV	4	0	4 - 4	4	0	4 - 4	5	1	4 - 6	7	1	6 - 9	9	1	8 - 10
AMPM	2	0 ^e	2 - 3	3	0	2 - 3	3	0	3 - 4	4	1	3 - 5	5	0	4 - 5
Max. yolk	14	3 ^f	12 - 18	7	3 ^a	0 - 10									
<u>Myomeres</u>															
to PY	38	1 ^g	37 - 40	36	2 ^a	30 - 38									
OPAF	6	2 ⁱ	4 - 8	6	1	4 - 8	9	1	6 - 11	18	6	9 - 28			
OP2							23	1	22 - 24	24	1	22 - 26	24	1 ^d	23 - 27
ODF	15	1 ^g	13 - 16	16	1	12 - 18	16	1 ^c	15 - 18						
OD							19	1	18 - 20	17	1	16 - 19	17	1 ^d	16 - 18
PV	40	1 ^g	39 - 40	40	1	38 - 41	40	1	38 - 42	38	1	36 - 40	38	1 ^g	37 - 39
Total	48	1 ^g	47 - 49	48	1	47 - 49	48	1	47 - 49	49	1	47 - 51	49	1 ^g	47 - 49
After PV	9	1 ^g	8 - 9	8	1	7 - 9	8	1	7 - 10	10	1	8 - 12	11	1 ^g	10 - 12

^aN = 14. ^bN = 7. ^cN = 10. ^dN = 9. ^eN = 4. ^fN = 3. ^gN = 8. ^hN = 11. ⁱN = 6.

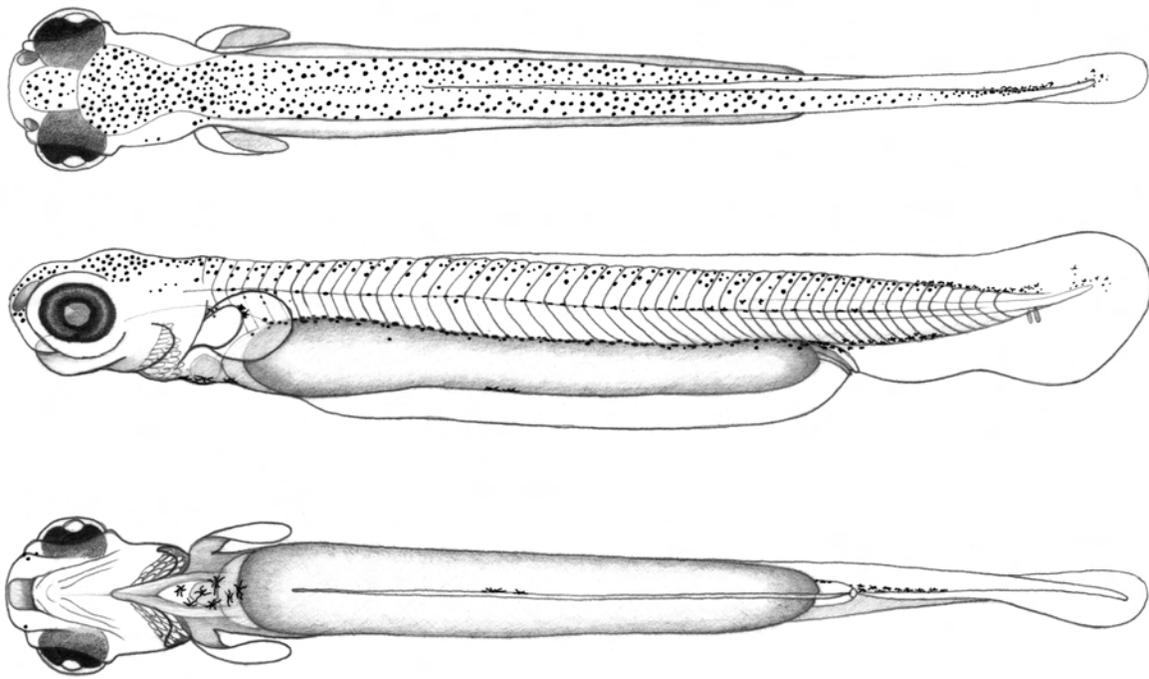


Fig. 8. *Catostomus clarkii* protolarva, 11.5 mm SL, 12.1 mm TL (almost mesolarva). (Collected in 1984 from the Gila River near Cliff, New Mexico.)

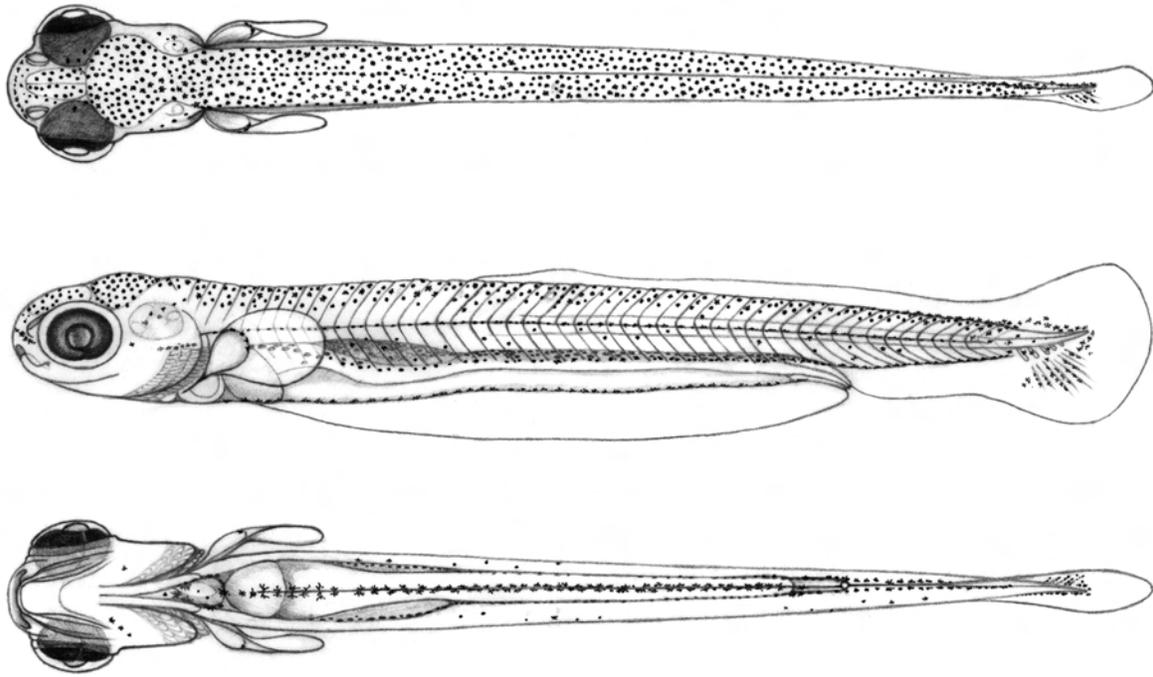


Fig. 9. *Catostomus clarkii* flexion mesolarva, recently transformed, 13.3 mm SL, 14.1 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

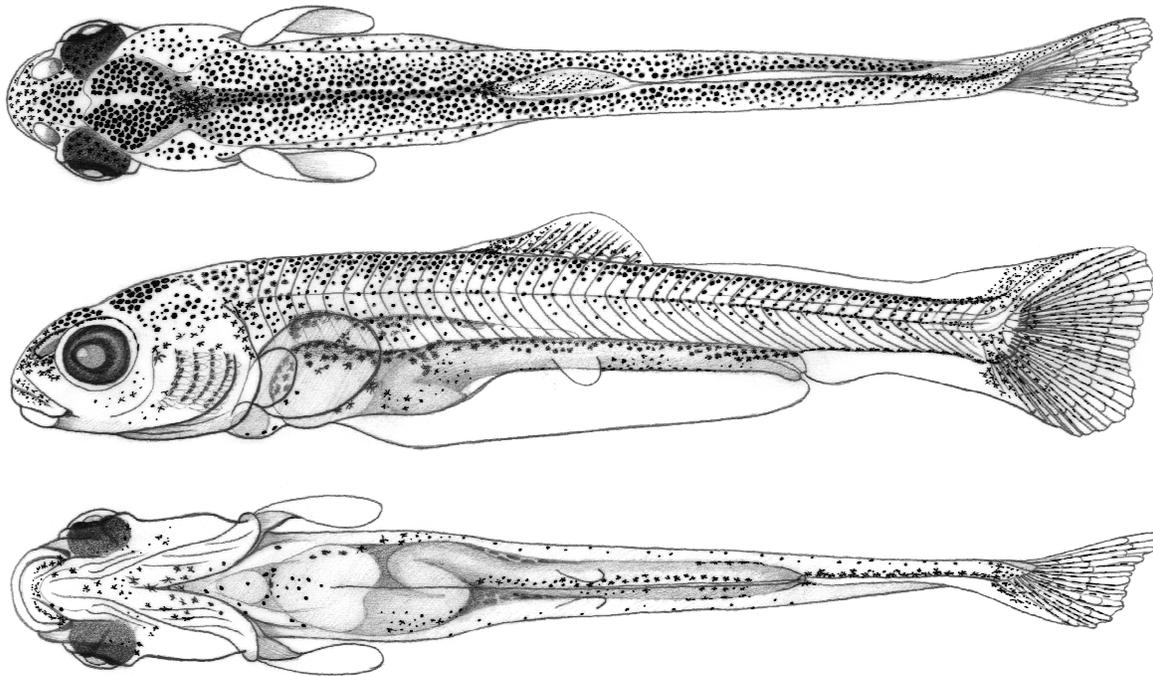


Fig. 10. *Catostomus clarkii* postflexion mesolarva, 16.2 mm SL, 18.3 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

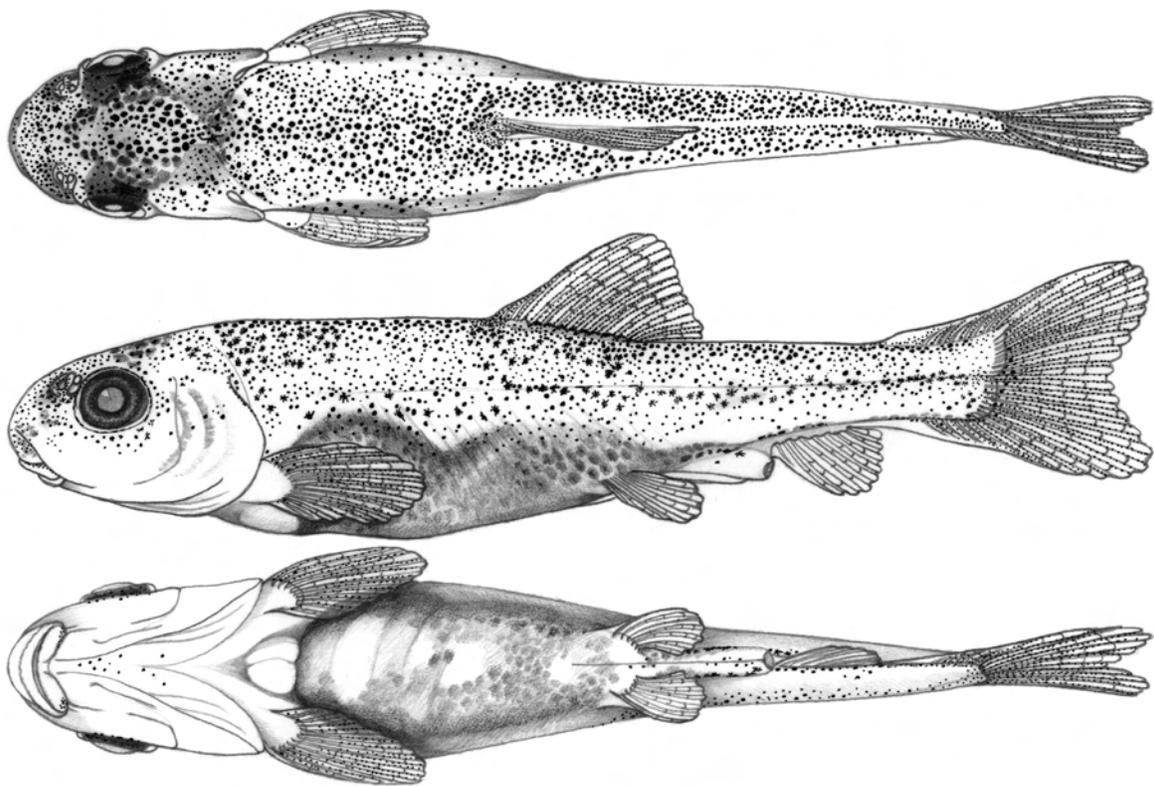


Fig. 11. *Catostomus clarkii* metalarva, 20.9 mm SL, 24.4 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

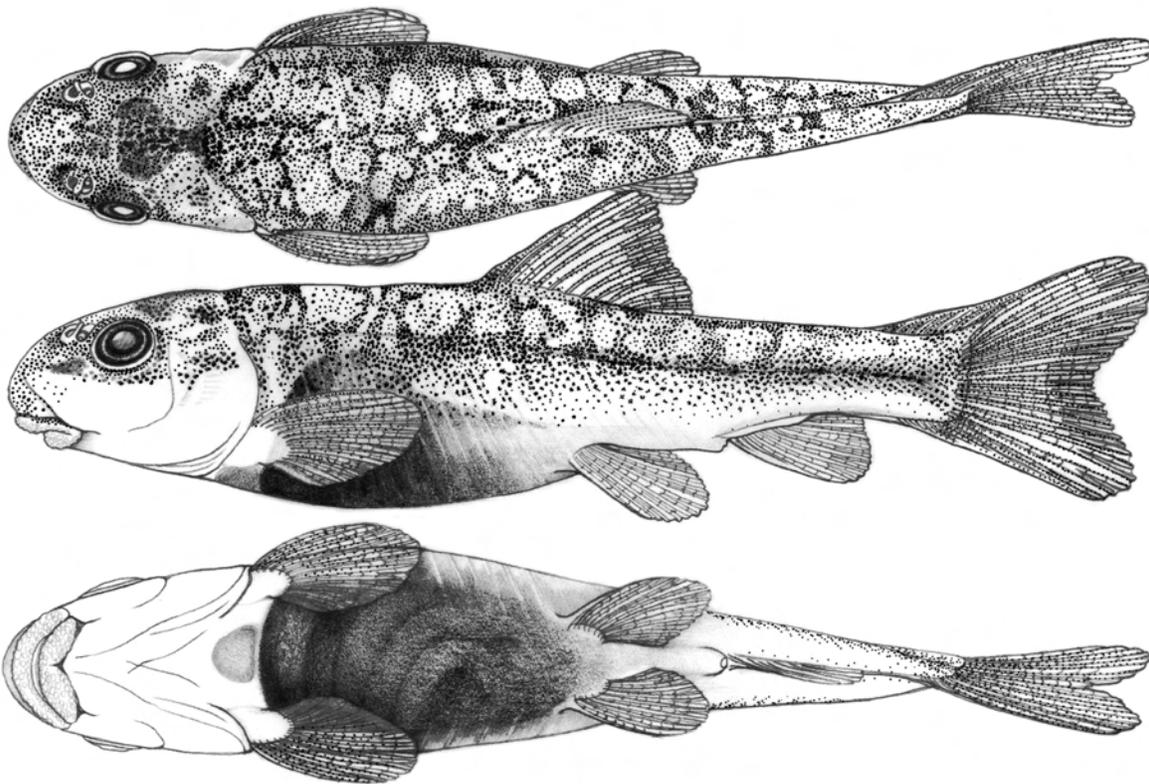


Fig. 12. *Catostomus clarkii* juvenile, 30.9 mm SL, 36.8 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

Species Account – *Catostomus insignis*

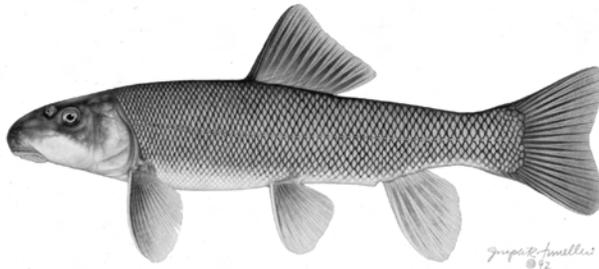


Fig. 13. *Catostomus insignis* adult (© Joseph R. Tomelleri).

Adult Description: Typically 27-47 cm TL, but up to nearly 80 cm TL. Heavy-bodied and fusiform with a ventral mouth and lacking a distinct dorsal keel. Head large, 20% of TL, with relatively large eyes. Lower lip lobes moderately large and fleshy with moderately large papillae and a nearly full median cleft, continuous with upper lip (not notched) at outer corners. Dorsal fin moderate in size, usually with truncate posterior margin. Caudal peduncle depth usually about 8% of SL. Typically bi-colored, brown above and yellow below. (Also, Table 6.)

Reproduction: Non-guarding, open-substrate lithophil. Spawn from February-July, usually March-May, when day-time water temperatures reach 11-19°C. Usually spawn over gravel-cobble riffles, where demersal, adhesive eggs develop in interstitial spaces. Water-hardened eggs are 3.0-3.6 (usually 3.2-3.6) mm diameter.

Young: Hatch in 7-8 d when incubated for 3 d at 15-16°C and 4-5 d at 20-22°C. Late protolarvae and mesolarvae are transported in considerable numbers downstream after emergence from spawning substrate. Larvae occupy near-shore, low-velocity channel margins, backwaters, eddies, and pools. Mesolarvae consume early instars of chironomids and other small invertebrates.

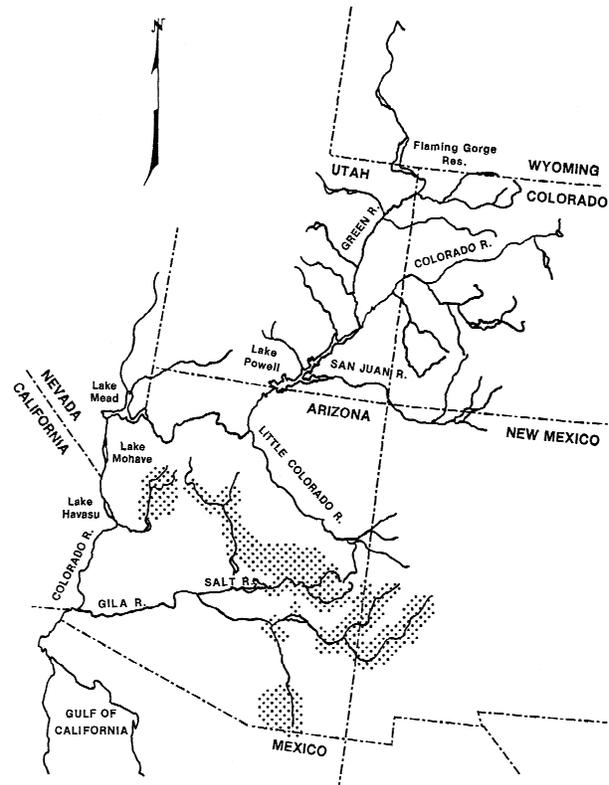


Fig. 14. Recent distribution of *Catostomus insignis* in the Colorado River Basin.

Table 6. Selected juvenile and adult meristics for *Catostomus insignis*. (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 values in parentheses.)

Character	Original	Literature	Character	Original	Literature
Dorsal-fin rays - P	(10) <u>11-12</u>	(10)11-12(13)	Dorsal-fin rays - R	(2)3-4	–
Anal-fin rays - P	7	7(8)	Anal-fin rays - R	2-3	–
Caudal-fin rays - P	18	18(19)	Caudal-fin rays - RD	<u>10-11-12-13</u>	–
Pectoral-fin rays	<u>16-17</u> (18)	16-18	Caudal-fin rays - RV	(8)9-10	–
Pelvic-fin rays	10-11	9-11	Lateral scales	(51-) <u>53-58</u>	54- <u>60-62-67</u>
Vertebrae	47-48	–	Gill rakers	–	24- <u>26-30</u>

Table 7. Size at onset of selected developmental events for *Catostomus insignis*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	9-10(11)	(9)10-11	Dorsal - P	14-15	16-17	18	21-22
Eyes pigmented	11	11	Anal - P	18	20-21	(18)19-21(22)	(22)23-24(25)
Yolk assimilated	(13)14-16	(14)15-17	Caudal - P	(12)13-14	(13)14-15	(13)14-16	(14)15-17
Finfold absorbed	(24)25-26	30-32(33)	Caudal - R	16-17	18	21-24	25-29
Pectoral-fin buds	*	*	Pectoral	17-18	19-20	22-23	27
Pelvic-fin buds	14-16	15-18	Pelvic	18-19(20)	22-23	21(22)	25
* before hatching			Scales	30-31	36-37	32-33	39-40

References: Baird and Girard 1854b, Bestgen unpublished data, Bestgen 1989, Bestgen et al. 1987a & b, Clarkson and Minckley 1988, Hubbs and Miller 1953, Hubbs et al. 1943, Minckley 1973, Moore 1968, Smith 1966, Sublette et al. 1990, Winn and Miller 1954.

Table 8. Size at developmental interval (left) and gut phase (right) transitions for *Catostomus insignis*. (See Figure 5 for phases of gut folding. Rare values in parentheses.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	(12)13-14	(13)14-15	2 - 90° bend	(18)19-20	(22)23
Postflexion mesolarva	(13)14-16	(14)15-17	3 - Full loop	22	26-27
Metalarva	(18)19-21(22)	(22)23-24(25)	4 - Partial crossover	(24)25-26	30-32
Juvenile	(24)25-26	30-32(33)	5 - Full crossover	(31)32-33	(37-)39-40

Table 9. Summary of morphometrics and myomere counts by developmental phase for *Catostomus insignis*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. SD value of 0 actually between 0.0 and 0.5.)

	Protolarvae (N=15)			Flexion mesolarvae (N=21)			Postflexion mesolarvae (N=14)			Metalarvae (N=15)			Juveniles (N=17)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	12	1	11 - 14	14	1	12 - 16	17	2	13 - 20	22	2	18 - 26	32	5	24 - 40
TL, mm	12	1	11 - 15	15	1 ^a	13 - 17	20	2	15 - 23	27	3	22 - 33	38	5	30 - 48
<u>Lengths %SL</u>															
AS to AE	2	0	1 - 3	3	1	2 - 4	5	2	3 - 7	8	1	6 - 9	10	1	8 - 11
PE	8	1	8 - 10	10	1	9 - 11	12	2	10 - 15	15	1	13 - 17	17	1	16 - 18
OP1	15	1	14 - 17	18	1	17 - 20	23	2	19 - 27	28	1	26 - 30	29	1	27 - 31
OP2							52	2 ^b	50 - 56	56	2	52 - 58	57	1	54 - 58
PY	78	1 ^c	76 - 79	72	4 ^d	57 - 77									
OPAF	32	17 ^e	21 - 68	25	2 ^a	22 - 29	29	3	24 - 34	52	12	35 - 67			
ODF	35	2 ^b	33 - 38	37	1	35 - 39	42	2 ^c	39 - 47						
OD							48	1 ^b	47 - 50	49	1	47 - 51	50	1	48 - 51
ID							63	1 ^f	62 - 65	65	1	64 - 66	66	1	64 - 67
PV	79	1	77 - 81	78	1	77 - 80	80	1	78 - 81	77	1	75 - 79	76	1	75 - 77
OA							79	1 ^e	77 - 80	76	1	75 - 78	76	1	74 - 77
IA							86	^g	86 - 86	85	1	83 - 86	84	1	83 - 85
AFC							111	1 ^c	109 - 113	114	1	112 - 117	115	1	114 - 116
PC	104	1	102 - 107	107	1	104 - 108	114	3	109 - 118	120	2	117 - 124	121	1	119 - 123
Y	62	4 ^b	54 - 66	43	16 ^a	0 - 58									
P1	5	2	3 - 10	11	1	8 - 13	12	1	11 - 14	17	1	14 - 20	17	1	15 - 19
P2							4	2	0 - 7	12	1	10 - 14	14	1	12 - 15
D							18	2 ⁱ	16 - 20	23	1	22 - 26	24	1	22 - 26
A							10	^g	10 - 10	13	1	11 - 15	16	1	15 - 17
<u>Depths %SL</u>															
at BPE	9	1	8 - 11	11	1	11 - 13	14	1	12 - 17	18	1	17 - 20	19	0	18 - 19
OP1	11	1	10 - 13	12	1	11 - 14	17	2	13 - 20	21	1	19 - 24	23	0	22 - 24
OD	15	2 ^c	11 - 18	11	1	9 - 14	14	3	10 - 20	20	2	17 - 22	22	1	20 - 24
BPV	6	1	5 - 7	7	0	6 - 7	7	1	6 - 9	10	1	9 - 12	12	1	11 - 13
AMPM	3	1	2 - 4	5	0	4 - 5	7	1	5 - 8	8	1	7 - 9	9	0	8 - 10
Max. yolk	12	3 ^b	9 - 20	4	3	0 - 9									
<u>Widths %SL</u>															
at BPE	9	1	8 - 10	11	0	10 - 11	13	1	11 - 16	17	1	16 - 19	18	0	17 - 18
OP1	7	1 ^c	6 - 8	8	1	7 - 10	11	2	9 - 14	16	2	13 - 19	18	1	17 - 20
OD	11	3 ^c	8 - 19	7	1	5 - 10	8	2	6 - 10	14	1	12 - 16	16	1	14 - 17
BPV	4	0	3 - 4	4	0	4 - 5	5	1	4 - 6	7	1	7 - 9	9	1	8 - 10
AMPM	2	0	2 - 3	3	0	2 - 3	3	0	2 - 4	4	0	4 - 5	4	0	4 - 5
Max. yolk	12	4 ⁱ	8 - 18	5	3 ^k	0 - 10									
<u>Myomeres</u>															
to PY	38	1 ^l	36 - 39	35	3 ^k	27 - 38									
OPAF	13	9 ^e	5 - 30	6	1 ^a	5 - 9	6	1	5 - 9	20	7	9 - 28			
OP2							21	1 ^b	20 - 22	21	1	20 - 22	21	1 ^m	20 - 23
ODF	12	1 ^m	10 - 14	14	1 ^a	11 - 15	15	1 ^c	13 - 17						
OD							18	1 ^b	17 - 19	17	1	16 - 18	17	1 ^m	16 - 18
PV	39	1 ^m	37 - 40	39	1 ^a	38 - 41	39	1	38 - 40	37	1	36 - 39	37	1 ^m	36 - 39
Total	47	1 ^m	46 - 48	48	1 ^a	46 - 49	48	1	47 - 49	48	1	46 - 50	48	1 ^m	47 - 49
After PV	9	1 ^m	7 - 9	9	1 ^a	8 - 9	9	1	8 - 10	10	1	8 - 12	11	1 ^m	8 - 12

^aN = 20. ^bN = 12. ^cN = 13. ^dN = 19. ^eN = 7. ^fN = 4. ^gN = 1. ^hN = 11. ⁱN = 6. ^jN = 5. ^kN = 18. ^lN = 9. ^mN = 10.

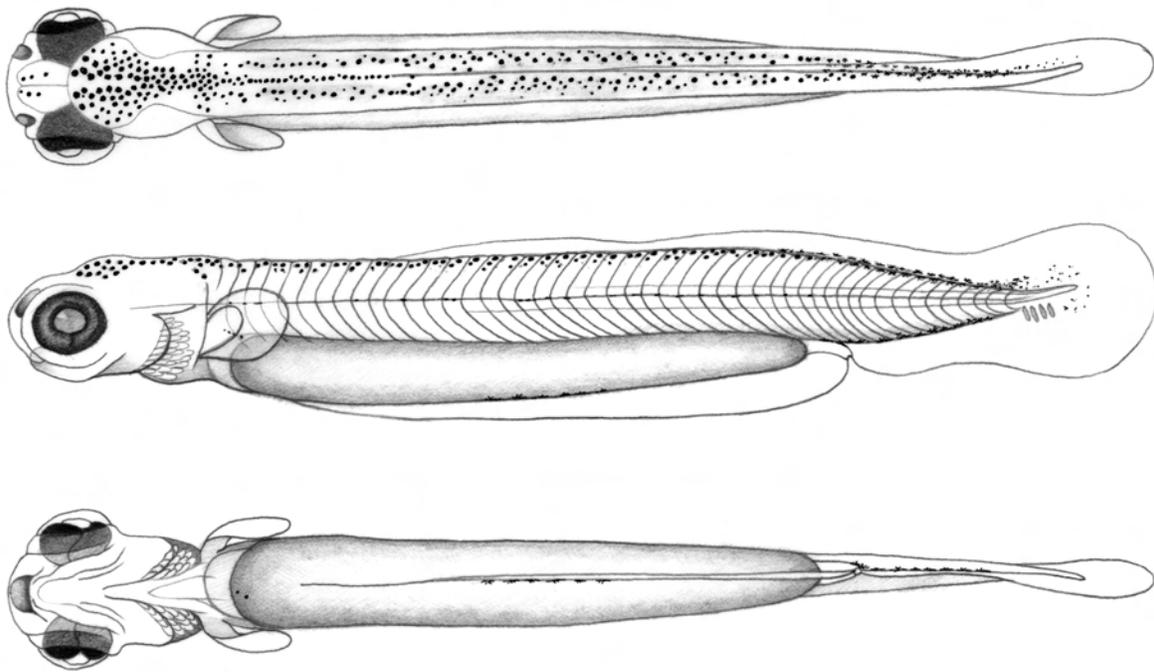


Fig. 15. *Catostomus insignis* protolarva, 14.3 mm SL, 15.3 mm TL (almost flexion mesolarva). (Collected in 1984 from the Gila River near Cliff, New Mexico.)

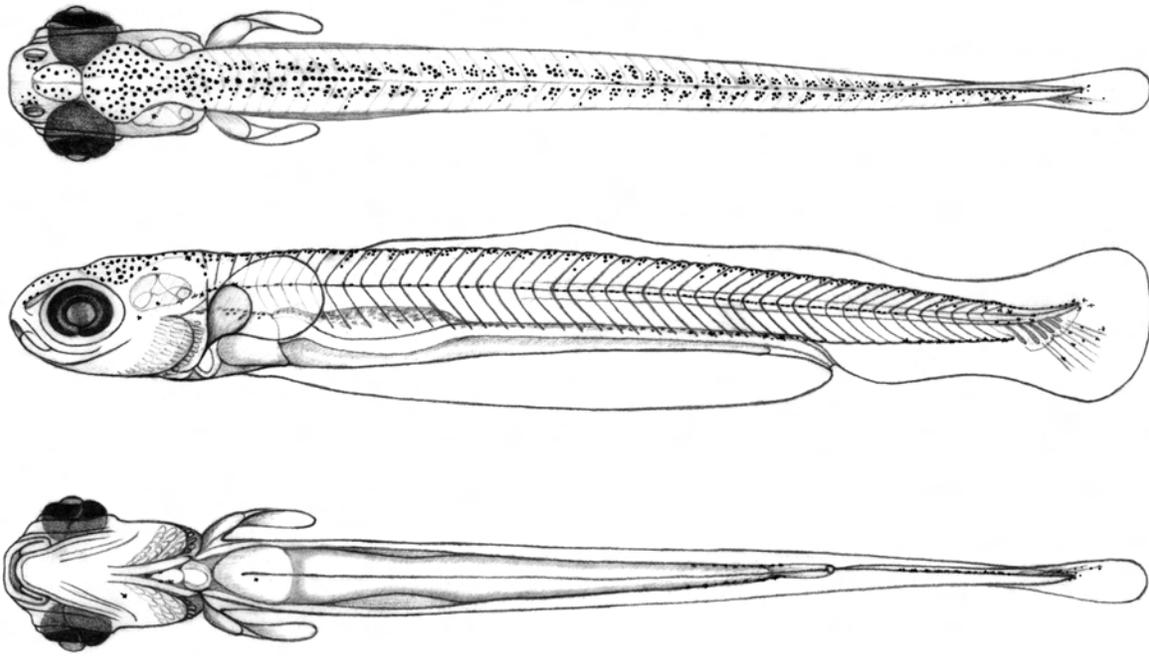


Fig. 16. *Catostomus insignis* flexion mesolarva, recently transformed, 15.7 mm SL, 16.7 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

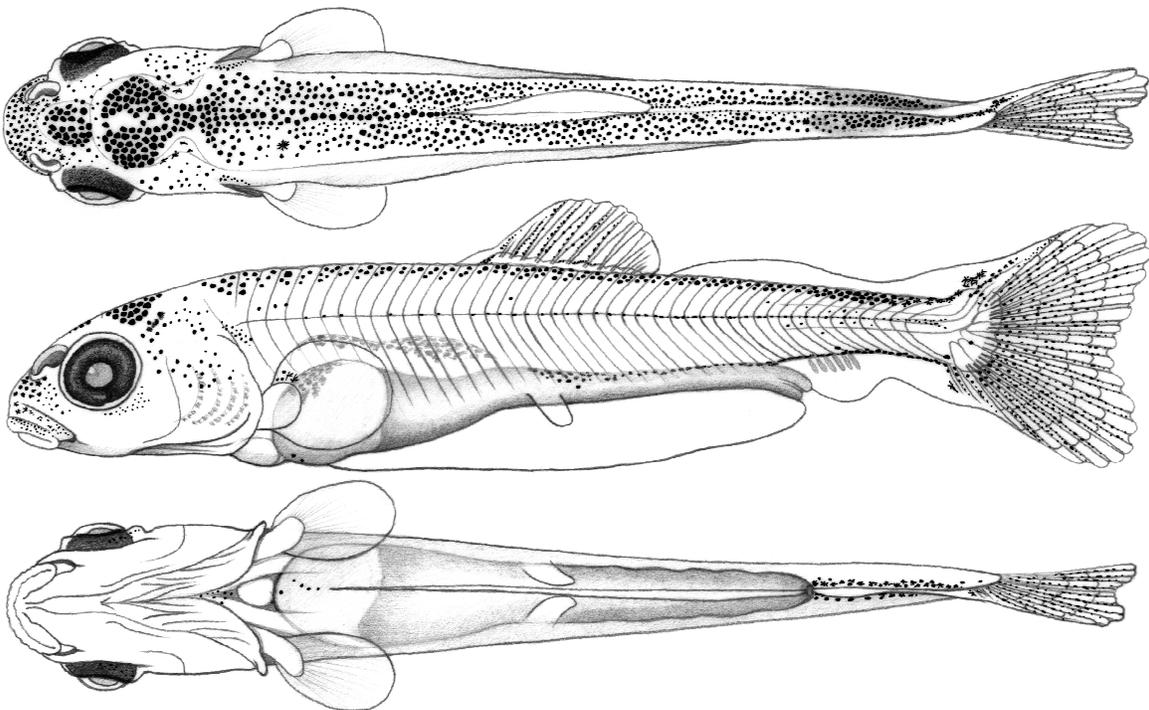


Fig. 17. *Catostomus insignis* postflexion mesolarva, 18.1 mm SL, 20.9 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

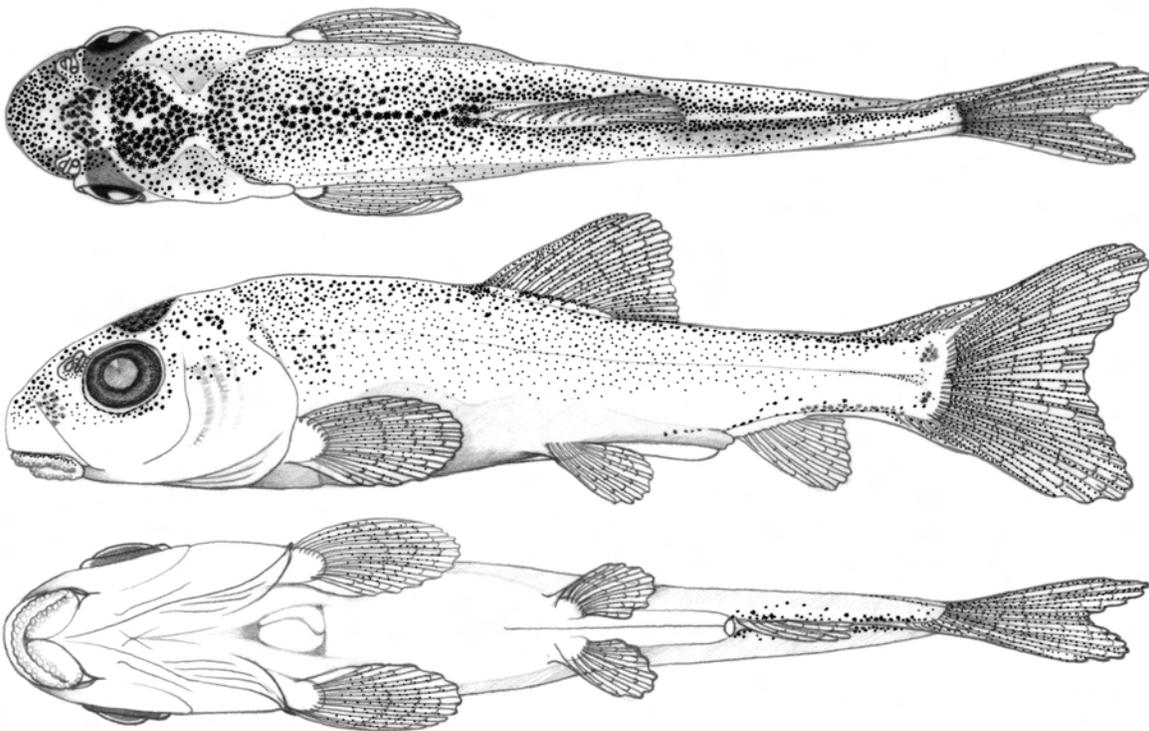


Fig. 18. *Catostomus insignis* metalarva, 21.9 mm SL, 26.3 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

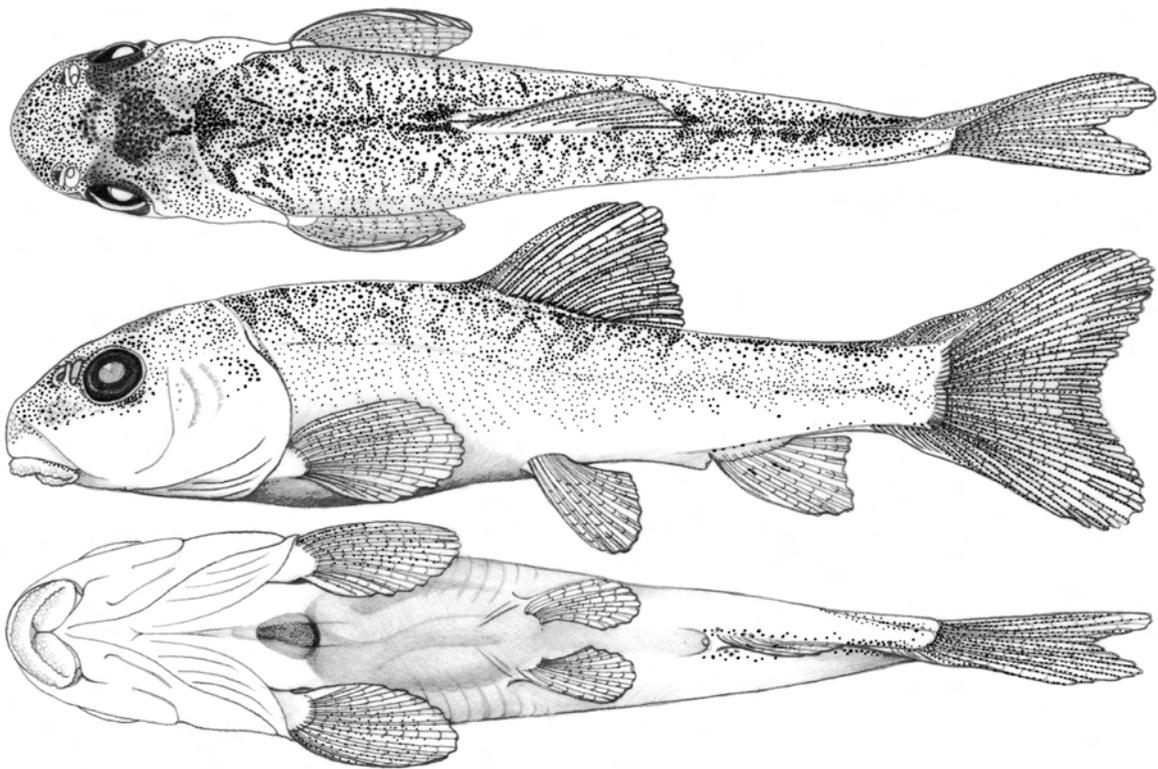


Fig. 19. *Catostomus insignis* juvenile, 30.8 mm SL, 36.9 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

Species Account – *Catostomus latipinnis*



Fig. 20. *Catostomus latipinnis* adult (© Joseph R. Tomelleri).

Adult Description: Usually 30-40 cm, but up to 60 cm TL. Lacking conspicuous predorsal keel. Caudal peduncle slender, typically $\leq 6\%$ SL. Mouth inferior, moderate in size; lacking prominent cartilaginous ridges along inside of jaws. Lips large, fleshy, profuse with large papillae, without notches at corners; lower lip with a deep median cleft allowing one or no rows of papillae to span the two lobes; lobes extend beyond vertical from nostrils, sometimes to eyes. Dorsal fin large and falcate. Scales small. Fontanelle present. (Also, Table 10.)

Reproduction: Non-guarding, open-substrate lithophil. Spawn from April to August, mostly May to mid-June, 6 to at least 13°C (also early autumn in Grand Canyon, possibly elsewhere). Usually over gravel-cobble bars or riffles, or coarse gravel in <1.2 m of water. Sometimes migrate to spawning grounds. Water-hardened eggs 3.8-3.9 mm diameter, demersal, initially adhesive.

Young: Larvae, predominately mesolarvae, drift day or night depending on conditions. Young typically occupy slow to quiet and shallow waters along shore and in backwaters or pools; often in the marginal areas of swift-flowing streams; not common in sluggish, very warm areas.

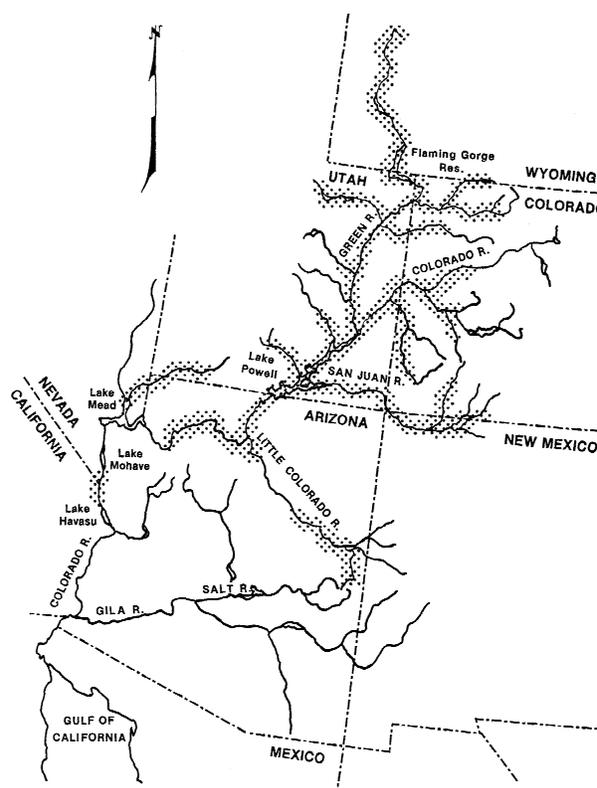


Fig. 21. Recent distribution of *Catostomus latipinnis* in the Colorado River Basin.

Table 10. Selected juvenile and adult meristics for *Catostomus latipinnis*. (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 values in parentheses.)

Character	Observed*	Literature	Character	Observed*	Literature
Dorsal-fin rays - P	(11)12-13(14)	(10)11-12-13-14(15)	Dorsal-fin rays - R	3-4	–
Anal-fin rays - P	7	7(8)	Anal-fin rays - R	(1)2-3	–
Caudal-fin rays - P	18	–	Caudal-fin rays - RD	10- <u>11</u> -14	–
Pectoral-fin rays	15- <u>16</u> -17	18	Caudal-fin rays - RV	9- <u>10</u> -11	–
Pelvic-fin rays	(9)10(11)	9- <u>10</u> -11	Lateral scales	–	89-98-105-116(-120)
Vertebrae	47-50	–	Gill rakers	–	25- <u>27</u> -31-32(-35)

*From Snyder 1981 and Snyder and Muth 1990 and 2004.

Table 11. Size at onset of selected developmental events for *Catostomus latipinnis*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	(8-)10-11	(8-)10-11	Dorsal - P	15	16	17-18	20-22
Eyes pigmented	(9)10 or *	(9)10 or *	Anal - P	17	18-19	19-20(21)	23-24
Yolk assimilated	(14)15(16)	(15)16-17	Caudal - P	13	13(14)	(14)15(16)	(15)16(17)
Finfold absorbed	23-24(25)	28-29(31)	Caudal - R	(15-)17	(16-)18(19)	23	28-29
Pectoral-fin buds	(9) or *	(9) or *	Pectoral	17	18-19	19-22	22-27
Pelvic-fin buds	(15)16(17)	17-18	Pelvic	17-18	19-20	23	(28)29
* before hatching			Scales	(36)37-39	(44)45-49	39-42	48-51

References: Baird & Girard 1854a, Baxter & Stone 1995, Behnke et al. 1982, Beckman 1952, Bezzerides & Bestgen 2002, Carlson et al. 1979, Douglas & Douglas 2000, Holden 1973, Hubbs & Hubbs 1947, Hubbs & Miller 1953, Hubbs et al. 1943, Jordan & Evermann 1896, Joseph et al. 1977, La Rivers 1962, McAda 1977, Miller 1952, Minckley 1973, Mueller & Wydoski 2004, Prewitt 1977, Sigler & Miller 1963, Snyder 1981, Snyder & Muth 1990 & 2004, Sublette et al. 1990, Tyus et al. 1982, Wheeler 1997, Winn & Miller 1954, Woodling 1985.

Table 12. Size at developmental interval (left) and gut phase (right) transitions for *Catostomus latipinnis*. (See Figure 5 for phases of gut folding. Rare values in parentheses. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	13	13(14)	2 - 90° bend	(17)18(-20)	(20)21(-24)
Postflexion mesolarva	(14)15(16)	(15)16(17)	3 - Full loop	(19-)21-25(-27)	(23-)26-30(-33)
Metalarva	19-20(21)	23-24	4 - Partial crossover	(22)23-32(-37)	(27)28-39(-46)
Juvenile	23-24(25)	28-29(-31)	5 - Full crossover	(29-)35-42	(36-)40-51

Table 13. Summary of morphometrics and myomere counts by developmental phase for *Catostomus latipinnis*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. Mean and SD values of 0 actually between 0.0 and 0.5. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

	Protolarvae (N=9)			Flexion mesolarvae (N=10)			Postflexion mesolarvae (N=20)			Metalarvae (N=15)			Juveniles (N=19)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	11	1	10 - 13	14	1	13 - 15	17	2 ^m	14 - 20	22	1	20 - 25	32	6	23 - 43
TL, mm	12	1	11 - 13	14	1	14 - 16	19	3 ^m	15 - 24	27	2 ^h	24 - 31	40	7	29 - 53
<u>Lengths %SL</u>															
AS to AE	2	0	2 - 3	3	1	3 - 4	6	1	3 - 7	7	1	6 - 8	8	1	7 - 10
PE	7	1	6 - 9	9	1	8 - 10	12	1	9 - 14	13	1	12 - 14	14	1	13 - 15
OP1	14	1	12 - 16	18	1	16 - 19	23	2	19 - 27	26	1	24 - 28	25	1	24 - 28
OP2							53	1 ^a	50 - 54	55	1	52 - 57	55	1	52 - 57
PY	78	2	75 - 81	69	9	48 - 75	60	8 ^b	50 - 72						
OPAF	54	19	32 - 77	26	3	22 - 32	34	5 ^c	27 - 44	55	11	34 - 67			
ODF	35	2	33 - 38	38	2	35 - 40	44	3 ^d	36 - 48	45	0 ⁱ	45 - 45			
OD							50	1 ^a	49 - 51	49	1	47 - 51	48	1	46 - 49
ID							64	1 ^e	62 - 67	65	1	62 - 67	65	1	61 - 66
PV	79	1	77 - 81	77	1	75 - 78	78	1	76 - 80	75	2	74 - 78	74	1	72 - 76
OA							78	1 ^f	76 - 80	75	1	74 - 78	75	1	72 - 77
IA							84	1 ^g	83 - 84	82	1	81 - 84	82	1	80 - 85
AFC							110	2 ^m	107 - 112	113	1	111 - 114	114	1 ^j	112 - 116
PC	103	1	102 - 105	105	1	104 - 107	113	4 ^m	107 - 123	122	2 ^h	117 - 125	123	1	121 - 125
Y	61	5	54 - 67	42	17 ^l	0 - 54	7	14 ^m	0 - 46						
P1	6	2	3 - 9	11	1	9 - 12	12	1	10 - 15	16	1	14 - 18	18	1	16 - 19
P2							4	2	0 - 7	11	2	9 - 13	14	1	11 - 15
D							18	2 ^a	15 - 21	22	1	20 - 24	24	1	23 - 26
A							8	1 ^d	5 - 9	12	2	9 - 14	14	1	12 - 16
<u>Depths %SL</u>															
at BPE	8	1	7 - 9	10	1	9 - 11	13	1	11 - 16	16	1	15 - 17	16	1	15 - 17
OP1	9	1	8 - 10	11	1	10 - 12	16	2	13 - 18	19	1	16 - 21	19	1	17 - 22
OD	14	1	13 - 15	11	1	9 - 13	14	3 ^c	10 - 19	19	2	16 - 22	19	1	17 - 22
BPV	5	1	4 - 6	6	0	5 - 6	8	1	6 - 10	11	1	9 - 12	11	1	10 - 13
AMPM	3	1	2 - 3	3	0	3 - 4	6	1	4 - 7	7	0	6 - 8	7	0	7 - 8
Max. yolk	12	3	9 - 16	5	3 ^l	0 - 9	0	1 ^m	0 - 3						
<u>Widths %SL</u>															
at BPE	8	1	6 - 9	10	1	9 - 12	13	1	10 - 15	16	1	14 - 17	15	1	15 - 17
OP1	7	1	6 - 9	7	1	6 - 8	11	1	8 - 13	14	1	13 - 16	16	1	14 - 17
OD	10	1	7 - 11	6	1	5 - 8	8	2	6 - 12	12	1	10 - 15	13	2	11 - 17
BPV	3	0	3 - 4	4	1	4 - 6	6	1	4 - 8	7	1	6 - 8	8	1	6 - 9
AMPM	2	0	1 - 2	2	0	1 - 2	3	0	2 - 3	4	0	3 - 4	4	0	3 - 5
Max. yolk	13	3	9 - 18	5	3 ^l	0 - 9	1	2 ^m	0 - 5						
<u>Myomeres</u>															
to PY	38	1	37 - 39	34	5	22 - 38	28	6 ^b	21 - 35						
OPAF	23	11	10 - 37	7	2	5 - 10	9	3 ^c	6 - 15	22	8 ^c	9 - 32			
OP2							21	1 ^a	19 - 23	22	1 ^e	21 - 24	22	1 ^k	21 - 23
ODF	12	2	10 - 15	13	1	12 - 15	15	1 ^h	12 - 17	15	1 ⁱ	14 - 15			
OD							18	1 ^a	17 - 21	18	1 ^e	16 - 19	18	1 ^k	17 - 19
PV	39	1	38 - 40	39	1	38 - 40	39	1	37 - 40	37	1 ^e	36 - 38	37	1 ^k	36 - 38
Total	48	1	47 - 49	48	1	47 - 49	48	1	47 - 49	47	1 ^e	46 - 48	48	1 ^k	47 - 48
After PV	9	1	8 - 10	9	1	8 - 11	9	1	8 - 10	10	0 ^e	9 - 10	11	1 ^k	9 - 12

^aN = 17. ^bN = 6. ^cN = 19. ^dN = 12. ^eN = 14. ^fN = 15. ^gN = 7. ^hN = 13. ⁱN = 2. ^jN = 18. ^kN = 9. ^lN = 11. ^mN = 25.

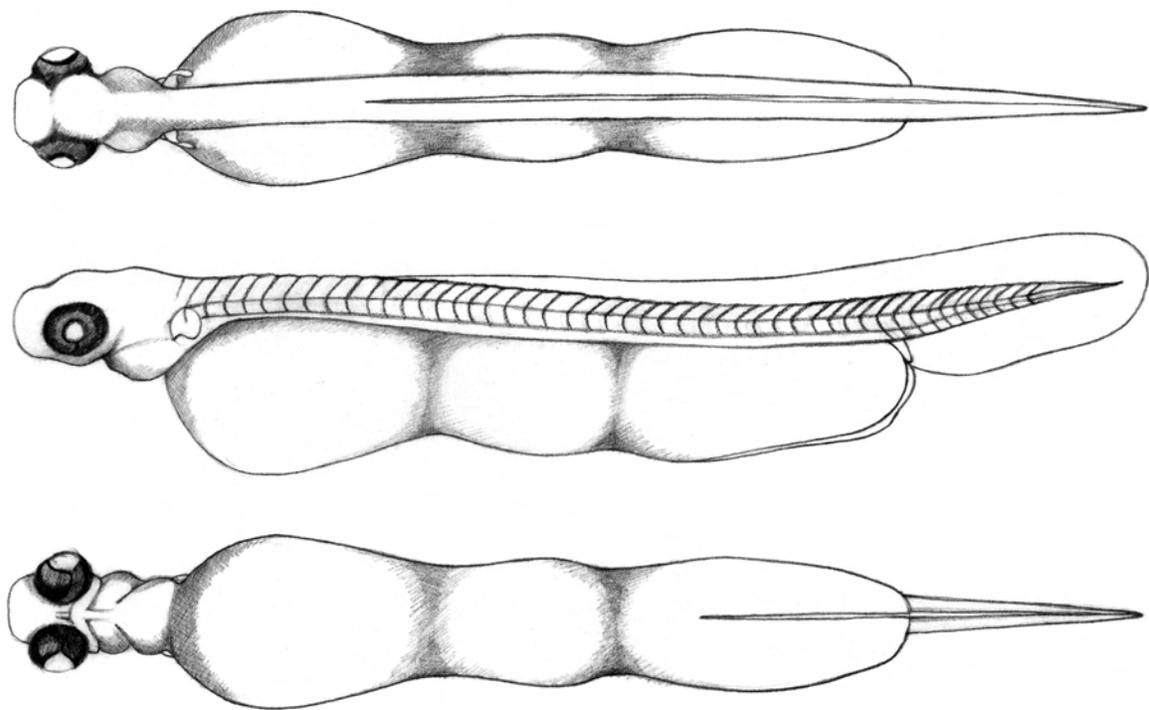


Fig. 22. *Catostomus latipinnis* protolarva, recently hatched, 10.3 mm SL, 10.6 mm TL. (Cultured in 1978 with stock from the Yampa River, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

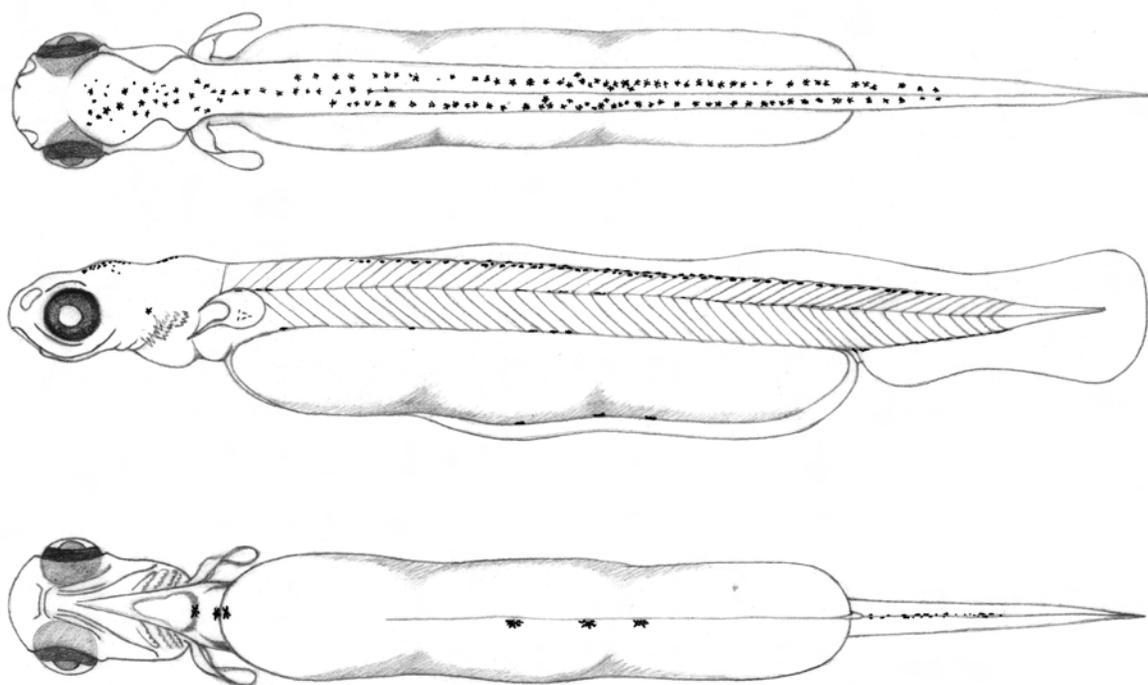


Fig. 23. *Catostomus latipinnis* protolarva, 12.4 mm SL, 12.9 mm TL. (Cultured in 1978 with stock from the Yampa River, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

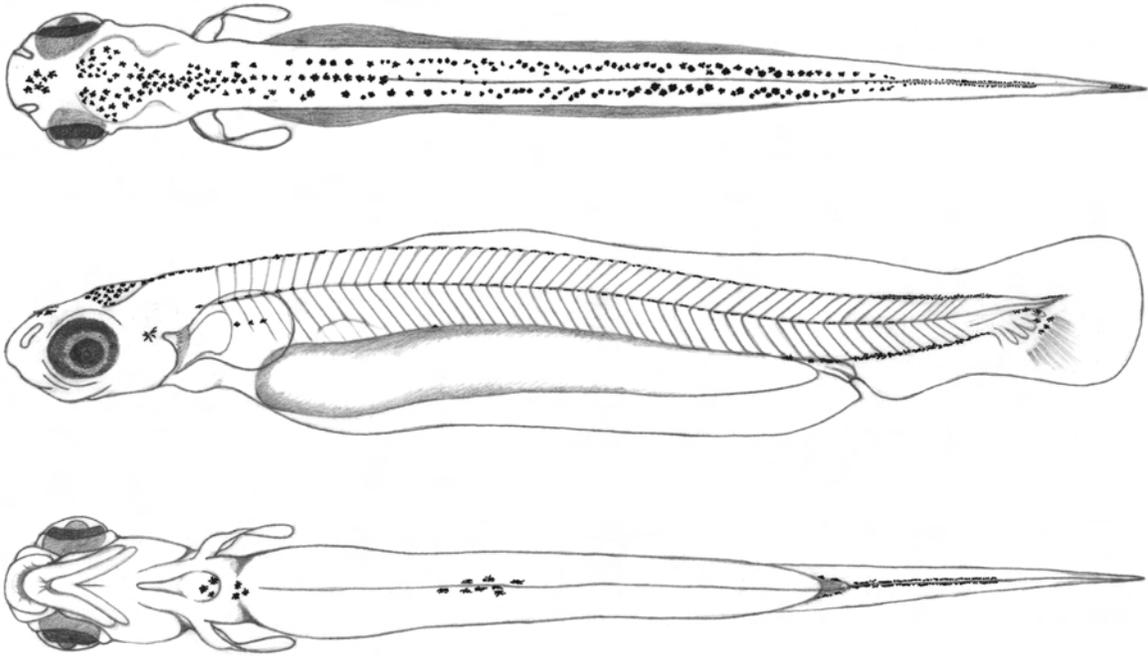


Fig. 24. *Catostomus latipinnis* flexion mesolarva, recently transformed, 13.0 mm SL, 14.0 mm TL. (Cultured in 1978 with stock from the Yampa River, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

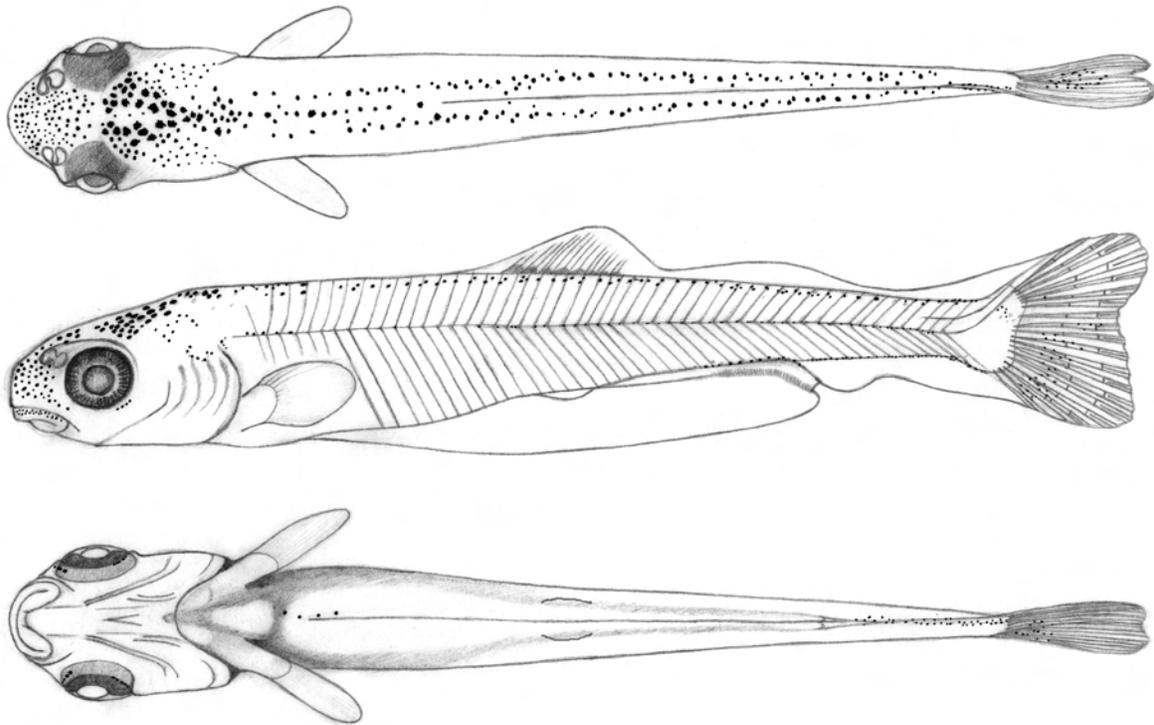


Fig. 25. *Catostomus latipinnis* postflexion mesolarva, 16.8 mm SL, 18.9 mm TL. (Collected in 1976 from the White River, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

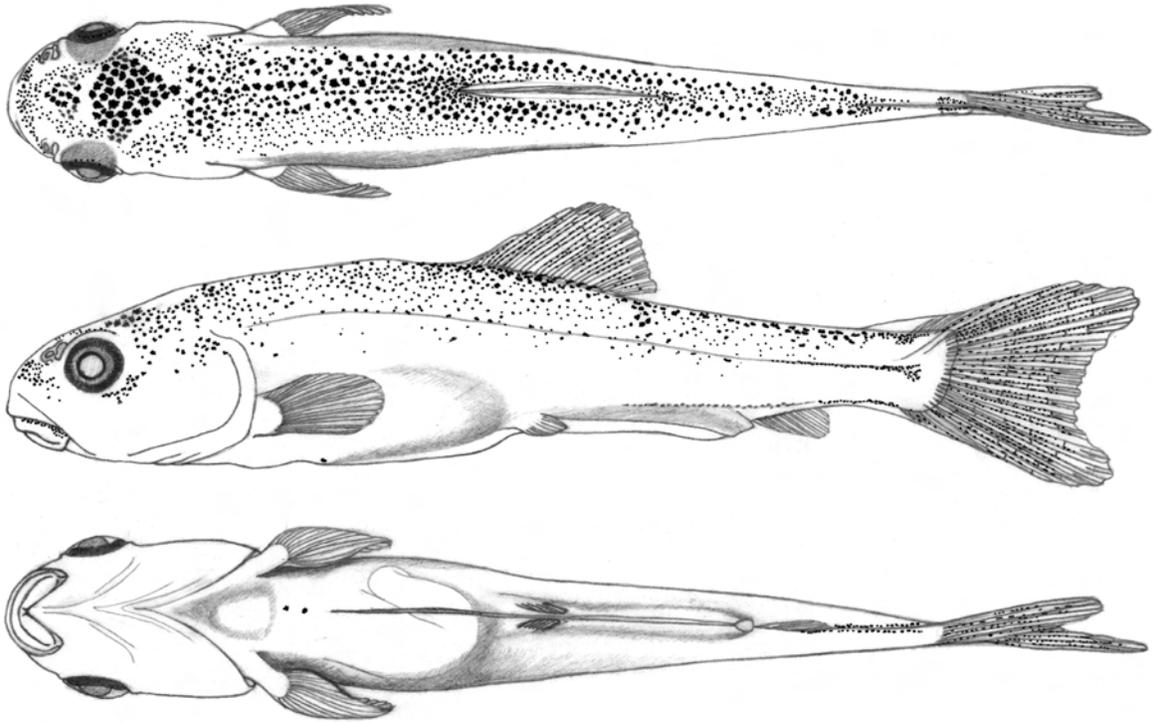


Fig. 26. *Catostomus latipinnis* metalarva, recently transformed, 20.5 mm SL, 24.5 mm TL. (Collected in 1976 from the White River, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

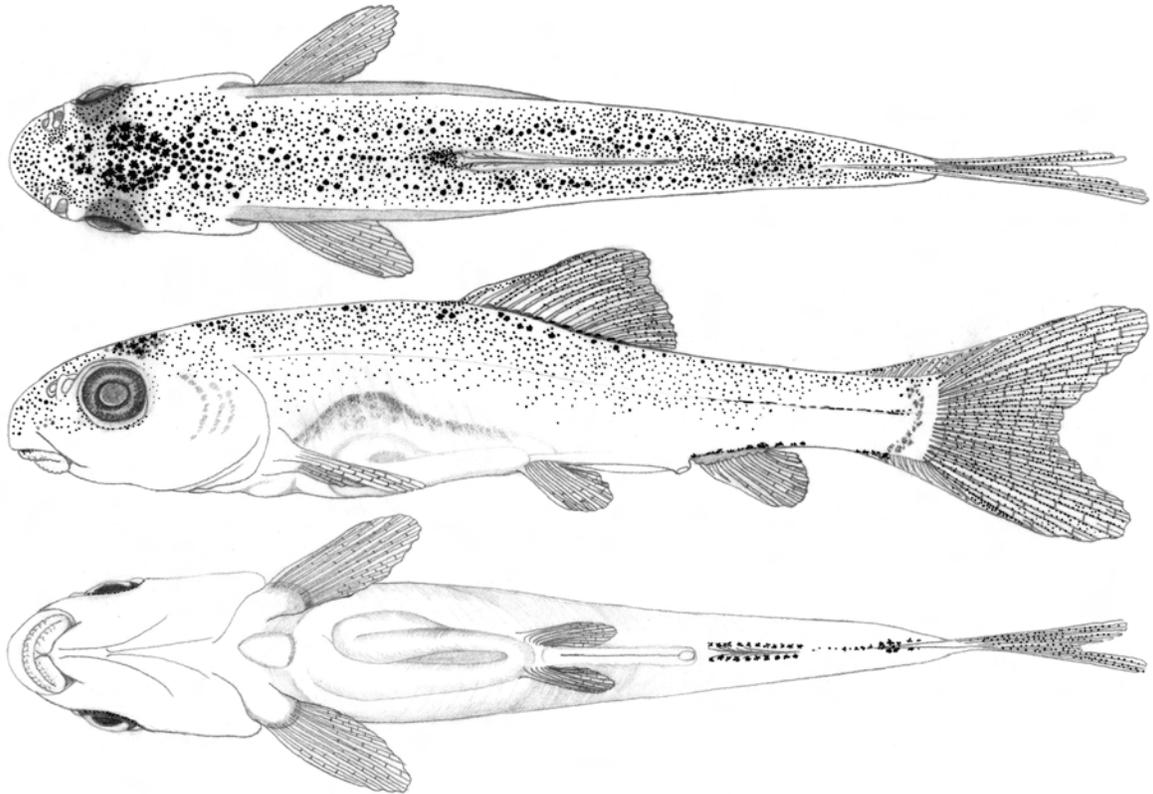


Fig. 27. *Catostomus latipinnis* metalarva, 22.7 mm SL, 27.5 mm TL. (Collected in 1976 from the White River, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

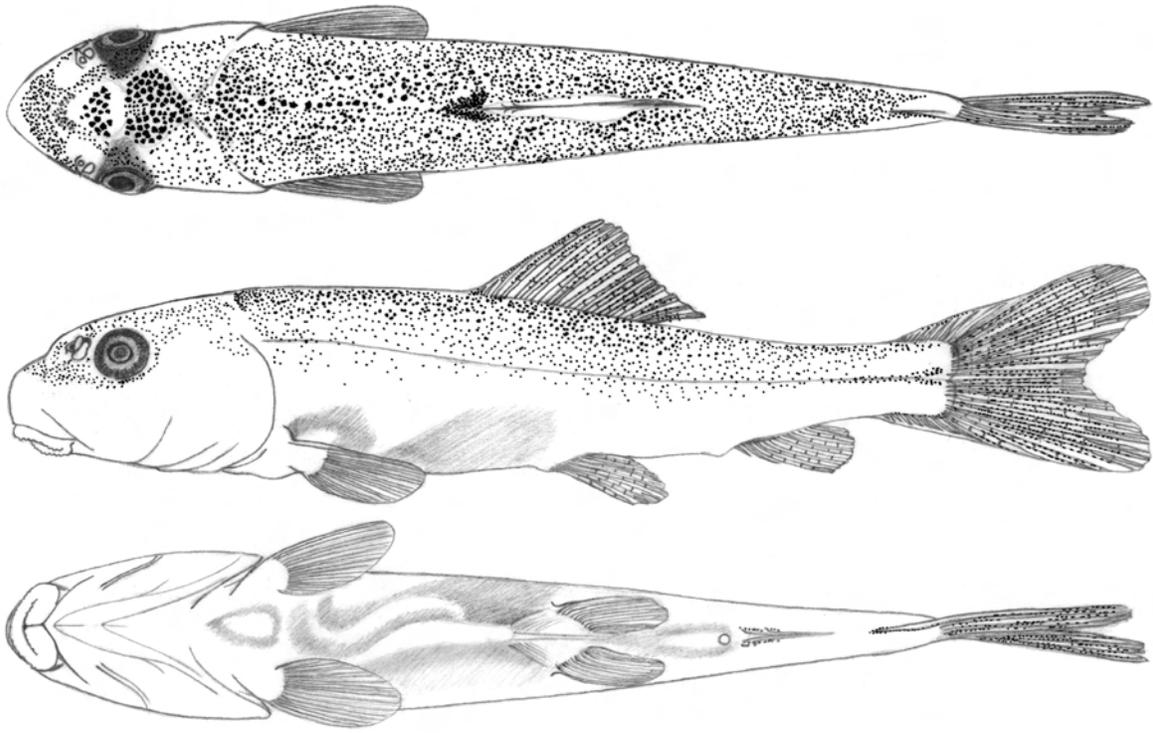


Fig. 28. *Catostomus latipinnis* juvenile, recently transformed, 26.6 mm SL, 32.0 mm TL. (Collected in 1976 from the White River, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

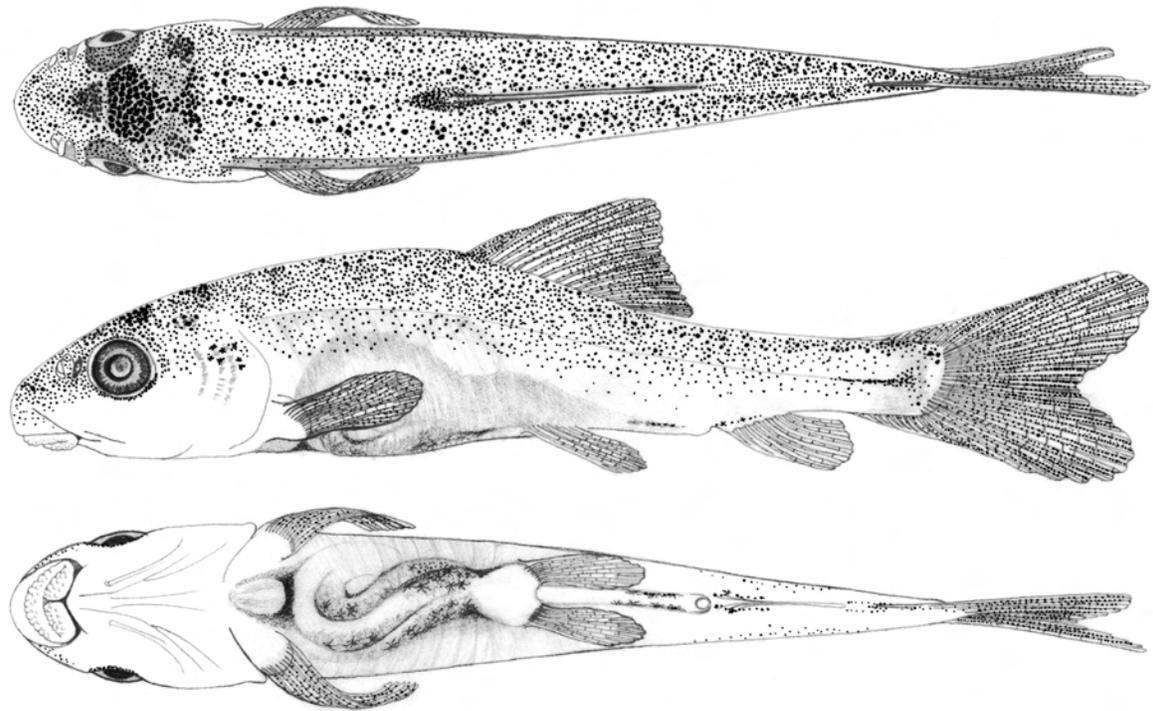


Fig. 29. *Catostomus latipinnis* juvenile, 31.6 mm SL, 38.0 mm TL. (Collected in 1976 from the White River, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

Species Account – *Xyrauchen texanus*

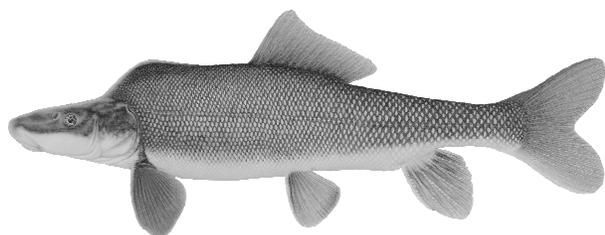


Fig. 30. *Xyrauchen texanus* adult (© Joseph R. Tomelleri).

Adult Description: Usually 40-60 cm, but up to 90 cm TL. Conspicuous predorsal keel. Caudal peduncle deep. Mouth inferior, moderate in size. Lips moderately to weakly papillose, without notches at corners. Lower lip with median cleft that completely separates the two lobes. Fontanelle well developed. Peritoneum black. (Also, Table 14.)

Reproduction: Non-guarding, open-substrate lithophil; possible redd excavator. Spawn usually with rising water levels in mid-April to early June at 6-19°C in the Upper Colorado River Basin, Nov. to May, mostly Jan. to mid-April, at 10-21°C in Lake Mohave. Spawn over gravel-cobble bars or riffles in rivers near tributaries, in backwaters, or over wave-washed sand, gravel, and cobble along shore or in coves of reservoirs; usually in <1 m of water, but up to 6 m. Water-hardened eggs 2.1-3.2, usually 2.5-2.8, mm diameter, demersal, and initially adhesive. Hatching success best at 12-20°C.

Young: At 18-20°C, hatch in 6-7 d, swim up in 12-13 d, and swim down in 27 d; at 15°C, 11 d, 17-21 d, and 38 d respectively. Remain in substrate until swim up, then drift or migrate to nursery grounds in backwaters, coves, or along shore. Attracted by light at night. At about 25 mm TL travel in large schools in warm shallows along shore.

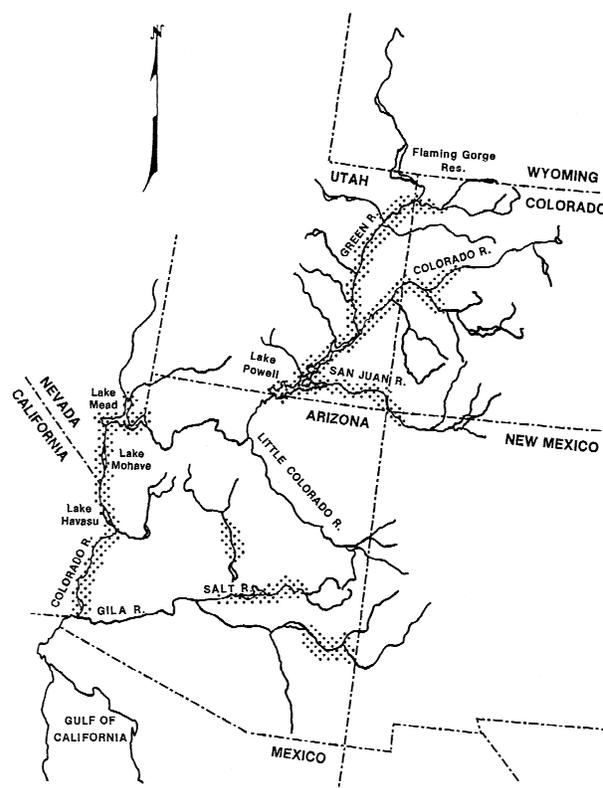


Fig. 31. Recent distribution of *Xyrauchen texanus* in the Colorado River Basin. (includes stocked reaches.)

Table 14. Selected juvenile and adult meristics for *Xyrauchen texanus*. (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 values in parentheses.)

Character	Observed*	Literature	Character	Observed*	Literature
Dorsal-fin rays - P	(12)13-14-15-16	(12)13-14-15-16	Dorsal-fin rays - R	3-4(5)	–
Anal-fin rays - P	(6)7	7	Anal-fin rays - R	(1)2-3	–
Caudal-fin rays - P	18	18	Caudal-fin rays - RD	10-11-12-13	–
Pectoral-fin rays	15-16-17-18	16	Caudal-fin rays - RV	7-8-9-10	–
Pelvic-fin rays	(9)10-11	10	Lateral scales	–	68-76-78-87(-95)
Vertebrae	45-46-47	–	Gill rakers	–	44-50

*From Snyder 1981 and Snyder and Muth 1990 and 2004.

Table 15. Size at onset of selected developmental events for *Xyrauchen texanus*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	7-9	7-10	Dorsal - P	13-14	(14)15	15(-17)	17(-20)
Eyes pigmented	(7)8(9) or *	(7)8-9 or *	Anal - P	(13-)15	(14-)17	15-17	18-20
Yolk assimilated	(9)10-11	(10)11-12	Caudal - P	(10)11(12)	11-12	(11)12-13	(13)14
Finfold absorbed	(21)22-23(24)	27-30	Caudal - R	14	15-16	19-20(-24)	23-24(-30)
Pectoral-fin buds	7 or *	7 or *	Pectoral	(13-)15	(15-)17	16-18	20-22
Pelvic-fin buds	(13)14	15	Pelvic	(13-)15-17	(15-)18-20	16-17	20-21
* before hatching			Scales	24-28	30-35	33-36(37)	42-45

References: Abbott 1860, Baxter and Simon 1970, Beckman 1952, Behnke et al. 1982, Bestgen 1990, Bozek et al. 1984 & 1991, Burdick 2003, Douglas 1952, Ellis 1914, Hubbs and Miller 1953, Jordan and Evermann 1896, La Rivers 1962, McAda 1977, Miller et al. 1982, Minckley 1973, Moyle 1976, Ryden 1997, Sigler and Miller 1963, Snyder 1981, Snyder and Muth 1990 & 2004, Toney 1974, Tyus et al. 1982 & 1987, Wick et al. 1982, Winn and Miller 1954, Woodling 1985.

Table 16. Size at developmental interval (left) and gut phase (right) transitions for *Xyrauchen texanus*. (See Figure 5 for phases of gut folding. Rare values in parentheses. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	(10)11(12)	11-12	2 - 90° bend	(14)15(-17)	(16)17(-20)
Postflexion mesolarva	(11)12-13	(13)14	3 - Full loop	17	20
Metalarva	15-17	18-20	4 - Partial crossover	18-25(26)	22-30(-32)
Juvenile	(21)22-23(24)	27-30	5 - Full crossover	(22-)26-28(-31)	(27-)32-35(-38)

Table 17. Summary of morphometrics and myomere counts by developmental phase for *Xyrauchen texanus*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. Mean and SD values of 0 actually between 0.0 and 0.5. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

	Protolarvae (N=25)			Flexion mesolarvae (N=13)			Postflexion mesolarvae (N=25)			Metalarvae (N=30)			Juveniles (N=33)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	10	1	8 - 11	12	1	11 - 13	14	1	12 - 17	19	2	15 - 24	28	4	22 - 37
TL, mm	10	1	9 - 12	12	1	11 - 14	16	2	13 - 20	23	3	18 - 30	36	6	27 - 47
<u>Lengths %SL</u>															
AS to AE	2	0	1 - 3	2	1	2 - 3	5	1	3 - 7	7	1	4 - 9	8	1	6 - 9
PE	8	0	7 - 8	9	1	7 - 10	11	2	9 - 14	14	1	12 - 17	15	1	13 - 16
OP1	16	1	14 - 17	18	1	16 - 20	22	2	20 - 27	27	1	25 - 30	28	2	25 - 31
OP2							52	1 ^c	50 - 54	56	2	51 - 58	57	2	54 - 60
PY	76	4	66 - 82	75	^b	75 - 75									
OPAF	30	12	22 - 66	27	2	24 - 30	31	3	27 - 36	42	9	34 - 69			
ODF	34	2	32 - 39	37	3	33 - 44	42	3	36 - 45	45	2 ^g	43 - 47			
OD							49	1 ^d	47 - 51	49	1	47 - 51	49	1	46 - 52
ID							66	1 ^e	65 - 67	67	1	65 - 69	67	1	65 - 70
PV	79	2	76 - 81	79	1	78 - 81	81	1	78 - 84	77	2	75 - 81	77	1	75 - 80
OA							81	1 ^f	79 - 82	77	1	76 - 79	78	1	75 - 80
IA							86	0 ^f	85 - 86	84	1	83 - 86	84	1	82 - 86
AFC							110	2	107 - 114	114	1	111 - 117	115	1	113 - 118
PC	105	1	103 - 106	106	1	104 - 108	113	4	108 - 119	123	2	120 - 128	125	1	123 - 128
Y	44	23	0 - 68	4	14	0 - 50									
P1	7	3	3 - 11	10	1	9 - 11	11	1	9 - 13	15	1	12 - 18	17	1	15 - 19
P2							3	3	0 - 7	12	2	8 - 14	15	1	12 - 16
D							19	1 ^e	18 - 21	24	2	21 - 29	27	1	23 - 29
A							7	1 ^g	5 - 9	12	1 ^h	9 - 15	15	1	12 - 16
<u>Depths %SL</u>															
at BPE	9	1	8 - 10	11	1	9 - 13	13	2	11 - 16	16	1	15 - 18	18	1	16 - 20
OP1	11	1	9 - 12	13	1	10 - 14	16	2	13 - 20	20	1	18 - 23	22	1	20 - 23
OD	10	2	7 - 13	9	1	6 - 11	14	3	9 - 20	19	2	16 - 23	23	2	18 - 27
BPV	5	1	4 - 6	6	0	5 - 6	7	1	5 - 9	11	1	8 - 14	13	1	11 - 14
AMPM	3	0	2 - 4	4	1	3 - 5	6	1	4 - 7	8	1	7 - 9	8	0	7 - 9
Max. yolk	5	3	0 - 9	0	1	0 - 2									
<u>Widths %SL</u>															
at BPE	9	1	7 - 11	11	1	10 - 12	12	1	11 - 14	15	1	14 - 17	16	1	15 - 18
OP1	6	1	5 - 8	8	1	6 - 9	10	2	8 - 14	15	2	12 - 17	18	1	15 - 20
OD	6	2	4 - 9	5	0	5 - 6	8	2	5 - 11	11	2	8 - 15	16	2	12 - 20
BPV	3	0	2 - 4	3	0	3 - 4	5	1	3 - 6	6	1	4 - 9	8	1	6 - 9
AMPM	2	0	1 - 3	2	0	2 - 2	3	0	2 - 4	3	0	2 - 4	4	0	3 - 4
Max. yolk	5	3	0 - 9	0	1	0 - 5									
<u>Myomeres</u>															
to PY	37	2 ^a	30 - 38	37	^b	37 - 37									
OPAF	10	6	5 - 31	7	0	6 - 8	7	1	6 - 9	10	5 ⁱ	6 - 30			
OP2							20	1 ^c	19 - 22	20	1 ⁱ	19 - 22			
ODF	12	1	10 - 16	13	1	12 - 16	14	1	12 - 17	14	1 ^g	12 - 15			
OD							18	1 ^d	16 - 20	16	1 ⁱ	15 - 18			
PV	39	1	37 - 41	38	1	37 - 39	39	1	38 - 40	37	1 ⁱ	36 - 39			
Total	48	1	46 - 49	47	1	46 - 49	47	1	46 - 49	46	1 ⁱ	44 - 48			
After PV	9	1	7 - 10	9	1	8 - 10	8	1	7 - 9	9	1 ⁱ	7 - 12			

^aN = 20. ^bN = 1. ^cN = 18. ^dN = 17. ^eN = 7. ^fN = 5. ^gN = 6. ^hN = 29. ⁱN = 27.

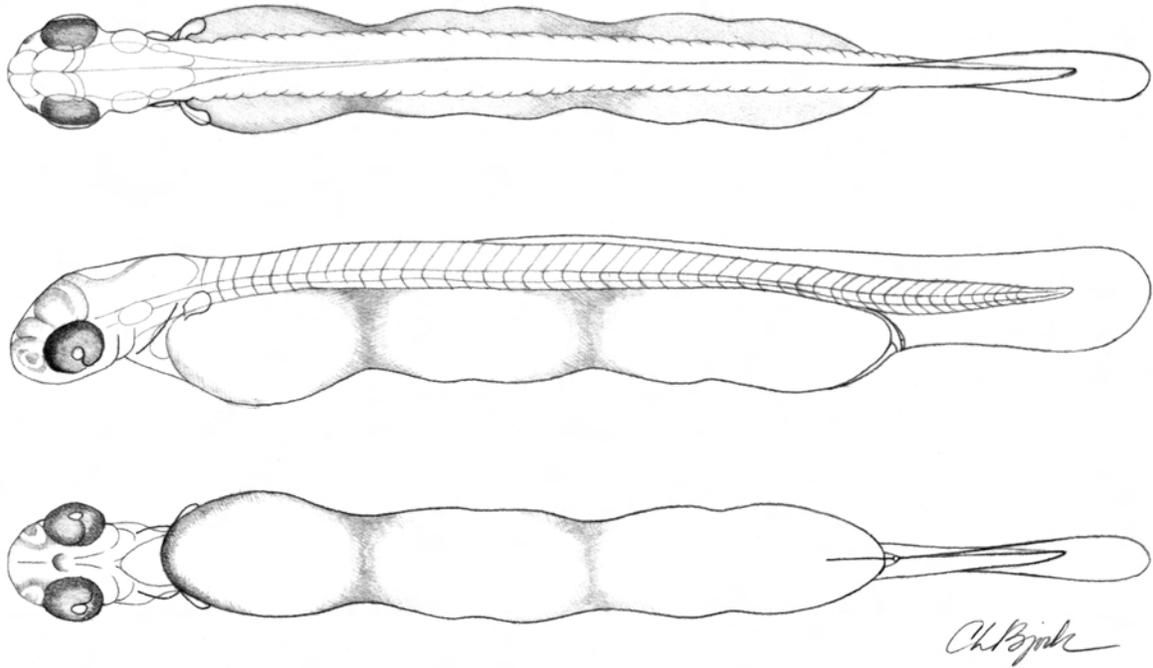


Fig. 32. *Xyrauchen texanus* protolarva, recently hatched, 9.2 mm SL, 9.4 mm TL. (Cultured in 1980 from stock in Colorado River gravel pits near Clifton, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

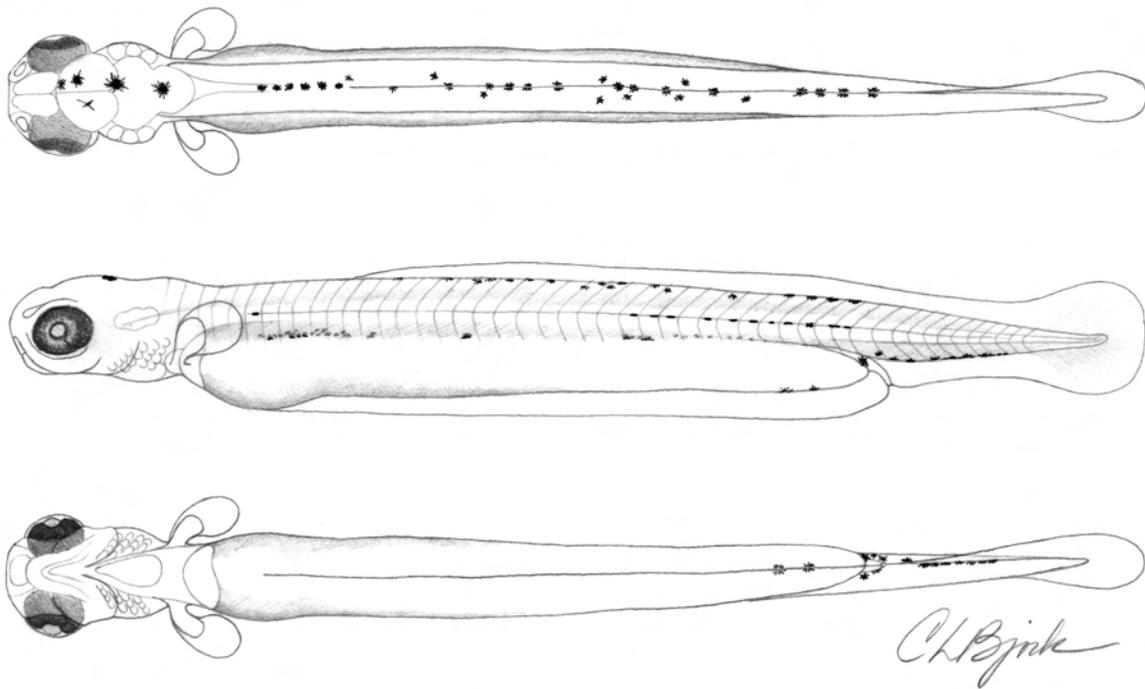


Fig. 33. *Xyrauchen texanus* protolarva, 10.5 mm SL, 10.9 mm TL. (Cultured in 1980 from stock in Colorado River gravel pits near Clifton, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

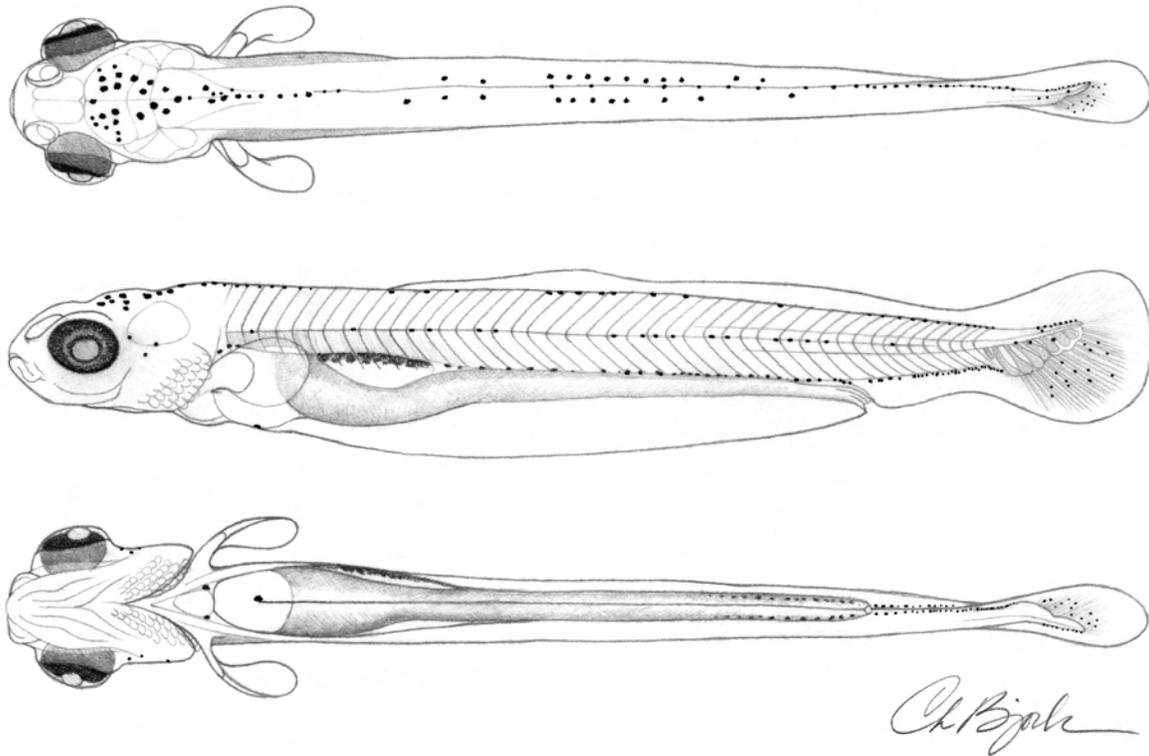


Fig. 34. *Xyrauchen texanus* flexion mesolarva, recently transformed, 12.5 mm SL, 12.9 mm TL. (Cultured in 1980 from stock in Colorado River gravel pits near Clifton, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

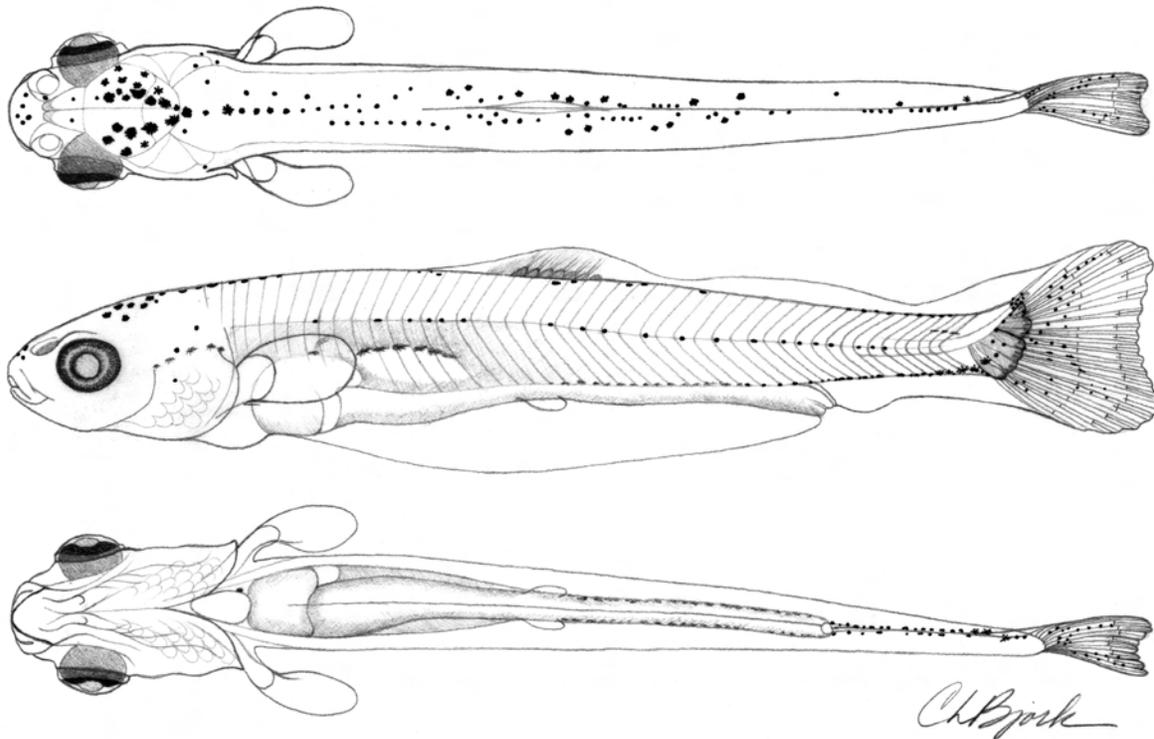


Fig. 35. *Xyrauchen texanus* postflexion mesolarva, 14.4 mm SL, 16.0 mm TL. (Cultured in 1980 from stock in Colorado River gravel pits near Clifton, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

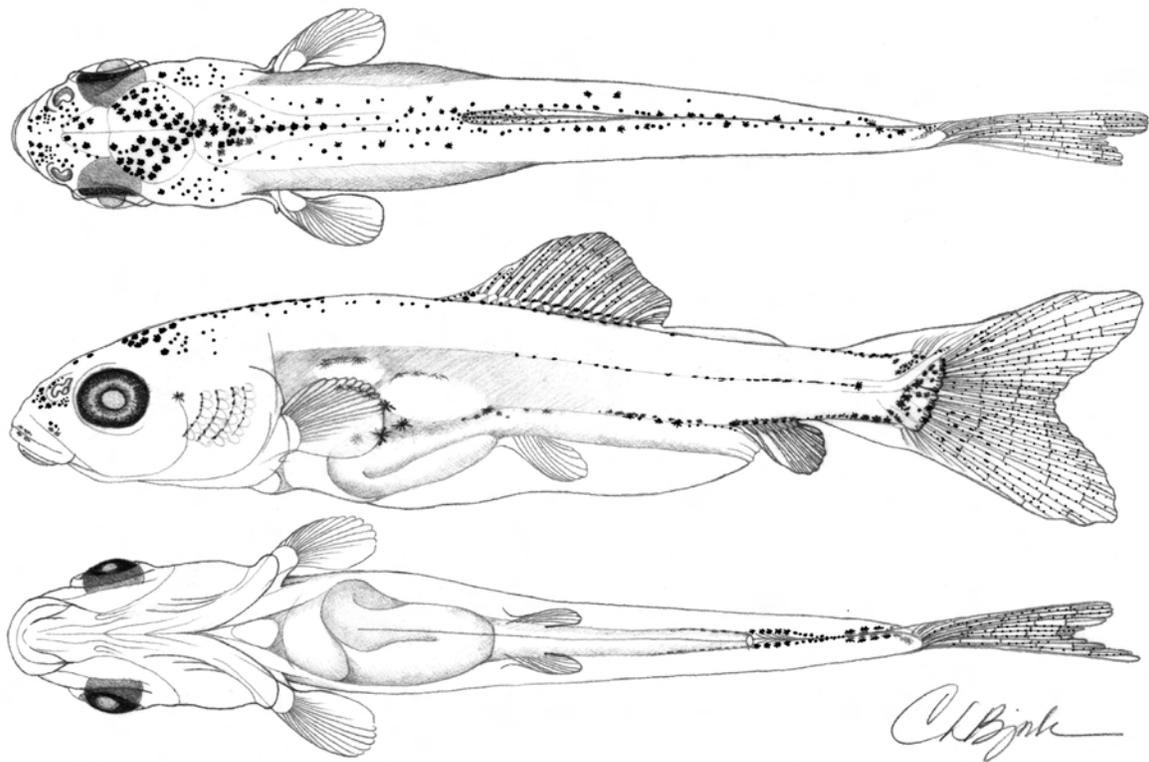


Fig. 36. *Xyrauchen texanus* metalarva, recently transformed, 16.2 mm SL, 19.4 mm TL. (Cultured in 1980 from stock in Colorado River gravel pits near Clifton, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

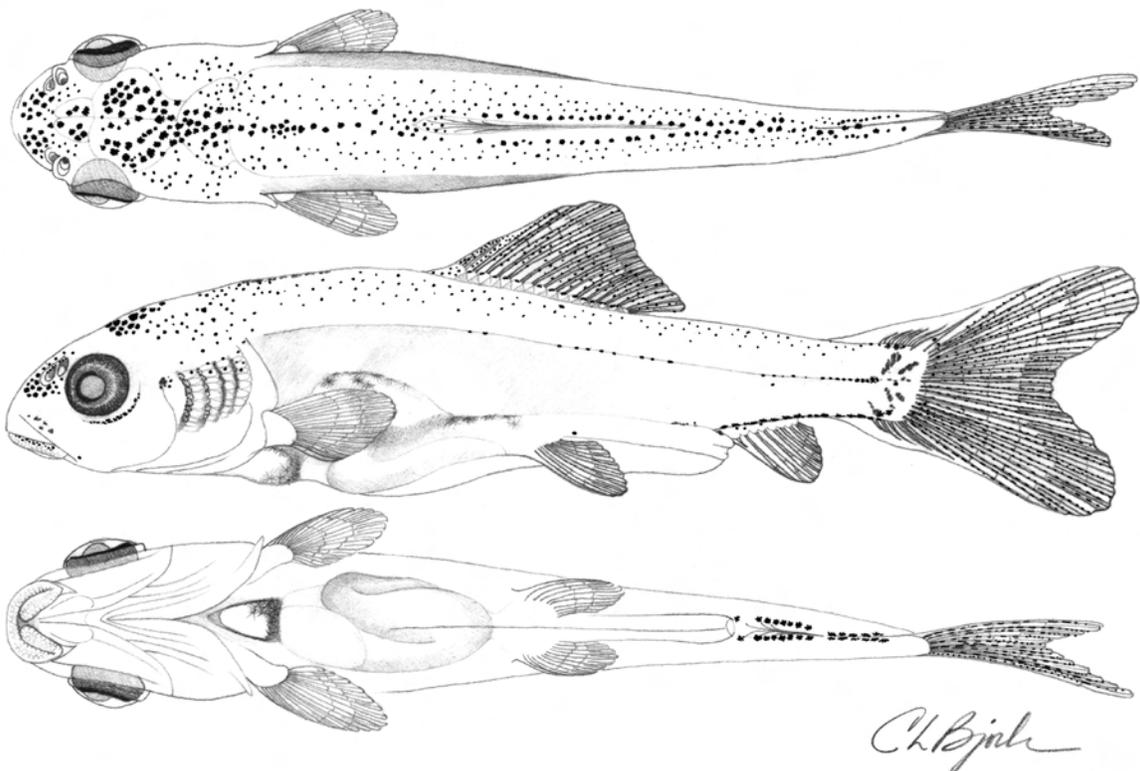


Fig. 37. *Xyrauchen texanus* metalarva, 18.8 mm SL, 22.8 mm TL. (Cultured in 1980 from stock in Colorado River gravel pits near Clifton, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

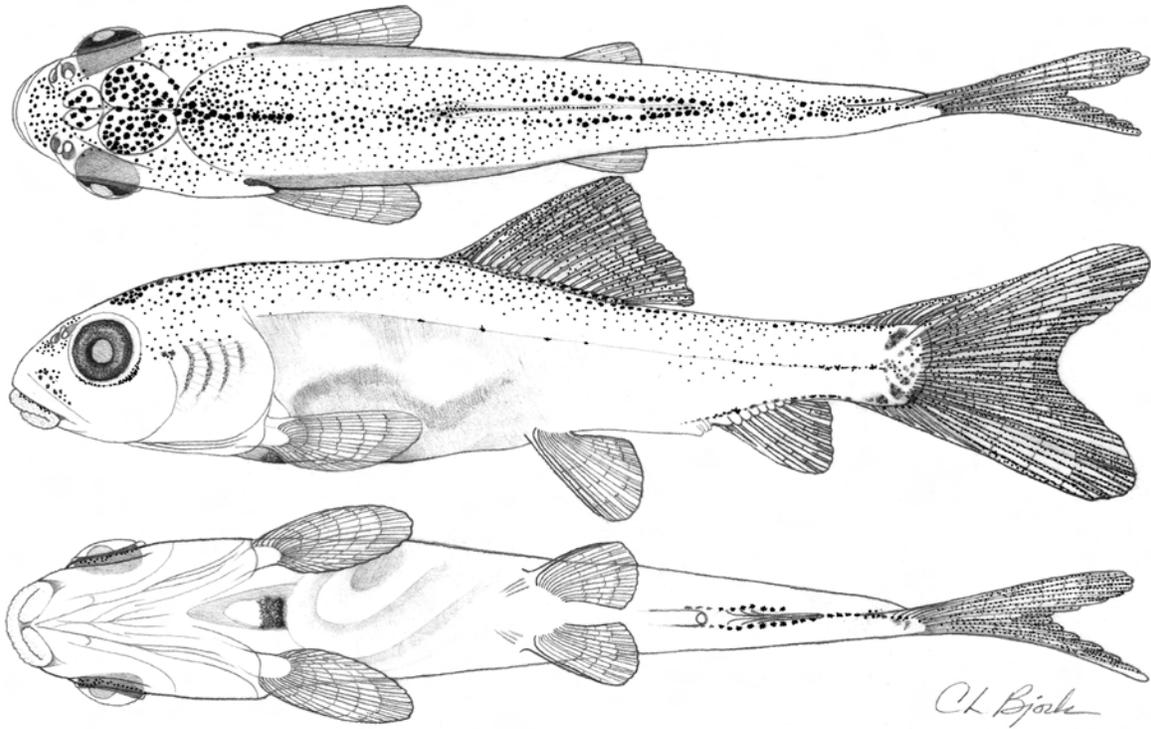


Fig. 38. *Xyrauchen texanus* juvenile, recently transformed, 21.6 mm SL, 27.0 mm TL. (Cultured in 1980 from stock in Colorado River gravel pits near Clifton, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

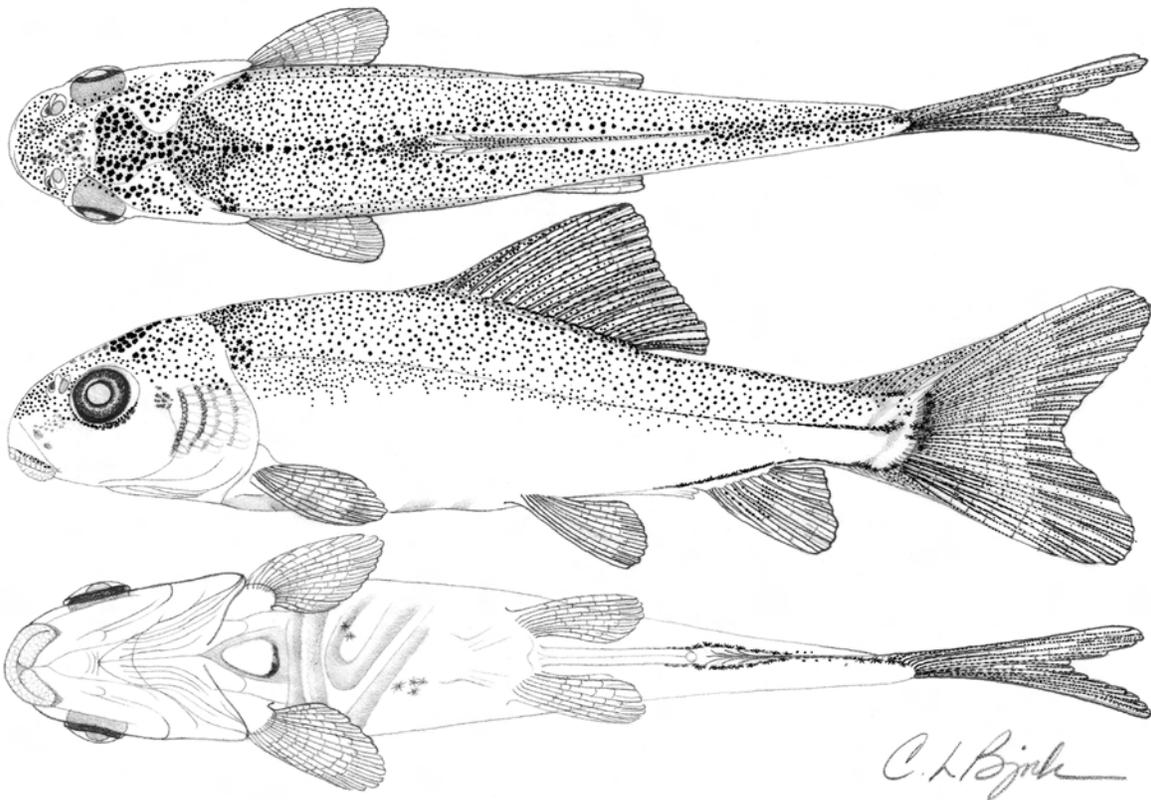


Fig. 39. *Xyrauchen texanus* juvenile, 30.2 mm SL, 37.4 mm TL. (Cultured in 1980 from stock in Colorado River gravel pits near Clifton, Colorado. From Snyder 1981 and Snyder and Muth 1990 and 2004.)

Species Account – *Agosia chrysogaster*

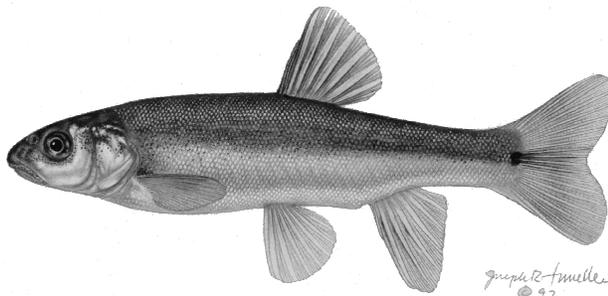


Fig. 40. *Agosia chrysogaster* adult (© Joseph R. Tomelleri).

Adult description: Usually <65 mm, rarely greater than 100 mm TL. Body fusiform with a relatively large head and rounded snout. Mouth slightly sub-terminal with a small maxillary barbel. Eye is relatively large. Long coiled gut with black peritoneum. Dorsal fin origin over or nearly over pelvic fin origin. Anal fin elongated in females. Scales small. Body brown or gray above and white below a lateral stripe that terminates in a small caudal spot; caudal-fin pigment darkest along middle rays. Breeding males sometimes weakly yellow on ventral aspects of the head and abdomen. (Also, Table 18.)

Reproduction: Non-guarding open-substrate, or possible nest-guarding, psammophils or lithophils. Spawn December-July, possibly into September, but mostly March- May. In some populations, non-adhesive eggs are deposited in saucer-shaped depressions excavated by males in sand or gravel in shallow, near-shore areas with little or no current. Egg diameter 2.2-2.8 mm, modally 2.5-2.6 mm.

Young: Hatch in 4 d at > 24°C. Larvae present in waters with diel temperatures as low as 7-15.5°C (late March). Late protolarvae and larger individuals subject to downstream transport as evidenced by drift-net captures. Larvae occupy near-shore, low-velocity, areas over sand along channel margins and in backwaters, eddies, and pools. Larvae consume early instars of chironomids, mayflies, other small invertebrates, and detritus.

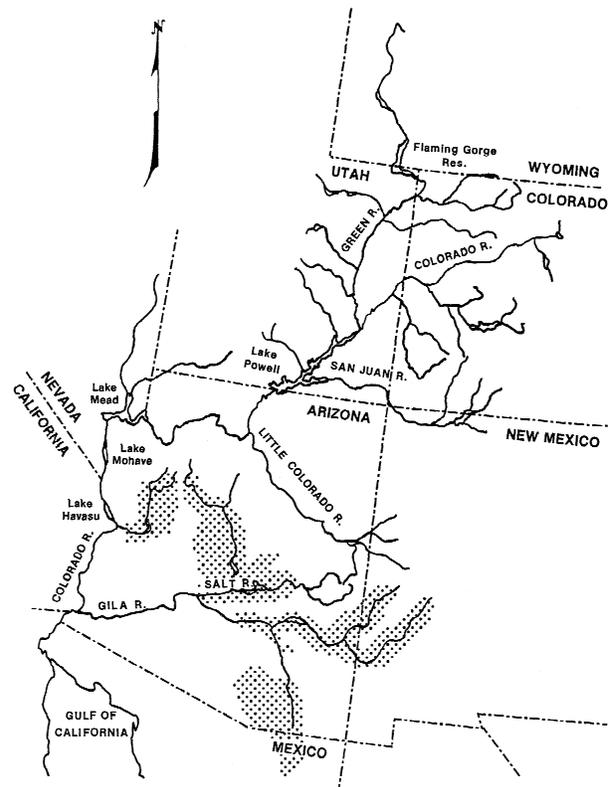


Fig. 41. Recent distribution of *Agosia chrysogaster* in the Colorado River Basin.

Table 18. Selected juvenile and adult meristics for *Agosia chrysogaster*. (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. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

Character	Observed	Literature	Character	Observed	Literature
Dorsal-fin rays - P	(7)8(9)	8 [(8)9(-11)*]	Dorsal-fin rays - R	2-3	–
Anal-fin rays - P	7	6-7 [(7)8(9)*]	Anal-fin rays - R	<u>2</u> -3	–
Caudal-fin rays - P	19(20)	19(20)	Caudal-fin rays - RD	9-11(12)	–
Pectoral-fin rays	(14)15-17(-19)	(6?) <u>16</u> -17(18)	Caudal-fin rays - RV	8-10(11)	–
Pelvic-fin rays	8-9	<u>7</u> -8-9	Lateral scales	(77)81-93	(60-)70- <u>73</u> -90-95
Vertebrae	38 (N=3)	–	Pharyngeal teeth	–	0,4/4,0

*Counts from Hendrickson (1987) and Sublette, et al. (1990) that appear one too high, perhaps including longest rudimentary ray.

Table 19. Size at onset of selected developmental events for *Agosia chrysogaster*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	5(6)	5-6	Dorsal - P	(8)9(10)	(9)10(11)	(10)11-12	12-14
Eyes pigmented	5(6)	5-6	Anal - P	9-10	10-11	11-12	(12)13-14
Yolk assimilated	(6)7	7(8)	Caudal - P	7	7(8)	9	(9)10
Finfold absorbed	(15)16(17)	(18)19-20	Caudal - R	9	10(11)	(14)15(16)	(17)18(19)
Pectoral-fin buds	*	*	Pectoral	(9)10	11-12	14(15)	17(18)
Pelvic-fin buds	(9)10	10-11	Pelvic	12(13)	14(15)	14-15	17-18
* before hatching			Scales	22-25(-31)	27-30(-38)	(23-)25(-31)	(28)29-30(-38)

References: Arizona Game and Fish Department 2002, Bestgen unpublished data, Bestgen et al. 1987b, Girard 1856, Hendrickson 1987, Minckley 1973, Minckley and Barber 1971, Moore 1968, Page and Burr 1991, Sublette et al. 1990, Winn and Miller 1954.

Table 20. Size at developmental interval (left) and gut phase (right) transitions for *Agosia chrysogaster*. (See Figure 5 for phases of gut folding. Rare values in parentheses.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	7	7(8)	2 - 90° bend	10-11	12
Postflexion mesolarva	9	(9)10	3 - Full loop	14	17
Metalarva	11-12	(12)13-14	4 - Partial crossover	(15)16-19(20)	(17-)19-23(24)
Juvenile	(15)16(17)	(18)19-20	5 - Full crossover	(19-)24-25	(23-)29-30

Table 21. Summary of morphometrics and myomere counts by developmental phase for *Agosia chrysogaster*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. SD value of 0 actually between 0.0 and 0.5.)

	Protolarvae (N=17)			Flexion mesolarvae (N=15)			Postflexion mesolarvae (N=24)			Metalarvae (N=29)			Juveniles (N=39)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	6	0	6 - 7	8	1	7 - 9	10	1	9 - 12	14	1	11 - 17	24	7	15 - 42
TL, mm	7	0	6 - 7	8	1	7 - 10	12	1	10 - 14	16	2	12 - 20	29	9	18 - 50
<u>Lengths %SL</u>															
AS to AE	2	0	2 - 3	3	0	2 - 3	4	1	3 - 5	5	1	4 - 6	6	1	4 - 8
PE	10	1	9 - 12	11	1	10 - 12	12	1	10 - 13	13	1	12 - 14	14	1	11 - 15
OP1	19	1	18 - 20	21	1	19 - 22	24	1	20 - 26	26	1	24 - 27	26	1	23 - 28
OP2							49	1 ^b	48 - 52	52	2	48 - 54	52	1	50 - 54
PY	57	7 ^a	43 - 64												
OPAF	29	2	25 - 32	30	2	25 - 33	34	2	31 - 39	43	4 ^e	36 - 54			
ODF	40	3	31 - 44	42	2	37 - 47	45	2	39 - 49						
OD							51	1 ^c	50 - 53	51	1	49 - 54	51	1	49 - 53
ID							64	1 ^a	62 - 65	65	1	63 - 67	65	1	63 - 66
PV	66	1	64 - 68	68	1	66 - 70	71	1	69 - 74	69	1	68 - 71	69	1	67 - 71
OA							69	1 ^d	68 - 71	68	1	67 - 70	68	1	66 - 70
IA							77	1 ^a	76 - 79	78	1	76 - 80	77	1	76 - 79
AFC							111	1 ^e	109 - 114	113	1	111 - 115	113	1	111 - 115
PC	106	1	105 - 107	107	1	105 - 109	113	2	110 - 115	118	2	115 - 121	120	1	118 - 124
Y	29	18	0 - 50												
P1	12	1	10 - 14	14	1	12 - 16	15	2	13 - 21	16	1	14 - 18	18	1 ^h	16 - 21
P2							5	2 ^b	2 - 7	9	2	5 - 13	15	2	11 - 24
D							16	2 ^b	12 - 18	21	2	15 - 24	22	1	20 - 27
A							12	1 ^f	10 - 13	15	1	12 - 17	18	2	15 - 22
<u>Depths %SL</u>															
at BPE	14	1	12 - 15	14	1	13 - 16	17	1	15 - 18	18	1	17 - 20	18	1	16 - 20
OP1	15	1	14 - 18	16	1	15 - 17	19	1	16 - 21	22	1	20 - 25	23	1	21 - 25
OD	11	1	10 - 14	12	1	11 - 13	14	1	12 - 16	20	2	15 - 25	22	1	18 - 25
BPV	9	1	7 - 10	8	1	7 - 9	10	1	8 - 11	12	1	11 - 14	14	1	12 - 17
AMPM	4	0	4 - 5	5	0	4 - 5	7	1	5 - 8	9	1	8 - 10	10	1	9 - 11
Max. yolk	5	4	0 - 13												
<u>Widths %SL</u>															
at BPE	14	1	13 - 15	15	1	13 - 17	17	1	14 - 19	18	1	16 - 19	17	1	15 - 19
OP1	10	1	9 - 11	11	1	10 - 12	14	1	12 - 16	17	1	15 - 20	18	1	15 - 20
OD	6	1	5 - 7	6	0	6 - 7	9	1	7 - 11	13	2	9 - 17	15	1	12 - 20
BPV	5	0	4 - 6	5	0	4 - 5	6	1	5 - 8	8	1	7 - 9	10	1	8 - 14
AMPM	3	0	2 - 3	3	0	2 - 3	4	1	3 - 5	5	0	4 - 5	5	1	4 - 6
Max. yolk	7	4	0 - 12												
<u>Myomeres</u>															
to PY	22	4 ^a	14 - 25												
OPAF	8	1	5 - 10	8	1	5 - 10	8	1	6 - 10	12	2	9 - 17			
OP2							16	1 ^b	15 - 17	17	1	15 - 18	17	1 ^g	16 - 18
ODF	13	2	9 - 15	13	1	11 - 14	13	1	11 - 15						
OD							17	1 ^a	16 - 18	17	1	16 - 18	16	1 ^g	15 - 17
PV	26	1	24 - 27	26	1	26 - 27	27	1	26 - 28	26	1	25 - 27	26	1 ^g	24 - 27
Total	38	1	36 - 39	37	1	37 - 39	38	1	37 - 39	38	1	37 - 39	37	1 ⁱ	37 - 38
After PV	12	1	11 - 14	11	1	10 - 12	11	1	10 - 12	12	1	11 - 13	12	1 ^j	11 - 13

^aN = 15. ^bN = 17. ^cN = 22. ^dN = 18. ^eN = 23. ^fN = 13. ^gN = 2.8. ^hN = 38. ⁱN = 27. ^jN = 30.

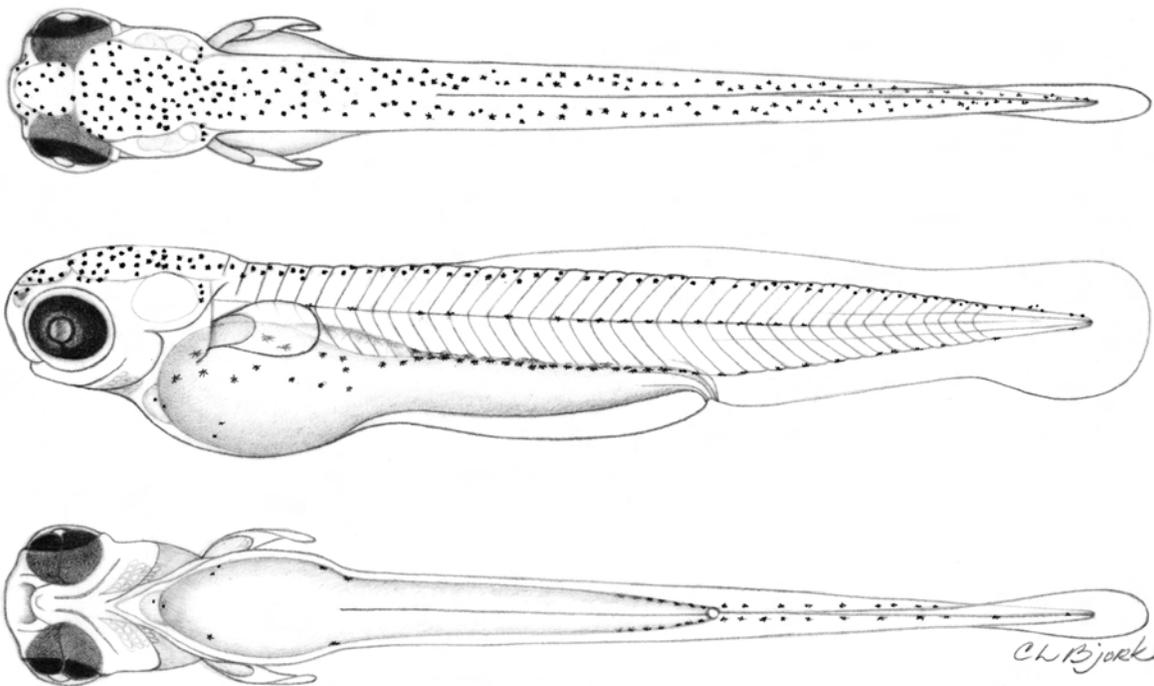


Fig. 42. *Agosia chrysogaster* protolarva, 6.0 mm SL, 6.3 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

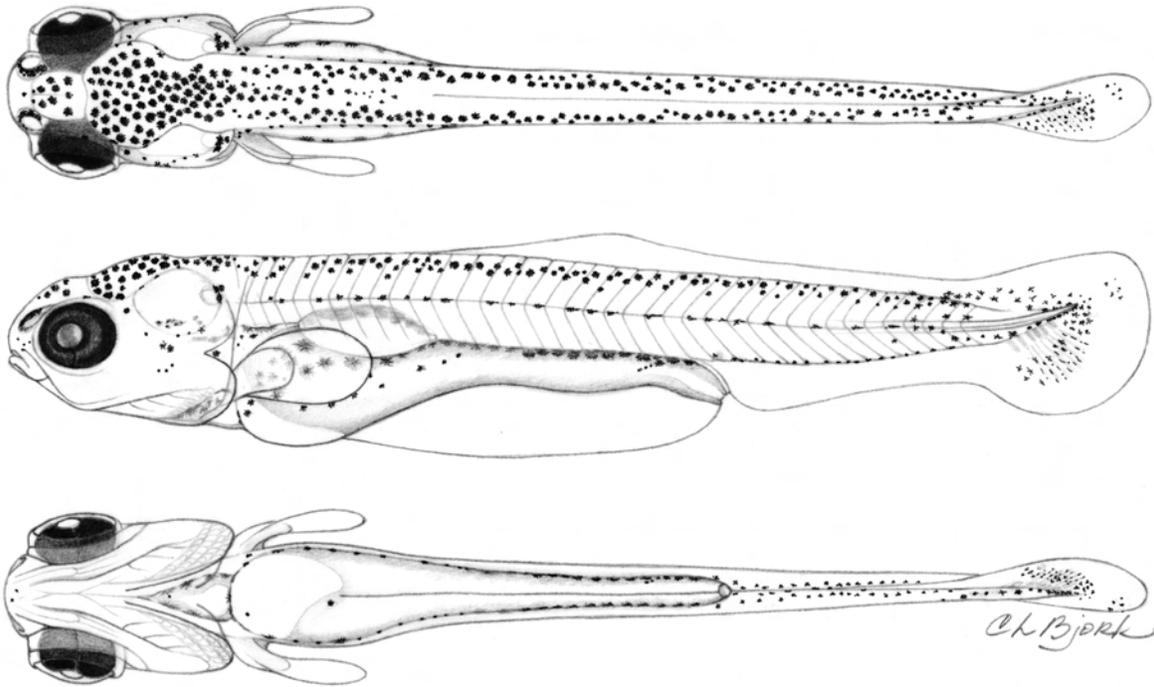


Fig. 43. *Agosia chrysogaster flexion* mesolarva, recently transformed, 7.6 mm SL, 8.2 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

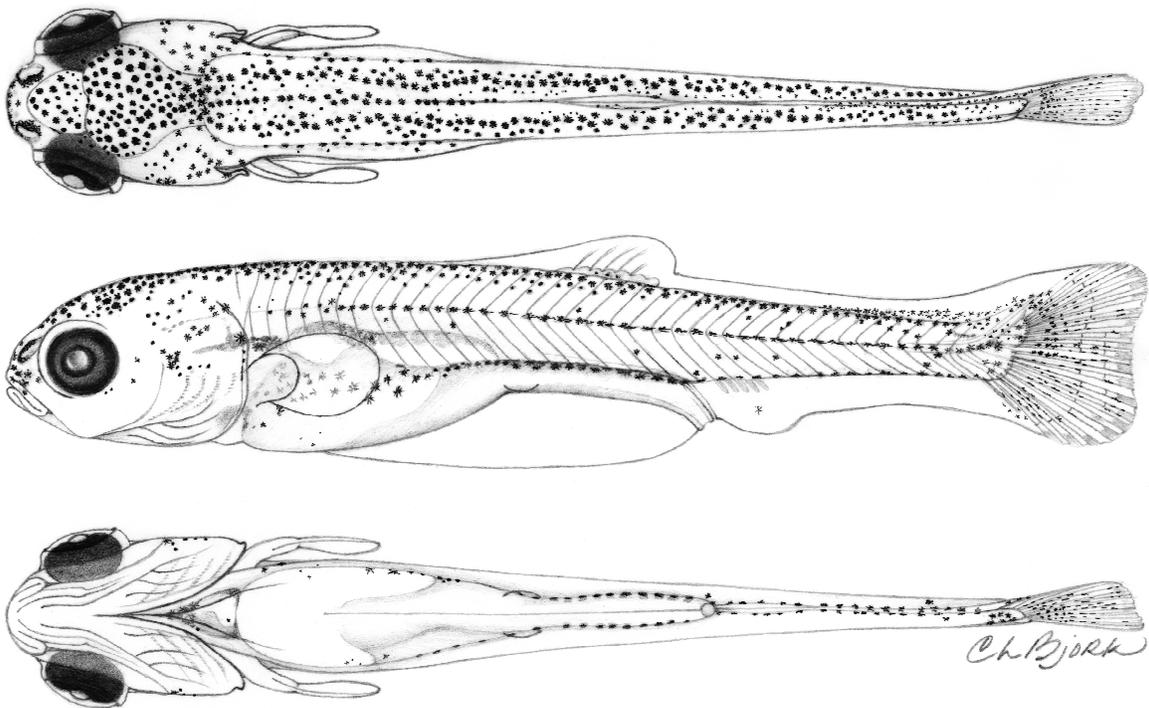


Fig. 44. *Agosia chrysogaster postflexion* mesolarva, 10.0 mm SL, 11.2 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)



Fig. 45. *Agosia chrysogaster* metalarva, 13.6 mm SL, 16.3 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

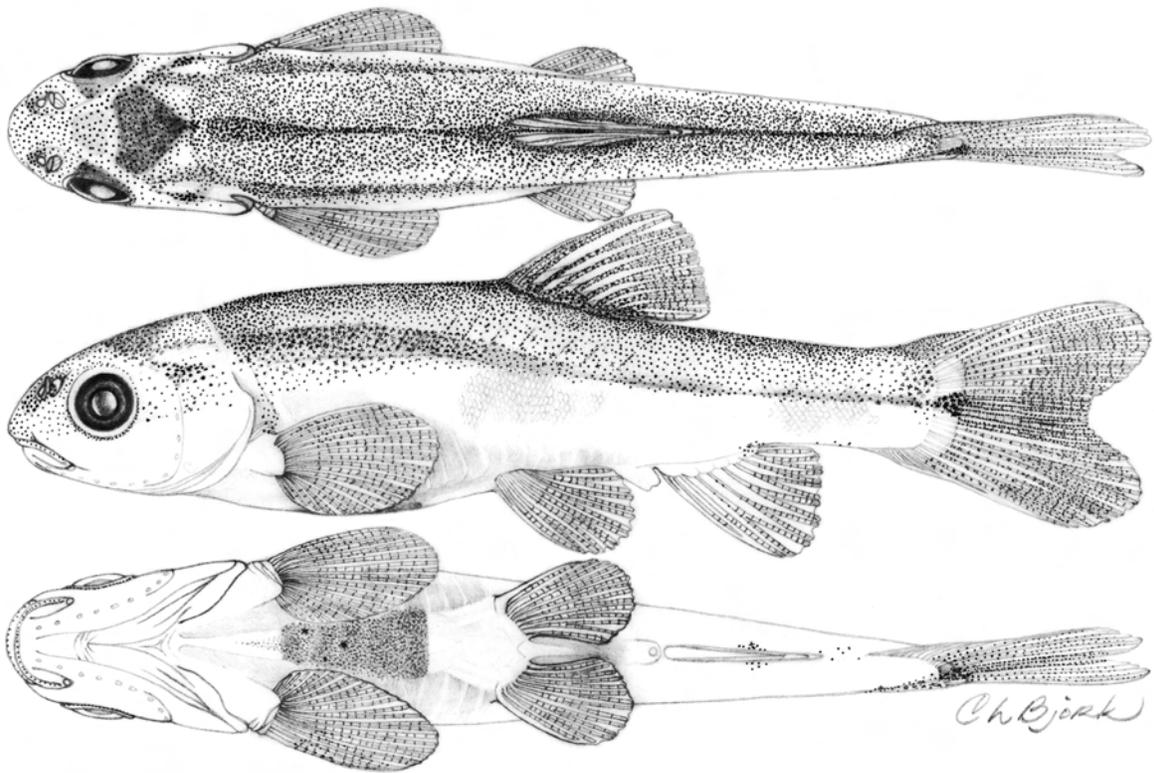


Fig. 46. *Agosia chrysogaster* juvenile, 31.7 mm SL, 38.1 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

Species Account – *Gila elegans*

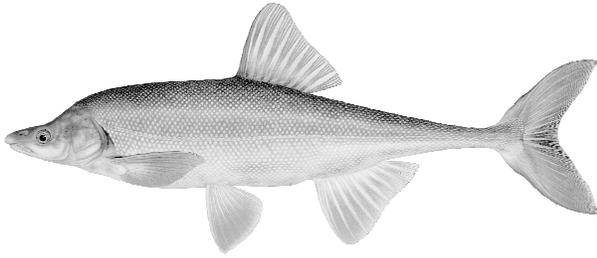


Fig. 47. *Gila elegans* adult (© Joseph R. Tomelleri).

Adult description: Up to 50 cm TL. Head small, strongly depressed anteriorly, concave over and behind eyes, and arching posteriorly, in larger specimens to a moderately high nuchal hump. Body very streamlined, elongate, and somewhat compressed, narrowing to an extremely slender and long caudal peduncle with least depth 15-20% of head length (HL). Mouth terminal to subterminal, slightly oblique. Eyes small, about 14% of HL. Fins large; dorsal origin well behind pelvics; caudal deeply forked. Scales small, coverage often incomplete or deeply embedded dorsally, ventrally and on caudal peduncle. Gray to olivaceous on dorsal surface, silver laterally, white ventrally. Breeding males orange-red ventrolaterally with small tubercles on anterior body; less pronounced in females. (Also, Table 22.)

Reproduction: Non-guarding, open-substrate lithophils. Spawn May to early July at water temperatures of 17-21° in eddies or pools over gravel shelf, cobble, or boulders. Water-hardened eggs demersal, adhesive, and 2.0-2.4 mm in diameter.

Young: At 20-21°C, hatch in 4-7 d and swim up 2-3 d later. Young mostly found in near-shore, low-velocity habitats (e.g., backwaters) over silt, sand, or gravel. In laboratory, preferred 24°C.

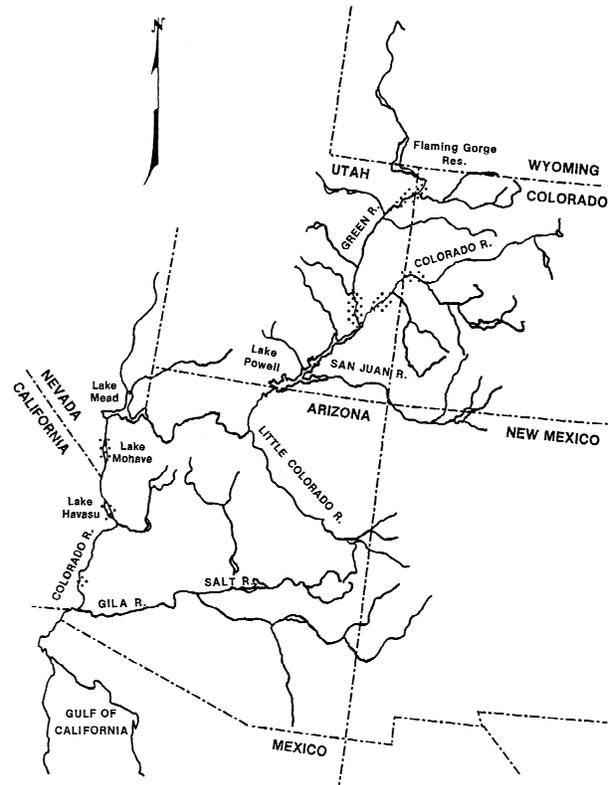


Fig. 48. Recent distribution of *Gila elegans* in the Colorado River Basin. (includes stocked reaches.)

Table 22. Selected juvenile and adult meristics for *Gila elegans*. (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. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

Character	Observed*	Literature	Character	Observed	Literature
Dorsal-fin rays - P	10(11)	(9) <u>10</u> -11	Dorsal-fin rays - R	–	–
Anal-fin rays - P	<u>10</u> -11	(9) <u>10</u> -11	Anal-fin rays - R	–	–
Caudal-fin rays - P	(17)18- <u>19</u> (20)	(18)19	Caudal-fin rays - RD	–	–
Pectoral-fin rays	14- <u>16</u> -17	16	Caudal-fin rays - RV	–	–
Pelvic-fin rays	(8)9	<u>9</u> -10	Lateral scales	–	75-88-99-110
Vertebrae	49- <u>50</u> -51	(46-)48- <u>49</u> -51	Pharyngeal teeth	–	2,5/4,2

*From Muth (1990).

Table 23. Size at onset of selected developmental events for *Gila elegans*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses. From Muth 1990, supplemented with original data.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	5-6	6-7	Dorsal - P	9	10	11(12)	13
Eyes pigmented	6*	6*	Anal - P	9	10	11(12)	13
Yolk assimilated	8-9	9	Caudal - P	(7)8	8-9	(8)9	(9-) <u>11</u>
Finfold absorbed	22(23)	28(29)	Caudal - R	9-10	10-11	≤22(23)	≤28(29)
Pectoral-fin buds	6 or *	7 or *	Pectoral	9-10	11-12	14	17
Pelvic-fin buds	10-11	11-12	Pelvic	10-11	11-13	15	18
* before hatching			Scales	≤25	≤31	–	–

References: Arizona Game and Fish Department 2002, Baird and Girard 1853a & b, Balon 1981, Baxter and Simon 1970, Beckman 1952, Benke and Benson 1983, Bozek et al. 1984, Hammon 1982 & 1985, Holden 1968, Holden and Stalnaker 1970, LaRivers 1962, Marsh 1985, Minckley 1973, Minckley and DeMarais 2000, Miller 1946, Moore 1968, Moyle 1976, Muth 1990, Page and Burr 1991, Rinne 1976, Sigler and Miller 1963, Smith et al. 1979, Valdez and Clemmer 1982, Vanicek and Kramer 1969.

Table 24. Size at developmental interval (left) and gut phase (right) transitions for *Gila elegans*. (See Figure 5 for phases of gut folding. Rare values in parentheses. From Muth 1990, supplemented with original data.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	(7)8	8-9	2 - 90° bend	(11)12-15	13-16
Postflexion mesolarva	(8)9	(9-)11	3 - Full loop	(19)20-22	24-27
Metalarva	11(12)	13	4 - Partial crossover	not applicable	
Juvenile	22(23)	28(29)	5 - Full	not applicable	

Table 25. Summary of morphometrics and myomere counts by developmental phase for *Gila elegans*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. SD value of 0 actually between 0.0 and 0.5. From Muth 1990, except as noted.)

	Protolarvae (N=37)			Flexion mesolarvae (N=20)			Postflexion mesolarvae (N=4)			Metalarvae (N=34)			Juveniles (N=52)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	7	0	7 - 8	9	1	8 - 9	10	1	9 - 11	16	3	11 - 22	31	6	22 - 44
TL, mm	8	0	7 - 9	9	1	9 - 11	12	1	11 - 13	19	4	13 - 28	39	8	28 - 54
<u>Lengths %SL</u>															
AS to AE	3	0	2 - 3	3	0	2 - 4		^c	3 - 4	4	1	3 - 6	5	0	5 - 6
PE	9	1	7 - 10	9	1	8 - 10	11	0	11 - 11	12	1	11 - 14	12	1	11 - 13
OP1	18	1	16 - 21	21	1	19 - 24	22	0	22 - 24	25	1	23 - 28	24	1	22 - 26
OP2								^c	44 - 46	47	1	44 - 49	45	1	44 - 47
PY		^f	63		^e	50 - 52			29 - 31			31 - 55			
OPAF			28 - 38			29 - 32			43 - 46		^c	46 - 48			
ODF			39 - 42			42 - 45			50 - 53	51	^{1d}	50 - 57	51	1	49 - 54
OD									62 - 69	65	2	62 - 69	65	1	62 - 66
ID									66 - 69	67	1	66 - 69	63	1	60 - 65
PV	65	2	62 - 70	67	2	63 - 70	67	1	65 - 68	67	^{1d}	65 - 68	64	1	62 - 67
OA									75 - 82	77	2	75 - 82	76	1	74 - 78
IA					^b	105 - 111	110	^{1b}	110 - 111	111	^{2b}	110 - 113	112	^{1b}	111 - 114
AFC					^c	0 - 26	114	0	114 - 114	123	^{2d}	116 - 126	125	1	123 - 128
PC		^f	104 - 107	110	^{3b}	105 - 115									
Y			47			0 - 26			12 - 13	14	1	12 - 15	17	1	15 - 19
P1			4 - 12			12 - 13			2 - 3	10	4	5 - 16	16	1	15 - 18
P2								^c		19	2	15 - 23	22	1	20 - 24
D										17	2	14 - 20	21	2	17 - 23
A															
<u>Depths %SL</u>															
at BPE	12	1	10 - 13	13	1	12 - 14	14	0	14 - 14	16	1	15 - 17	16	1	15 - 17
OP1	12	^{1b}	10 - 14	14	^{1b}	12 - 17	14	^{1b}	12 - 17	20	^{2b}	16 - 24	22	^{1b}	20 - 24
OD	12	^{1b}	9 - 15	11	^{1b}	8 - 14	11	^{1b}	8 - 14	19	^{4b}	9 - 24	23	^{1b}	20 - 26
BPV	8	^{1b}	6 - 9	8	^{1b}	6 - 9	8	^{1b}	6 - 9	14	^{2b}	9 - 18	13	^{1b}	11 - 15
AMPM	4	^{0d}	3 - 4	4	1	3 - 5	5	0	5 - 6	7	0	6 - 7	6	0	6 - 7
Max. yolk		^f	12			0 - 4									
<u>Widths %SL</u>															
at BPE	12	1	11 - 14	13	1	11 - 14	13	1	13 - 14	15	1	14 - 16	15	1	14 - 16
OP1	9	^{1b}	8 - 11	10	^{2b}	7 - 11	10	^{2b}	7 - 11	16	^{1b}	14 - 18	18	^{1b}	16 - 21
OD	6	^{1b}	5 - 8	5	^{1b}	4 - 7	5	^{1b}	4 - 7	12	^{3b}	7 - 18	17	^{2b}	15 - 21
BPV	5	^{1b}	4 - 7	5	^{1b}	4 - 6	5	^{1b}	4 - 6	10	^{2b}	6 - 13	13	^{1b}	11 - 15
AMPM	3	0	2 - 3	2	0	2 - 3	3	1	2 - 3	3	0	2 - 4	4	0	3 - 4
Max. yolk		^f	14		^e	0 - 8									
<u>Myomeres; Vertebrae for Juveniles</u>															
to PY		^f	30												
OPAF		^f	17												
OP2							17 ^a	^c	17 - 17	17 ^a		16 - 18	16 ^a		15 - 17
ODF		^f	13												
OD							20	^{1b}	19 - 21	20 ^a		19 - 22	20 ^a		19 - 20
PV	30 ^a	^f	29 - 32	30 ^a		30 - 32	30 ^a		30 - 30	30 ^a		29 - 32	28 ^a		27 - 29
Total	51 ^a		49 - 51	51 ^a		50 - 52	51 ^a		50 - 51	50 ^a		49 - 52	50 ^a		49 - 51
After PV	21 ^a	^f	19 - 21	21 ^a		19 - 21	21 ^a		20 - 21	20 ^a		19 - 21	22 ^a		21 - 23

^aMode rather than mean. ^bStudy data not reported in Muth (1990), depths and widths for mesolarvae not divided and given here for both flexion and postflexion mesolarvae. ^cN = 2. ^dRange extended with study data not reported in Muth (1990). ^eOriginal data, N = 4. ^fMeasurement or count from Fig. 49, or range extended by such.

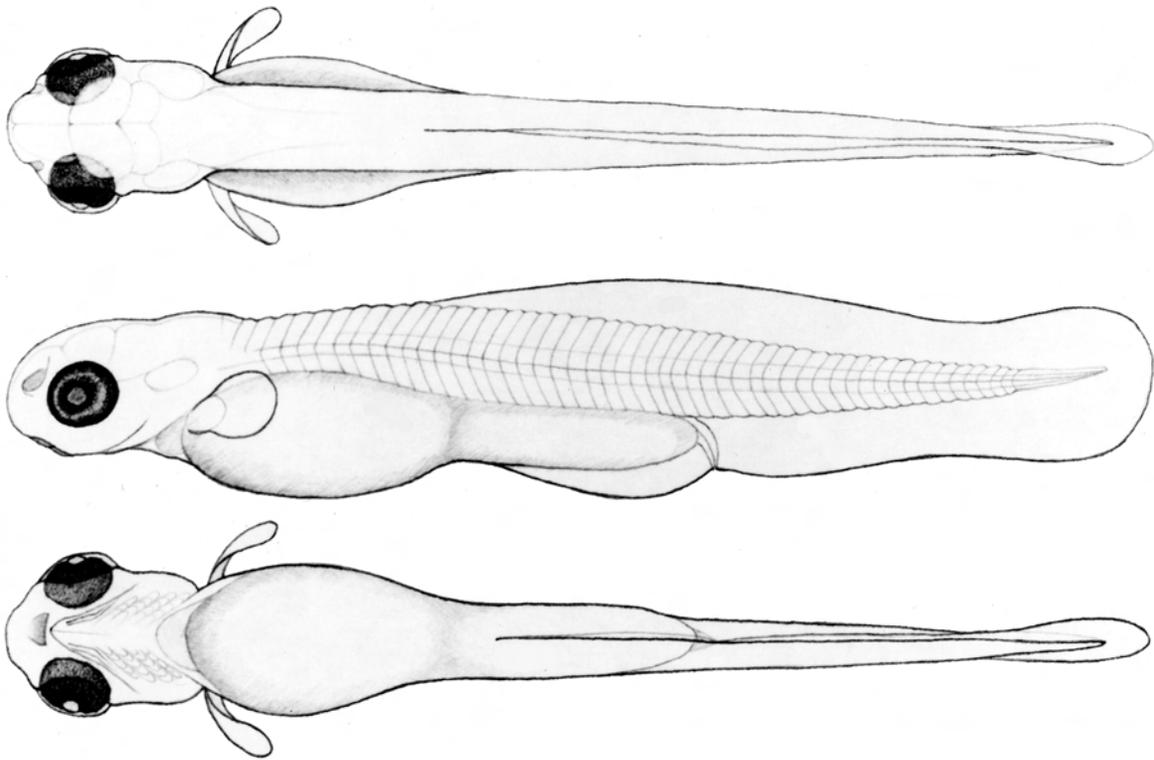


Fig. 49. *Gila elegans* protolarva, 7.0 mm SL, 7.5 mm TL. (Cultured in 1981 at Willow Beach National Fish Hatchery, Arizona, with stock from Lake Mohave. From Muth 1990.)

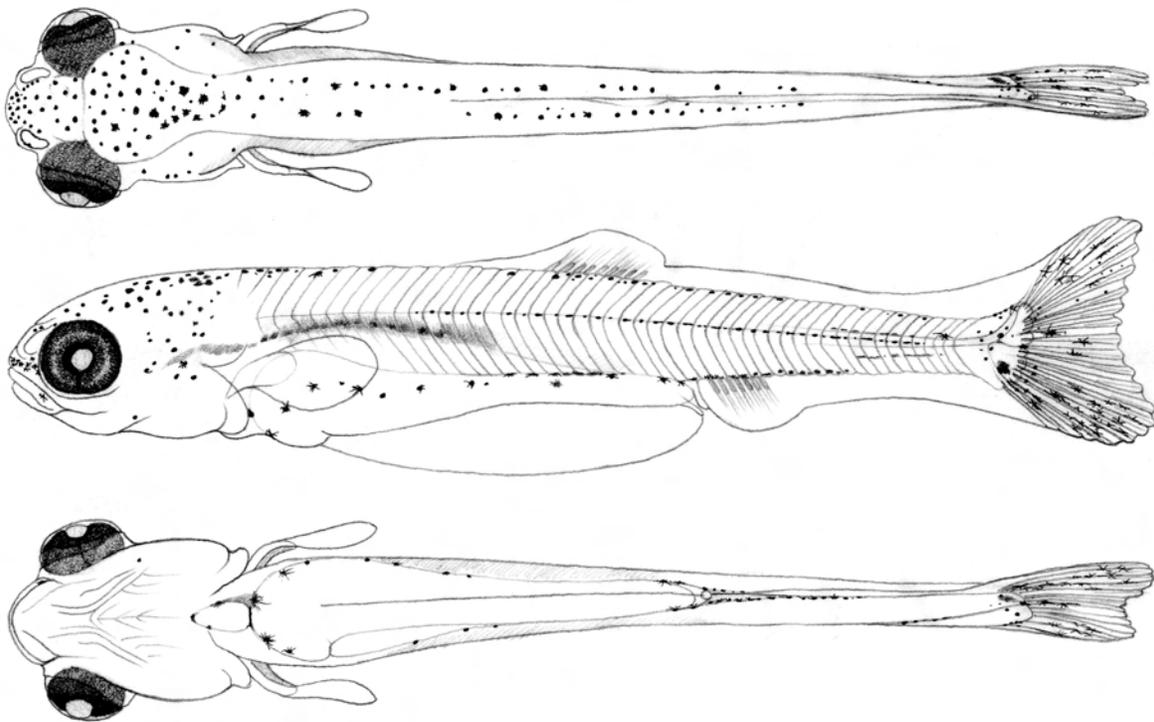


Fig. 50. *Gila elegans* postflexion mesolarva, 9.4 mm SL, 10.7 mm TL. (Cultured in 1981 at Willow Beach National Fish Hatchery, Arizona, with stock from Lake Mohave. From Muth 1990.)

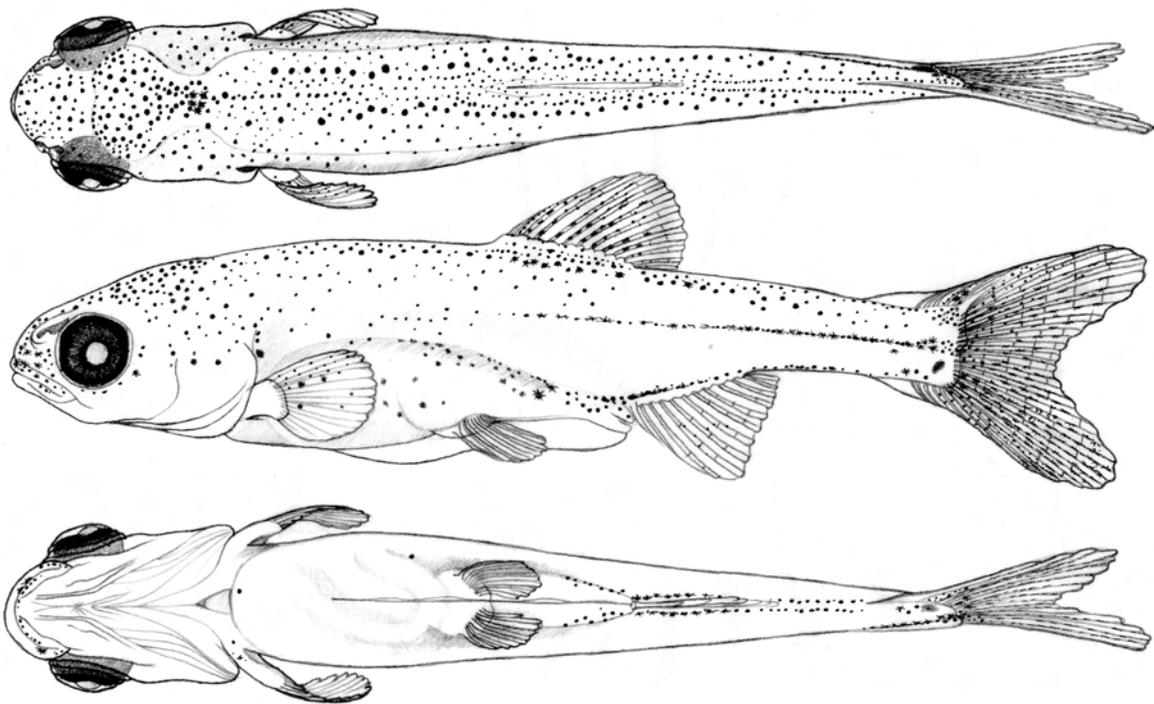


Fig. 51. *Gila elegans* metalarva, 15.0 mm SL, 18.2 mm TL. (Cultured in 1981 at Willow Beach National Fish Hatchery, Arizona, with stock from Lake Mohave. From Muth 1990.)

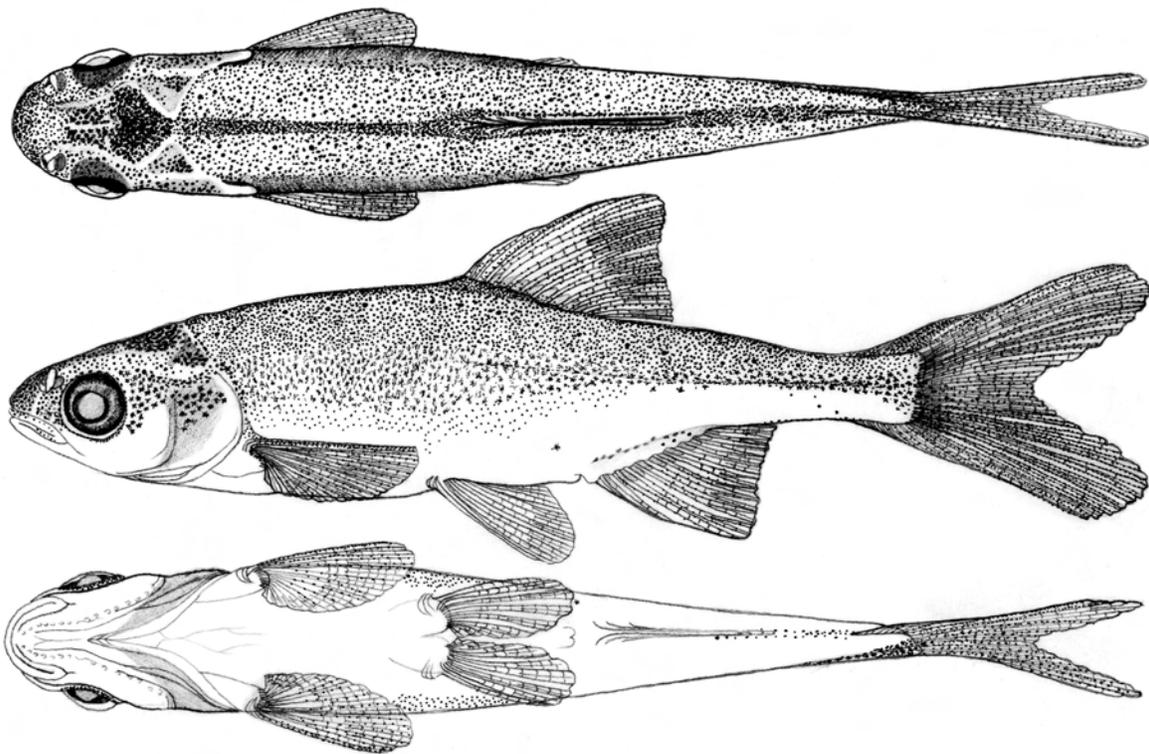


Fig. 52. *Gila elegans* juvenile, 34.0 mm SL, 42.7 mm TL. (Cultured in 1981 at Willow Beach National Fish Hatchery, Arizona, with stock from Lake Mohave. From Muth 1990.)

Species Account – *Gila robusta*

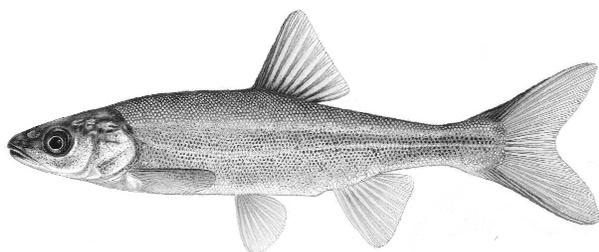


Fig. 53. *Gila robusta* adult (© Joseph R. Tomelleri).

Adult description: Usually <26 cm, but up to 43, possibly 50 cm TL. Body moderately streamlined, elongate, sometimes slightly arched behind head. Dorsal surface of head slightly depressed, flat or rounded. Mouth terminal, slightly oblique, not extending beyond anterior margin of small eyes. Caudal peduncle relatively short and moderately deep, usually 23-33% of HL. Fins small to moderately large, rounded, slightly falcate, dorsal origin well behind pelvic origin. Angle of line along base of anal fin extends through middle or top lobe of caudal fin. Scales small. Generally gray or olivaceous dorsally, sometimes with dark dorsolateral blotches in certain subspecies or populations; silver to white ventrolaterally. (Also, Table 26.)

Reproduction: Non-guarding, open-substrate lithophil. Usually mature in 4-5 yr. Spawn late May to late July at 16-20°C, typically ≥18°C, in shallow pools or eddies over gravel or cobble. Breeding males orange-red along ventrolateral surfaces with small tubercles on anterior portion of body, both less pronounced in females. Water-hardened eggs demersal, adhesive, and 2.7-3.1 mm in diameter.

Young: Hatch in 5-6 d and swim up 3-5 d later at 19-20°C. Larvae subject to capture in downstream drift. Young found mostly in near-shore, low-velocity habitats (e.g., eddies, backwaters, embayments) over silt, sand, gravel, or boulders.

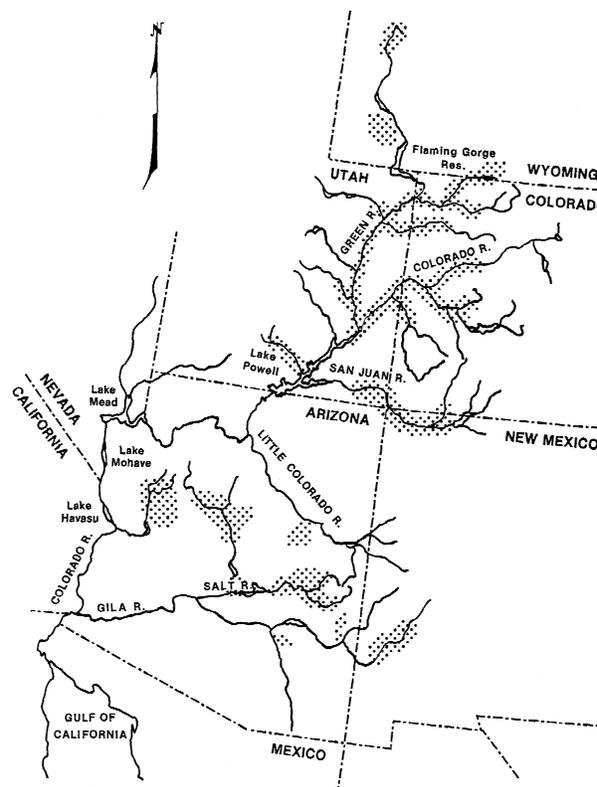


Fig. 54. Recent distribution of *Gila robusta* in the Colorado River Basin.

Table 26. Selected juvenile and adult meristics for *Gila robusta*. (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. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

Character	Observed*	Literature	Character	Observed*	Literature
Dorsal-fin rays - P	9	8-9(10)	Dorsal-fin rays - R	1-2-3	–
Anal-fin rays - P	(8)9-10	(7)8-9-10	Anal-fin rays - R	1-2-3	–
Caudal-fin rays - P	19(20)	19(20)	Caudal-fin rays - RD	(9)10-11	8
Pectoral-fin rays	(12-)14- <u>15-16-17</u>	(12-)14- <u>15-17</u>	Caudal-fin rays - RV	(9)10-11	7
Pelvic-fin rays	8-9	(7)8-9-10	Lateral scales	–	(71-)75-79-86-96(-99)
Vertebrae	44- <u>46-47</u>	(42)43- <u>46-48(49)</u>	Pharyngeal teeth	–	(1-)2,(4)5/4(5),(1-)2

*From Muth (1990) and original data prepared for Snyder (1981).

Table 27. Size at apparent onset of selected developmental events for *Gila robusta*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses. From Muth 1990 and Snyder 1981, with some original data.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	7(8)	(7)8(9)	Dorsal - P	10	11-12	(10-)12-13(14)	(11-)14-15(16)
Eyes pigmented	*	*	Anal - P	10(11)	12	12-13(14)	14-15(16)
Yolk assimilated	9-10(11)	10-11(12)	Caudal - P	(8)9-10	(9)10-11	10-11	(10-)11-12
Finfold absorbed	(18)19-20(-22)	(21-)24-25(-27)	Caudal - R	(10)11	(10-)12-13	16-19	20-23
Pectoral-fin buds	*	*	Pectoral	11-13	13-15	14-16	16-20
Pelvic-fin buds	(10)11-12	(12)13	Pelvic	12-14	14-16	14-17	18-21
* before hatching			Scales	≤24	≤29	–	–

References: Arizona Game and Fish Department 2002, Baird and Giard 1953a & b, Balon 1981, Baxter and Simon 1970, Beckman 1952, Behnke and Benson 1983, Behnke et al. 1982, Bestgen 1985, Bestgen et al. 1987b, Carlson et al. 1979, Gaufin et al. 1960, Holden 1968, Holden and Stalnaker 1970, Jordan and Evermann 1896, Joseph et al. 1977, Koster 1957, LaRivers 1962, Miller 1946, Minckley 1973, Minckley and DeMarais 2000, Moore 1968, Muth 1990, Muth et al. 1985, Page and Burr 1991, Rinne 1976, Sigler and Miller 1963, Smith et al. 1979, Snyder 1981, Sublette et al. 1990, Uyeno 1961, Vanicek and Kramer 1969, Winn and Miller 1954.

Table 28. Size at developmental interval (left) and gut phase (right) transitions for *Gila robusta*. (See Figure 5 for phases of gut folding. Rare values in parentheses. From Muth 1990 and Snyder 1981, supplemented with original data.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	(8)9-10	(9)10-11	2 - 90° bend	12-14	14-16
Postflexion mesolarva	10-11	(10-)11-12	3 - Full loop	28-34	36-43
Metalarva	12-13(14)	14-15(16)	4 - Partial crossover	(not applicable)	
Juvenile	(18)19-20(-22)	(21-)24-25(-27)	5 - Full	(not applicable)	

Table 29. Summary of morphometrics and myomere counts by developmental phase for *Gila robusta*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. SD value of 0 actually between 0.0 and 0.5. From Muth 1990, except as noted.)

	Protolarvae (N=22) ^a			Flexion mesolarvae (N=18)			Postflexion mesolarvae (N=22)			Metalarvae (N=55)			Juveniles (N=53)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	8	1	7 - 10	10	1	9 - 11	11	0	11 - 12	15	2	12 - 20	28	8	19 - 50
TL, mm	9	1	8 - 10	11	1	10 - 12	13	1	12 - 14	19	3	14 - 25	35	10	24 - 62
<u>Lengths %SL</u>															
AS to AE	3	0	2 - 4	4	1	2 - 5	4	0	3 - 5	6	1	4 - 9	6	1	5 - 8
PE	9	1	8 - 11	11	1	9 - 12 ^f	12	1	10 - 13	13	1	11 - 16	14	1	12 - 16
OP1	18	1	17 - 20	22	1	19 - 24	24	1	22 - 26	28	1	23 - 31 ^f	27	1	24 - 29
OP2							47	2 ⁱ	45 - 50	51	1	47 - 54 ^f	50	1	46 - 52
PY	-	bc	66 - 66	-	cs	48 - 64	-	su	57	-			-		
OPAF	-		29 - 55	-		28 - 37	-		33 - 41	-		39 - 59	-		
ODF	-		26 - 39	-		40 - 48	-		43 - 50	-	c	50 - 53	-		
OD							54	1 ^{hj}	52 - 55	55	2	51 - 58 ^f	54	1	49 - 57 ^f
ID							65	1 ^{hk}	64 - 65	66	1	63 - 69	66	1	61 - 69 ^f
PV	69	2	67 - 72	68	2	65 - 71	70	1	67 - 72	68	2	63 - 73	66	2	61 - 68 ^f
OA										67	2	64 - 72	66	2	64 - 69
IA										78	1	75 - 81	77	1	74 - 80 ^f
AFC							111	1	106 - 115 ^f	114	1	107 - 116 ^f	115	1	109 - 116 ^f
PC	-		103 - 106	-		105 - 113	115	3	110 - 121	123	3	116 - 128 ^f	126	2	118 - 129 ^a
Y	-	bc	49 - 62	-	st	0 - 45	-	ks	0 - 32	-			-		
P1	-		4 - 10	-		10 - 13	-		12 - 14	15	1	12 - 17	17	1	14 - 20 ^f
P2							-	m	2 - 4	6	1 ^o	3 - 13 ^f	12	2	9 - 15
D										18	1	14 - 22 ^f	20	1	18 - 24 ^f
A										16	1	10 - 19 ^f	18	2	16 - 21 ^f
<u>Depths %SL</u>															
at BPE	11	1 ^{bd}	10 - 16	13	1	11 - 15 ^f	14	1	12 - 15	16	1	14 - 18	17	1	14 - 19 ^f
OP1	17	4 ^{bc}	14 - 22	16	2 ^g	12 - 18	16	2 ^g	12 - 18	20	1 ^{hp}	17 - 22	20	1 ^{hr}	19 - 23
OD	14	1 ^{bc}	13 - 15	12	1 ^g	10 - 16	12	1 ^g	10 - 16	17	3 ^{hp}	13 - 21	20	1 ^{hr}	18 - 22
BPV	8	2 ^{bc}	6 - 10	9	1 ^g	8 - 11	9	1 ^g	8 - 11	13	2 ^{hp}	10 - 15	15	1 ^{hr}	13 - 18
AMPM	4	1 ^{bd}	2 - 5	4	1	4 - 6	6	0	5 - 7 ^f	7	1 ^o	6 - 9	8	0	7 - 10 ^f
Max. yolk	-	bc	10 - 18	-	st	0 - 9	-	ks	0 - 2	-			-		
<u>Widths %SL</u>															
at BPE	10	2 ^{bd}	8 - 13	13	1	10 - 14	15	1	14 - 16	16	1	13 - 19	16	1	13 - 18 ^f
OP1	14	6 ^{bc}	10 - 21	11	1 ^g	10 - 13	11	1 ^g	10 - 13	14	1 ^{hp}	12 - 17	14	1 ^{hr}	13 - 17
OD	8	0 ^{bc}	7 - 8	7	1 ^g	6 - 9	7	1 ^g	6 - 9	10	1 ^{hp}	8 - 13	12	1 ^{hr}	10 - 15
BPV	5	1 ^{bc}	4 - 5	5	1 ^g	4 - 6	5	1 ^g	4 - 6	8	1 ^{hp}	6 - 11	10	1 ^{hr}	8 - 12
AMPM	3	1 ^{bd}	2 - 4	3	0	2 - 4 ^f	3	0	3 - 4	4	1	2 - 5 ^f	4	0	2 - 5 ^f
Max. yolk	-	bc	12 - 23	-	cs	0 - 9	-	ks	0 - 9	-			-		
<u>Myomeres; Vertebrae for Juveniles</u>															
to PY	29	1 ^{bc}	28 - 30	-			-			-			-		
OPAF	14	4 ^{bc}	11 - 19	-			-			-			-		
OP2							16 ^d	n	15 - 18 ^f	16 ^d		15 - 17	17 ^d	p	15 - 17
ODF	12	1 ^{bc}	11 - 12	-			-			-			-		
OD							20	1 ^{hj}	19 - 21	19 ^d		17 - 20	19 ^d	p	18 - 20
PV	29 ^d		29 - 32	29 ^d		26 - 31 ^f	29 ^d		26 - 31 ^f	28 ^d		25 - 30	27 ^d	p	26 - 28
Total	46 ^d		45 - 48	46 ^d		43 - 48 ^f	47 ^d		43 - 48 ^f	46 ^d		44 - 48	46 ^d	p	44 - 47
After PV	17 ^d		13 - 19	18 ^d		15 - 18 ^f	18 ^d		15 - 19 ^f	18 ^d		16 - 19	19 ^d	p	18 - 20

^aIncludes original (new) data for 2 specimens. ^bIncludes measurement from Fig. 55. ^cN = 3. ^dN = 23. ^eMode rather than mean. ^fIncludes range extreme(s) from Snyder (1981). ^gData for whole mesolarval phase from Snyder 1981 (N = 13). ^hData from Snyder (1981). ⁱN = 7. ^jN = 10. ^kN = 2. ^lMuth (1990) portion of data approximated by subtracting dorsal caudal-fin-lobe lengths from corresponding total lengths. ^mN = 12. ⁿN = 8. ^oN = 33. ^pN = 30. ^qLower extreme from drawing in Fig. 61. ^rN = 27. ^sOriginal data. ^tN = 4. ^uN = 1.

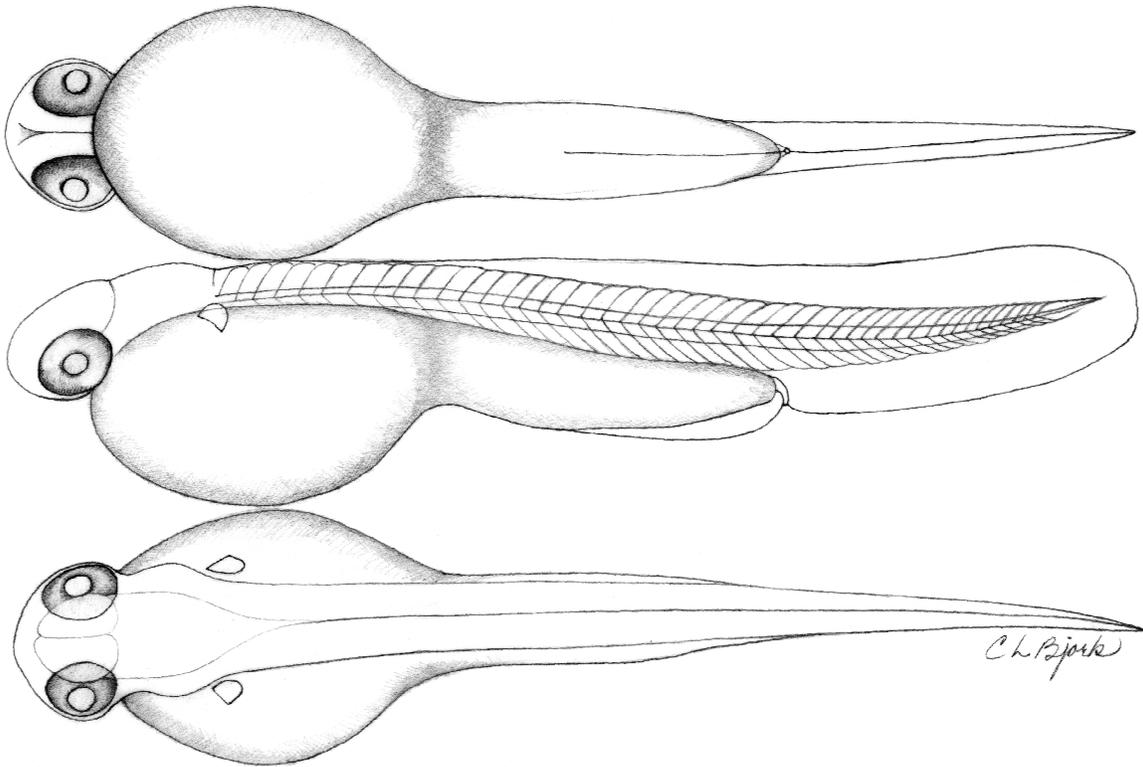


Fig. 55. *Gila robusta* protolarva, recently hatched, 7.3 mm SL, 7.6 mm TL. (Cultured in 1983 with stock from the Yampa River southwest of Craig, Colorado. From Muth 1990.)

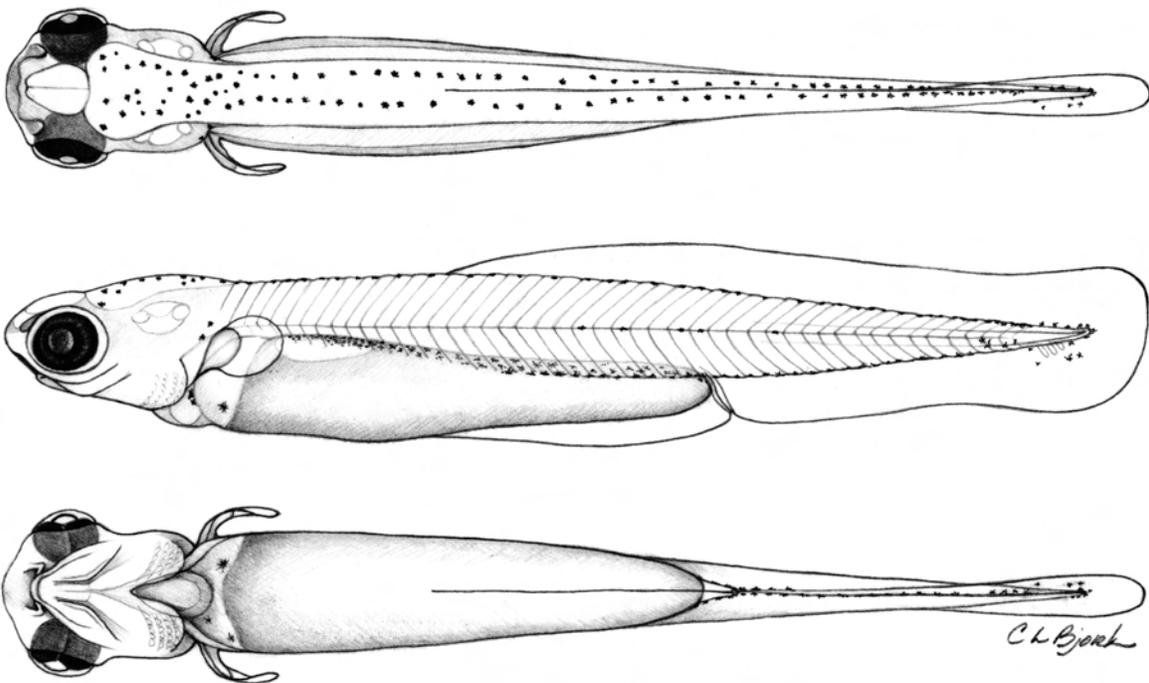


Fig. 56. *Gila robusta* protolarva, 8.9 mm SL, 9.4 mm TL. (Cultured in 1983 with stock from the Yampa River southwest of Craig, Colorado. Previously unpublished illustration.)

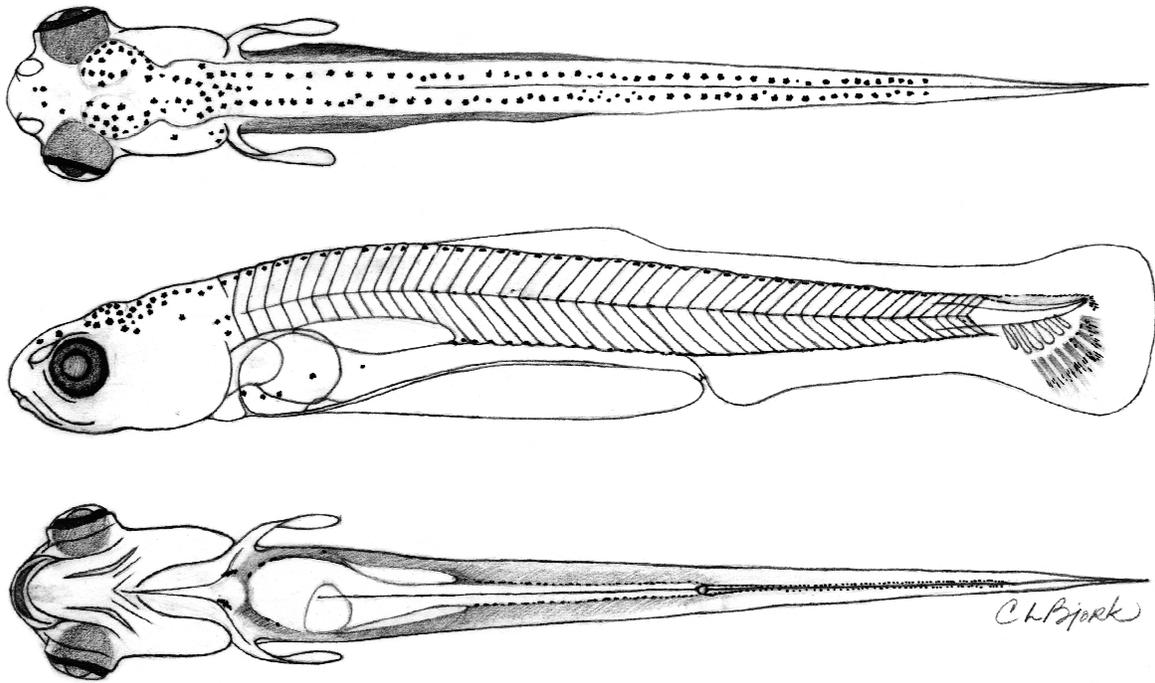


Fig. 57. *Gila robusta* flexion mesolarva, recently transformed, 9.3 mm SL, 9.8 mm TL. (Collected in late 1970s from the Yampa River, Colorado. From Muth 1990 and Snyder 1981.)

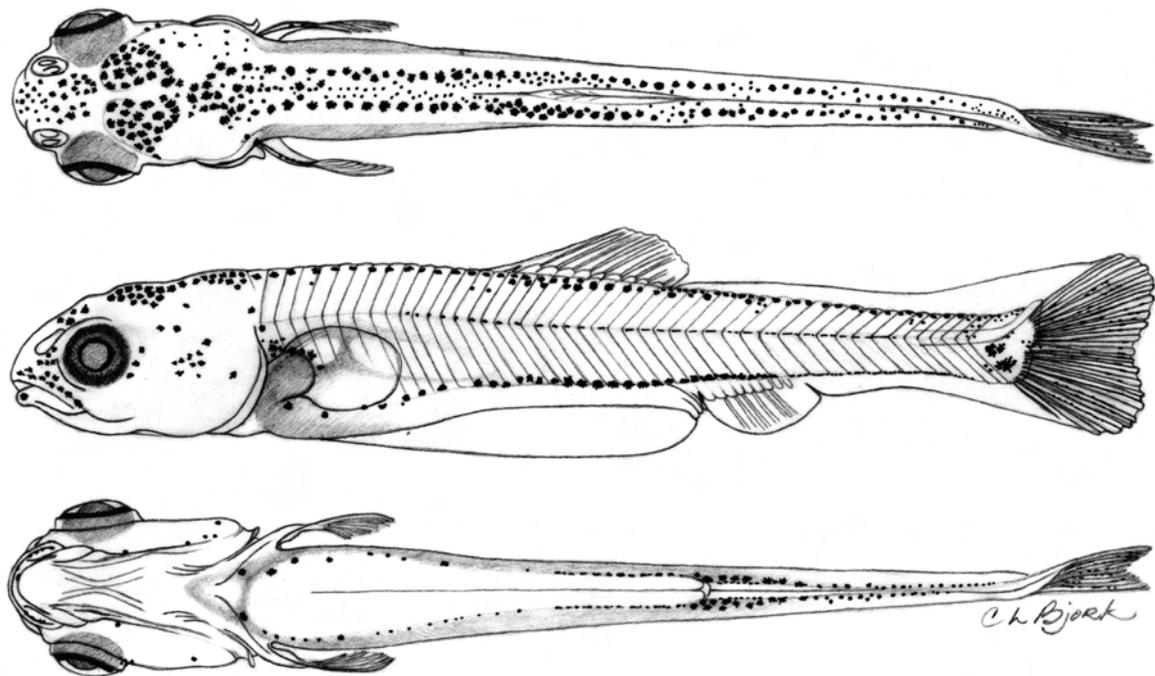


Fig. 58. *Gila robusta* postflexion mesolarva, 10.8 mm SL, 12.0 mm TL. (Collected in late 1970s from the Yampa River, Colorado. From Muth 1990 and Snyder 1981.)

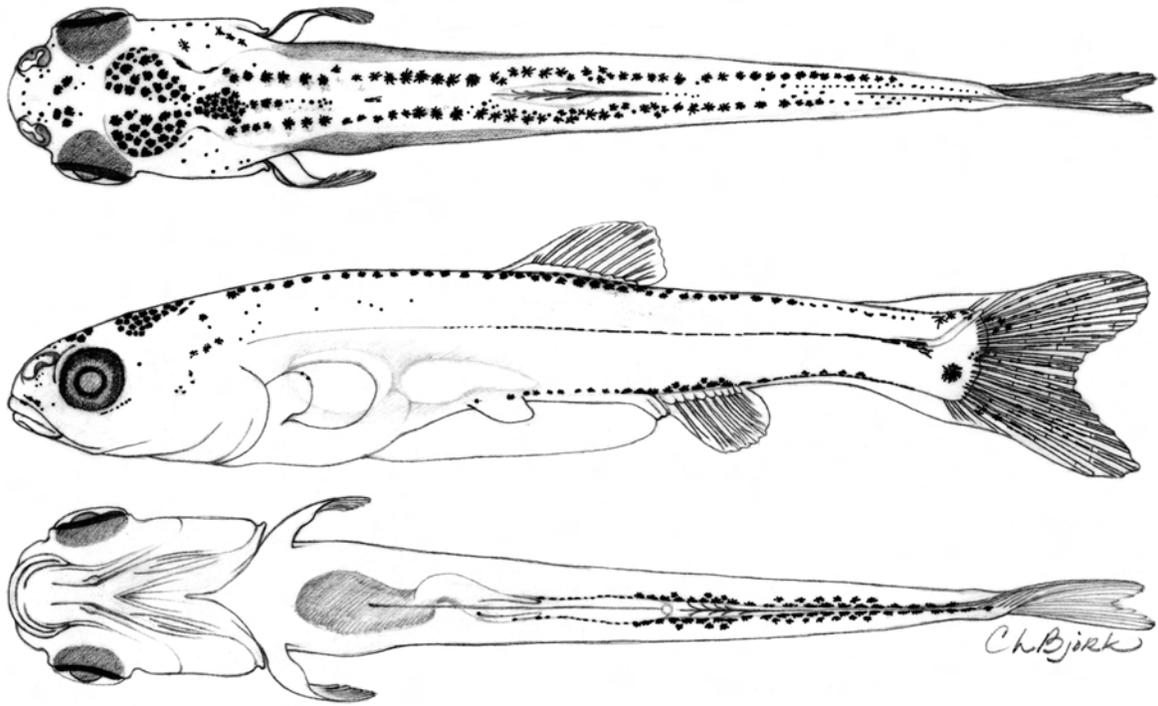


Fig. 59. *Gila robusta* metalarva, recently transformed, 12.1 mm SL, 14.0 mm TL. (Collected in late 1970s from the White River, Colorado. From Muth 1990 and Snyder 1981.)

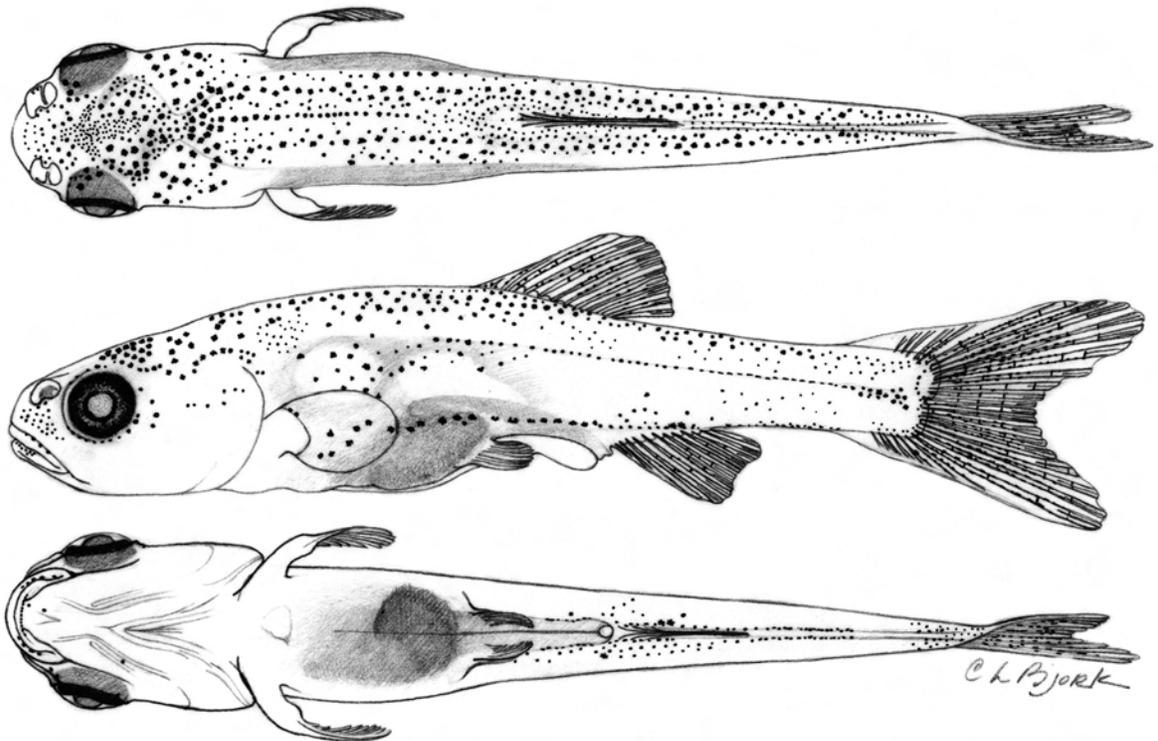


Fig. 60. *Gila robusta* metalarva, 14.7 mm SL, 18.0 mm TL. (Collected in late 1970s from the White River, Colorado. From Muth 1990 and Snyder 1981.)

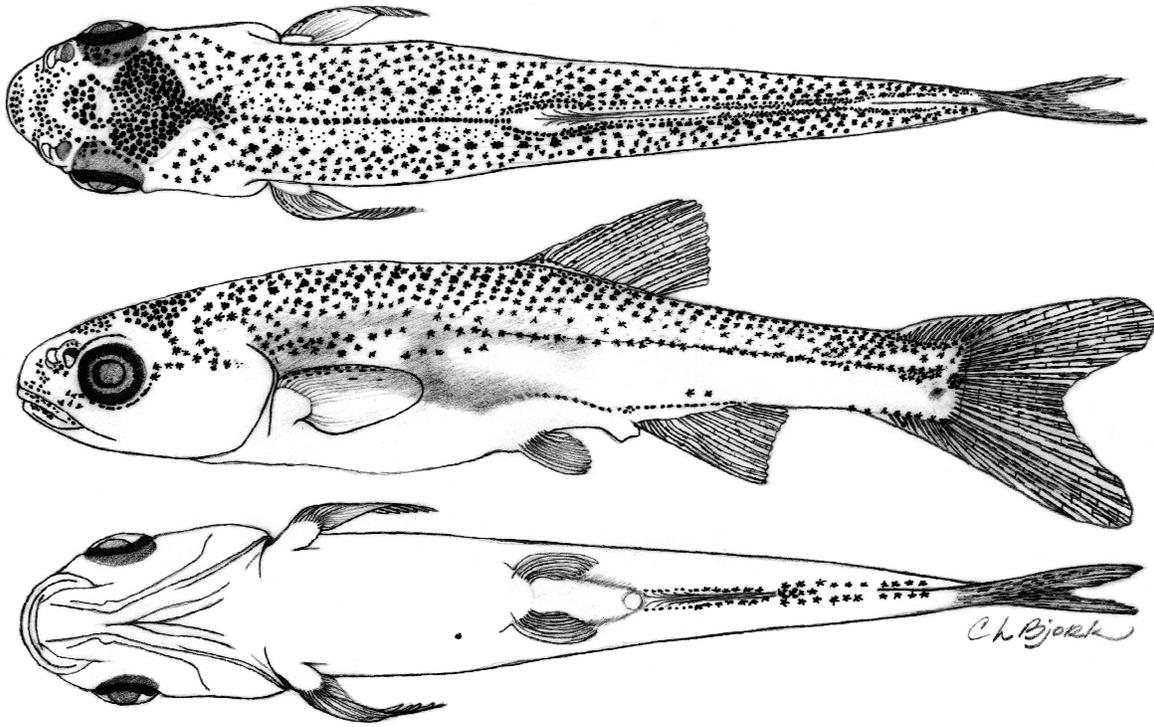


Fig. 61. *Gila robusta* juvenile, recently transformed, 20.3 mm SL, 24.1 mm TL. (Collected in late 1970s from the Yampa River, Colorado. From Muth 1990 and Snyder 1981.)

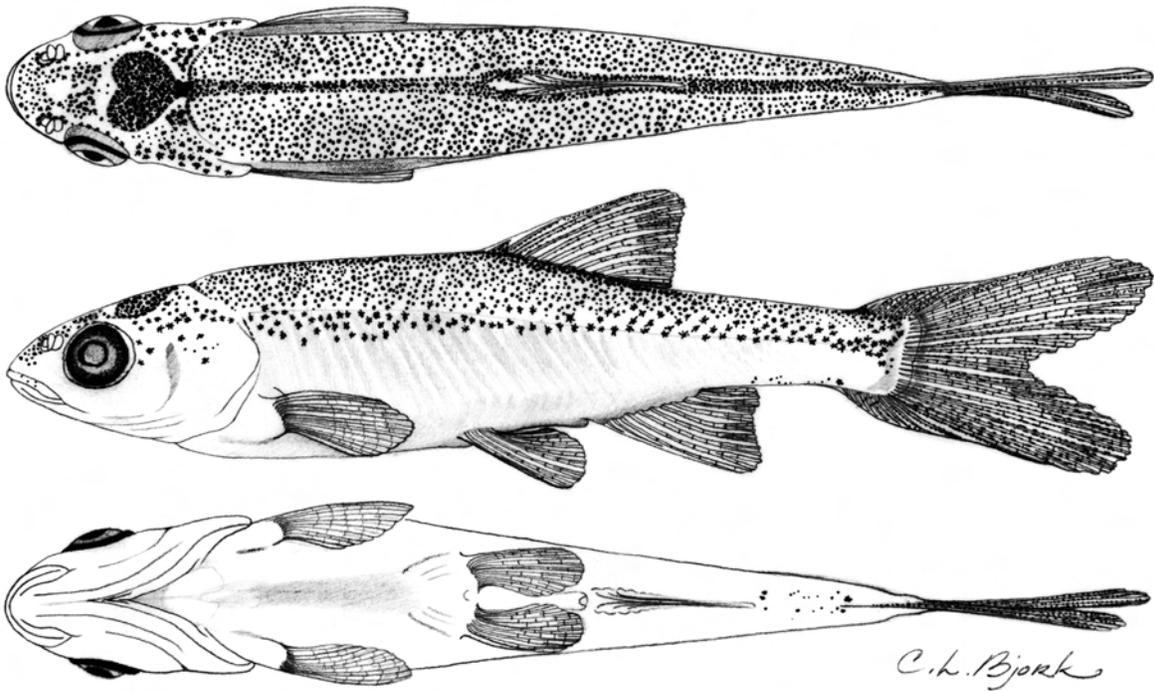


Fig. 62. *Gila robusta* juvenile, 29.6 mm SL, 37.0 mm TL. (Collected in late 1970s from the White River, Colorado. From Muth 1990 and Snyder 1981.)

Species Account – *Meda fulgida*

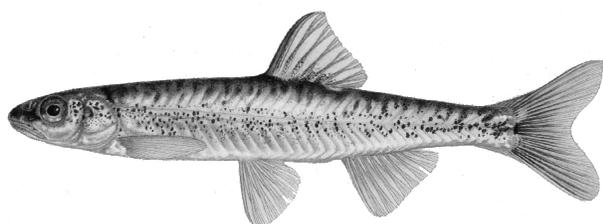


Fig. 63. *Meda fulgida* adult (© Joseph R. Tomelleri).

Adult description: Rarely exceed 75 mm TL. Body streamlined, slightly laterally compressed; snout rounded to somewhat pointed. Mouth large, subterminal, and slightly oblique. Eyes large. Dorsal fin behind pelvic fin origin, begins with stout, sharp spine (derived from a rudimentary ray) with a posterior groove that nests the partially spinous first principal ray (often counted as a second spine). Median margins of pelvic fins adnate to body. Essentially scaleless, some with vestigial scales embedded along beginning of lateral line. Sides silvery in life with black specks, often including uniquely square melanophores; greenish-brown above, white below; small dark spot on base of median caudal fin rays with small, very light areas above and below. Breeding males sometimes yellow or golden laterally. (Also, Table 30.)

Reproduction: Presumably non-guarding, open-substrate lithophils or psammophils. Spawn at water temperatures $\geq 19^\circ\text{C}$, mostly from late March through early June. Water-hardened egg diameter 1.7-2.1 mm, modally 1.8-1.9 mm.

Young: Just hatched larvae present in waters with diel temperatures of 10-18°C (early April). Late protolarvae and larger individuals subject to downstream transport, sometimes for considerable distances, as evidenced by drift-net captures. Larvae typically occupy near-shore, low-velocity, channel margins and backwaters, eddies, and pools over sand substrate. Larvae consume early instars of chironomids and other small invertebrates.

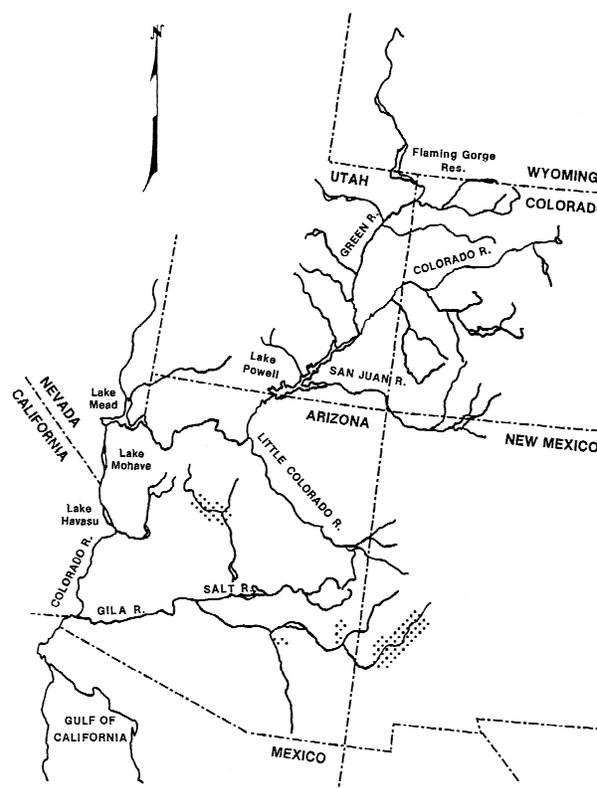


Fig. 64. Recent distribution of *Meda fulgida* in the Colorado River Basin.

Table 30. Selected juvenile and adult meristics for *Meda fulgida*. (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. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

Character	Observed	Literature	Character	Observed	Literature
Dorsal-fin rays - P	7	7(8) ^a	Dorsal-fin rays - R	1,1 ^b	I ^a
Anal-fin rays - P	(8)9(10)	8-9(10)	Anal-fin rays - R	2	—
Caudal-fin rays - P	(18)19(20)	19	Caudal-fin rays - RD	11-13(14)	—
Pectoral-fin rays	<u>14</u> -15	14-15	Caudal-fin rays - RV	10-12(13)	—
Pelvic-fin rays	<u>7</u> -8	(6)7	Lateral scales	none	vestigial or none
Vertebrae	39 (N=1)	(39) <u>40</u> -41(42)	Pharyngeal teeth	—	1(2),4(5)/4,1(2)

^a Dorsal fin formula including rudimentary-based spine is I,7 or i,I,7; if 1st principal ray is also treated as a spine, formula would be II,6 or i,II,6.

^b 1st rudimentary ray very tiny and becomes incorporated in anterior base of the long spine that forms from the 2nd (last) rudimentary ray.

Table 31. Size at onset of selected developmental events for *Meda fulgida*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	5	5	Dorsal - P	9-10	10-11	(11)12	(12)13-14
Eyes pigmented	*	*	Anal - P	10	11	12(13)	14(15)
Yolk assimilated	(6)7(8)	(6-)8(9)	Caudal - P	7(8)	(7)8(9)	9(-)11	(9)10(11)
Finfold absorbed	(25-)27->41	(31-)33->49	Caudal - R	9-10	10-11	(16-)21-24	(19-)25-28
Pectoral-fin buds	*	*	Pectoral	9-10	10-11	(15-)18(-)21	(18-)21-22(-)26
Pelvic-fin buds	11	(12)13	Pelvic	13(14)	(15)16	(14)15(16)	(16-)18(-)20
* before hatching			Scales	(not applicable)		(not applicable)	

References: Anderson 1978, Arizona Game and Fish Department 2002, Bestgen unpublished data, Bestgen et al. 1987b, Douglas et al. 1994, Girard 1856, Miller and Hubbs 1960, Minckley 1973, Moore 1968, Page and Burr 1991, Parmeter and Platania 2004, Propst et al. 1986, Sublette et al. 1990, Winn and Miller 1954.

Table 32. Size at developmental interval (left) and gut phase (right) transitions for *Meda fulgida*. (See Figure 5 for phases of gut folding. Rare values in parentheses.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	7(8)	(7)8(9)	2 - 90° bend	12-18	14-21(22)
Postflexion mesolarva	9(-11)	(9)10(11)	3 - Full loop	(18-)25->41	(22-)31->49
Metalarva	12(13)	14(15)	4 - Partial crossover	(25, usually NA)	(31, usually NA)
Juvenile	(25-)27->41	(31-)33->49	5 - Full crossover	(NA, not applicable)	

Table 33. Summary of morphometrics and myomere counts by developmental phase for *Meda fulgida*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. Mean and SD values of 0 actually between 0.0 and 0.5.)

	Protolarvae (N=12)			Flexion mesolarvae (N=11)			Postflexion Mesolarvae (N=16)			Metalarvae (N=28)			Larger metalarvae & juveniles (N=18)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	6	1	5 - 8	9	1	7 - 11	11	1	9 - 13	17	3	12 - 25	32	5	25 - 41
TL, mm	7	1	5 - 9	9	1	7 - 11	12	2	9 - 15	20	4	14 - 28	39	6	30 - 50
<u>Lengths %SL</u>															
AS to AE	2	1	2 - 3	4	1	3 - 5	5	1	4 - 6	6	1	4 - 7	6	1	4 - 7
PE	10	1	9 - 11	11	1	10 - 12	12	1	11 - 13	13	1	12 - 14	14	1	12 - 15
OP1	18	1	17 - 20	21	1	19 - 22	22	1	20 - 24	23	1	22 - 26	24	1	21 - 26
OP2							48	1 ^c	46 - 50	48	1	47 - 50	48	1	45 - 50
PY	59	6 ^a	44 - 66	47	^b	47 - 47									
OPAF	34	4	26 - 41	30	1	27 - 32	32	2	28 - 35	39	6	33 - 53	57	1 ^{ll}	48 - 63
ODF	44	1	42 - 46	46	2	43 - 48	49	1 ^d	47 - 50						
OD							52	1 ^e	50 - 53	50	1	49 - 53	50	1	48 - 52
ID							63	1 ^a	62 - 65	64	1	63 - 66	65	1	63 - 68
PV	65	2	64 - 68	66	2	64 - 69	69	1	66 - 71	67	2	64 - 70	65	1	64 - 69
OA							68	1 ^e	66 - 70	66	1	64 - 68	65	1	63 - 68
IA							77	2 ^f	74 - 79	78	1	76 - 79	78	1	76 - 80
AFC							111	2	108 - 114	113	1	111 - 115	114	2	112 - 117
PC	106	1	105 - 108	107	1	105 - 108	114	2	110 - 116	119	2	116 - 122	122	2	119 - 126
Y	37	18	0 - 56	1	4	0 - 13									
P1	13	1	9 - 15	14	1	12 - 15	14	1	13 - 16	16	1	14 - 18	19	1	15 - 21
P2							3	1 ^g	2 - 6	9	2	4 - 12	14	1	12 - 15
D							15	2 ^h	13 - 17	20	2	17 - 23	22	2	19 - 26
A							13	1 ^f	12 - 14	16	2	13 - 19	19	1	17 - 21
<u>Depths %SL</u>															
at BPE	13	1	12 - 17	13	0	13 - 14	14	0	13 - 15	15	1	13 - 16	14	1	13 - 16
OP1	17	3	14 - 27	15	1	13 - 17	17	1	16 - 18	19	1	17 - 20	18	1	16 - 20
OD	12	2	10 - 17	11	1	9 - 13	12	1	11 - 14	16	2	12 - 19	18	2	16 - 22
BPV	8	1	7 - 9	8	0	7 - 8	9	1	7 - 10	11	1	9 - 13	14	1	12 - 14
AMPM	4	0	4 - 4	4	1	4 - 5	6	1	4 - 8	8	1	7 - 9	8	0	7 - 8
Max. yolk	9	6	0 - 20	0	0	0 - 1									
<u>Widths %SL</u>															
at BPE	15	1	14 - 16	15	1	14 - 16	16	1	15 - 17	16	1	15 - 18	15	1	13 - 17
OP1	13	3	9 - 20	12	1	9 - 14	15	1	13 - 17	17	1	15 - 18	15	1	14 - 16
OD	6	1	5 - 9	6	1	5 - 7	8	1	6 - 9	11	1	9 - 14	13	1	11 - 16
BPV	5	0	4 - 6	5	0	4 - 5	6	1	5 - 7	8	1	6 - 10	9	1	8 - 11
AMPM	3	0	3 - 4	3	0	2 - 3	3	0	3 - 4	4	0	3 - 5	4	1	3 - 5
Max. yolk	11	6	0 - 22	0	1	0 - 2									
<u>Myomeres</u>															
to PY	23	3 ^a	16 - 26	18	^b	18 - 18									
OPAF	10	2	7 - 13	8	1	6 - 9	8	1	6 - 9	11	3 ^j	8 - 19	24	^{bl}	24 - 24
OP2							17	1 ^g	16 - 18	17	1 ^j	16 - 17	16	1 ^m	16 - 17
ODF	15	1	12 - 17	17	1	16 - 18	17	1 ^d	16 - 19						
OD							19	1 ⁱ	18 - 20	18	1 ^j	17 - 19	19	1 ^m	18 - 19
PV	27	1	25 - 28	27	1	26 - 28	28	1	27 - 29	28	0 ^j	27 - 28	26	1 ^m	25 - 27
Total	40	1	39 - 41	40	1	39 - 41	41	1	39 - 42	41	1 ^j	40 - 41	40	0 ^m	40 - 40
After PV	13	1	12 - 14	13	1	12 - 13	13	1	11 - 14	13	1 ^k	12 - 14	14	1 ⁿ	13 - 15

^aN = 11. ^bN = 1. ^cN = 8. ^dN = 15. ^eN = 13. ^fN = 6. ^gN = 8. ^hN = 9. ⁱN = 12. ^jN = 23. ^kN = 24. ^lMetalarvae only. ^mN = 3. ⁿN = 5.

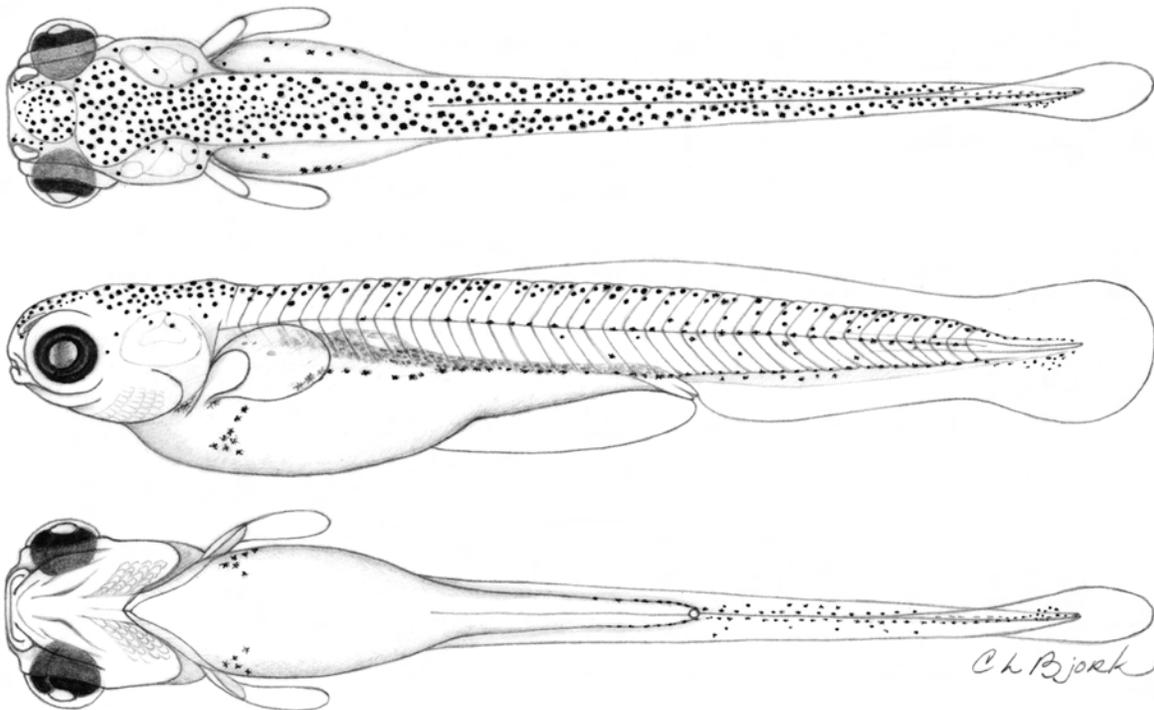


Fig. 65. *Meda fulgida* protolarva, 6.6 mm SL, 6.9 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

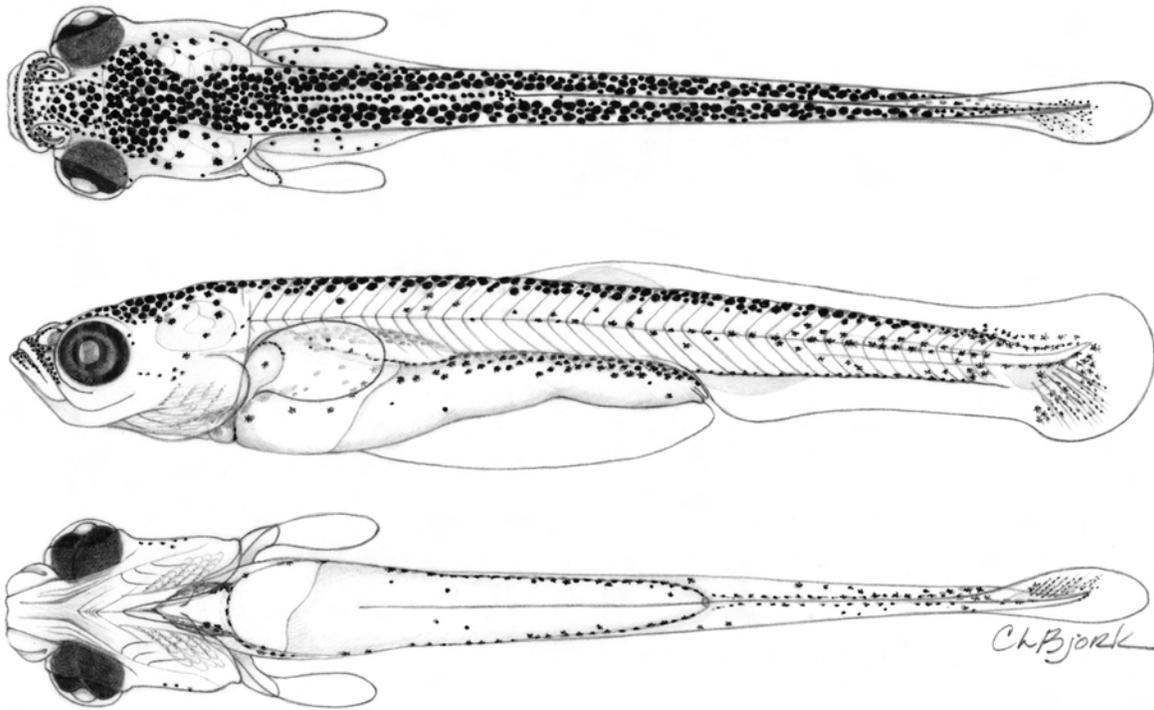


Fig. 66. *Meda fulgida* flexion mesolarva, recently transformed, 9.1 mm SL, 9.7 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

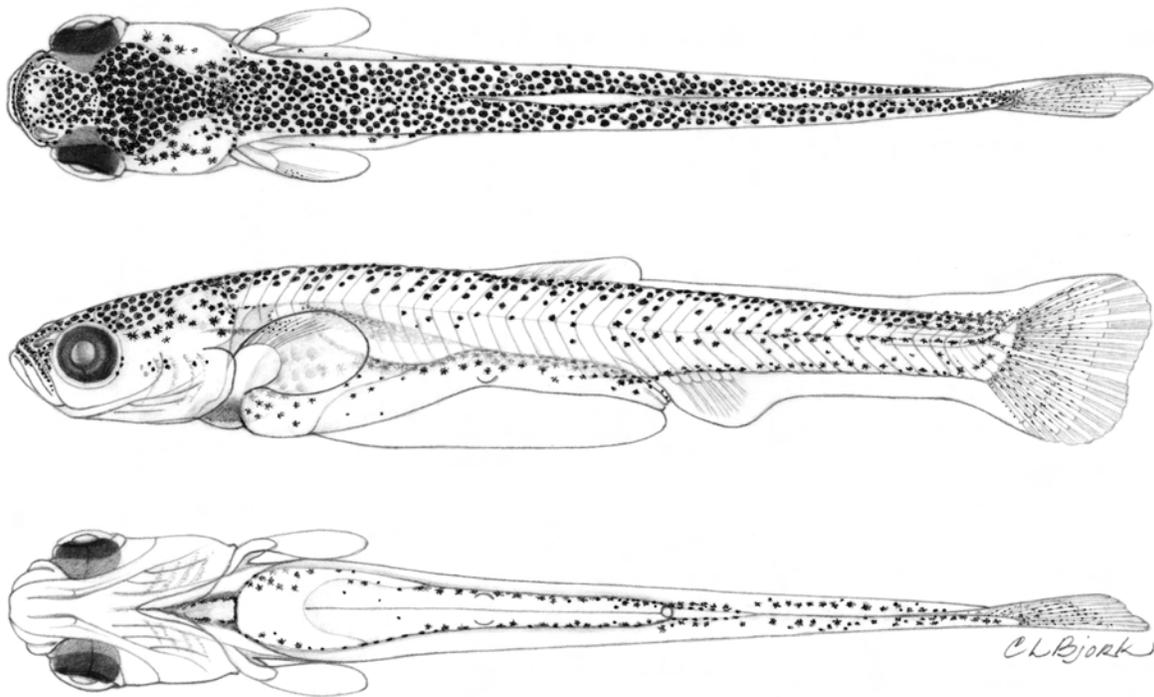


Fig. 67. *Meda fulgida* postflexion mesolarva, 11.4 mm SL, 13.0 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

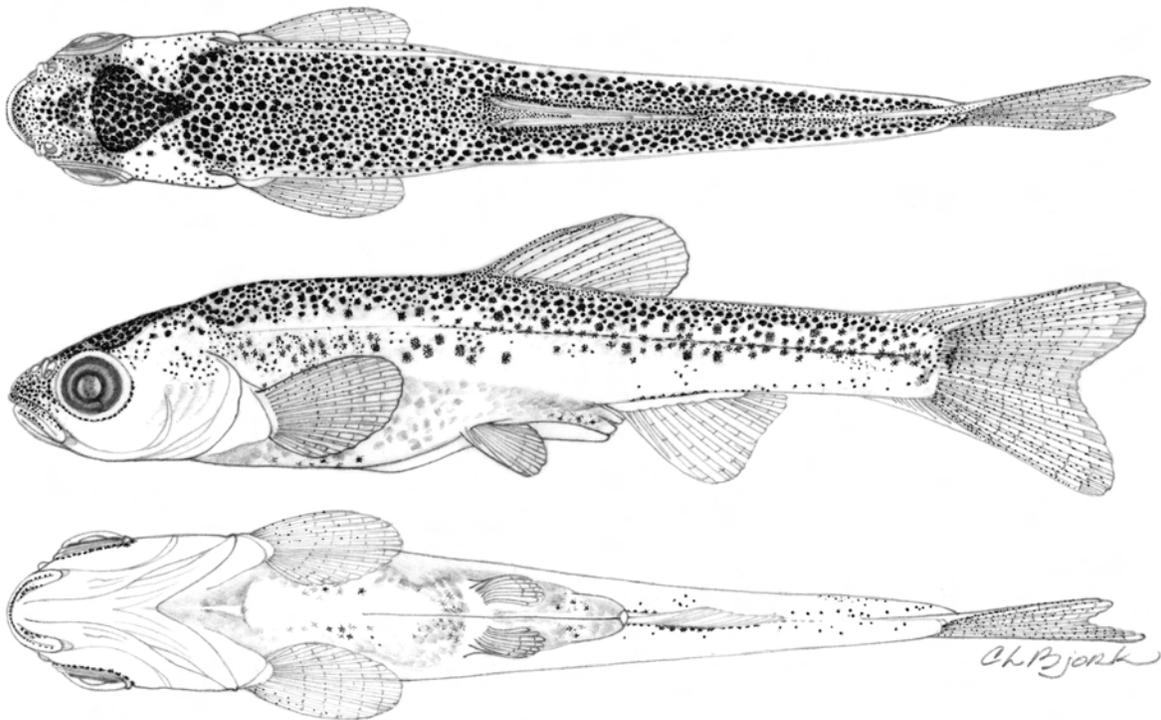


Fig. 68. *Meda fulgida* metalarva, 18.4 mm SL, 22.1 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

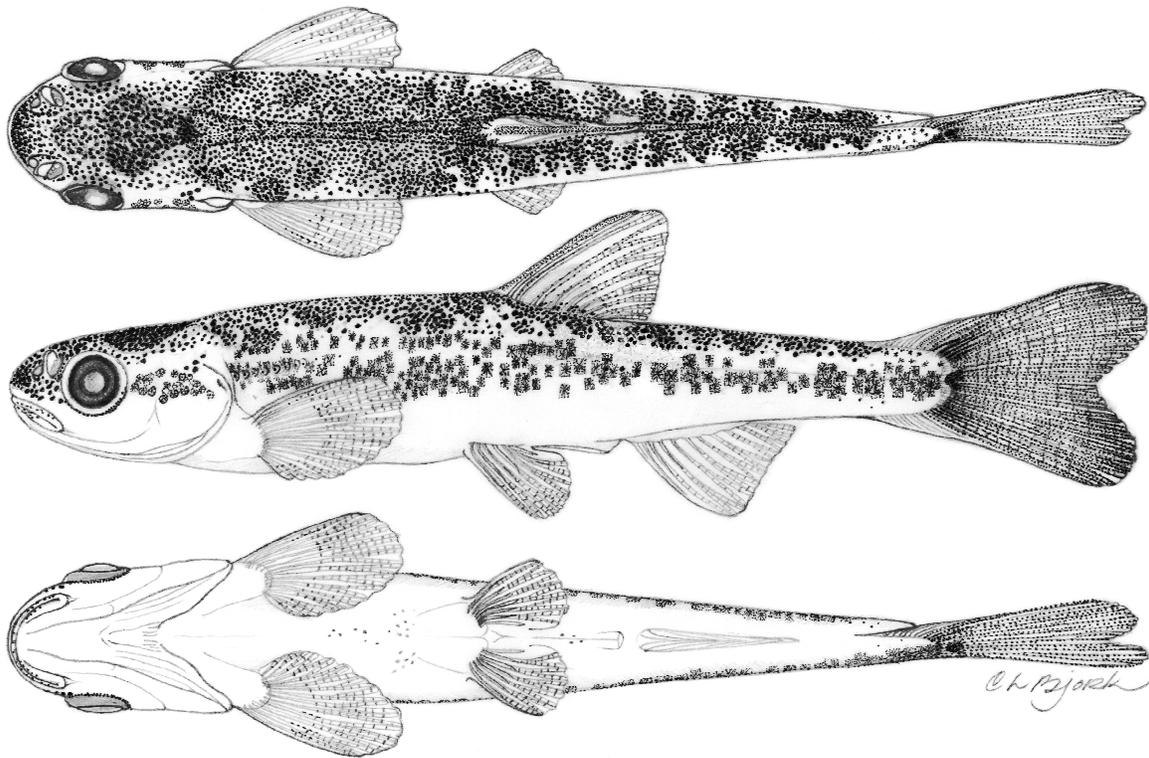


Fig. 69. *Meda fulgida* metalarva (almost juvenile), 30.1 mm SL, 36.3 mm TL. (Note remnant preanal finfold. Collected in 1984 from the Gila River near Cliff, New Mexico.)

Species Account – *Ptychocheilus lucius*

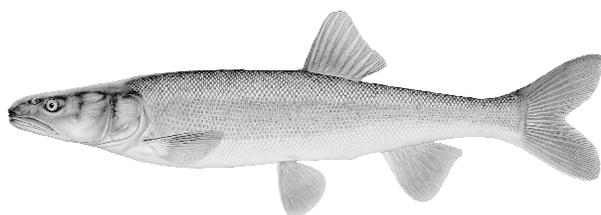


Fig. 70. *Ptychocheilus lucius* adult (© Joseph R. Tomelleri).

Adult description: Large, 45 to 180 cm TL. Fusiform body. Head large, 25% of SL, and somewhat dorso-ventrally flattened. Mouth large, terminal, and horizontal with thick lips; maxillary extending to at least middle of eye. Dorsal fin well back on body and caudal fin expansive. Scales moderately large. Typically green to tan above, silvery laterally, and white below. Breeding males tuberculate over head, paired fins, and ventral surface onto caudal peduncle and fin; females less tuberculate. (Also, Table 34.)

Reproduction: Non-guarding, open-substrate lithophil. In Upper Colorado River Basin, spawn when water reaches day-time highs of 16° (usually 18°) to 23°C in early June to early August, usually late June to late July, over gravel-cobble riffles. Water-hardened eggs are adhesive, demersal, and 1.9-2.2 mm in diameter and develop in the interstices of the substrate.

Young: Hatch in 6 d at 18°C and as little as 3 d at 30°C. Emerge 4-7 d later from spawning substrate as late protolarvae and mesolarvae (7 to 10 mm TL) and are transported in considerable numbers downstream. Larvae occupy near-shore, low-velocity channel margins, backwaters, eddies, and pools. Growth rate is directly related to water temperature. Larvae consume early instars of chironomids and other small invertebrates, larger juveniles add fish to their diet.

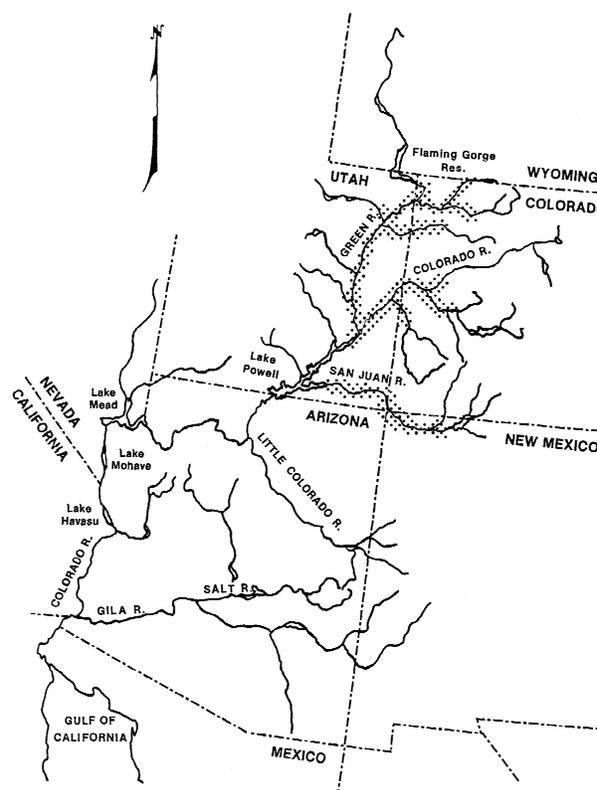


Fig. 71. Recent distribution of *Ptychocheilus lucius* in the Colorado River Basin.

Table 34. Selected juvenile and adult meristics for *Ptychocheilus lucius*. (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. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

Character	Observed*	Literature	Character	Observed*	Literature
Dorsal-fin rays - P	9(10)	9(10)	Dorsal-fin rays - R	2-3	—
Anal-fin rays - P	(8)9-10	(8)9(10)	Anal-fin rays - R	2-3	—
Caudal-fin rays - P	19	19	Caudal-fin rays - RD	8-9-10-11	—
Pectoral-fin rays	(14-)16-17(18)	14- <u>16-17</u> -18	Caudal-fin rays - RV	9-10	—
Pelvic-fin rays	8- <u>9</u>	8-9-10	Lateral scales	—	(76-)80-84-93-95(-98)
Vertebrae	47- <u>48-49</u>	47- <u>48-49</u>	Pharyngeal teeth	—	2,5/4,2

*From Snyder 1981, supplemented with original data.

Table 35. Size at onset of selected developmental events for *Ptychocheilus lucius*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses. From Snyder 1981, supplemented with original data.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	(5)6-7	6-7	Dorsal - P	8	9	(10)11-12	12(13)
Eyes pigmented	*	*	Anal - P	9-10	10	11-12	13-15
Yolk assimilated	(7)8(9)	8-9	Caudal - P	7-8(9)	8-9	(7)8-9	8-9(10)
Finfold absorbed	19-20(21)	(24)25(-27)	Caudal - R	(7)8-9(10)	8-9(10)	17	21
Pectoral-fin buds	6 or *	6 or *	Pectoral	11-12	13-15	16-17	20-21
Pelvic-fin buds	10-11	11-13	Pelvic	11-12	13-15	15	18-19
* before hatching			Scales	~27-31	35-40	—	—

References: Arizona Game and Fish Department 2002, Bestgen unpublished data, Bestgen 1996, Bestgen and Bundy 1998, Bestgen and Williams 1994, Bestgen et al. 1998, Girard 1856, Haynes et al. 1984, LaRivers 1962, Marsh 1985, Minckley 1973, Moore 1968, Muth and Snyder 1995, Nesler et al. 1988, Page and Burr 1991, Seethaler 1978, Sigler and Miller 1963, Snyder 1981, Sublette et al. 1990, Toney 1974, Vanicek 1967.

Table 36. Size at developmental interval (left) and gut phase (right) transitions for *Ptychocheilus lucius*. (See Figure 5 for phases of gut folding. Rare values in parentheses. From Snyder 1981, supplemented with original data.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	7-8(9)	8-9	2 - 90° bend	11-17	13-22
Postflexion mesolarva	(7)8-9	8-9(10)	3 - Full loop	31-38	41-50
Metalarva	(10)11-12	13-15	4 - Partial crossover	not applicable	
Juvenile	19-20(21)	(24)25(-27)	5 - Full	not applicable	

Table 37. Summary of morphometrics and myomere counts by developmental phase for *Ptychocheilus lucius*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. SD value of 0 actually between 0.0 and 0.5. Except as noted, from Snyder 1981, with data recalculated for flexion and postflexion mesolarvae.)

	Protolarvae (N=8)			Flexion mesolarvae (N=3)			Postflexion mesolarvae (N=16)			Metalarvae (N=11)			Juveniles (N=28)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	7	0	7 - 8	8	0	8 - 8	9	1	7 - 11	16	2	12 - 19	27	6	19 - 42
TL, mm	8	0	7 - 9	8	0	8 - 9	10	1	8 - 13	20	3	15 - 24	35	8	25 - 54
<u>Lengths %SL</u>															
AS to AE	3	1	1 - 4	3	0	3 - 3	4	1	3 - 5	6	1	5 - 9	6	1	5 - 8
PE	9	1	8 - 11	10	0	10 - 10	11	1	9 - 13	14	2	12 - 18	14	1	12 - 16
OP1	18	1	17 - 20	20	0	20 - 20	22	1	20 - 25	26	1	24 - 29	26	2	24 - 30
OP2										52	2	49 - 54	52	1	49 - 54
PY	65	3 ^a	60 - 68	55	14 ^{abd}	36 - 66									
OPAF	39	4 ^a	33 - 44	27	2 ^a	25 - 28	29	2 ^a	27 - 34	41	7 ^{ap}	34 - 56			
ODF	42	4 ^a	32 - 44	45	1 ^a	44 - 45	46	2 ^{ac}	44 - 49						
OD							55	1 ^f	53 - 57	55	2	51 - 57	55	1	53 - 56
ID							-	g	64	66	1	63 - 68	66	2	63 - 68
PV	68	1	67 - 69	67	0	67 - 68	70	2	67 - 74	68	1	65 - 69	67	1	64 - 69
OA										68	1 ^m	65 - 69	67	1 ^m	64 - 69
IA										79	2	75 - 82	79	2	76 - 82
AFC							107	2 ^h	105 - 111	112	2 ^p	108 - 117	113	2	110 - 116
PC	105	1	105 - 106	107	1 ^{do}	106 - 109	112	3	106 - 118	124	3	120 - 130	128	3 ^k	122 - 134
Y	49	4 ^a	42 - 55	23	21 ^{ado}	0 - 48									
P1	7	2	4 - 10	12	0	11 - 12	13	1	11 - 15	15	1	13 - 16	16	2 ^l	13 - 18
P2										10	2	7 - 14	15	1	11 - 17
D						-	g	13	19	2	16 - 23	22	1	18 - 25	
A									16	1	15 - 17	18	1	15 - 20	
<u>Depths %SL</u>															
at BPE	12	2	9 - 13	13	0	13 - 13	14	1	12 - 16	16	1	14 - 18	15	1	13 - 16
OP1	15	2	13 - 18	13	1	13 - 14	14	1	13 - 17	18	1	16 - 19	18	1	17 - 20
OD	14	1 ^b	12 - 15	11	0	11 - 11	11	1	10 - 14	16	1	15 - 18	19	1	17 - 21
BPV	8	1	6 - 9	8	0	8 - 8	8	1	7 - 10	13	1	11 - 15	15	1	14 - 17
AMPM	4	1	3 - 4	4	0	4 - 4	5	1	4 - 7	8	0	7 - 9	9	0	8 - 9
Max. yolk	13	2 ^a	9 - 15	3	3 ^{ado}	0 - 8									
<u>Widths %SL</u>															
at BPE	12	1	10 - 13	12	0	12 - 13	13	1	13 - 14	15	1	13 - 16	14	1	13 - 16
OP1	10	1	8 - 11	10	0	9 - 10	10	1	9 - 12	13	1	10 - 15	15	1	13 - 17
OD	7	2 ^b	5 - 10	6	0	6 - 6	6	1	5 - 8	10	1	8 - 12	13	2	10 - 16
BPV	5	1	4 - 7	5	0	4 - 5	5	1	4 - 7	8	1	7 - 11	11	2	8 - 14
AMPM	3	1	2 - 4	2	0	2 - 3	3	1	2 - 5	4	1	3 - 5	4	1	2 - 5
Max. yolk	12	3 ^a	9 - 18	6	5 ^{ado}	0 - 11									
<u>Myomeres</u>															
to PY	31	1 ^a	29 - 32	-	an	12 - 22									
OPAF	13	3 ^a	10 - 16	6	1 ^a	5 - 6	6	1 ^a	5 - 8	12	4 ^{ij}	8 - 22			
OP2										19	1	18 - 21	20	1 ^l	19 - 21
ODF	16	3 ^{ac}	10 - 17	18	1 ^a	17 - 18	18	1 ^{ac}	15 - 19						
OD							23	2 ⁱ	21 - 25	23	1	21 - 24	22	1 ^l	21 - 23
PV	33	0	32 - 33	34	1	33 - 34	34	1	31 - 35	33	1	31 - 34	32	1 ^l	30 - 34
Total	50	1	49 - 50	50	0	50 - 50	49	1	48 - 51	49	1	48 - 50	49	1 ^l	48 - 50
After PV	17	1	16 - 17	16	1	16 - 17	15	1	14 - 17	16	1	15 - 18	18	1 ^l	16 - 19

^aData summarized for but not reported by Snyder (1981). ^bN = 4. ^cN = 7. ^dIncludes new data. ^eN = 13. ^fN = 12. ^gN = 1. ^hN = 15. ⁱN = 7. ^jN = 9. ^kN = 22. ^lN = 26. ^mAssumed same as AS to PV. ⁿN = 2. ^oN = 6. ^pN = 10.

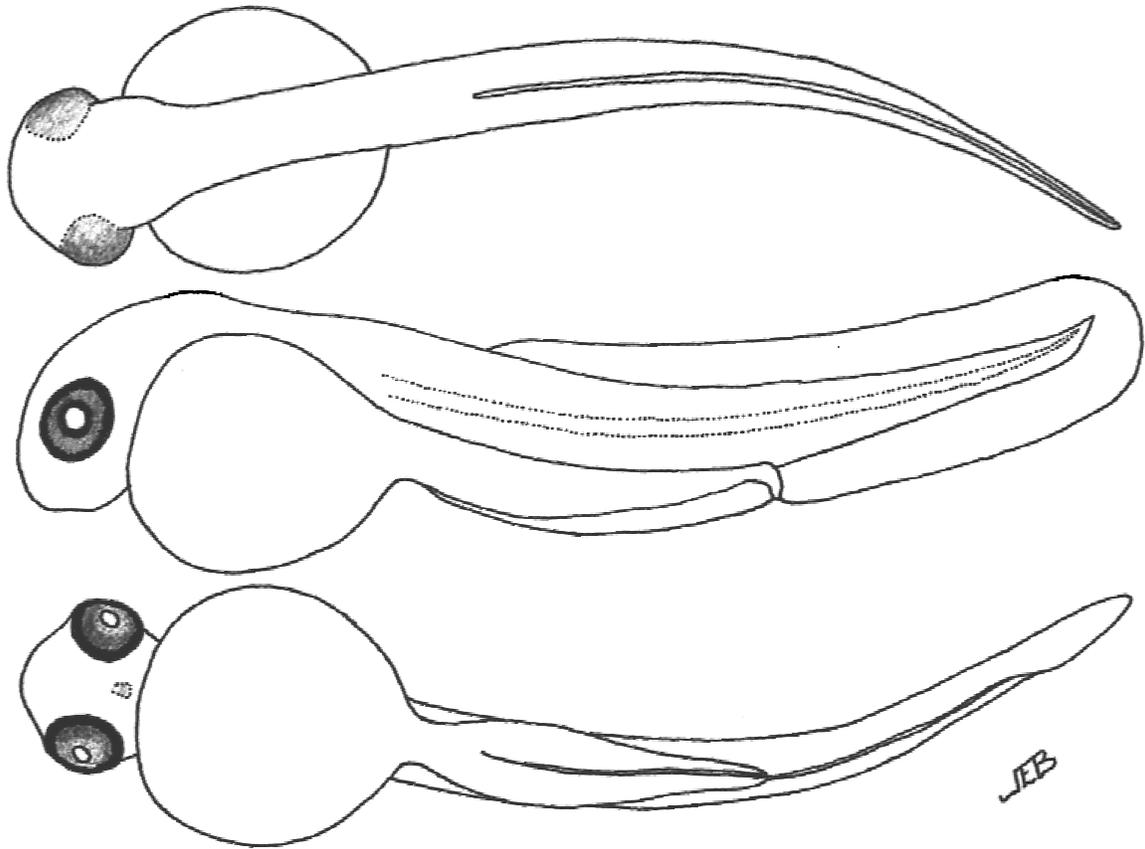


Fig. 72. *Ptychocheilus lucius* protolarva, recently hatched, 5.5 mm SL, 5.7 mm TL. (Cultured in 1975 by Willow Beach National Fish Hatchery, Arizona, in 1975 with stock from the lower Yampa River, Colorado. From Seethaler 1978.)

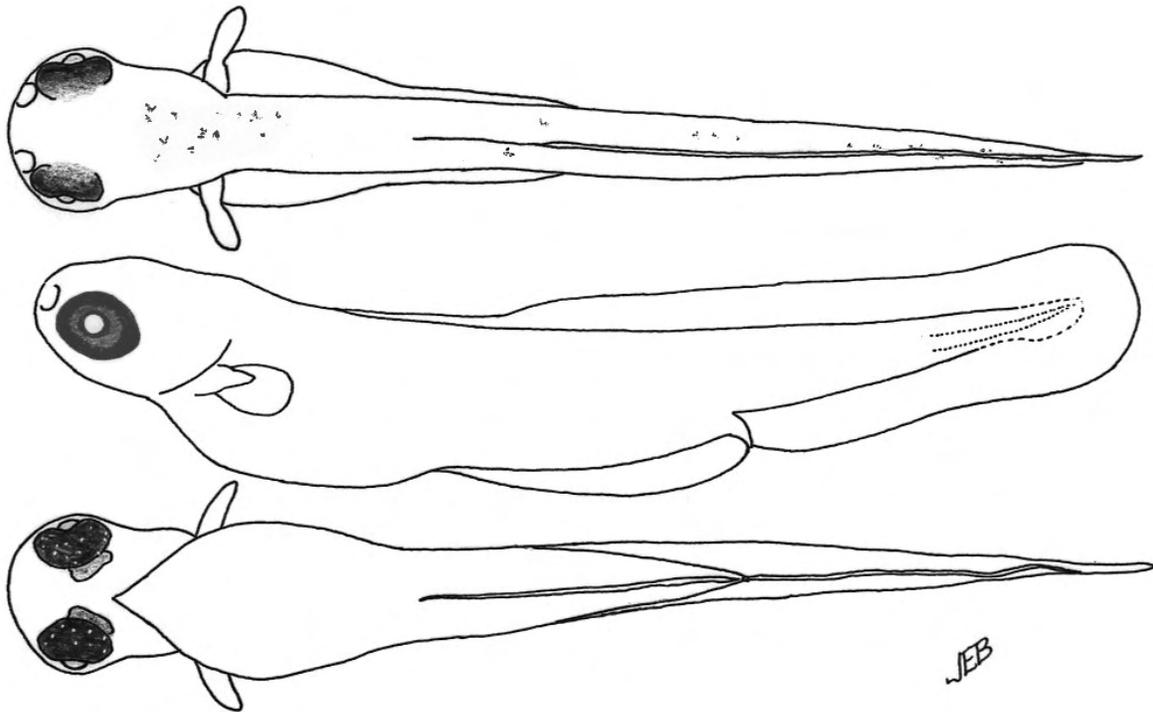


Fig. 73. *Ptychocheilus lucius* protolarva, 6.9 mm SL, 7.3 mm TL. (Cultured in 1975 by Willow Beach National Fish Hatchery, Arizona, in 1975 with stock from the lower Yampa River, Colorado. From Seethaler 1978.)

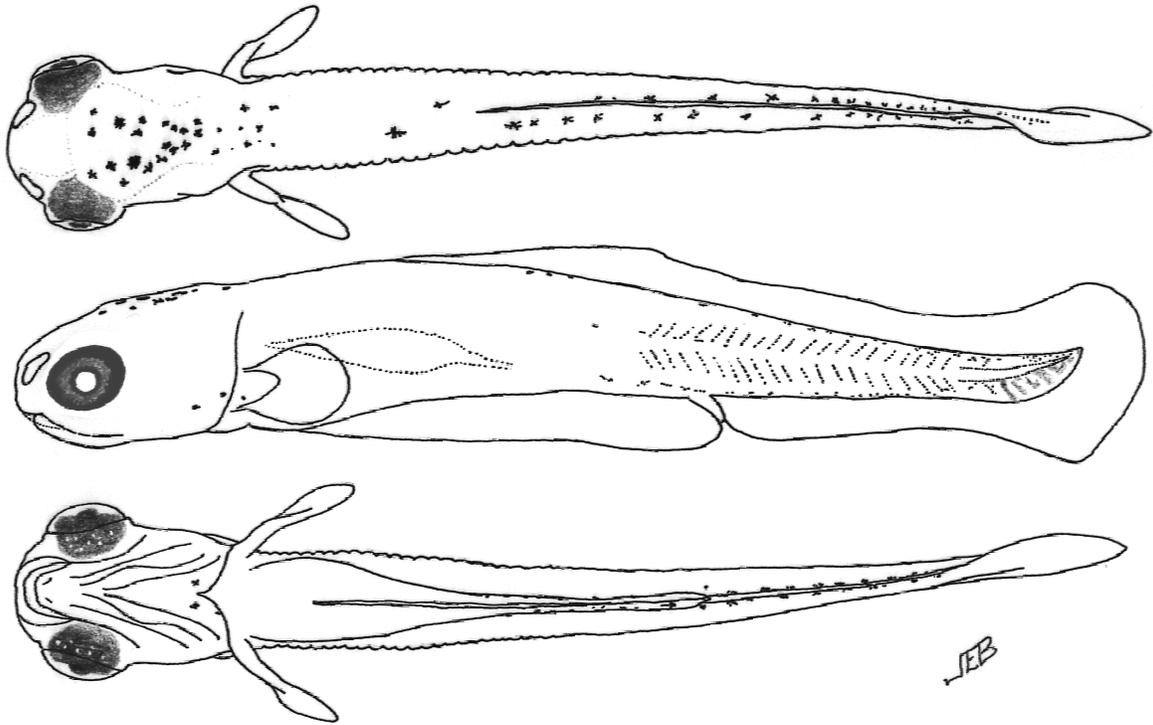


Fig. 74. *Ptychocheilus lucius* flexion mesolarva, recently transformed, 7.8 mm SL, 8.2 mm TL. (Cultured in 1975 by Willow Beach National Fish Hatchery, Arizona, in 1975 with stock from the lower Yampa River, Colorado. From Seethaler 1978.)

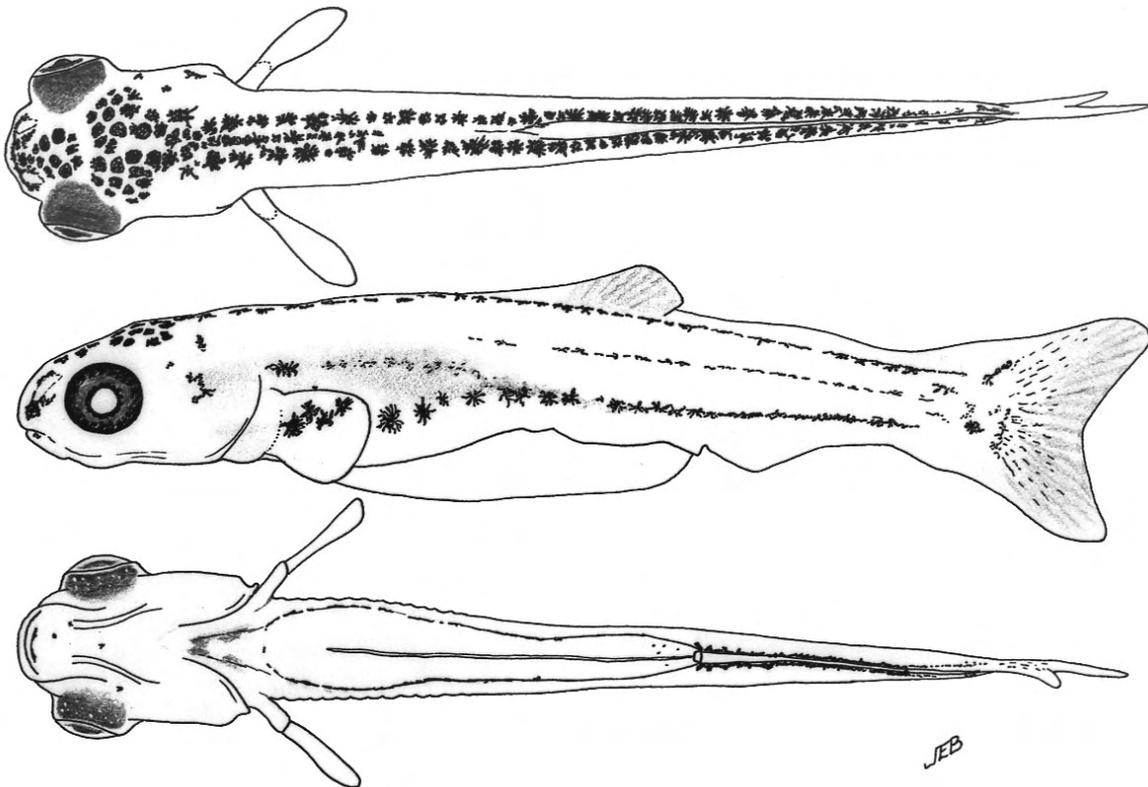


Fig. 75. *Ptychocheilus lucius* postflexion mesolarva, 8.7 mm SL, 10.0 mm TL. (Cultured in 1975 by Willow Beach National Fish Hatchery, Arizona, in 1975 with stock from the lower Yampa River, Colorado. From Seethaler 1978.)

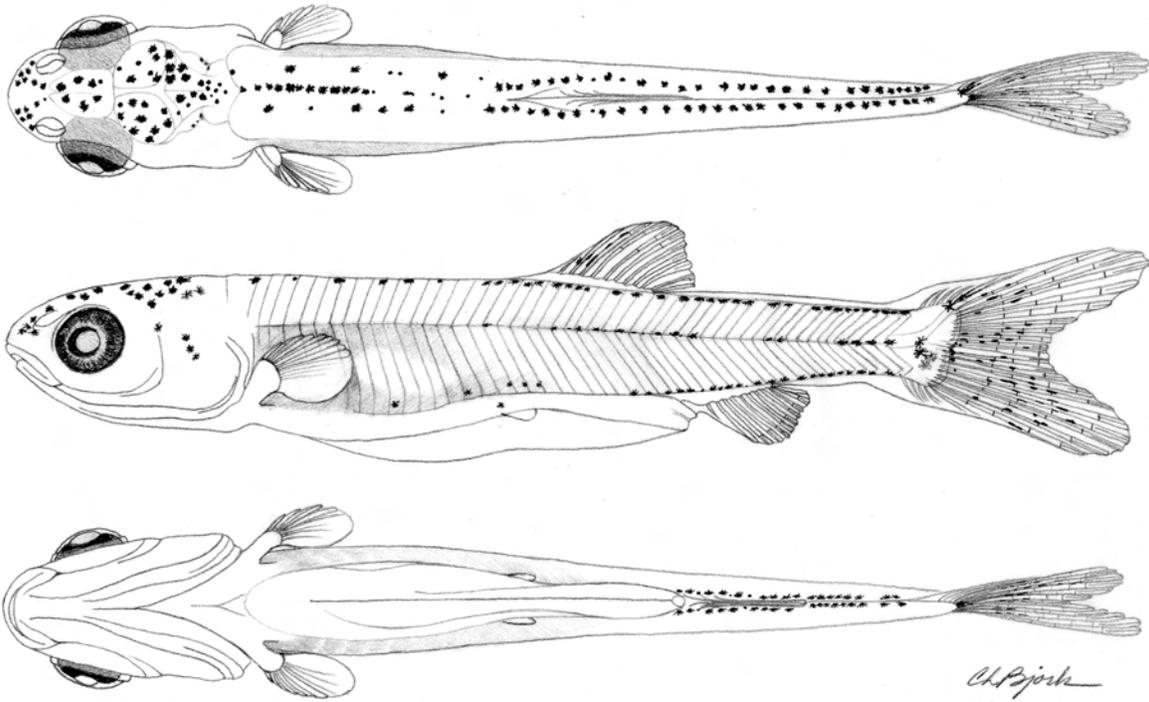


Fig. 76. *Ptychocheilus lucius* metalarva, recently transformed, 11.9 mm SL, 14.0 mm TL. (Collected in 1979 from the Colorado River, west of Grand Junction, Colorado. From Snyder 1981.)

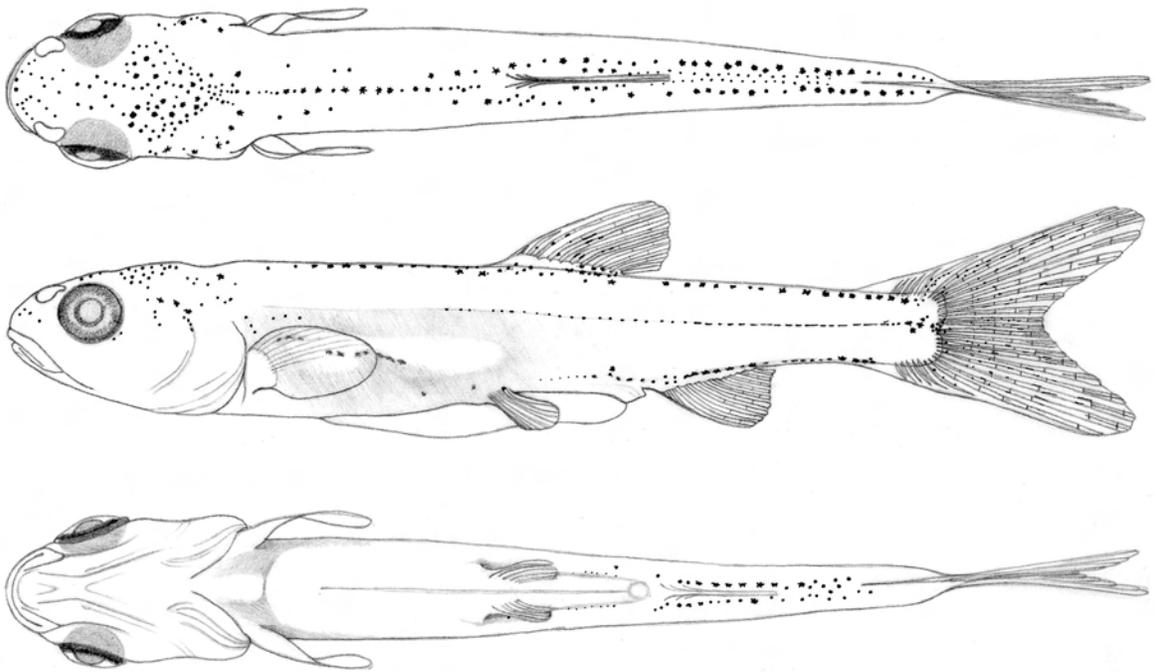


Fig. 77. *Ptychocheilus lucius* metalarva, 14.1 mm SL, 17.2 mm TL. (Collected in 1979 from the Colorado River, west of Grand Junction, Colorado. From Snyder 1981.)

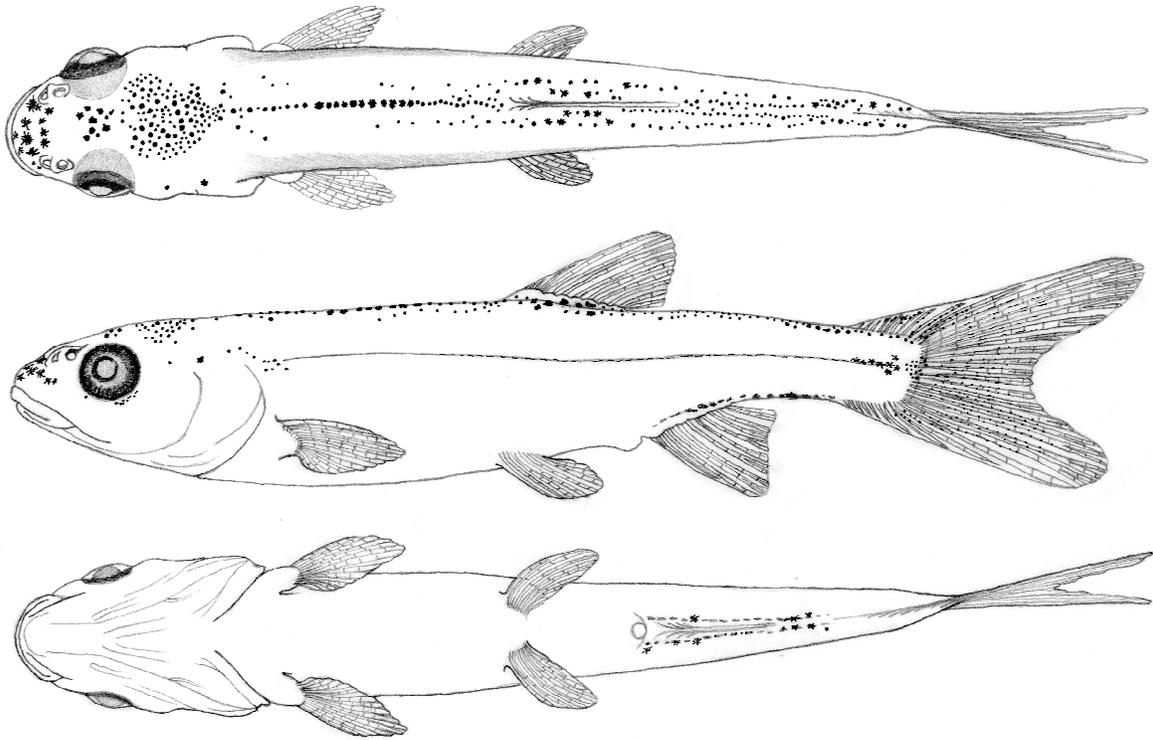


Fig. 78. *Ptychocheilus lucius* juvenile, recently transformed, 20.5 mm SL, 25.2 mm TL. (Collected in 1979 from the Colorado River, Colorado, in Black Rocks area near Utah border. From Snyder 1981)

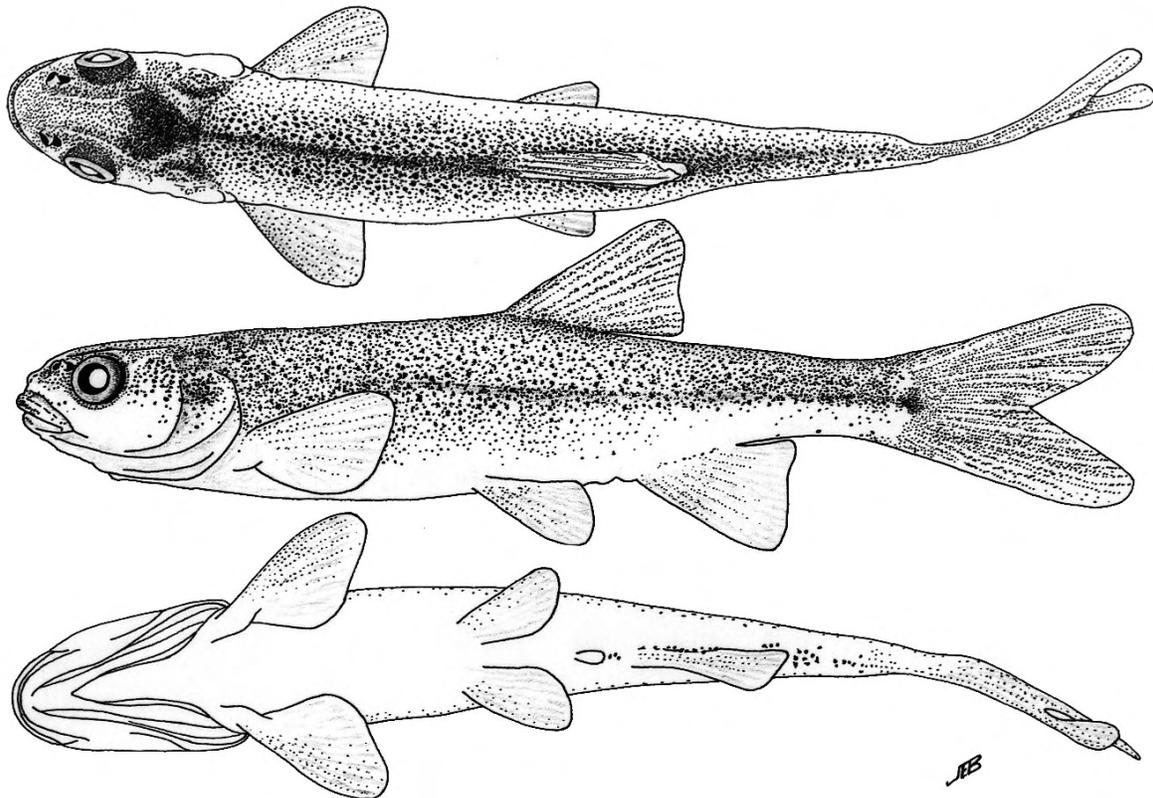


Fig. 79. *Ptychocheilus lucius* juvenile, 41.1 mm SL, 51.4 mm TL. (Cultured in 1975 by Willow Beach National Fish Hatchery, Arizona, in 1975 with stock from the lower Yampa River, Colorado. From Seethaler 1978.)

Species Account – *Rhinichthys cobitis*

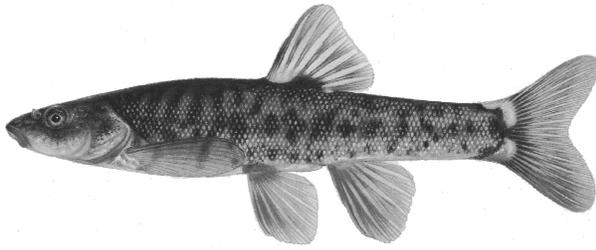


Fig. 80. *Rhinichthys cobitis* adult (© Joseph R. Tomelleri).

Adult description: Rarely exceed 75 mm TL. Body streamlined, fusiform, with a small, dorso-ventrally compressed head. Snout relatively long and sharp with median frenum connecting upper lip; mouth terminal, small, and oblique; eyes small and oriented dorsally. Dorsal fin origin over or slightly behind pelvic fin origin. Scales small. Mottled or blotched dorsally with darker brown or olive interspersed with yellow; yellow to white below. Proximal portion of caudal fin dark, spot-like, over centrals rays, white on rays above and below, and followed by vertical bands. Dark area on base of dorsal fin with white areas before and after. Breeding males red on ventral portions of body and head including the lips. (Also, Table 38.)

Reproduction: Nest-guarding lithophils. Spawn February to June, occasionally September, but mostly March to May over a 4-6 week period when water temperatures are 16-20°C. Adhesive eggs, round to oval, 1.8-2.3 mm max. diameter, deposited on accessible undersides of cobbles in riffles by male and guarded by male and possibly female.

Young: Hatch within 5 d at 18 to 20°C, remain in gravel for up to 5 d thereafter. Recently hatched larvae present in waters with diel temperatures of 9-19°C (early April). Late protolarvae and larger individuals subject to downstream transport as evidenced by drift-net captures. Larvae occupy near-shore, low-velocity channel margins, backwaters, eddies, and pools over sand substrate. Larvae consume early instars of chironomids, mayflies, and other small invertebrates.

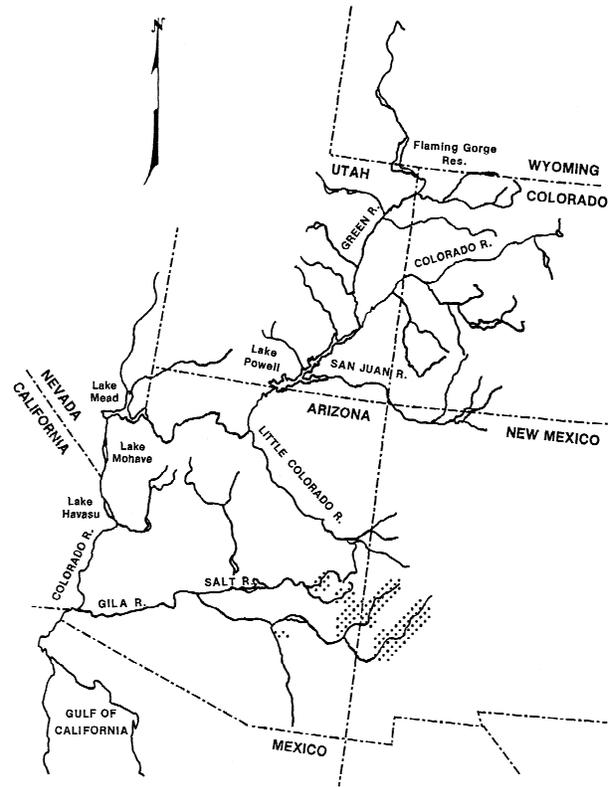


Fig. 81. Recent distribution of *Rhinichthys cobitis* in the Colorado River Basin.

Table 38. Selected juvenile and adult meristics for *Rhinichthys cobitis*. (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. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

Character	Observed	Literature	Character	Observed	Literature
Dorsal-fin rays - P	8	<u>8</u> -9	Dorsal-fin rays - R	2(3)	–
Anal-fin rays - P	(6)7	(6)7	Anal-fin rays - R	2	–
Caudal-fin rays - P	(18)19(20)	18- <u>19</u> -20	Caudal-fin rays - RD	7-10(11)	–
Pectoral-fin rays	<u>12</u> -14	12-14	Caudal-fin rays - RV	6-8(9)	–
Pelvic-fin rays	<u>7</u> -8-9(10)	7-8	Lateral scales	65-71(-73)	61-65(-70)
Vertebrae	38 (N = 1)	–	Pharyngeal teeth	–	1(2),4/4,1(2)

Table 39. Size at onset of selected developmental events for *Rhinichthys cobitis*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	5(6)	5-6	Dorsal - P	8(9)	(8)9	(9)10	(10)11(12)
Eyes pigmented	5(6)*	5-6*	Anal - P	9	10	(9)10	11-12
Yolk assimilated	(7)8	8-9	Caudal - P	(6)7-8	7-8	8(9)	9
Finfold absorbed	14(15)	17-18	Caudal - R	9(10)	10-11	14	(16)17
Pectoral-fin buds	*	*	Pectoral	9(10)	10-11	(13)14	(16)17
Pelvic-fin buds	9	10(11)	Pelvic	11(12)	13-14	13-14	15-16
* before hatching			Scales	20-21	25-26	21-24	26-31

References: Arizona Game and Fish Department 2002, Bestgen unpublished data, Bestgen et al. 1987b, Britt 1982, Childs 2004, David and Wirtanen 2001, Girard 1856, Marsh et al. 2003, Minckley 1973, Moore 1968, Page and Burr 1991, Propst and Bestgen 1991, Propst et al. 1988, Sublette et al. 1990, Vives and Minckley 1990, Winn and Miller 1954.

Table 40. Size at developmental interval (left) and gut phase (right) transitions for *Rhinichthys cobitis*. (See Figure 5 for phases of gut folding. Rare values in parentheses.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	(6)7-8	7-8	2 - 90° bend	12(-14)	14-15(-17)
Postflexion mesolarva	8(9)	9	3 - Full loop	>20, <42	>25, <53
Metalarva	(9)10	11-12	4 - Partial crossover	(not applicable)	
Juvenile	14(15)	17-18	5 - Full	(not applicable)	

Table 41. Summary of morphometrics and myomere counts by developmental phase for *Rhinichthys cobitis*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. SD value of 0 actually between 0.0 and 0.5.)

	Protolarvae (N=12)			Flexion mesolarvae (N=15)			Postflexion mesolarvae (N=11)			Metalarvae (N=26)			Juveniles (N=17)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	7	1	6 - 8	8	1	6 - 9	9	1	8 - 10	12	2	10 - 15	24	9	14 - 41
TL, mm	7	1	6 - 8	8	1	7 - 9	10	1	9 - 12	15	2	11 - 18	29	12	17 - 52
<u>Lengths %SL</u>															
AS to AE	3	1	2 - 4	4	1	3 - 5	4	1	3 - 6	6	1	4 - 8	8	1	7 - 9
PE	10	1	8 - 12	11	1	10 - 12	12	1	11 - 14	13	1	11 - 15	14	1	13 - 15
OP1	19	2	16 - 21	21	1	20 - 23	23	1	20 - 26	26	1	23 - 28	26	1	24 - 28
OP2							50	1 ^d	49 - 51	51	2	49 - 54	53	1	50 - 55
PY	64	5	51 - 69	60	5 ^b	47 - 66									
OPAF	41	10 ^a	28 - 57	32	4	27 - 39	33	4	28 - 40	45	9	32 - 61			
ODF	44	2	40 - 48	43	3	37 - 48	46	3	39 - 51	48	1 ^a	46 - 50			
OD							52	1 ^b	50 - 54	52	1	50 - 54	53	1	52 - 55
ID							65	1 ^d	64 - 65	65	2	63 - 69	67	1	64 - 68
PV	67	2	64 - 71	67	2	63 - 70	70	1	67 - 72	69	1	68 - 73	68	1	66 - 71
OA							69	1 ^e	68 - 71	68	1	67 - 70	68	1	66 - 70
IA							77	1 ^f	76 - 78	77	1	75 - 79	77	1	75 - 80
AFC							110	2	107 - 113	114	1	112 - 117	116	2	113 - 119
PC	106	1	105 - 107	107	1	106 - 109	111	3	108 - 114	119	2	115 - 122	122	2	118 - 127
Y	47	8	33 - 56	21	16	0 - 42									
P1	9	3	5 - 13	13	1	12 - 16	15	1	12 - 16	18	2	15 - 20	21	1	18 - 23
P2							4	1 ^d	3 - 5	10	3	4 - 17	16	2	11 - 19
D							17	0 ^d	16 - 17	21	1	19 - 24	23	1	21 - 25
A							12	0 ^f	12 - 12	17	2	12 - 19	21	2	17 - 23
<u>Depths %SL</u>															
at BPE	14	1	13 - 15	15	1	13 - 16	16	1	14 - 17	17	1	15 - 18	15	2	12 - 18
OP1	17	2	14 - 20	16	1	14 - 18	18	1	16 - 19	20	1	17 - 22	19	2	16 - 22
OD	15	3	11 - 19	13	1	11 - 14	14	1	13 - 15	16	2	13 - 20	18	2	16 - 22
BPV	10	1	8 - 11	9	1	9 - 10	10	1	9 - 11	12	1	10 - 14	13	1	11 - 17
AMPM	5	1	4 - 6	5	0	5 - 6	6	1	5 - 8	9	1	7 - 10	10	1	9 - 11
Max. yolk	11	6	2 - 17	2	2	0 - 8									
<u>Widths %SL</u>															
at BPE	14	1	13 - 15	15	1	13 - 16	16	1	16 - 17	18	1	17 - 20	16	2	13 - 20
OP1	12	2	10 - 17	11	1	11 - 14	14	1	13 - 17	17	2	13 - 20	18	2	15 - 21
OD	8	1	6 - 10	7	1	6 - 8	7	0	7 - 8	10	2	8 - 13	13	2	10 - 16
BPV	6	0	5 - 6	5	0	4 - 6	5	0	5 - 6	7	1	6 - 9	9	1	7 - 11
AMPM	3	1	3 - 4	3	0	3 - 4	3	0	3 - 4	4	1	3 - 5	4	1	4 - 5
Max. yolk	13	7	3 - 23	4	3	0 - 12									
<u>Myomeres</u>															
to PY	24	2	18 - 25	22	3 ^c	14 - 24									
OPAF	13	6 ^a	7 - 24	9	2	7 - 12	9	2	7 - 11	14	4	8 - 21			
OP2							17	1 ^d	16 - 18	17	1	16 - 18	17	1 ^c	16 - 18
ODF	14	1	11 - 16	14	1	12 - 16	15	2	12 - 17						
OD							18	1 ^e	17 - 19	18	1	16 - 20	17	1 ^c	16 - 18
PV	25	1	23 - 26	26	1	23 - 27	26	1	26 - 27	26	1	25 - 27	25	1 ^c	24 - 26
Total	36	1	34 - 37	37	1	35 - 38	37	1	36 - 38	38	1	36 - 39	38	1 ^c	37 - 39
After PV	10	0	10 - 11	11	1	10 - 12	11	1	10 - 12	11	1	10 - 13	13	0 ^b	13 - 14

^aN = 11. ^bN = 10. ^cN = 9. ^dN = 4. ^eN = 6. ^fN = 3. ^gN = 7.

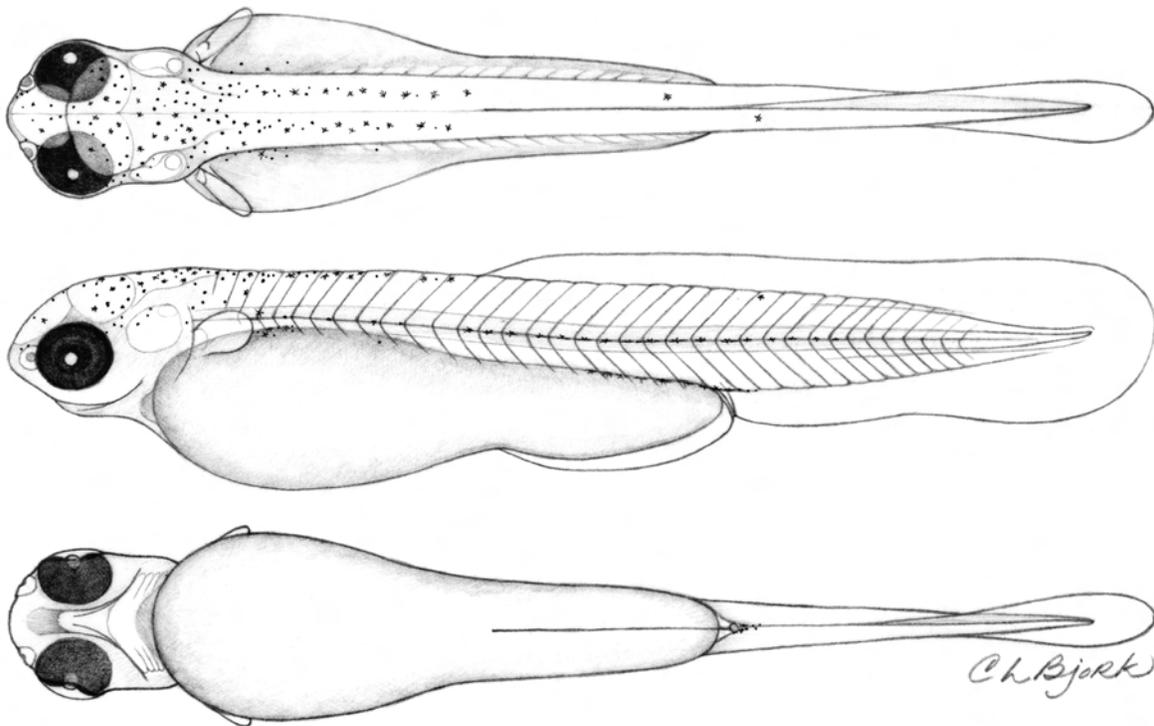


Fig. 82. *Rhinichthys cobitis* protolarva, 6.3 mm SL, 6.6 mm TL. (Cultured in 1984 with stock from the Gila River near Cliff, New Mexico.)

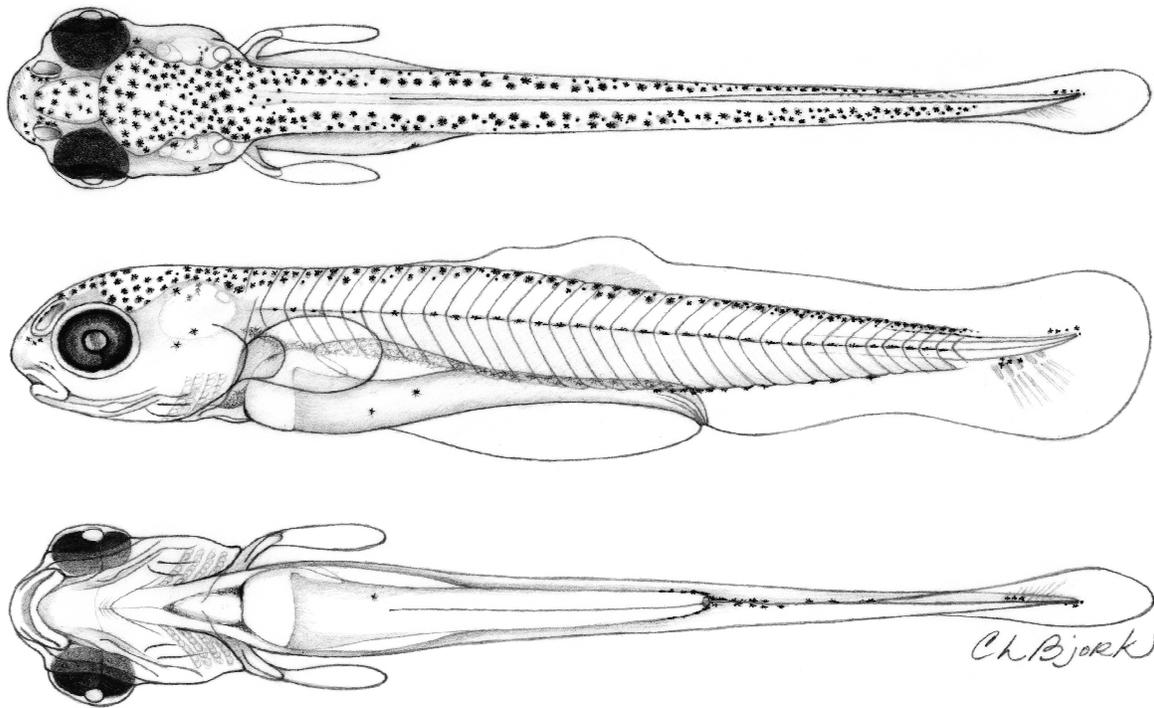


Fig. 83. *Rhinichthys cobitis* flexion mesolarva, recently transformed, 7.6 mm SL, 8.0 mm TL. (Cultured in 1984 with stock from the Gila River near Cliff, New Mexico.)

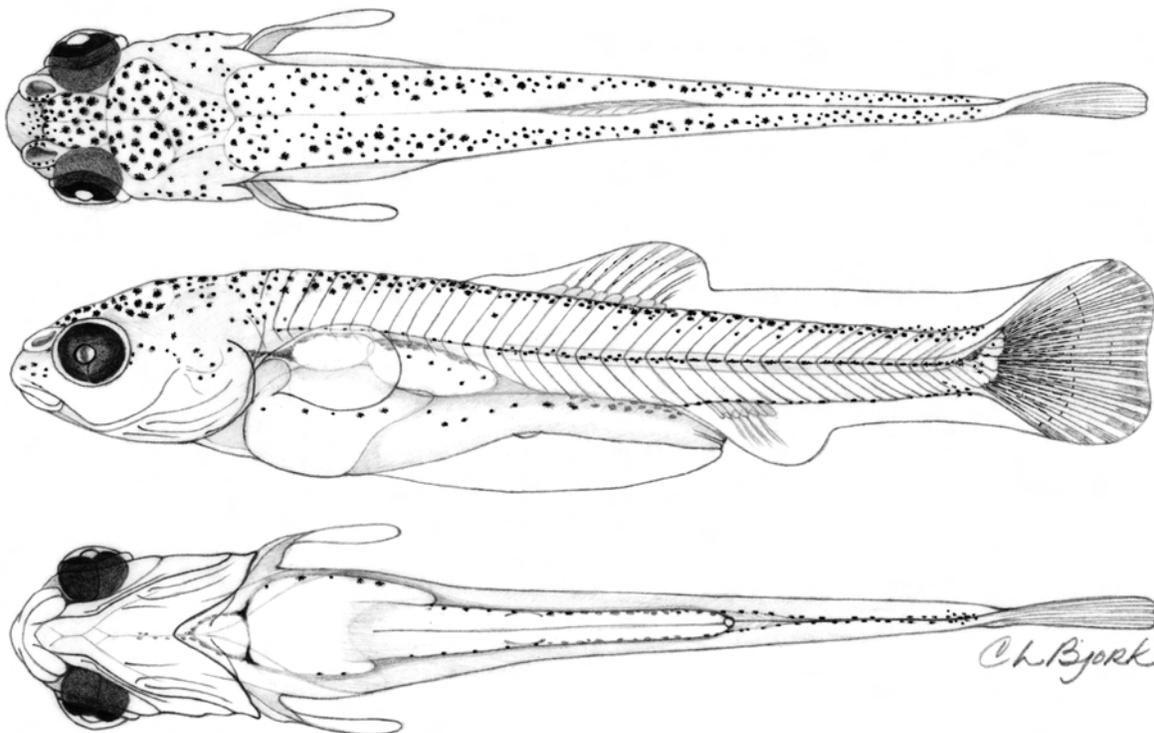


Fig. 84. *Rhinichthys cobitis* postflexion mesolarva, 9.9 mm SL, 11.2 mm TL. (Cultured in 1984 with stock from the Gila River near Cliff, New Mexico.)

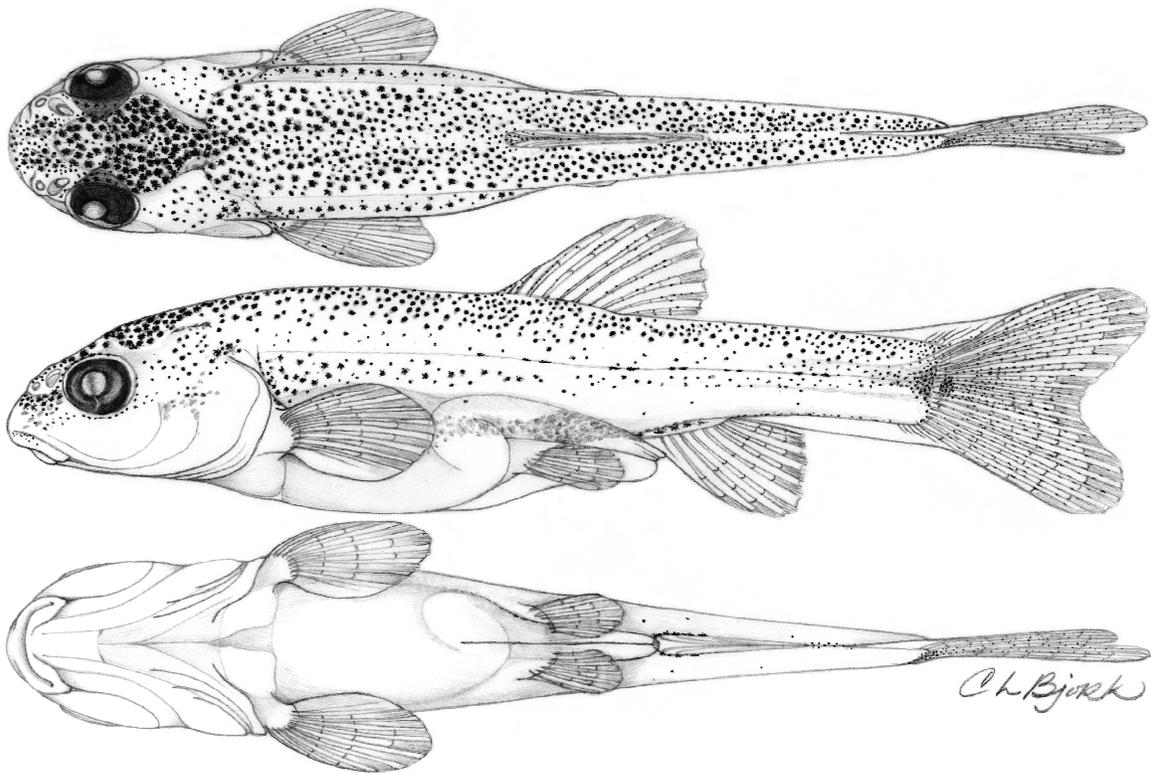


Fig. 85. *Rhinichthys cobitis* metalarva, 13.8 mm SL, 16.4 mm TL. (Collected in 1984 from the Gila River near Cliff, New Mexico.)

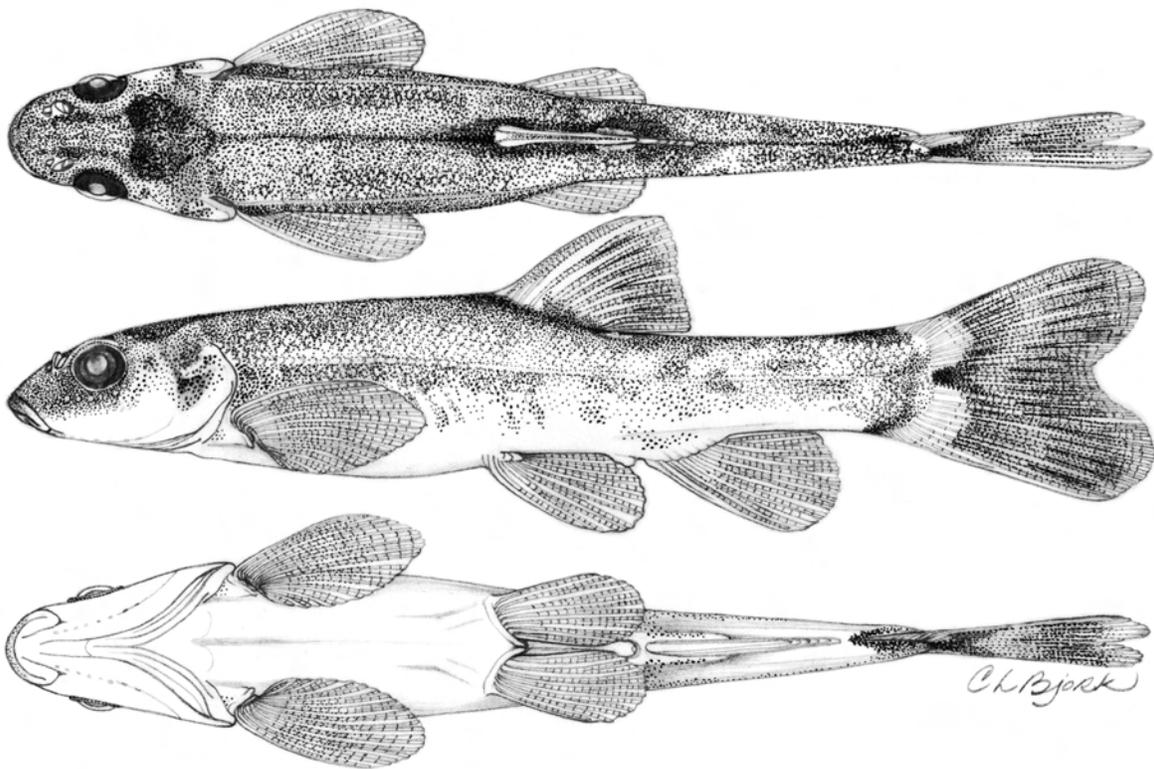


Fig. 86. *Rhinichthys cobitis* juvenile, 32.1 mm SL, 39.3 mm TL. (Collected in 1996 at junction of east and west forks of Gila River, New Mexico; from MSB 2544, 70% ethanol.)

Species Account – *Rhinichthys osculus*

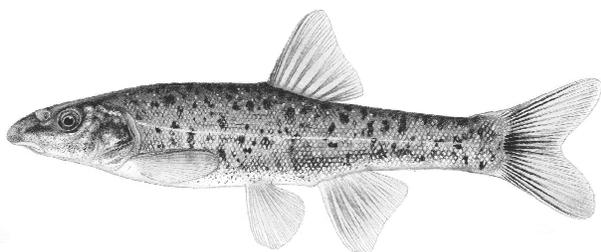


Fig. 87. *Rhinichthys osculus* adult (© Joseph R. Tomelleri).

Adult description: Up to 10 cm TL. Heavy, spindle-shaped body, round in cross section. Larger, more streamlined specimens with falcate dorsal and pectoral fins occur in larger rivers. Small sub-terminal mouth with small barbel in each corner and usually lacking an upper-lip frenum. Head about 25% of SL, somewhat dorso-ventrally flattened. Scales moderately small. Color highly variable; Gila River Basin specimens mostly olivaceous above and yellow to white below, often with dark blotches or 1-2 lateral bands. Breeding males red on ventral surfaces, particularly on lips and paired fin bases, tuberculate over head, paired fins, and ventral surface to caudal fin; females less tuberculate. (Also, Table 42.)

Reproduction: Non-guarding, open-substrate or nest-guarding lithophil. Spawn when water reaches day-time highs of 15 (usually 18) to 25°C in early March to late August, sometimes in response to high flows or streambed disturbance. In pairs or large groups, spawn in shallow gravel-cobble riffles or runs, depositing adhesive eggs in interstices or under rocks, or the male constructs and defends a nest. Water-hardened eggs probably 1.6-2.2 mm based on congeners.

Young: Hatch in 6 d at 18-19°C and remain in gravel for several days; drift downstream as later protolarvae and mesolarvae (6-9 mm TL) to nursery grounds. Larvae occupy near-shore, low-velocity, channel margins, backwaters, eddies, and pools; consume early instars of chironomids and other small invertebrates.

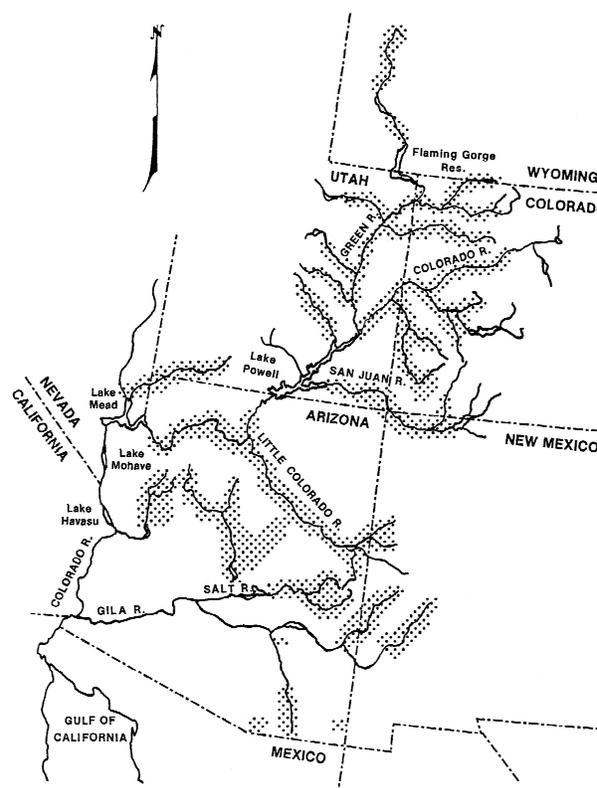


Fig. 88. Recent distribution of *Rhinichthys osculus* in the Colorado River Basin.

Table 42. Selected juvenile and adult meristics for *Rhinichthys osculus*. (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. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

Character	Observed*	Literature	Character	Observed*	Literature
Dorsal-fin rays - P	7-8	(6)7-8-9	Dorsal-fin rays - R	1-2-3	–
Anal-fin rays - P	6- <u>7</u> -8	6- <u>7</u> -8	Anal-fin rays - R	1-2-3	–
Caudal-fin rays - P	(18)19	(18)19(20)	Caudal-fin rays - RD	(5-) <u>8-10</u> -11	–
Pectoral-fin rays	12- <u>13-14</u> -15	(10-) <u>13-14</u> (15)	Caudal-fin rays - RV	(6-) <u>8-10</u>	–
Pelvic-fin rays	(6)7- <u>8</u>	7- <u>8</u> -9	Lateral scales	–	(47-)55-80(-90)
Vertebrae	38-40	37-38	Pharyngeal teeth	–	(0)1- <u>2,4</u> /4,1- <u>2</u> (0)

*From Snyder 1981, supplemented with original data.

Table 43. Size at onset of selected developmental events for *Rhinichthys osculus*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses. From Snyder 1981, supplemented with original data.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	5-6	5-6(7)	Dorsal - P	7-8	8-9	9-10(11)	(10)11(12)
Eyes pigmented	*5?	*5?	Anal - P	8	9	9-10(11)	(10)11(12)
Yolk assimilated	6-8(9)	(6)7-9(10)	Caudal - P	6-7	7(8)	8-9	(8)9(10)
Finfold absorbed	15-16(17)	18-19(20)	Caudal - R	9-10	10-11	15-16	18-19(20)
Pectoral-fin buds	*	*	Pectoral	9-10	11-12	13-15(16)	16-18(20)
Pelvic-fin buds	9-10	(10)11	Pelvic	11-12	13-14	(12)13-14	(14)15-17
* before hatching			Scales	17-18	(20)21-22	19-24	24-30

References: Arizona Game and Fish Department 2002, Baxter and Simon 1970, Beckman 1952, Bestgen unpublished data, Bestgen et al. 1998, Childs 1998, Girard 1856, John 1963, Kaya 1991, LaRivers 1962, Minckley 1973, Moore 1968, Moyle 1976, Mueller 1984, Muth and Snyder 1995, Page and Burr 1991, Sigler and Miller 1963, Simpson and Wallace 1978, Scott and Crossman 1973, Snyder 1981, Sublette et al. 1990, Winn and Miller 1954.

Table 44. Size at developmental interval (left) and gut phase (right) transitions for *Rhinichthys osculus*. (See Figure 5 for phases of gut folding. Rare values in parentheses. From Snyder 1981, supplemented with original data.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	6-7	7(8)	2 - 90° bend	10-11	(11)12-13
Postflexion mesolarva	8-9	(8)9(10)	3 - Full loop	18-26	22-32
Metalarva	9-10(11)	(10)11(12)	4 - Partial crossover	(not applicable)	
Juvenile	15-16(17)	18-19(20)	5 - Full	(not applicable)	

Table 45. Summary of morphometrics and myomere counts by developmental phase for *Rhinichthys osculus*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. SD value of 0 actually between 0.0 and 0.5. Except as noted, from Snyder 1981, with data recalculated for flexion and postflexion mesolarvae.)

	Protolarvae (N=5) ^d			Flexion mesolarvae (N=12)			Postflexion mesolarvae (N=10)			Metalarvae (N=41)			Juveniles (N=53)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	6	1	5 - 7	8	1 ^v	6 - 9	9	1	8 - 10	12	2	9 - 16	25	8	15 - 42
TL, mm	7	1	5 - 8	8	1 ^v	7 - 10	10	1	9 - 12	15	3	11 - 20	30	10	18 - 50
<u>Lengths %SL</u>															
AS to AE	2	1	2 - 3	3	1	3 - 4	4	1	3 - 6	5	1	4 - 6	6	1	4 - 8
PE	10	2	8 - 12	12	1	11 - 13	13	1	11 - 15	13	1	11 - 15	13	1	11 - 15
OP1	18	2	16 - 21	22	1	20 - 25	24	2	22 - 27	25	1	23 - 28	24	2	21 - 28
OP2							49	2 ^g	48 - 51	51	2	48 - 54	50	2	45 - 53
PY	64	3 ^{bc}	61 - 68	60	3 ^{bhv}	57 - 66									
OPAF	35	8 ^b	29 - 47	36	5 ^b	30 - 44	41	8 ^b	30 - 53	47	6 ^{bj}	36 - 58			
ODF	43	2 ^b	41 - 45	47	5 ^b	37 - 55	-	^{bd}	43						
OD							53	2	51 - 56	55	2	51 - 58	53	2 ^p	50 - 57
ID							65	2 ^h	64 - 69	67	1 ^k	65 - 70	65	2 ^q	62 - 69
PV	66	3	63 - 69	66	2	63 - 70	68	2	65 - 71	65	2	63 - 69	63	2 ^p	57 - 65
OA							67	1 ^{be}	65 - 69	65	2 ^u	63 - 69	63	2 ^{pu}	57 - 65
IA										75	1 ^l	72 - 77	73	2 ^r	70 - 77
AFC							111	2 ⁱ	110 - 113	112	2 ^k	106 - 114	112	2 ^r	109 - 115
PC	106	1	104 - 107	107	3	105 - 116	115	4	110 - 122	119	2	114 - 124	121	2	117 - 126
Y	39	22 ^b	0 - 56	9	15 ^{bvw}	0 - 43									
P1	9	2	6 - 12	13	1	12 - 14	13	1	11 - 15	14	2	11 - 18	17	1	14 - 20
P2							3	3 ^g	1 - 6	7	3 ^k	2 - 13	13	1 ^s	10 - 16
D							14	5 ⁱ	10 - 19	18	2 ^k	13 - 22	21	1 ^s	18 - 24
A							13	^d	13 - 13	15	2 ^k	10 - 20	19	2 ^s	16 - 22
<u>Depths %SL</u>															
at BPE	13	2	11 - 15	13	1 ^e	12 - 14	14	1 ^c	13 - 15	17	1 ^m	15 - 18	16	1 ^t	13 - 18
OP1	15	3	12 - 20	14	2	12 - 18	17	2	15 - 21	20	1	15 - 23	21	1	18 - 24
OD	13	3	10 - 16	11	1 ^f	10 - 13	13	1 ^e	12 - 15	17	2 ^k	13 - 21	20	1 ^s	18 - 23
BPV	8	1	7 - 10	9	1	8 - 10	10	1	9 - 12	13	2	10 - 16	16	1	13 - 19
AMPM	4	1	3 - 5	5	1	4 - 6	6	1	5 - 8	8	1	6 - 10	10	1	9 - 12
Max. yolk	8	6 ^b	0 - 16	1	2 ^{bvw}	0 - 6									
<u>Widths %SL</u>															
at BPE	13	2	11 - 14	13	1 ^e	13 - 14	15	1 ^c	14 - 16	17	1 ^m	15 - 19	15	2 ^t	12 - 18
OP1	11	3	8 - 16	10	2	8 - 14	12	3	10 - 18	14	2	12 - 18	16	2	13 - 21
OD	7	1	5 - 9	7	1 ^f	6 - 8	7	1 ^e	6 - 9	10	2 ^k	7 - 13	14	2 ^r	11 - 18
BPV	5	1	3 - 5	6	1	4 - 8	6	1	5 - 8	9	1	6 - 11	12	2	9 - 16
AMPM	2	1	2 - 3	3	1	1 - 5	3	1	2 - 6	4	1	2 - 5	6	1	3 - 7
Max. yolk	10	7 ^b	0 - 20	2	3 ^{bvw}	0 - 10									
<u>Myomeres</u>															
to PY	24	1 ^{bc}	22 - 24												
OPAF	11	3 ^b	8 - 16	8	1 ^{bf}	6 - 9	8	1 ^{bh}	7 - 9	13	3 ^{bn}	8 - 20			
OP2							17	1 ^g	16 - 17	16	1 ^o	14 - 17	16	1 ^r	13 - 17
ODF	14	1 ^b	12 - 15	15	1 ^{bf}	13 - 16	-	^{bd}	14						
OD							18	2 ^e	17 - 21	19	1 ^k	16 - 20	18	1 ^r	16 - 20
PV	25	1	23 - 26	25	1 ^f	23 - 26	25	1 ^e	24 - 26	24	1 ^k	23 - 27	23	1 ^r	21 - 25
Total	37	3	34 - 40	38	1	37 - 39	38	1	37 - 40	38	1	36 - 40	38	1 ^r	36 - 40
After PV	12	2	10 - 14	13	1 ^f	11 - 14	13	1 ^e	12 - 14	14	1 ^k	11 - 16	15	1 ^r	12 - 17

^aIncludes new data for 4 specimens. ^bData summarized for but not reported by Snyder (1981). ^cN = 4. ^dN = 1. ^eN = 6. ^fN = 8. ^gN = 2. ^hN = 5. ⁱN = 3. ^jN = 19. ^kN = 30. ^lN = 27. ^mN = 26. ⁿN = 16. ^oN = 29. ^pN = 52. ^qN = 45. ^rN = 46. ^sN = 47. ^tN = 43. ^uAssumed same as AS to PV. ^vIncludes new data. ^wN = 19.

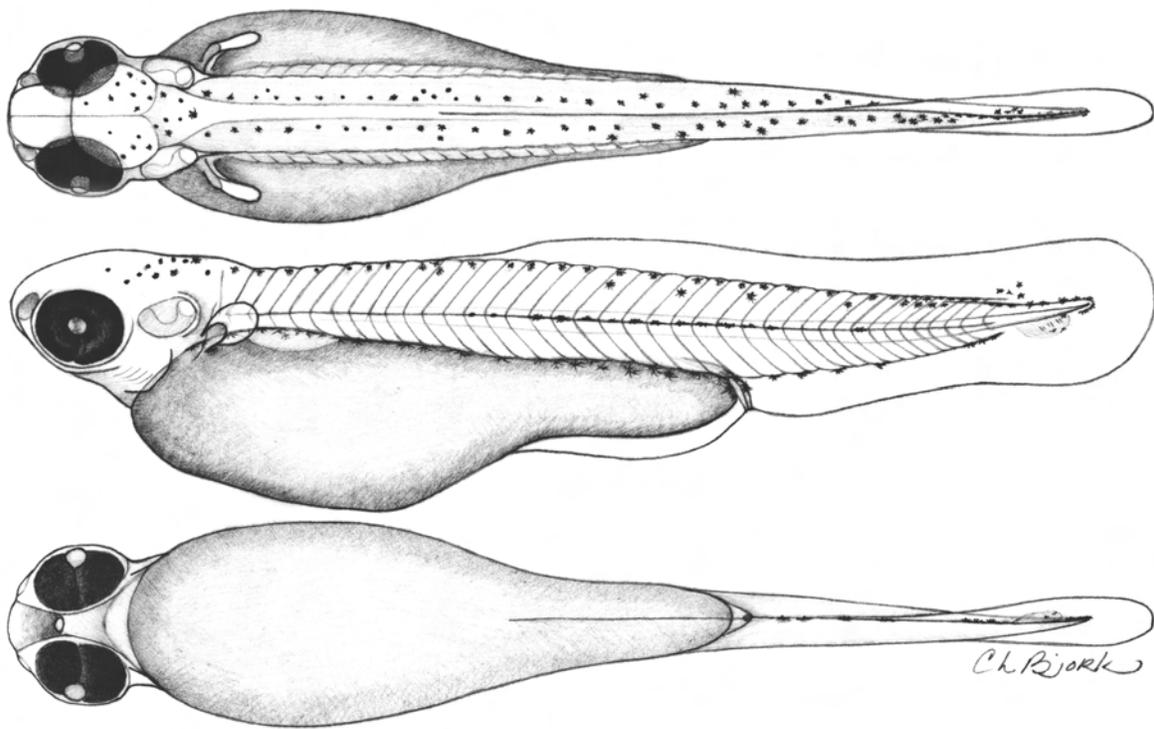


Fig. 89. *Rhinichthys osculus* protolarva, 6.7mm SL, 7.0 mm TL. (Collected in 1994 from the Gunnison River, Colorado. Previously unpublished illustration.)

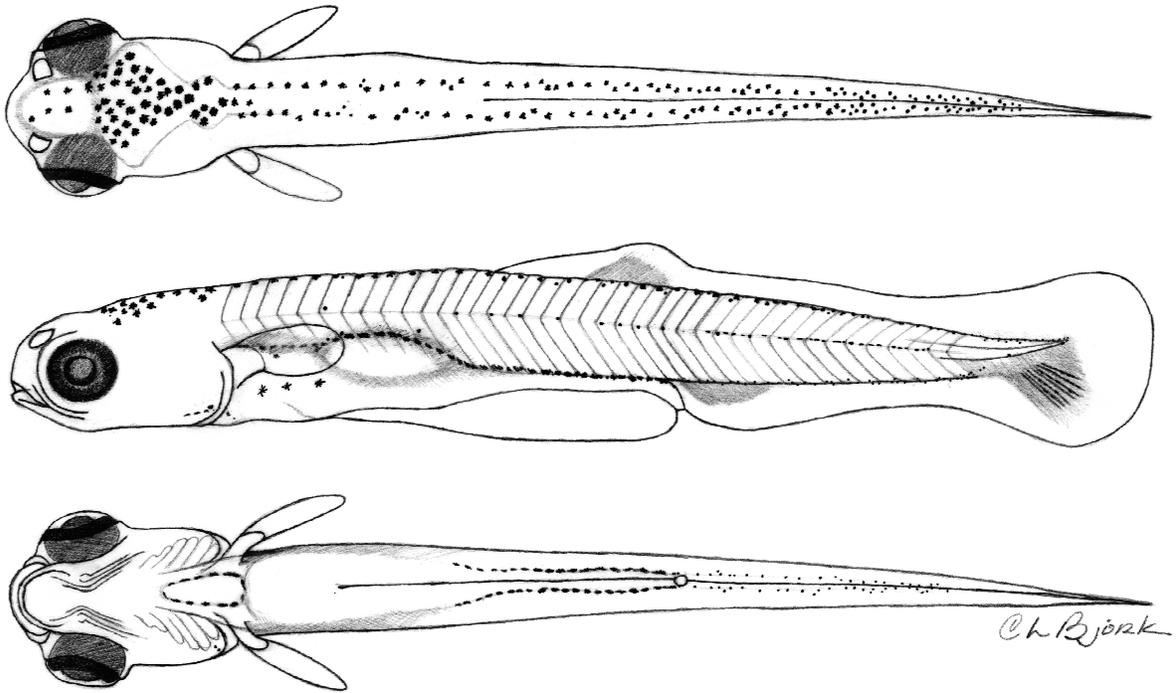


Fig. 90. *Rhinichthys osculus* flexion mesolarva, recently transformed, 6.5 mm SL, 7.0 mm TL. (Collected in late 1970s from the Yampa River, Colorado. From Snyder 1981.)

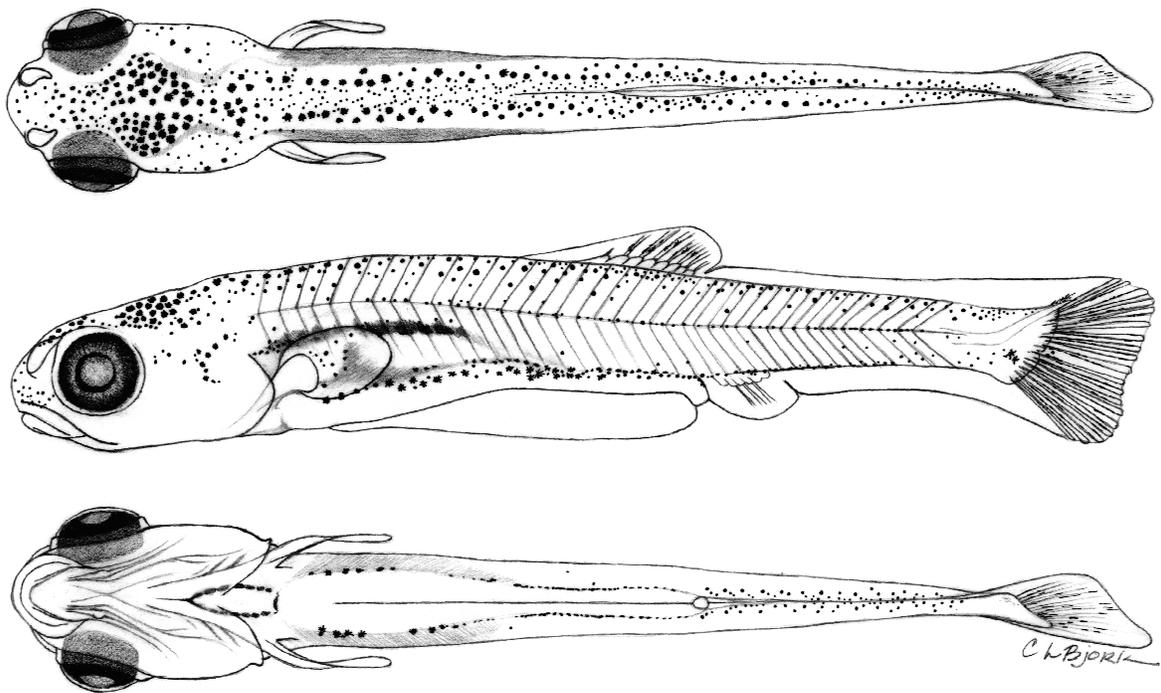


Fig. 91. *Rhinichthys osculus* postflexion mesolarva, 9.0 mm SL, 9.8 mm TL. (Collected in late 1970s from the Yampa River, Colorado. From Snyder 1981.)

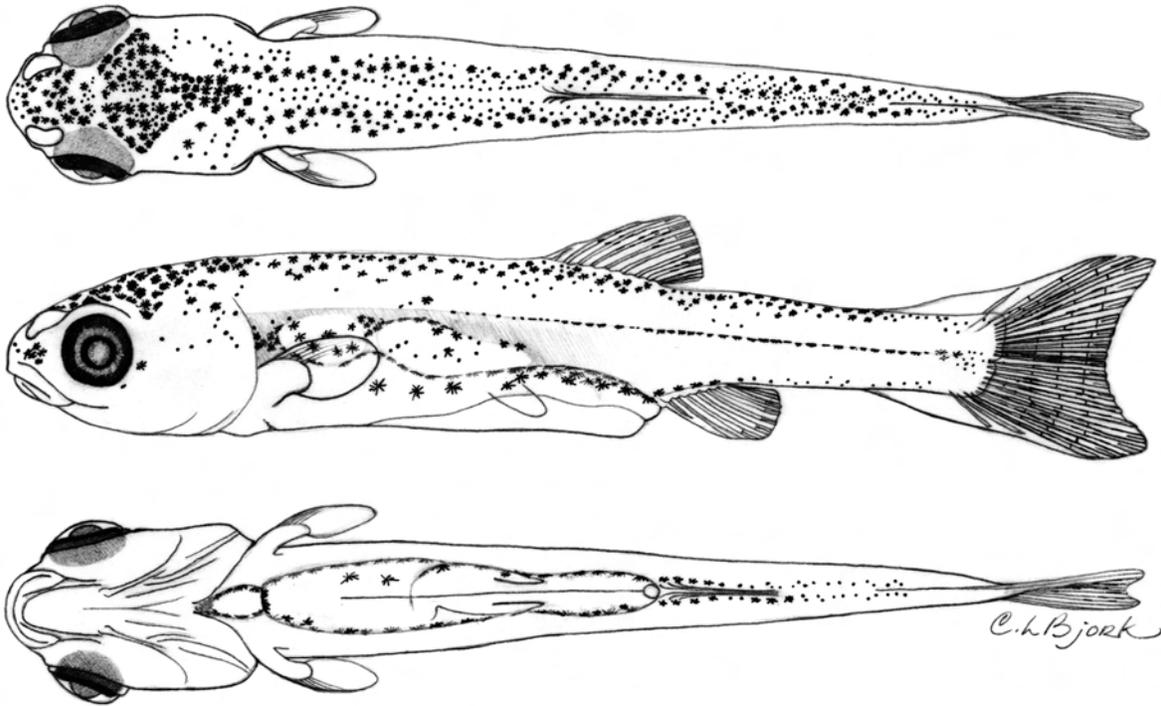


Fig. 92. *Rhinichthys osculus* metalarva, recently transformed, 10.8 mm SL, 12.4 mm TL. (Collected in late 1970s from the Yampa River, Colorado. From Snyder 1981.)

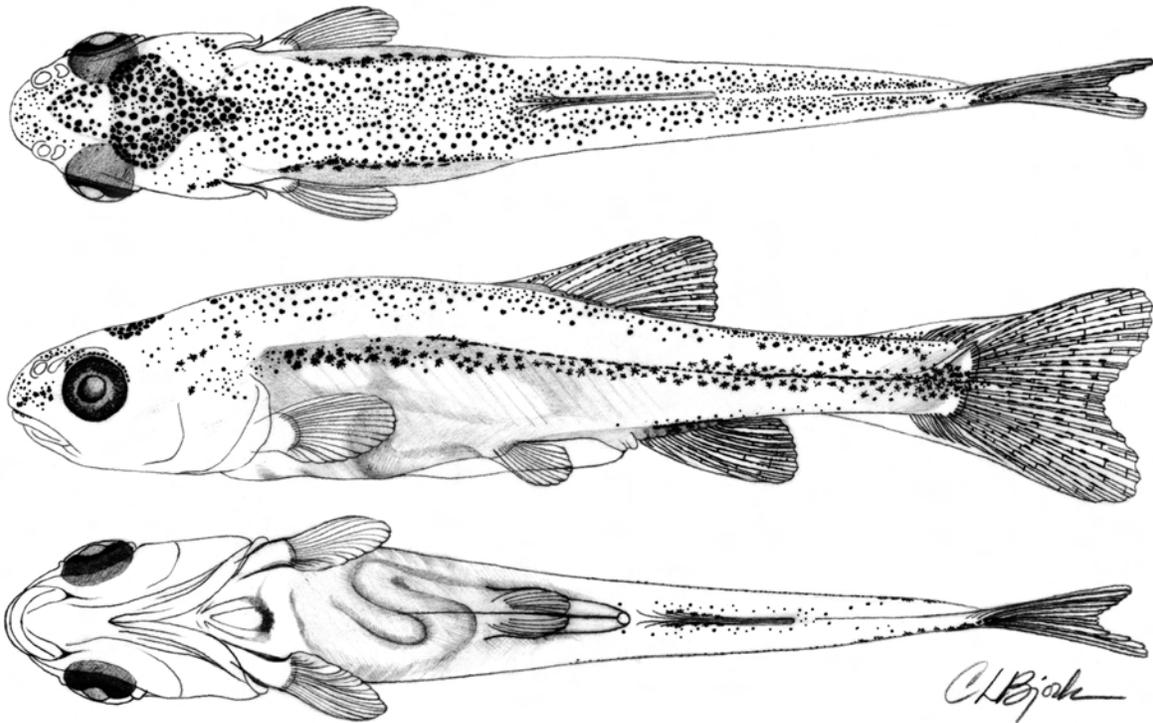


Fig. 93. *Rhinichthys osculus* metalarva, 14.2 mm SL, 16.4 mm TL. (Collected in late 1970s from the Yampa River, Colorado. From Snyder 1981.)

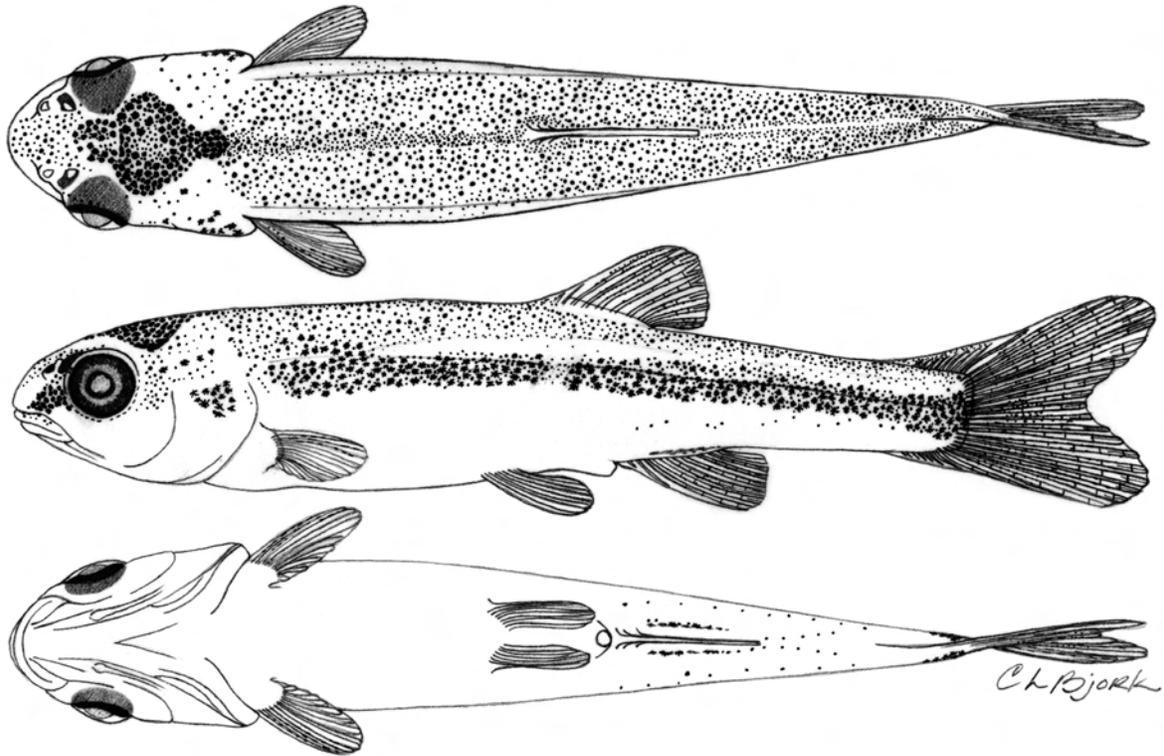


Fig. 94. *Rhinichthys osculus* juvenile, recently transformed, 17.7 mm SL, 21.0 mm TL. (Collected in late 1970s from the Yampa River, Colorado. From Snyder 1981.)

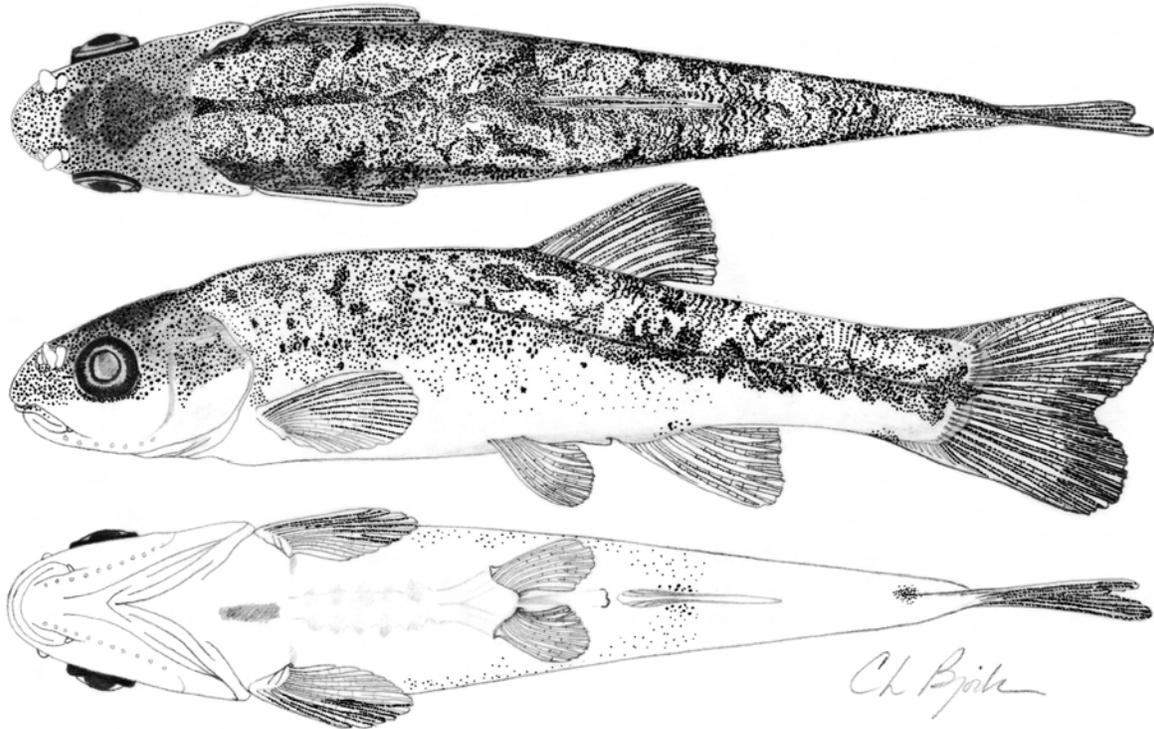


Fig. 95. *Rhinichthys osculus* juvenile, 32.2 mm SL, 38.0 mm TL. (Collected in late 1970s from the Yampa River, Colorado. From Snyder 1981.)

Species Account – *Cyprinella lutrensis*

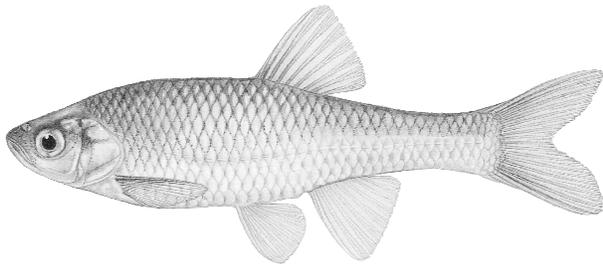


Fig. 96. *Cyprinella lutrensis* adult (© Joseph R. Tomelleri).

Adult description: Small, 5-9 cm TL. Deep-bodied and laterally compressed. Mouth terminal, small, oblique, and without barbels. Head relatively small, about 22 % of SL, and snout blunt. Scales relatively large and diamond-shaped, lateral line decurved. Usually olivaceous above, silvery laterally, and white below. Breeding males often metallic blue dorsally and laterally, white below, and with red fins; have small tubercles concentrated on the head and snout and over the ventral surface. (Also, Table 46.)

Reproduction: Non-guarding, brood-hiding, crevice spawner. Spawn from early March to mid-September, when water reaches day-time highs of at least 16°C, usually in low-velocity areas such as backwaters or pools. Males are territorial. Females spawn adhesive eggs in crevices of rocks, woody debris, or aquatic vegetation. Water-hardened eggs 1.0-1.3 mm in diameter.

Young: Hatch in 3-5 d at 21-28°C. Larvae occupy near-shore, low-velocity channel margins, backwaters, eddies, and pools and consume early instars of chironomids and other small invertebrates, algae and detritus; larger individuals may consume fish larvae.

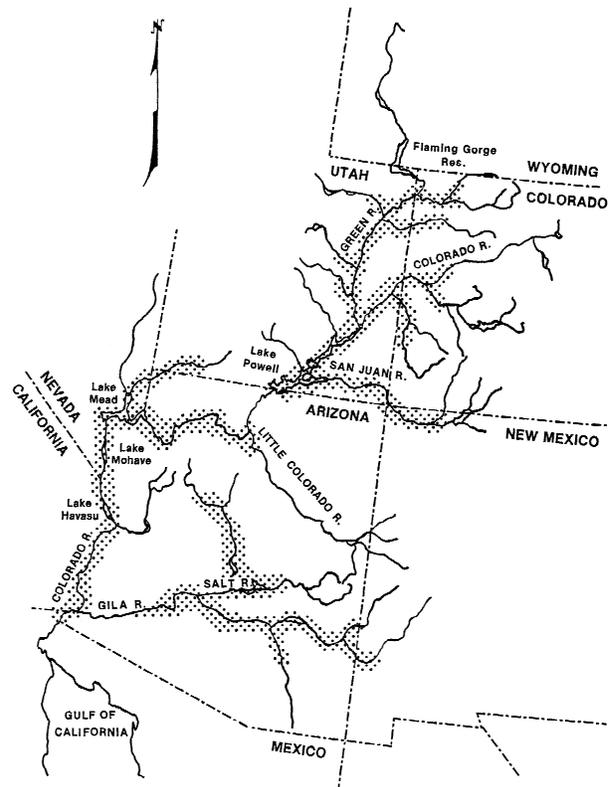


Fig. 97. Recent distribution of *Cyprinella lutrensis* in the Colorado River Basin.

Table 46. Selected juvenile and adult meristics for *Cyprinella lutrensis*. (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. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

Character	Observed*	Literature	Character	Observed*	Literature
Dorsal-fin rays - P	(7)8-9	(6-)8(9)	Dorsal-fin rays - R	2-3(4)	–
Anal-fin rays - P	(7)8-9-10	(7)8-9-10(-13)	Anal-fin rays - R	2-3	–
Caudal-fin rays - P	(18)19	(18)19	Caudal-fin rays - RD	5- <u>10</u> -13	–
Pectoral-fin rays	(12-) <u>14-15</u> -16	(9-)14(-16)	Caudal-fin rays - RV	6- <u>10</u> -11	–
Pelvic-fin rays	8- <u>9</u>	8- <u>9</u> (10)	Lateral scales	–	30-32-37-40
Vertebrae	35-36	32-36	Pharyngeal teeth	–	<u>0</u> -1,4(5)/4,0-1

*Original data from Snyder (1981).

Table 47. Size at onset of selected developmental events for *Cyprinella lutrensis*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses. Mostly from Snyder 1981.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	3-4	(3)4	Dorsal - P	6	7	7-8	8-9
Eyes pigmented	*	*	Anal - P	(6)7	(7)8	(7)8	9
Yolk assimilated	(4)5	5	Caudal - P	5	(5)6	6	7
Finfold absorbed	(9)10(-12)	(10-)12-13(-15)	Caudal - R	7	8	10(11)	12(13)
Pectoral-fin buds	*	*	Pectoral	(5)6	(6)7	9-10	11-13
Pelvic-fin buds	7-8	8-9	Pelvic	9	10-11	10	12-13
* before hatching			Scales	12-13	15-16	(15)16	19-20

References: Beckman 1952, Clay 1975, Eddy and Underhill 1974, Gale 1986, Lentsch et al. 1996, Minckley 1973, Muth and Snyder 1995, Page and Burr 1991, Perry 1979, Perry and Menzel 1979, Pflieger 1975, Ruppert et al. 1993, Saksena 1962, Snyder 1981, Sublette et al. 1990, Taber 1969.

Table 48. Size at developmental interval (left) and gut phase (right) transitions for *Cyprinella lutrensis*. (See Figure 5 for phases of gut folding. Rare values in parentheses. Mostly from Snyder 1981.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	5	(5)6	2 - 90° bend	8-10	(9)10-12
Postflexion mesolarva	6	7	3 - Full loop	26	33
Metalarva	(7)8	9	4 - Partial crossover	not applicable	
Juvenile	10(-12)	12-13(-15)	5 - Full	not applicable	

Table 49. Summary of morphometrics and myomere counts by developmental phase for *Cyprinella lutrensis*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. SD value of 0 actually between 0.0 and 0.5. Except as noted, from Snyder 1981 with original data recalculated for flexion and postflexion mesolarvae.)

	Protolarvae (N=3)			Flexion mesolarvae (N=5)			Postflexion mesolarvae (N=5)			Metalarvae (N=11)			Juveniles (N=46)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	5	0	5 - 5	6	0	5 - 6	7	0	6 - 8	9	1	7 - 11	20	9	10 - 40
TL, mm	5	0	5 - 5	6	0	6 - 7	8	1	7 - 9	11	1	9 - 13	25	11	13 - 50
<u>Lengths %SL</u>															
AS to AE	2	0	2 - 2	4	1	3 - 5	4	1	4 - 6	5	1	5 - 7	6	1	4 - 8
PE	9	1	8 - 9	11	1	9 - 13	12	1	11 - 13	13	1	12 - 15	14	1	12 - 15
OP1	20	1	19 - 22	21	2	19 - 23	23	1	21 - 24	25	2	22 - 28	25	2	22 - 28
OP2										49	1	47 - 51	49	1	46 - 52
PY	-	ah	- 65												
OPAF	38	0 ^a	37 - 38	37	2 ^a	34 - 38	38	1 ^a	37 - 38	47	8 ^a	37 - 57			
ODF	47	3 ^a	44 - 49	46	3 ^a	42 - 49	50	2 ^{ab}	47 - 51						
OD							49	1 ^b	49 - 50	52	1	49 - 54	50	1	47 - 52
ID							63	c	63 - 63	66	1	63 - 67	63	2	60 - 67
PV	63	1	62 - 64	65	2	61 - 67	66	1	65 - 67	64	2	61 - 67	62	1	60 - 64
OA										64	2 ^d	61 - 67	62	1 ^d	60 - 64
IA										77	2	74 - 78	76	1	73 - 78
AFC							111	1 ^e	110 - 112	112	3	109 - 118	114	2	111 - 118
PC	107	1	106 - 108	109	2	108 - 111	114	2	111 - 116	119	3	116 - 126	125	2	120 - 129
Y	-	ah	0 - 58												
P1	11	2	10 - 13	13	1	11 - 15	14	1	13 - 16	13	2	11 - 18	19	1	15 - 22
P2										8	3	3 - 12	14	1 ^f	11 - 17
D							14	c	14 - 14	19	1	17 - 21	22	1	20 - 24
A										16	2	13 - 21	20	1	17 - 23
<u>Depths %SL</u>															
at BPE	11	0	11 - 12	12	1	11 - 13	12	1	12 - 13	15	2	12 - 18	16	1	14 - 18
OP1	12	1	10 - 13	13	1	11 - 14	15	1	14 - 16	18	2	14 - 21	21	2	17 - 24
OD							14	0 ^b	14 - 15	17	1	15 - 19	20	3	17 - 25
BPV	8	1	7 - 8	10	2	8 - 13	11	1	10 - 12	13	1	11 - 15	17	2	13 - 20
AMPM	4	1	3 - 4	4	1	3 - 5	7	1	6 - 8	9	1	8 - 10	10	1	8 - 12
Max. yolk	-	ah	0 - 21												
<u>Widths %SL</u>															
at BPE	12	0	11 - 12	13	1	12 - 14	13	1	12 - 14	14	1	12 - 16	14	1	12 - 16
OP1	10	1	9 - 11	10	2	9 - 13	10	0	10 - 11	12	1	11 - 13	14	1	11 - 16
OD							7	0 ^b	7 - 8	10	1	8 - 11	12	2	9 - 16
BPV	5	1	4 - 6	5	2	4 - 8	7	1	6 - 7	8	1	7 - 9	10	1	8 - 14
AMPM	3	1	2 - 4	3	1	2 - 4	3	1	2 - 4	4	1	2 - 5	4	1	3 - 7
Max. yolk	-	ah	0 - 24												
<u>Myomeres</u>															
to PY	-	ah	- 19												
OPAF	9	0 ^a	9 - 9	9	2 ^a	7 - 13	9	2 ^a	7 - 11	12	4 ⁱⁱ	7 - 17			
OP2										14	2	12 - 16	13	1 ^s	11 - 15
ODF	11	1 ^{ac}	10 - 11	13	1 ^a	11 - 14	14	1 ^{ac}	14 - 15						
OD							16	1 ^b	15 - 16	16	2	13 - 19	15	1 ^s	12 - 18
PV	21	1	20 - 21	22	2	20 - 24	23	1	22 - 24	21	1	19 - 24	21	1 ^s	19 - 24
Total	35	0	35 - 35	35	1	34 - 36	36	1	35 - 37	36	1	34 - 37	35	1 ^s	34 - 36
After PV	14	1	14 - 15	13	1	12 - 15	13	1	12 - 15	14	1	12 - 17	14	1 ^s	11 - 16

^aData summarized for but not reported by Snyder (1981). ^bN = 3. ^cN = 1. ^dAssumed same as AS to PV. ^eN = 4. ^fN = 45. ^gN = 39. ^hNone of specimens analyzed had yolk, maximum yolk values from Figure 98. ⁱN = 9.

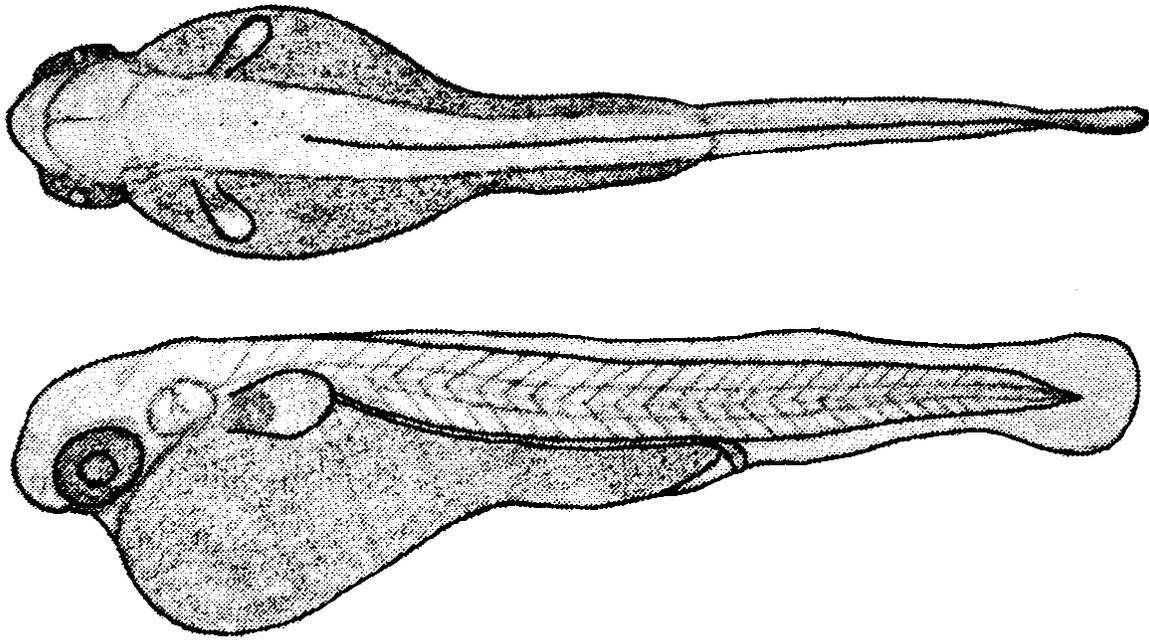


Fig. 98. *Cyprinella lutrensis* protolarva, recently hatched, 3.1 mm SL, 3.3 mm TL. (From Taber 1969.)

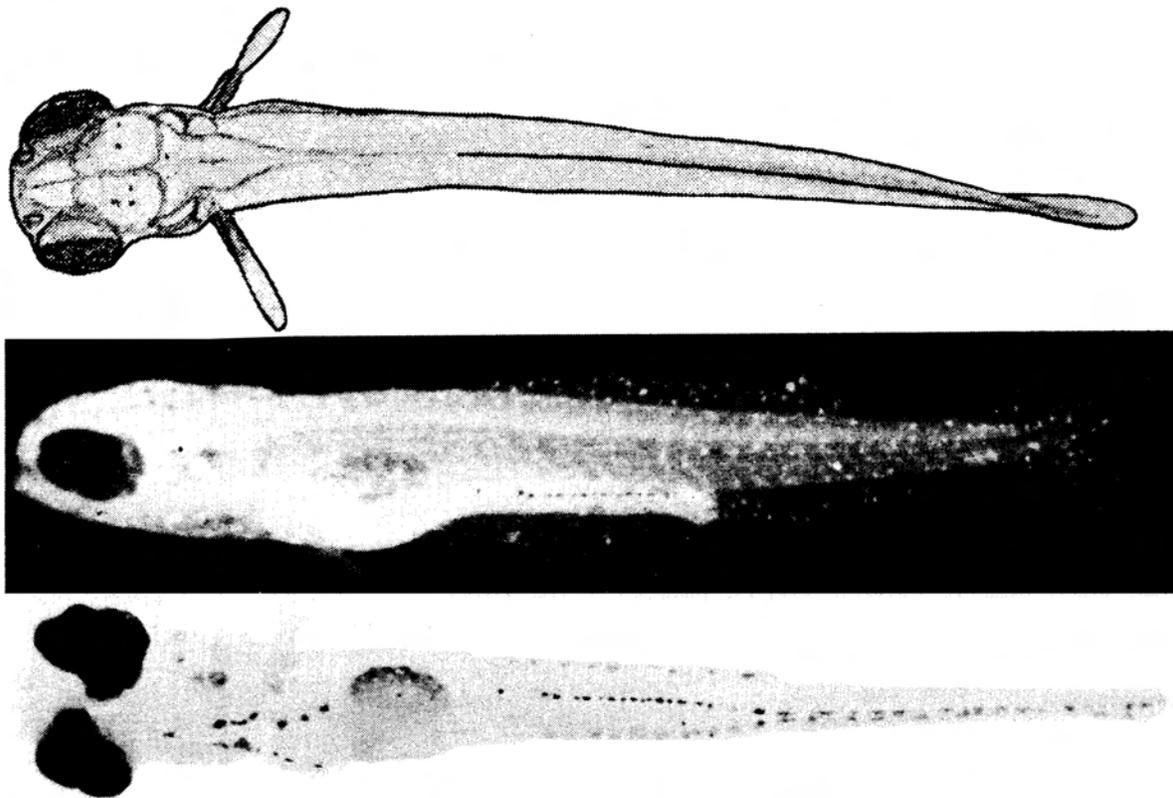


Fig. 99. *Cyprinella lutrensis* protolarva, 4.6, 4.4, and 4.4 mm SL (top to bottom), 4.8, 4.7, and 4.7 mm TL. (From Taber 1969 and Perry 1979.)

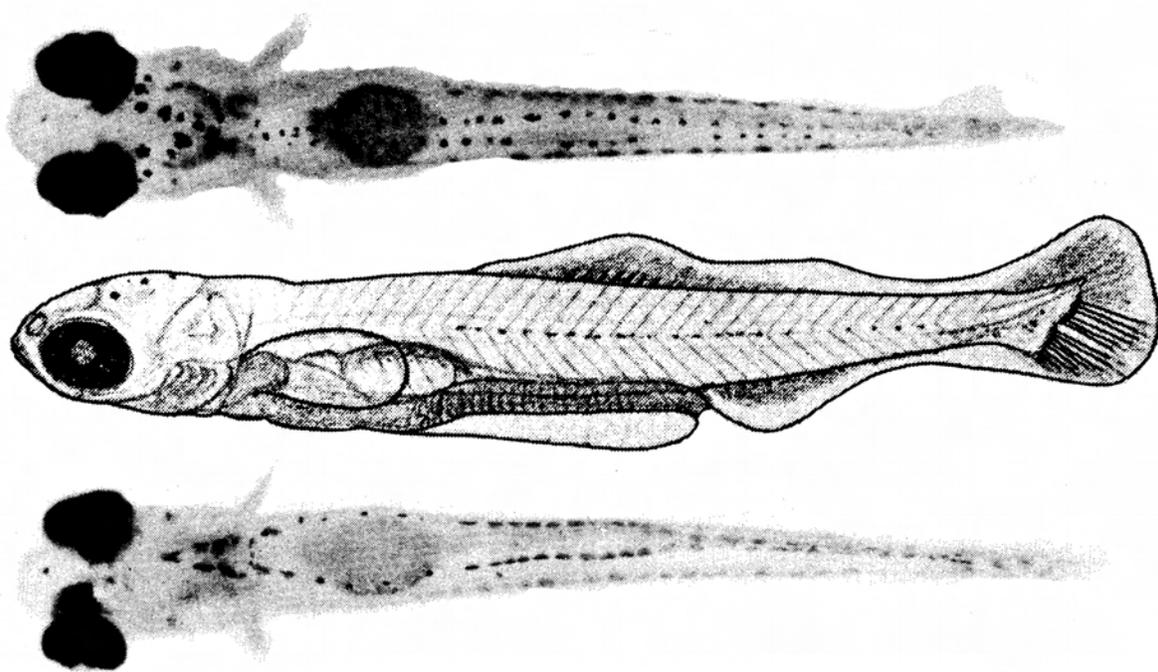


Fig. 100. *Cyprinella lutrensis* flexion mesolarva, 6.3, 5.7, and 6.3 mm SL (top to bottom), 7.0, 6.0, and 7.0 mm TL. (From Taber 1969 and Perry 1979.)

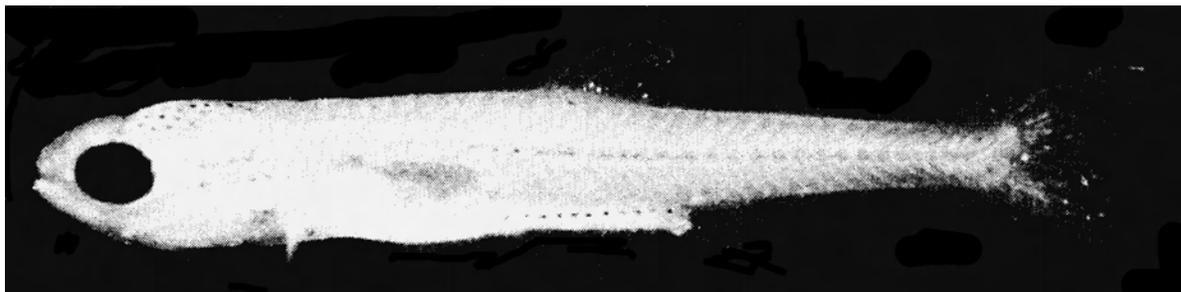


Fig. 101. *Cyprinella lutrensis* postflexion mesolarva, 7.3 mm SL, 8.1 mm TL. (From Taber 1969.)

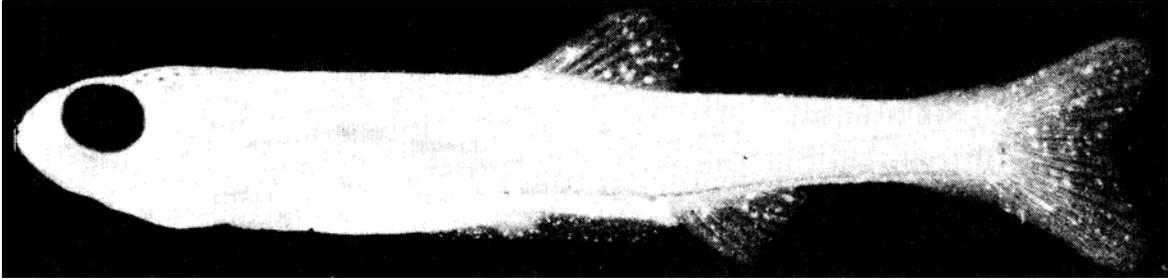


Fig. 102. *Cyprinella lutrensis* metalarva, recently transformed, 7.9 mm SL, 9.2 mm TL. (From Perry 1979.)

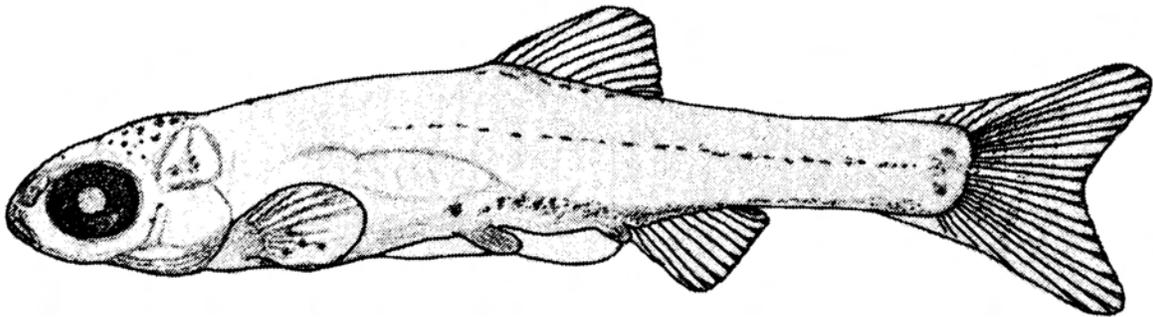


Fig. 103. *Cyprinella lutrensis* metalarva, 8.0 mm SL, 9.5 mm TL. (From Taber 1969.)

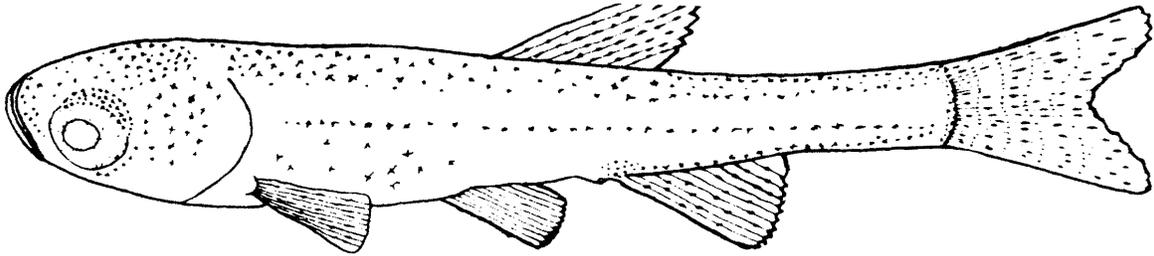


Fig. 104. *Cyprinella lutrensis* juvenile, recently transformed, 13.7 mm SL, 16.4 mm TL. (From Saksena 1962.)

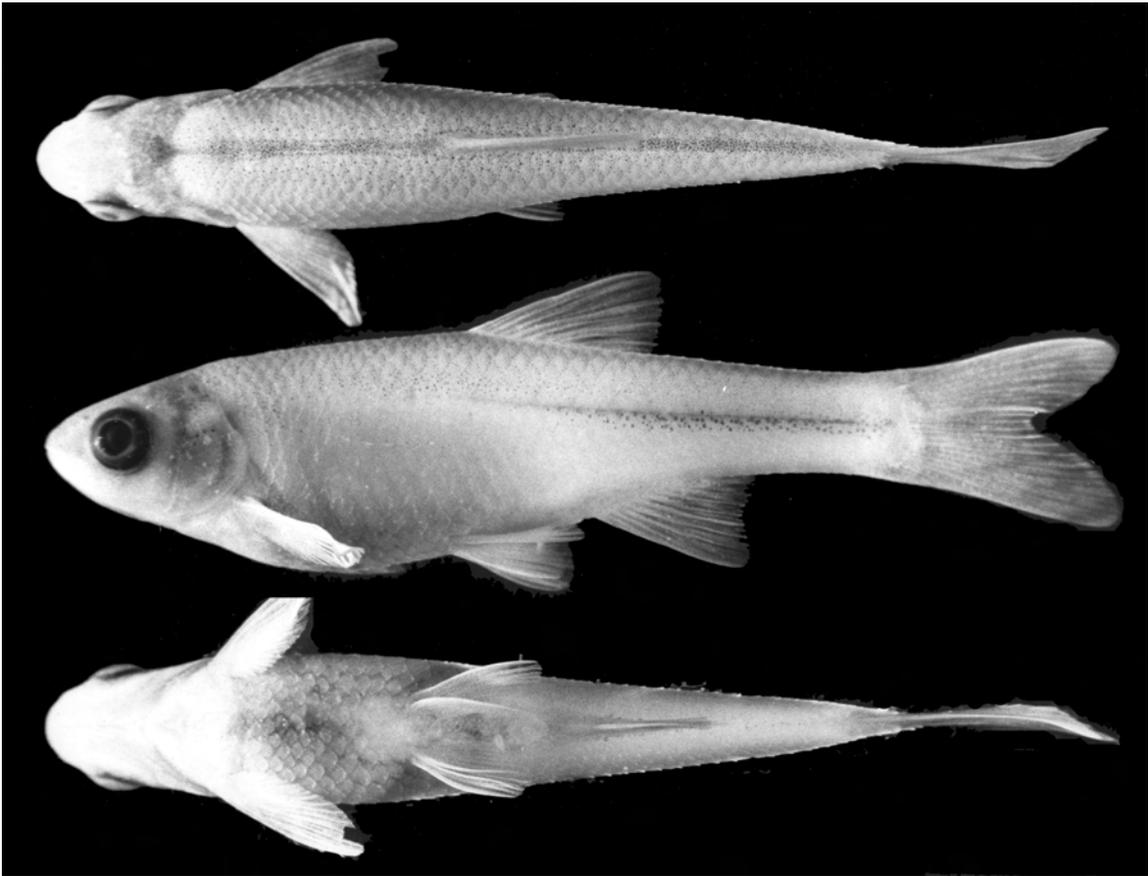


Fig. 105. *Cyprinella lutrensis* juvenile, 33 mm SL, 41 mm TL. (Previously unpublished photographs.)

Species Account – *Cyprinus carpio*

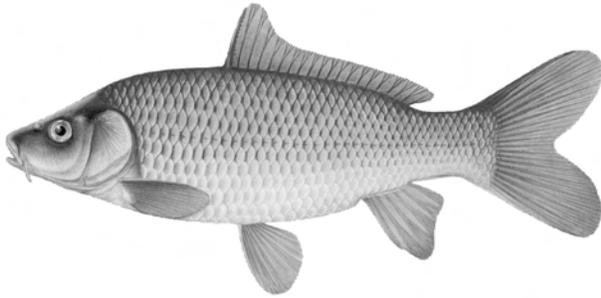


Fig. 106. *Cyprinus carpio* adult (© Joseph R. Tomelleri).

Adult description: Large, 30-120 cm TL. Deep-bodied, laterally compressed, dorsally arched and often ventrally flat. Mouth terminal, moderate in size, somewhat oblique, and with a pair of barbels at the corners of the mouth. Head relatively large, about 29 % of SL, with a large eye. Dorsal fin long; first principal ray of dorsal and anal fin spine-like and serrated on the posterior margin. Scales very large and round. Usually dark to olivaceous or coppery-colored above, copper or golden-yellow laterally and ventrally; breeding males orange ventrally. (Also, Table 50.)

Reproduction: Non-guarding, open-substrate phytophil. Spawn from early March to August, when water reaches day-time highs of at least 15°C, scattering adhesive eggs usually over flooded terrestrial or submerged aquatic vegetation in low-velocity areas such as backwaters, pools, flooded tributary mouths, or flood plains. Water-hardened eggs are 1.3-2.1 mm in diameter.

Young: Hatch in 3-5 d at 15-20°C. Larvae occupy near-shore, low-velocity channel margins, backwaters, eddies, and pools and consume early instars of chironomids, plankton, and other small invertebrates, algae, and detritus.

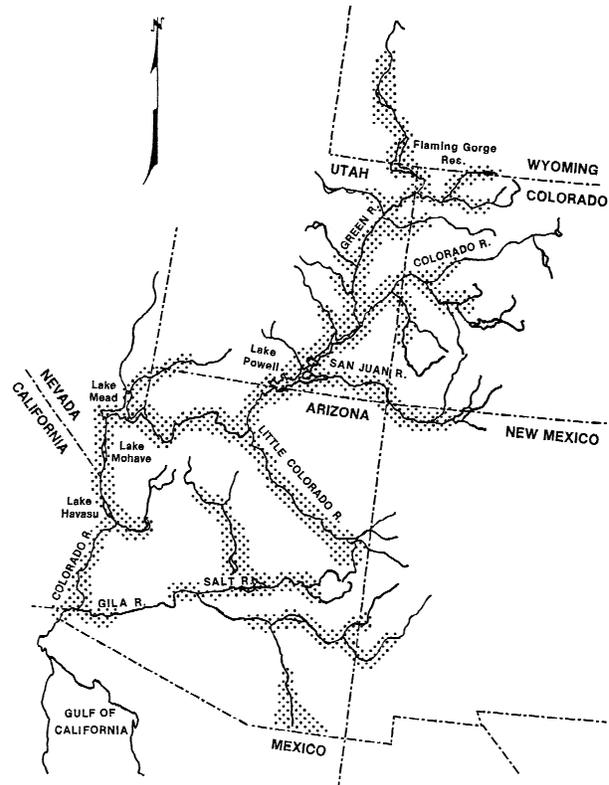


Fig. 107. Recent distribution of *Cyprinus carpio* in the Colorado River Basin.

Table 50. Selected juvenile and adult meristics for *Cyprinus carpio*. (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. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

Character	Observed*	Literature	Character	Observed*	Literature
Dorsal-fin rays - P	(17)18-21	(16-)18-22(-24)**	Dorsal-fin rays - R	(1)2-3	1-4
Anal-fin rays - P	–	5- <u>6</u> -7(8)**	Anal-fin rays - R	(1)2	1-3
Caudal-fin rays - P	19	(18)19(20)	Caudal-fin rays - RD	(5-)7-10	3-7
Pectoral-fin rays	(12-)14-18(19)	14- <u>15</u> -16-17	Caudal-fin rays - RV	(5-)7-9	5-7
Pelvic-fin rays	(6-)8- <u>9</u>	(5-)8-9	Lateral scales	–	32-35-38-41
Vertebrae	37-38	(32-)35-36(-39)	Pharyngeal teeth	–	1,1(2),3/3,1(2),1

*Original data from Snyder (1981). **First principal ray is spine-like (thickened and hardened) and serrated on posterior margin; rudimentary rays before it are also spine-like.

Table 51. Size at onset of selected developmental events for *Cyprinus carpio*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses. Mostly from Snyder 1981.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	(3)4-5(6)	(3)4-5(-7)	Dorsal - P	(8)9-11	(9)10-12(13)	(12)13-16(-18)	15-19(-21)
Eyes pigmented	*	*	Anal - P	10-11	11-13	12-13	15-16
Yolk assimilated	6-7(8)	6-8	Caudal - P	7-8	(7)8	(8)9(10)	(9)10(11)
Finfold absorbed	16-19(-21)	20-23(-26)	Caudal - R	9-11	10-13	15-16(17)	18-19(20)
Pectoral-fin buds	*	*	Pectoral	11-12	13-15	(14-)16-17	(17-)19-21
Pelvic-fin buds	9-11(12)	10-12(-15)	Pelvic	12	14-15	(15-)17-19	(19-)21-23
* before hatching			Scales	13-16	16-19	18-21	22-25

References: Balon 1974, Beckman 1952, Becker 1983, Gerlach 1983, Heufelder and Fuiman 1982, Jones et al. 1978, LaRivers 1962, Lentsch et al. 1996, Lippson and Moran 1974, Minckley 1973, Moyle 1976, Page and Burr 1991, Scott and Crossman 1973, Snyder 1981, Sublette et al. 1990.

Table 52. Size at developmental interval (left) and gut phase (right) transitions for *Cyprinus carpio*. (See Figure 5 for phases of gut folding. Rare values in parentheses. Mostly from Snyder 1981.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	7-8	(7)8	2 - 90° bend	8-12 (-15)	(8)9-15(-19)
Postflexion mesolarva	(8)9(10)	(9)10(11)	3 - Full loop	12-15	15-19
Metalarva	(12)13-16(-18)	15-19(-21)	4 - Partial crossover	16-21	19-26
Juvenile	16-19(-21)	20-23(-26)	5 - Full	≥(16-)20	≥(19-)26

Table 53. Summary of morphometrics and myomere counts by developmental phase for *Cyprinus carpio*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. SD value of 0 actually between 0.0 and 0.5. Except as noted, from Snyder 1981 with original data recalculated for flexion and postflexion mesolarvae.)

	Protolarvae (N=6)			Flexion mesolarvae (N=4)			Postflexion mesolarvae (N=13)			Metalarvae (N=19)			Juveniles (N=12)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	6	1	5 - 8	9	1	8 - 10	11	1	8 - 13	15	1	14 - 17	30	8	19 - 42
TL, mm	7	1	5 - 8	9	1	8 - 11	13	2	10- 16	19	1	17 - 21	37	9	23 - 50
<u>Lengths %SL</u>															
AS to AE	4	1	3 - 5	5	1	4 - 7	6	1	5 - 7	7	1	6 - 8	9	1	8 - 11
PE	11	1	10 - 13	13	2	12 - 15	15	2	13- 18	15	1	13 - 18	17	1	15 - 18
OP1	20	2	17 - 23	25	1	25 - 26	30	2	26 - 33	32	2	29 - 35	31	2	27 - 33
OP2										52	2	50 - 54	53	2	50 - 56
PY	-	^{ak}	63 - 65	-	^l										
OPAF	-	^a	34 - 48	39	4 ^a	37 - 45	43	7 ^{ab}	29 - 57	-	^{am}	47 - 64			
ODF	-	^a	37 - 47	48	1 ^a	46 - 49	49	2 ^{ac}	48 - 51						
OD							49	1 ^d	48 - 52	49	1	47 - 51	48	1	46 - 49
ID										81	1 ^c	79 - 83	82	1	80 - 84
PV	72	2	70 - 75	75	1	74 - 75	76	1	74 - 77	74	2	72 - 77	75	1	73 - 77
OA										74	2 ^f	72 - 77	75	1 ^f	73 - 77
IA										82	1	80 - 84	84	1	81 - 85
AFC							111	1	109 - 113	111	2	109 - 114	111	2	109 - 115
PC	107	2	106 - 110	109	1	108 - 110	119	4	112 - 125	122	2	119 - 125	122	2	118 - 127
Y	-	^{ai}	0 - 44	-	^l	0 -									
P1	10	3	4 - 13	13	2	12 - 15	13	1	11 - 16	13	1	12 - 15	15	2 ^g	12 - 18
P2							5	3 ^d	2 - 9	9	1	8 - 10	14	2	11 - 17
D										34	2	31 - 36	38	2	37 - 41
A										13	1	10 - 15	17	2	14 - 19
<u>Depths %SL</u>															
at BPE	14	1	13 - 15	16	2	13 - 18	19	3	12 - 23	22	1	21 - 24	23	1	21 - 24
OP1	15	1	13 - 17	18	2	16 - 20	23	2	19 - 27	27	2	25 - 30	32	2	29 - 35
OD	14	2	12 - 16	13	2	11 - 16	20	4	13 - 25	27	2	23 - 30	34	2	31 - 36
BPV	7	1	6 - 7	7	1	7 - 8	12	3	7 - 15	15	1	14 - 17	21	2	18 - 23
AMPM	3	1	2 - 5	6	1	5 - 7	9	1	7 - 10	10	1	8 - 11	12	1	11 - 13
Max. yolk	-	^{ak}	0 - 17	-	^l	0 -									
<u>Widths %SL</u>															
at BPE	13	2	12 - 16	14	1	13 - 14	18	1	15 - 20	20	1	19 - 20	20	1	18 - 21
OP1	9	2	6 - 11	11	1	10 - 12	14	1	11 - 16	18	1	16 - 19	21	2	19 - 23
OD	7	2	5 - 10	7	1	7 - 8	12	3	7 - 20	16	1	14 - 17	20	2	18 - 22
BPV	4	1	3 - 5	6	1	5 - 7	8	1	6 - 11	10	1	9 - 12	14	3	10 - 17
AMPM	2	1 ⁱ	1 - 3	3	1	2 - 5	4	2	2 - 6	5	1	3 - 6	6	2	4 - 9
Max. yolk	-	^{ac}	0 - 8	-	^l	0 -									
<u>Myomeres</u>															
to PY	-	^{am}	23 - 23	-	^l										
OPAF				8	2 ^a	6 - 11	10	2 ^{ah}	8 - 15	-					
OP2				14	1 ⁱ	13 - 15	14	1 ⁱ	13 - 15	13	1 ⁱ	11 - 14	13	1 ⁱ	12 - 14
ODF	-			11	1 ^a	10 - 12	11	1 ^{ac}	10 - 12						
OD				12	1 ^j	11 - 13	11	1 ^j	11 - 13	11	1 ⁱ	10 - 12	10	1 ⁱ	9 - 11
PV	26	0	26 - 27	28	1	27 - 28	27	1 ^d	26 - 28	25	0 ^j	25 - 26	24	1 ⁱ	24 - 25
Total	38	1	37 - 38	38	1	38 - 39	38	1 ^d	37 - 38	37	1 ⁱ	36 - 37	37	1 ⁱ	36 - 37
After PV	12	1	10 - 12	11	1	10 - 11	11	1 ^d	10 - 12	12	1 ⁱ	11 - 13	12	1 ⁱ	11 - 13

^aData summarized for but not reported by Snyder (1981). ^bN = 12. ^cN = 3. ^dN = 10. ^eN = 8. ^fAssumed same as AS to PV. ^gN = 11. ^hN = 9. ⁱN = 5. ^jN = 7. ^kN = 2. ^lTrace amount of yolk in 7.6 mm SL specimen, not measured. ^mN = 4. ⁿN = 18.

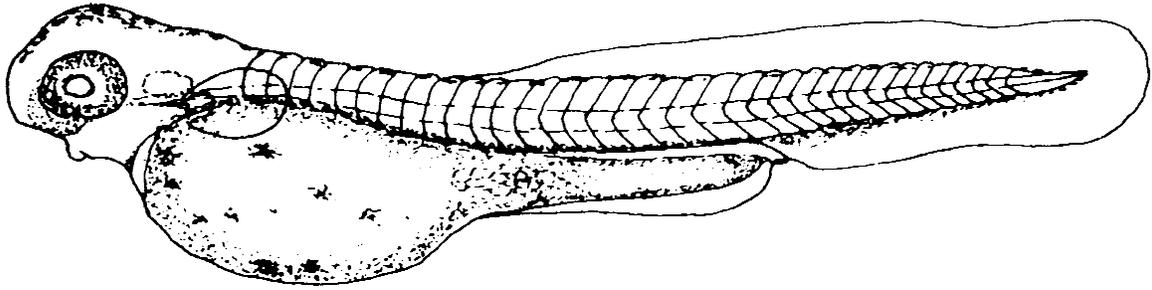


Fig. 108. *Cyprinus carpio* protolarva, recently hatched, 5.3 mm SL, 5.6 mm TL. (From Wang and Kernehan 1979.)

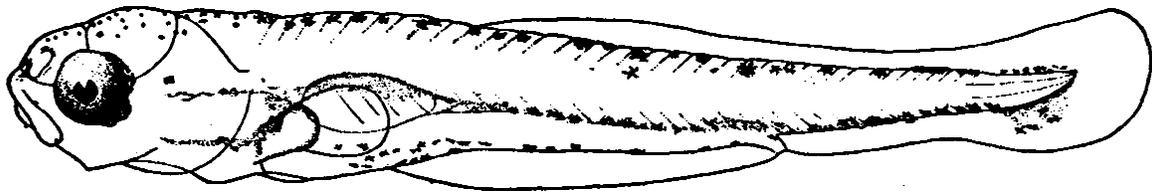


Fig. 109. *Cyprinus carpio* protolarva, 7.0 mm SL, 7.5 mm TL. (From Fish 1932, mistakenly described as *Moxostoma aureolum*.)

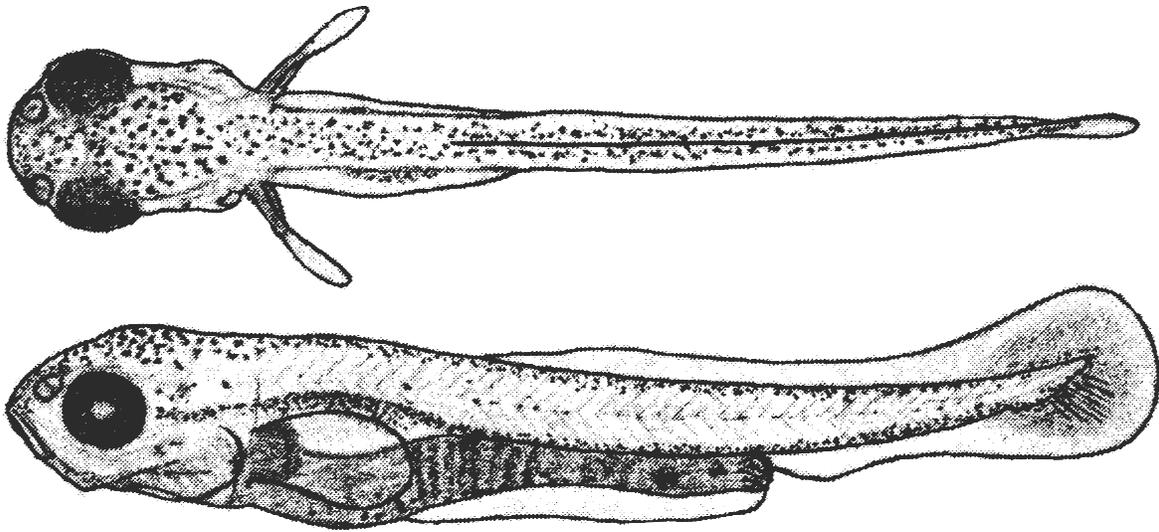


Fig. 110. *Cyprinus carpio* flexion mesolarva, recently transformed, 8.1 mm SL, 8.5 mm TL. (From Taber 1969.)

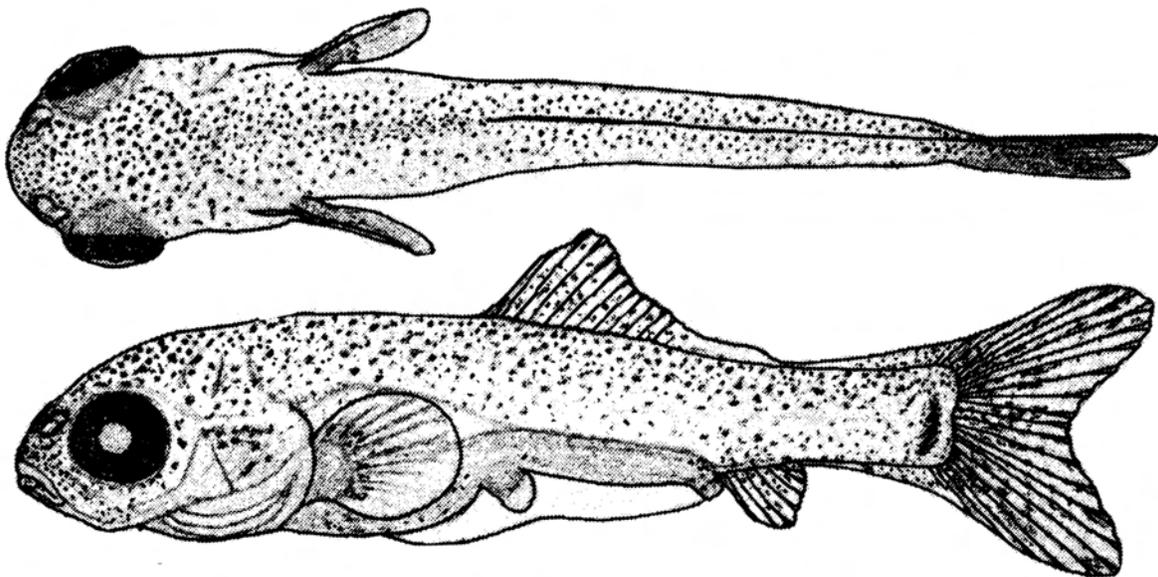


Fig. 111. *Cyprinus carpio* postflexion mesolarva, 10.8 mm SL, 13.0 mm TL. (From Taber 1969.)

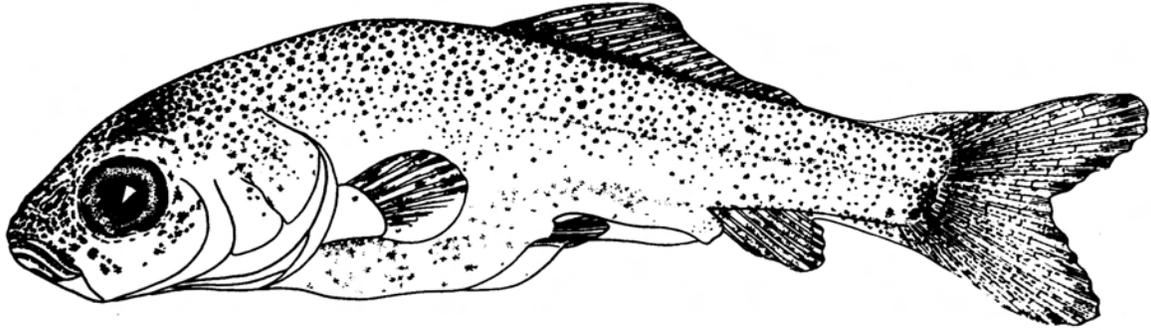


Fig. 112. *Cyprinus carpio* metalarva, recently transformed, 12.5 mm SL, 15.0 mm TL. (From Bragensky 1960.)

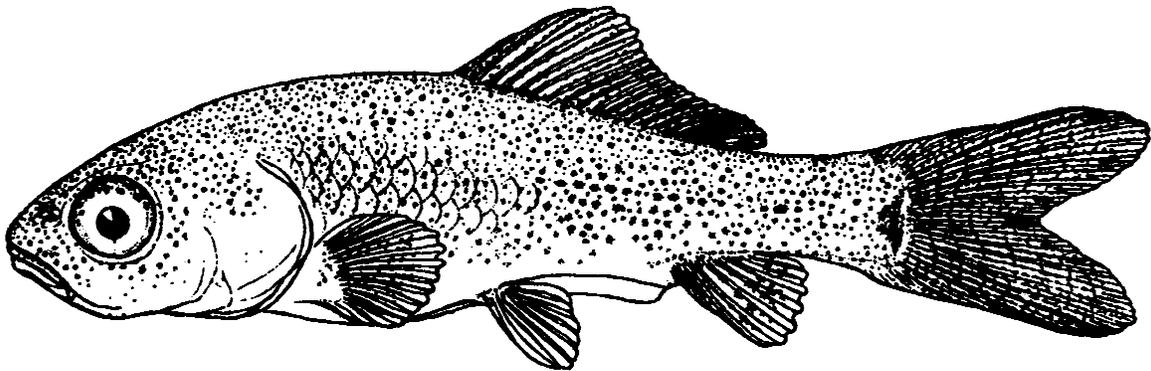


Fig. 113. *Cyprinus carpio* metalarva, 15.2 mm SL, 19.0 mm TL. (From Nakamura 1969.)

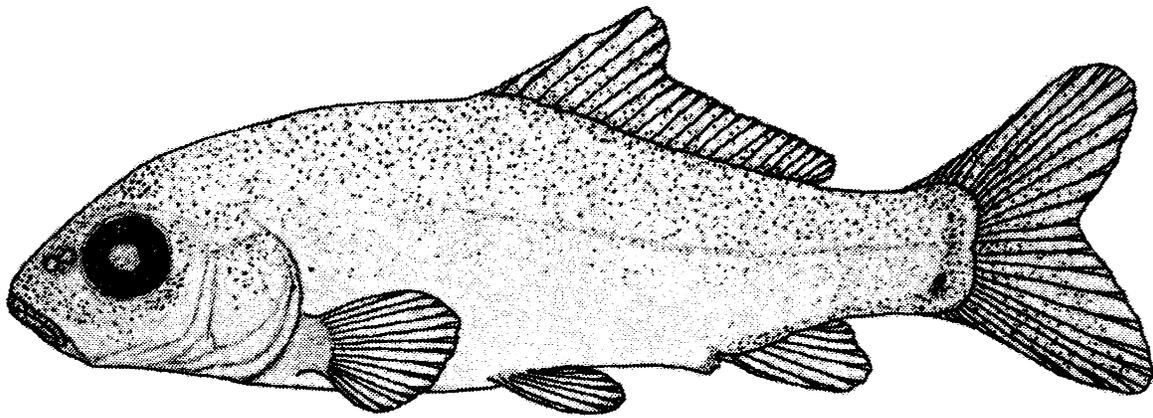


Fig. 114. *Cyprinus carpio* juvenile, recently transformed, 20.8 mm SL, 24.5 mm TL. (From Taber 1969.)

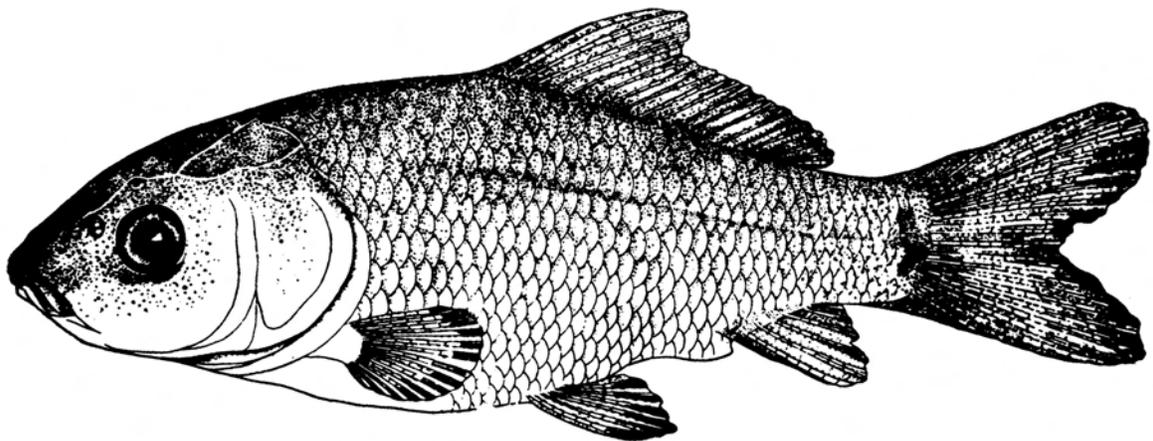


Fig. 115. *Cyprinus carpio* juvenile, 24.5 mm SL, 30.0 mm TL. (From Bragensky 1969.)

Species Account – *Pimephales promelas*

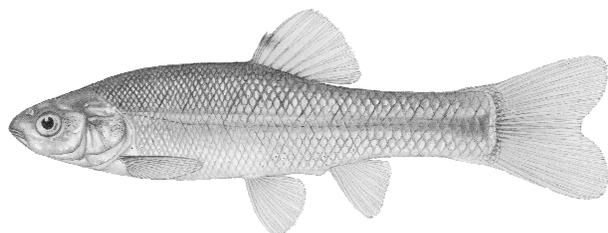


Fig. 116. *Pimephales promelas* adult (© Joseph R. Tomelleri).

Adult description: Small, 5-10 cm TL. Heavy-bodied and round to oval in cross section. Mouth terminal, small, somewhat oblique, and without barbels. Head and snout rounded, head about 25 % of SL. Dorsal fin short and rounded; last rudimentary ray is short and thickened. Scales moderately large in lateral series, but smaller and crowded dorsally before dorsal fin. Usually olivaceous above, silvery-grey laterally, and white below, sometimes with a moderately distinct single lateral band. Breeding males often black dorsally and dark brown laterally with light vertical bands behind head and between dorsal and pelvic fins, or with dark saddles over body; have a few heavy tubercles concentrated on snout. (Also, Table 54.)

Reproduction: Guarding nest spawner. Spawn from early March to mid-September, or later when water reaches day-time highs of at least 16-18°C, usually in low-velocity areas such as backwaters or pools. Territorial males mate with several females, one at a time. Females deposit clutches of adhesive eggs on the exposed undersides of solid surfaces (e.g., rocks, vegetation); males guard the eggs which are 1.2-1.6 mm in diameter.

Young: Hatch in 4-6 d at 23-30°C. Larvae occupy near-shore, low-velocity channel margins, backwaters, eddies, and pools and consume early instars of chironomids and other small invertebrates, as well as algae and detritus.

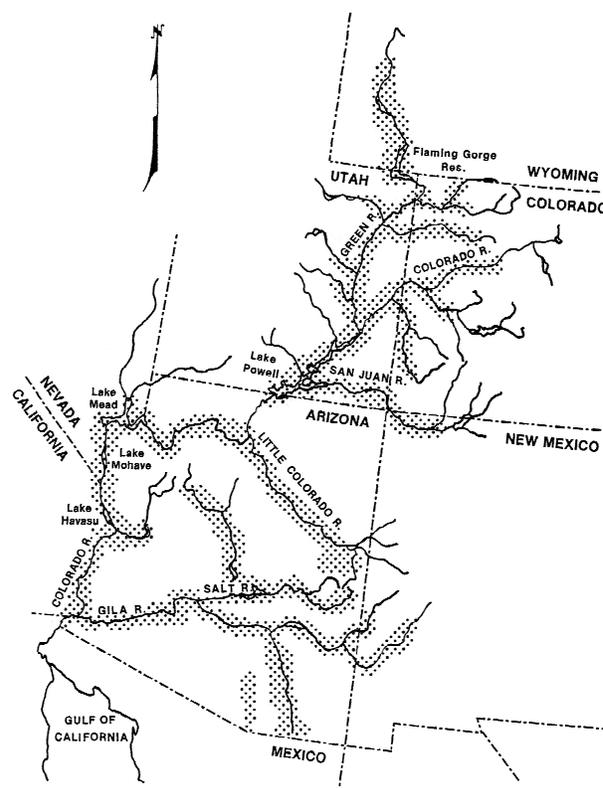


Fig. 117. Recent distribution of *Pimephales promelas* in the Colorado River Basin.

Table 54. Selected juvenile and adult meristics for *Pimephales promelas*. (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. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

Character	Observed*	Literature	Character	Observed*	Literature
Dorsal-fin rays - P	(7)8(9)	(7)8(9)	Dorsal-fin rays - R	2	1
Anal-fin rays - P	7	7	Anal-fin rays - R	–	–
Caudal-fin rays - P	19	19	Caudal-fin rays - RD	–	–
Pectoral-fin rays	14- <u>15-16</u> -17	14- <u>15-16</u> -18	Caudal-fin rays - RV	–	–
Pelvic-fin rays	<u>8-9</u>	<u>8-9</u>	Lateral scales	–	40-44- <u>48</u> -54(-60)
Vertebrae	<u>35-36-37-38</u>	<u>35-37-38</u>	Pharyngeal teeth	–	0,4/4,0

*Original data from Snyder (1981).

Table 55. Size at onset of selected developmental events for *Pimephales promelas*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses. Mostly from Snyder et al. 1977 and Snyder 1981.)

Event or structure	Onset or formation		Fin rays or scales	First formed		Last formed	
	mm SL	mm TL		mm SL	mm TL	mm SL	mm TL
Hatched	4(5)	4(5)	Dorsal - P	–	–	8-9	9-10
Eyes pigmented	*	*	Anal - P	–	–	8-9	9-10
Yolk assimilated	4-5(6)	5(6)	Caudal - P	6-7	6-7	7-8	(7)8
Finfold absorbed	13-15	16-18	Caudal - R	–	–	~13-15	~16-18
Pectoral-fin buds	*	*	Pectoral	–	–	–	–
Pelvic-fin buds	8-9	9-10	Pelvic	–	–	–	–
* before hatching			Scales	–	–	16-<23	20-<28

References: Andrews and Flickinger 1972, Baxter and Simon 1970, Becker 1983, Beckman 1952, Eddy and Underhill 1974, Gale and Buynak 1982, Heufelder and Fuiman 1982, Hubbs and Lagler 1958, Lentsch et al. 1996, Minckley 1973, Moore 1968, Moyle 1976, Muth and Snyder 1995, Page and Burr 1991, Perry 1979, Perry and Menzel 1979, Pflieger 1975, Snyder 1981, Snyder et al. 1977, Scott and Crossman 1973, Sublette et al. 1990.

Table 56. Size at developmental interval (left) and gut phase (right) transitions for *Pimephales promelas*. (See Figure 5 for phases of gut folding. Rare values in parentheses. From Snyder et al. 1977 and Snyder 1981.)

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion mesolarva	6-7	6-7	2 - 90° bend	8-11	10-13
Postflexion mesolarva	7-8	(7)8	3 - Full loop	11(12)	(13)14
Metalarva	8-9	9-10	4 - Partial crossover	15-19	18-23
Juvenile	13-15	16-18	5 - Full	19-20	(23)24(25)

Table 57. Summary of morphometrics and myomere counts by developmental phase for *Pimephales promelas*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. Data for mesolarvae not segregated into flexion and postflexion subphases; no data for juveniles. SD value of 0 actually between 0.0 and 0.5. Except as noted, approximated by calculation or adjustment from Snyder et al. 1977.)

	Protolarvae (N=5)			Flexion & Postflexion Mesolarvae (N=5)			Metalarvae (N=5)		
	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range	\bar{x}	\pm SD	Range
SL, mm	5		4 - 5	7		6 - 8	10		8 - 13
TL, mm	5		4 - 6	8		6 - 9	12		9 - 16
<u>Lengths %SL</u>									
AS to AE	2		1 - 2	3		3 - 3	5		5 - 5
PE	9		8 - 10	12		12 - 14	14		13 - 16
OP1	19		18 - 21	22		21 - 24	27		24 - 30
OP2							54		51 - 57
PY	-	^a	- 61						
OPAF	-	^a	31 - 56	-					
ODF	42		39 - 45	46		41 - 50			
OD				-			54		50 - 57
ID							-		
PV	62		61 - 64	69		65 - 72	71		65 - 75
OA									
IA									
AFC				109		107 - 112	113		111 - 117
PC	105		105 - 106	112		109 - 116	120		116 - 123
Y	-	^a	0 - 53						
P1	12		5 - 14	12		12 - 14	13		12 - 15
P2							6		2 - 10
D							-		
A							-		
<u>Depths %SL</u>									
at BPE	15	^b	13 - 16	16	^b	15 - 17	19	^b	16 - 22
OP1	15	^c	13 - 24	15	^c	13 - 16	19	^c	16 - 23
OD				-					
BPV	-			-			-		
AMPM	-			-			-		
Max. yolk	-	^a	0 - 22						
<u>Widths %SL</u>									
at BPE									
OP1	11	^c	7 - 20	10	^c	10 - 13	16	^c	12 - 20
OD				-			-		
BPV	-			-			-		
AMPM	-			-			-		
Max. yolk	-	^d	0 - 20						
<u>Myomeres</u>									
to PY	-								
OPAF	-			-			-		
OP2				-			14		12 - 15
ODF	12		10 - 13	12		10 - 13			
OD				-			15		12 - 16
PV	23		21 - 24	24		22 - 25	23		22 - 25
Total	36		34 - 37	37		35 - 38	35		34 - 36
After PV	13		13 - 15	13		12 - 14	12		11 - 13

^aData extracted from drawings of protolarvae in Snyder et al. (1977), N = 1 for AS-PY, N = 2 for others. ^bMaximum head depth, including yolk in smallest protolarvae. ^cMaximum body depth or width, probably near or somewhat behind OP1. ^dBased on maximum body width for protolarvae which would also be maximum width of yolk for specimens with much yolk.

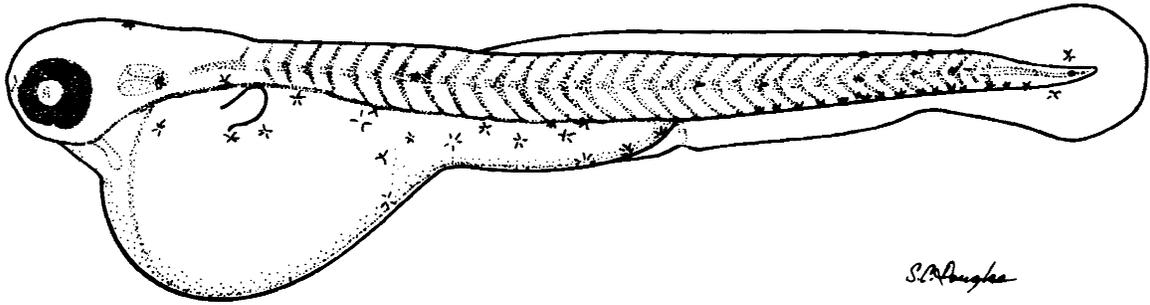


Fig. 118. *Pimephales promelas* protolarva, recently hatched, 4.1 mm SL, 4.3 mm TL. (From Snyder et al. 1977.)

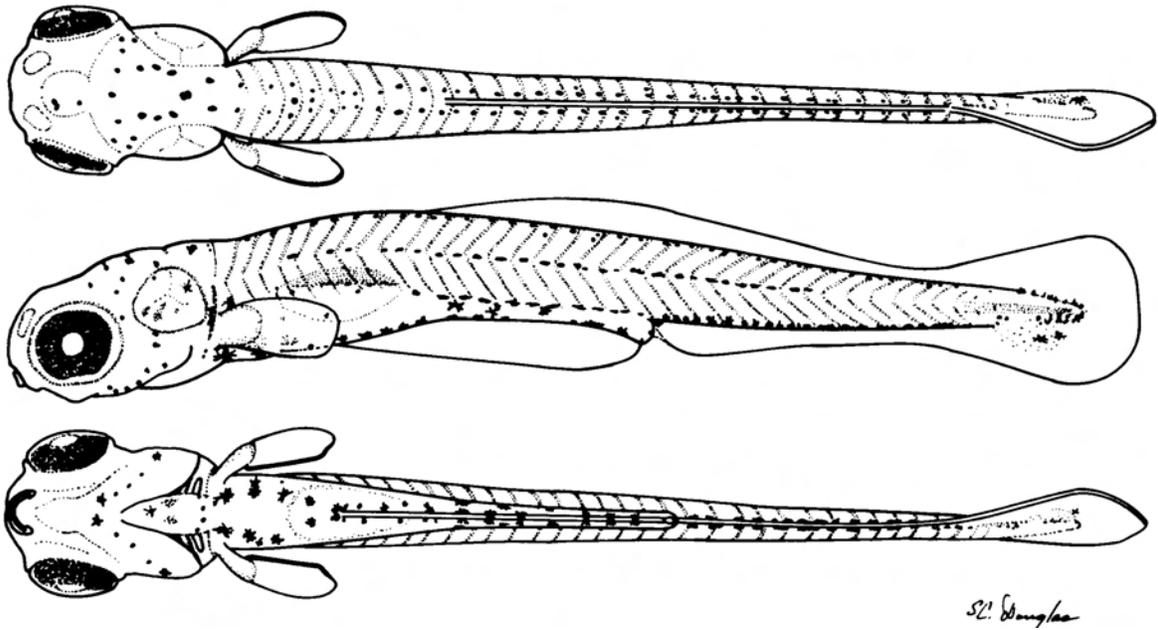


Fig. 119. *Pimephales promelas* protolarva, 5.3 mm SL, 5.6 mm TL. (From Snyder et al. 1977.)

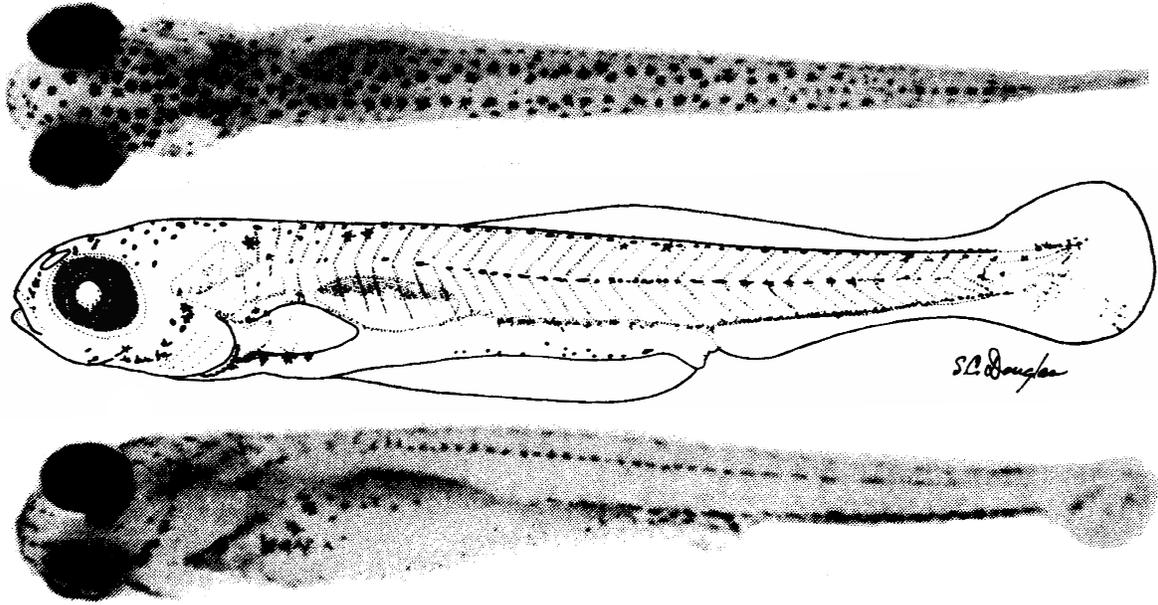


Fig. 120. *Pimephales promelas* flexion mesolarva, recently transformed, 7.5, 6.1, and 7.5 mm SL (top to bottom), 8.0, 6.5, and 8.0 mm TL. (From Snyder et al. 1977 and Perry 1979.)

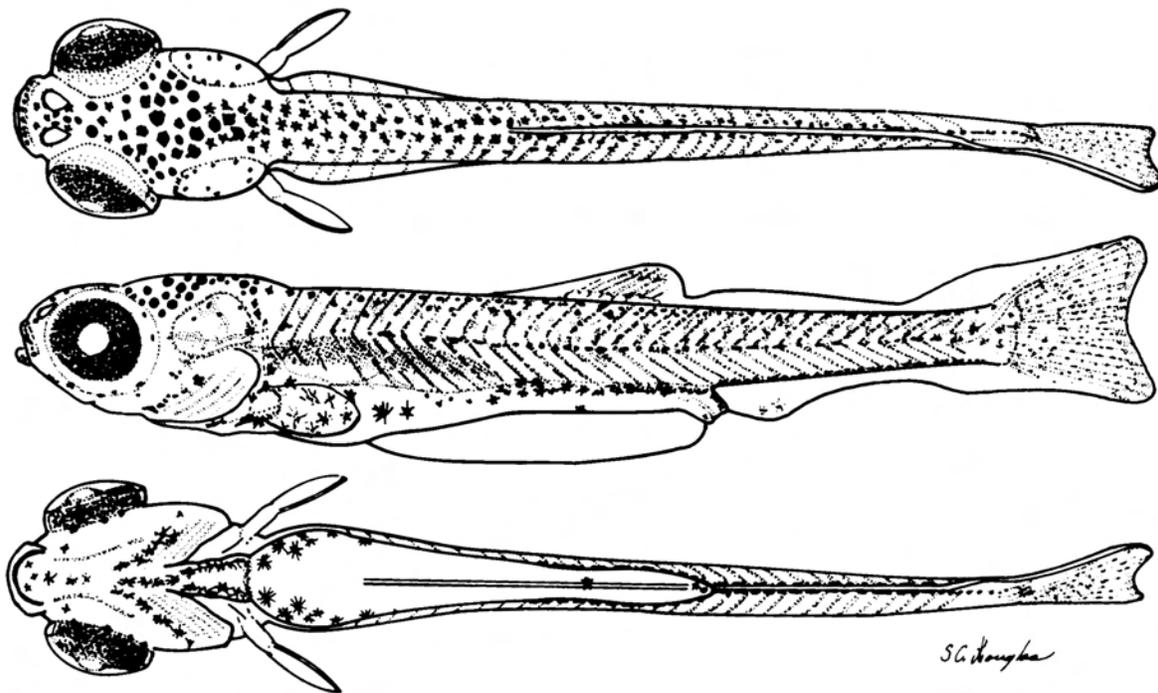


Fig.121. *Pimephales promelas* postflexion mesolarva, 7.0 mm SL, 7.9 mm TL. (From Snyder et al. 1977.)

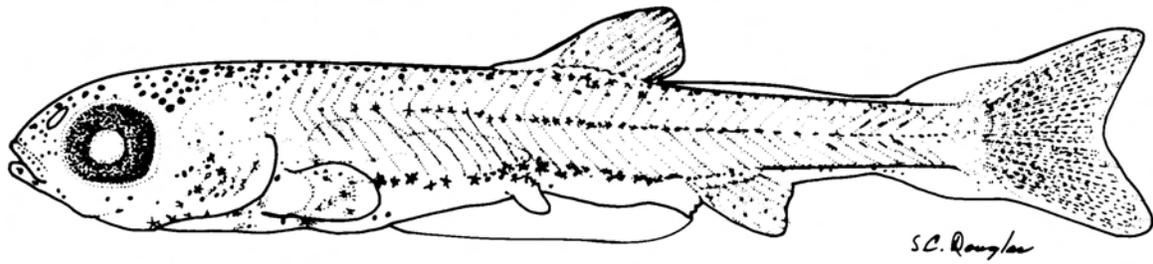


Fig. 122. *Pimephales promelas* metalarva, recently transformed, 8.0 mm SL, 9.3 mm TL. (From Snyder et al. 1977.)

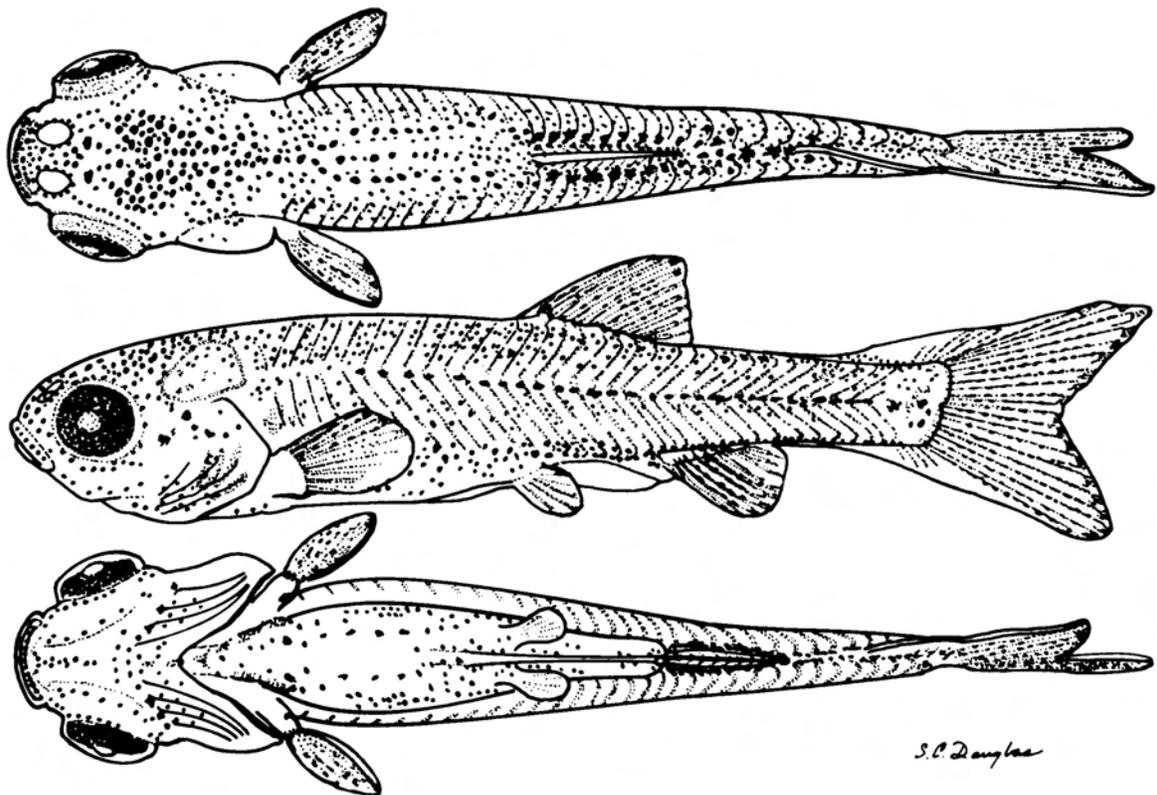


Fig. 123. *Pimephales promelas* metalarva, 12.0 mm SL, 14.3 mm TL. (From Snyder et al. 1977.)

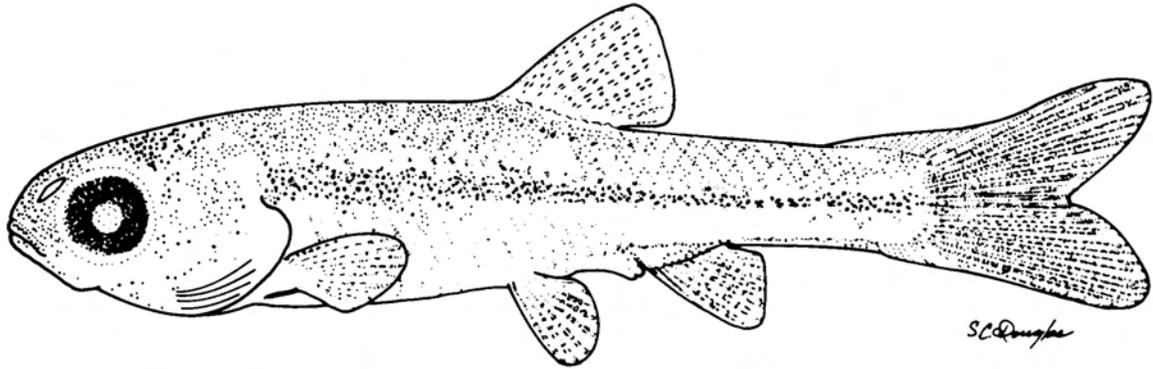


Fig. 124. *Pimephales promelas* juvenile, recently transformed, 16.0 mm SL, 19.6 mm TL. (From Snyder et al. 1977.)

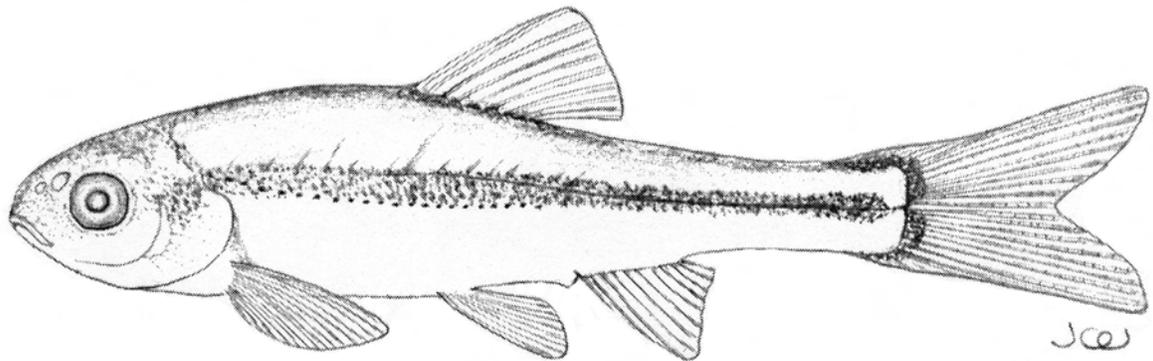


Fig. 125. *Pimephales promelas* juvenile, 33.7 mm SL, 42.5 mm TL. (From Wang 1986.)

Comparative Summary Tables

The following tables summarize the more diagnostically useful data in the species accounts in a convenient comparative format and supplement the species accounts with comparative information on pigmentation and special characters. All data in these tables are included in the computer-interactive keys, but along with the descriptive species accounts, these tables are provided to help confirm identities determined through the keys or as an alternative to the keys.

The tables are organized in three sets of six tables for the native catostomids, native cyprinids, and non-native cyprinids, respectively. Each set includes a table comparing size at the onset of selected developmental events (Tables 58, 65, 71), selected meristics (Tables 59, 66, 72), the more diagnostically useful morphometrics (Tables 60, 67, 73), size relative to pigmentation of the eyes and body in protolarvae and peritoneal pigmentation in metalarvae and early juveniles (Tables 61, 68, 74), selected melanophore pigmentation patterns, coded by developmental phase (Tables 62, 69, 75), and miscellaneous other characters (Tables 63, 70, 76). The catostomid set also includes a seventh table (Table 64) comparing dimensions of the frontoparietal fontanelle.

Native Catostomids

Table 58. Comparison of size (mm SL) at onset of or transition to developmental intervals, gut phases, and other developmental events for larvae and early juveniles of native catostomids of the Gila River Basin. (Rare values in parentheses.)

Character	<i>Catostomus clarkii</i>	<i>Catostomus insignis</i>	<i>Catostomus latipinnis</i>	<i>Xyrauchen texanus</i>
Egg diameter	3.0-3.4	(3.0-)3.2-3.6	3.8-3.9	2.5-2.8
Phase/period transitions				
Embryo to larva	(8)9-10	9-10(11)	(8-)10-11	7-9
Protolarva to flexion mesolarva	(10)11-12	(12)13-14	13	(10)11(12)
Flexion to postflexion mesolarva	(13)14(15)	(13)14-16	(14)15(16)	(11)12-13
Postflexion mesolarva to metalarva	(15)16(-18)	(18)19-21(22)	19-20(21)	15-17
Metalarva to juvenile	(22)23-24(25)	(24)25-26	23-24(25)	(21)22-23(24)
Gut phase transitions				
1 to 2 (90° bend)	(13)14-15(16)	(18)19-20	(17)18(-20)	(14)15(-17)
2 to 3 (full loop)	(15)16-17	22	(19-)21-25(-27)	17
3 to 4 (partial crossover)	(16)17(18)	(24)25-26	(22)23-32(-37)	18-25(26)
4 to 5 (full crossover)	18-19	(31)32-33	(29-)35-42	(22-)26-28(-31)
Onset of selected events				
Eyes pigmented	10	11	(9)10 ^a	(7)8(9) ^a
Yolk assimilated	12-14	(13)14-16	(14)15(16)	(9)10-11
Finfold absorbed	(22)23-24(25)	(24)25-26	23-24(25)	(21)22-23(24)
Pectoral-fin buds	^a	^a	(9) ^a	7 ^a
Pelvic-fin buds	13-14	14-16	(15)16(17)	(13)14
Fin rays first observed				
Dorsal, principal	13-14	14-15	15	13-14
Anal, principal	15-16	18	17	(13-)15
Caudal, principal	(10)11-12	(12)13-14	13	(10)11(12)
Caudal, rudimentary	13-14	16-17	(15-)17	14
Pectoral	(13)14-15	17-18	17	(13-)15
Pelvic	15-16	18-19(20)	17-18	(13-)15-17
Full fin ray counts first observed				
Dorsal, principal	(14)15-16	18	17-18	15(-17)
Anal, principal	(15)16(-18)	(18)19-21(22)	19-20(21)	15-17
Caudal, principal	(13)14(15)	(13)14-16	(14)15(16)	(11)12-13
Caudal, rudimentary	21-23(-25)	21-24	23	19-20(-24)
Pectoral	18	22-23	19-22	16-18
Pelvic	(18)19-20	21(22)	23	16-17
Scales, lateral series				
First observed	28-29	30-31	(36)37-39	24-28
Full series first observed	29-34	32-33	39-42	33-36(37)

^a (Or) before hatching.

Table 59. Comparison of selected meristics for larvae and early juveniles of native catostomids of the Gila River Basin. (Character range is followed by the mean or more typical range. See Figure 4 for methods of counting myomeres and fin rays. ODF = origin of dorsal finfold, OP2 = origin of pelvic buds or fins, PV = posterior margin of the vent. Vertebra counts include four for the Weberian complex; dorsal-fin-ray counts are of principal rays; scale counts are of the lateral line or series. Data previously published by other authors are given in parentheses; references are listed in corresponding species accounts.)

Character	<i>Catostomus clarkii</i>	<i>Catostomus insignis</i>	<i>Catostomus latipinnis</i>	<i>Xyrauchen texanus</i>
Myomeres to ODF				
Protolarvae	13-16, 15	10-14, 12	10-15, 12	10-16, 12
Flexion mesolarvae	12-18, 16	11-15, 14	12-15, 13	12-16, 13
Postflexion mesolarvae	15-18, 16	13-17, 15	12-17, 15	12-17, 14
Myomeres to OP2				
Postflexion mesolarvae	22-24, 23	20-22, 21	19-23, 21	19-22, 20
Metalarvae	22-26, 24	20-22, 21	21-24, 22	19-22, 20
Myomeres to PV				
Proto- & mesolarvae	38-42, 40	37-41, 39	37-40, 39	37-41, 38-39
Metalarvae	36-40, 38	36-39, 37	36-38, 37	36-39, 37
All larvae	36-42, 38-40	36-41, 37-39	36-40, 37-39	36-41, 37-39
Myomeres, total				
Proto- & mesolarvae	47-49, 48	46-49, 47-48	47-49, 48	46-49, 47-48
Metalarvae	47-51, 49	46-50, 48	46-48, 47	44-48, 46
All larvae	47-51, 48-49	46-50, 47-48	46-49, 47-48	44-49, 46-48
Vertebrae	46-48 (45-51, 46-49)	47-48 –	47-50 –	45-47, 46 –
Dorsal-fin rays	10-12, 10-11 (8-12, 10-11)	10-12, 11 (10-13, 11-12)	11-14, 12-13 (10-15, 12-13)	12-16, 14-15 (12-16, 14-15)
Lateral-line scales	70-75 (61-104, 67-95)	51-58, 53-58 (54-67, 60-62)	– (89-120, 98-105)	– (68-95, 76-87)

Table 60. Comparison of the more diagnostic differences in morphometrics for larvae and juveniles (≤ 40 mm SL) of native catostomids of the Gila River Basin. (Except as indicated, all data are percentages of standard length, % SL, presented as ranges followed by means. HL = head length measured to the origin of the pectoral fin, AS to OP1. See Figure 4 for other abbreviations and methods of measurement.)

Developmental Phase Character	<i>Catostomus clarkii</i>	<i>Catostomus insignis</i>	<i>Catostomus latipinnis</i>	<i>Xyrauchen texanus</i>
Protolarvae (with pigmented eyes)				
Eye diameter ^a	6-8, 7	6-8, 7	5-6, 5	5-6, 6
Eye diameter, % HL ^a	39-45, 42	38-49, 43	34-40, 37	31-38, 35
AS-to-ODF length	34-42, 39	33-38, 35	33-38, 35	32-39, 34
Yolk length ^b	58-63, 61	54-66, 62	54-67, 61	0-68, 44
Pectoral-fin length	3-8, 6	3-10, 5	3-9, 6	3-11, 7
Depth at BPE ^b	9-11, 10	8-11, 9	7-9, 8	8-10, 9
Depth at OP1 ^b	10-15, 12	10-13, 12	8-10, 9	9-12, 11
Depth at OD ^{b,c}	11-19, 15	11-18, 15	13-15, 14	7-13, 10
Max. yolk depth ^b	9-18, 12	9-20, 12	9-16, 12	0-9, 5
Width at OD ^{b,c}	9-16, 12	8-19, 11	7-11, 10	4-9, 6
Max. yolk width ^b	12-18, 14	8-18, 12	9-18, 13	0-9, 5
Flexion mesolarvae				
Eye diameter, % HL ^a	33-42, 38	35-42, 39	32-37, 34	28-39, 34
AS-to-OPAF length	19-26, 23	22-29, 25	22-32, 26	24-30, 27
AS-to-PV length	76-80, 78	77-80, 78	75-78, 77	78-81, 79
Yolk length	0-59, 48	0-58, 43	0-54, 42	0-50, 4
Depth at OP1	11-13, 12	11-14, 12	10-12, 11	10-14, 13
Depth at AMPM	4-5, 4	4-5, 5	3-4, 3	3-5, 4
Max. yolk depth	0-8, 5	0-9, 4	0-9, 5	0-2, 0
Width at OD	5-9, 7	5-10, 7	5-8, 6	5-6, 5
Max. yolk width	0-10, 7	0-10, 5	0-9, 5	0-5, 0
Postflexion mesolarvae				
Eye diameter, % HL ^a	28-33, 30	29-38, 32	24-35, 27	27-33, 30
AS-to-OP2 length	54-57, 56	50-56, 52	50-54, 53	50-54, 52
AS-to-ODF length	43-47, 45	39-47, 42	36-48, 44	36-45, 42
AS-to-OD length	47-50, 49	47-50, 48	49-51, 50	47-51, 49
AS-to-ID length ^{d,e}	59-66, 63	62-65, 63	62-67, 64	65-67, 66
AS-to-PV length	79-82, 81	78-81, 80	76-80, 78	78-84, 81
AS-to-OA length	78-79, 79	77-80, 79	76-80, 78	79-82, 81
AS-to-IA length ^f	85-85, 85	86-86, 86	83-84, 84	85-86, 86
Dorsal-fin-base length ^{d,e,g}	11-17, 14	15-16, 15	12-17, 15	16-18, 17
Yolk length	0	0	0-46, 7	0
Depth at BPE	14-17, 15	12-17, 14	11-16, 13	11-16, 13
Max. yolk depth	0	0	0-3, 0	0
Width at BPE	13-16, 14	11-16, 13	10-15, 13	11-14, 12
Max. yolk width	0	0	0-5, 1	0
Metalarvae				
Eye diameter, % HL ^a	24-31, 28	24-30, 27	22-25, 24	24-32, 27
AS-to-PE length	12-15, 14	13-17, 15	12-14, 13	12-17, 14
AS-to-OP1 length	23-27, 25	26-30, 28	24-28, 26	25-30, 27
AS-to-OP2 length	54-61, 58	52-58, 56	52-57, 55	51-58, 56
AS-to-ID length ^e	63-66, 64	64-66, 65	62-67, 65	65-69, 67
AS-to-OA length	75-79, 76	75-78, 76	74-78, 75	76-79, 77
AS-to-IA length	82-86, 84	83-86, 85	81-84, 82	83-86, 84
Caudal-fin length ^h	14-21, 18	17-24, 20	17-25, 22	20-28, 23
Dorsal-fin (D) length ^e	20-23, 22	22-26, 23	20-24, 22	21-29, 24
Dorsal-fin-base length ^{e,g}	14-18, 16	15-18, 16	14-17, 16	16-21, 18
Depth at BPE	15-18, 17	17-20, 18	15-17, 16	15-18, 16
Width at BPE	15-18, 16	16-19, 17	14-17, 16	14-17, 15
Width at OD	11-19, 15	12-16, 14	10-15, 12	8-15, 11

(continued)

Table 60. Continued.

Developmental Phase Character	<i>Catostomus clarkii</i>	<i>Catostomus insignis</i>	<i>Catostomus latipinnis</i>	<i>Xyrauchen texanus</i>
Juveniles <40 mm SL				
Eye diameter, % HL ^a	22-29, 26	21-27, 24	19-26, 23	21-30, 25
AS-to-AE length	7-11, 9	8-11, 10	7-10, 8	6-9, 8
AS-to-PE length	14-17, 15	16-18, 17	13-15, 14	13-16, 15
AS-to-OP1 length	24-27, 26	27-31, 29	24-28, 25	25-31, 28
AS-to-OP2 length	57-60, 58	54-58, 57	52-57, 55	54-60, 57
AS-to-OD length	47-50, 49	48-51, 50	46-49, 48	46-52, 49
AS-to-ID length ^e	64-66, 65	64-67, 66	61-66, 65	65-70, 67
AS-to-PV length	74-76, 75	75-77, 76	72-76, 74	75-80, 77
AS-to-OA length	74-76, 75	74-77, 76	72-77, 75	75-80, 78
AS-to-IA length	82-84, 83	83-85, 84	80-85, 82	82-86, 84
Caudal-fin length ^h	15-21, 17	19-23, 21	21-25, 23	23-28, 25
Dorsal-fin (D) length ^e	22-25, 23	22-26, 24	23-26, 24	23-29, 27
Dorsal-fin-base length ^{e,g}	14-18, 16	14-19, 16	14-18, 16	16-20, 18
Anal-fin (A) length	12-18, 15	15-17, 16	12-16, 14	12-18, 15
Depth at BPE	17-18, 17	18-19, 19	15-17, 16	16-20, 18
Depth at OP1	19-23, 21	22-24, 23	17-22, 19	20-23, 22
Depth at OD	18-22, 21	20-24, 22	17-22, 19	18-27, 23
Depth at BPV	10-12, 11	11-13, 12	10-13, 11	11-14, 13
Width at BPE	16-18, 17	17-18, 18	15-17, 15	15-18, 16
Width at OP1	17-20, 18	17-20, 18	14-17, 16	15-20, 18

^a Eye diameter = (AS to PE)-(AS to AE).

^b Ignore differences in maximum values since they may be affected by developmental state at hatching.

^c OD for protolarvae and early flexion mesolarvae is approximated at one-half of standard length (AS to PHP).

^d Applicable only to specimens with a full complement of dorsal-fin pterygiophores or principal rays.

^e For *Xyrauchen texanus* with a rare count of only 12 or 13 principal dorsal-fin rays, lengths for this character may be less than the range reported herein (all specimens analyzed for these measures had ≥ 14 principal dorsal-fin rays or pterygiophores).

^f Applicable only to specimens with a full complement of anal-fin pterygiophores.

^g Dorsal-fin base = (AS to ID)-(AS to OD).

^h Caudal-fin length = (AS to PC)-(AS to PHP), total length minus standard length.

Table 61. Comparison of size (mm SL) relative to melanophore pigmentation of the eyes and bodies for protolarvae and lateral to ventral peritoneum for postflexion mesolarvae (P), metalarvae (M), and early juveniles (J, ≤ 40 mm SL) of native catostomids of the Gila River Basin. (For peritoneal pigmentation, size is preceded by initials for the applicable developmental intervals. Rare values are given in parentheses.)

Character	<i>Catostomus clarkii</i>	<i>Catostomus insignis</i>	<i>Catostomus latipinnis</i>	<i>Xyrauchen texanus</i>
Eye pigmentation, protolarvae^a				
Unpigmented	≤ 10	≤ 11	≤ 10	≤ 9
Light to moderate	10-12	11-13	9-11	7-10
Dark	$\geq (10)11$	$\geq (12)13$	≥ 11	≥ 9
Body pigmentation, protolarvae^a				
Unpigmented	≤ 10	$\leq 11(12)$	≤ 10	≤ 11
1-12 melanophores on dorsum	10	12	9-11	8-12
≥ 13 melanophores on dorsum	$\geq (10)11$	≥ 12	≥ 11	≥ 9
Peritoneal pigmentation^b				
Lateral, P and M only ^c				
Absent	–	PM all	PM ≤ 22	PM ≤ 24
Sparse or patchy	PM ≤ 17	PM $\geq (16)17$	PM ≥ 19	PM ≥ 14
Uniformly light	PM ≤ 21	(M ≥ 21)	–	–
Uniformly dark	PM ≥ 15	–	–	–
Ventrolateral surfaces				
Absent (or obscured in J)	P ≤ 16	PMJ all	PMJ all	PMJ all
Sparse or patchy	PM 14-21	(PMJ ≥ 18)	MJ ≥ 23	MJ 20-37
Uniformly light	PM 15-21	–	(J ≥ 35)	(J 26-37)
Uniformly dark	MJ $\geq (17)18$	–	(J ≥ 38)	(J 35-37)
Ventral surface				
Absent	PM ≤ 21	PMJ all	PMJ all	PMJ all
Sparse or patchy	PM 15-21	–	MJ ≥ 22	J 23-37
Uniformly light	MJ 17-21(-29)	–	(J ≥ 38)	J ≥ 29
Uniformly dark	MJ ≥ 18	–	(J ≥ 38)	J ≥ 32

^a Some to most specimens of each species will hatch with eyes or eyes and body well pigmented.

^b Pigmentation of the peritoneum is subsurface and should not be confused with surface or cutaneous pigmentation. Also, pigment might be apparent in the dorsal and dorsolateral portions of the peritoneum of smaller larvae and should not be interpreted as pigment in the lateral region.

^c In juveniles, lateral pigmentation of the peritoneum usually is obscured by muscle.

Table 62. Comparison of selected melanophore pigmentation patterns for larvae and juveniles (≤ 40 SL) of native catostomids of the Gila River Basin. (Key to characters and their states is given below. Character numbers correspond to those in the computer-interactive key. Rare character states are enclosed in parentheses. NA = not applicable.)

Character number	<i>Catostomus clarkii</i>	<i>Catostomus insignis</i>	<i>Catostomus latipinnis</i>	<i>Xyrauchen texanus</i>
Protolarvae (after pigment is well established)				
22.	(1),2	1-2	1-2	1-2
23.	1-3	1	1	1
24.	1-2,(3)	2-3	1-3	1-3
25.	1	(2),3	2-3	2-3
38.	1	1	1	1,(2)
39.	1,(2)	1	1	1-2,(3)
40.	1	1	1-2	1-2
41.	(1-2),3-4	1-2	1-3	1-2
54.	1	1	1	1
Flexion Mesolarvae				
21.	(2),3	(1-2),3	1-3	1-3
22.	2	2	2	1-2
23.	2-3	1	1	1
24.	1-2,(3)	2	1-2	1-3
25.	1	(2),3	2-3	2-3
26.	NA	1-2	1-2	1
31.	(1),2-3	(1),2-3	2-3	1-3
32.	3	1-3	1-2	1
33.	(2),3	1-2	1	1
38.	1-2	1,(2)	1	1-2
39.	1-3	1	1	1-3
40.	(1),2	1-2	1-2	1-2
41.	(1-2),3-5	1-4,(5)	(1),2-3,(4)	1-2
54.	(1),2	1-2	1	1
55.	2-4	1	1,(2,4)	1
Postflexion Mesolarvae				
21.	3	3	(1),2-3	(1),2-3
23.	2	1-2,(3)	1-3	1,(2-3)
24.	2	1-2	1,(2)	1-2
25.	1	1-3	1-3	1-2,(3)
26.	NA	2,NA	(1),2,NA	1,NA
27.	1	1	(1),2	1-2
31.	3	3	2-3	(2),3
32.	3	(1-2),3	1-3	1-3
33.	3	1-3	1-2	1-2
38.	(1),2	(1),2	1,(2)	(1),2
39.	(1),2,(3)	1,(2)	1,(2-3)	1-2,(3)
40.	(1),2	1-2	1-2	(1),2
41.	3-4	(1),2-5	(1),2-3,(4)	1-2
45.	1-2	1-2	1-2	1,(2)
46.	1,(2)	1	1	1
47.	(1),2	1-2	1,(2)	1,(2)
53.	1	1	1	1
54.	2	(1),2	1-2	1-2
55.	3-4	1-2	1,(2),3-4	1-2
Metalarvae				
28.	1-2	1-2	1	1
29.	1	1-2	1-2	1
30.	2	2	2	2
31.	3	3	3	3
32.	3	3	(2),3	(1),2-3
33.	3	3	(1),2-3	1-2
34.	1	1,(4)	1	1
38.	1-2	1-2	1,(2)	1,(2)

(continued)

Table 62. Continued.

Character number	<i>Catostomus clarkii</i>	<i>Catostomus insignis</i>	<i>Catostomus latipinnis</i>	<i>Xyrauchen texanus</i>
39.	(1),2,(3)	1	1	1
40.	(1),2	1-2	1-2	1,(2)
41.	3-4	1-2,(3-4)	(1),2,(3)	1,(2)
48.	1	1,(2)	1,(2)	(1),2
49.	1-3	1-2,(3)	1,(2-3)	(1),2
50.	1,3	1,(3)	1	1-2
51.	3	3	1,(2)	1,(2)
52.	1-2	1-2	1	1
53.	1	1	1	1
54.	1-2	1-2	1,(2)	1,(2)
Juveniles				
28.	(1),2	(1),2	1,(2)	1
29.	1,(2)	(1),2	1-2	1-2
30.	2	2	2	2
34.	1	1,(3-4)	1	1
35.	3	3	2-3	1-3
36.	3	(2),3	1-2,(3)	1-2,(3)
37.	1	1-2	1	1
38.	1,(2)	1,(2)	1	1,(2)
39.	1,(2-3)	1	1	1,(2)
40.	1-2	1,(2)	1-2	1,(2)
41.	1,(2-4),NA[obscured]	1-2,(3)	1-2,(3)	1-2
48.	1,(2)	1-2	(1),2	2
49.	3	(1-2),3	1,(2-3)	1-2,(3)
50.	1,3	1	1-2	(1),2
51.	3	3	1-3	1-3
52.	1-2	1-2	1	1-2
53.	1	1	1	1
54.	1-2	1,(2)	1	1,(2)

Key to pigment characters and states (applicable developmental phases in brackets—pr = protolarvae, fm = flexion mesolarvae, pm = postflexion mesolarvae, mt = metalarvae, ej = early juveniles):

21. Snout [fm-pm]

1. unpigmented.
2. pigmented with 1-5 melanophores.
3. pigmented with 6 or more melanophores.

22. Dorsal surface of head [pr-fm]

1. unpigmented or pigmented only over hindbrain (posterior to middle of eyes).
2. pigmented over both mid- and hindbrain (anterior and posterior to middle of eyes).

23. Pigmentation across dorsal surface of body between head and last myomere (for specimens with greater than 12 melanophores on dorsal surface)[pr-pm]

1. not scattered or sparsely scattered with at least a partial, distinct, lengthwise line or narrow band of melanophores (sometimes in oblique pairs or clusters) on or lateral to dorsal midline.
2. densely scattered over all or most of back with at least a partial, distinct, lengthwise line or narrow band of melanophores (sometimes in oblique pairs or clusters) on or lateral to dorsal midline.
3. densely scattered over all or most of back with no distinct, lengthwise lines or narrow bands of melanophores.

24. Dorsal midline from shortly behind head to near last myomeres [pr-pm]

1. with up to 24 melanophores in a short, well-spaced, or distinctly discontinuous line (two or more well-spaced segments), or without any distinct line of melanophores.
2. with at least 25 melanophores but in a short or distinctly discontinuous line (two or more well-separated segments).
3. with at least 25 melanophores in a distinct continuous or nearly continuous full-length line.

25. Pigmentation on dorsal surfaces lateral to midline from shortly behind head to about 2/3 distance to last myomeres [pr-pm]

1. absent, sparsely scattered, or densely scattered over back with no distinct, lengthwise lines or narrow bands of melanophores along either side of dorsal midline [character 26 NA].
2. scattered or not, with a distinct, short or discontinuous (well separated segments) line or narrow band of melanophores (sometimes in oblique pairs or clusters) along one or both sides of dorsal midline.
3. scattered or not, with a distinct, continuous or nearly continuous, full-length line or narrow band of melanophores (sometimes in oblique pairs or clusters) along each side of dorsal midline.

(continued)

Table 62. Continued.

26. Melanophores in lines lateral and parallel to dorsal midline between head and 2/3 distance to last myomeres mostly [fm-pm; NA if character 25 is state 1]
 1. in single file.
 2. in obliquely oriented pairs or clusters resulting in a herringbone pattern down the back.
27. Dorsal surface of end of urostyle (uroneural) [pm]
 1. with few to no melanophores (pigmentation not distinctly greater than elsewhere in vicinity).
 2. with a prominent series of melanophores.
28. Pigmentation on dorsal surface of body between head and last myomere [mt-ej]
 1. scattered more or less evenly (with or without emphasis on distinct lines of melanophores or melanophore clusters on or lateral and parallel to dorsal midline).
 2. scattered in a blotchy or mottled pattern (with or without emphasis on distinct lines of melanophores or melanophore clusters on or lateral and parallel to dorsal midline).
29. Distinct spot or aggregation of pigment at origin of dorsal fin [mt-ej]
 1. absent or obscure.
 2. prominent.
30. Pigment on or between pterygiophores of dorsal fin [mt-ej]
 1. absent or not obvious (essentially white).
 2. obvious (light to strong).
31. Lateral surface of head posterior to eyes [fm-mt]
 1. unpigmented.
 2. pigmented with 1-5 melanophores.
 3. pigmented with more than 5 melanophores.
32. Lateral surface of body above horizontal myosepta (lateral midline) and below dorsolateral surface (exclusive of pigmentation associated with horizontal myosepta, air bladder or visceral-cavity peritoneum) [fm-mt]
 1. unpigmented.
 2. pigmented with 1-5 melanophores.
 3. pigmented with more than 5 melanophores.
33. Lateral surface of body below horizontal myosepta (or lateral midline; exclusive of pigmentation associated with horizontal myosepta, air bladder, gut, or visceral-cavity peritoneum) [fm-mt]
 1. unpigmented.
 2. pigmented with 1-5 melanophores.
 3. pigmented with more than 5 melanophores.
34. Mid-lateral surface of body [pigmentation, large spots -- mt-ej]
 1. with no distinct, near-eye-size spots of pigment.
 2. with 1 distinct, near-eye-size spot of pigment on caudal peduncle near base of caudal fin.
 3. with 2 distinct, near-eye-size spots of pigment, one between head and dorsal fin and the other between pelvic and anal fins (sometimes with a very faint or indistinct third near-eye-size spot near the base of the tail).
 4. with 3 distinct, near-eye-size spots of pigment, one between head and dorsal fin, the second between pelvic and anal fins, and the third on the caudal peduncle near the base of the tail.
 5. with 1 or more distinct, near-eye-size spots of pigment, but not as in character states 2-4.
35. 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) [ej]
 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 mottled pattern (continuous with dorsal and dorsolateral surface pattern) down to horizontal myoseptum and at least partially to bottom-of-eye level below.
36. Pigmentation on lateral to ventrolateral surfaces of body below bottom-of-eye level (exclusive of melanophores associated with horizontal myosepta, air bladder, visceral cavity peritoneum, or gut) [ej]
 1. absent including caudal peduncle.
 2. absent except on caudal peduncle.
 3. present.
37. Pigmentation outlining scales [presence -- ej]
 1. absent or light.
 2. bold.
38. Melanophores under chin (anterior ventral surface of lower jaw) [pr-ej]
 1. absent.
 2. present.
39. Melanophores on ventral to ventrolateral surfaces of preopercles and opercles (gill covers) [pr-ej]
 1. absent.
 2. present, but not consisting of or including a distinct oblique row of 3 or more melanophores near or along the margin of either preopercle.
 3. consisting of or including a distinct oblique row of 3 or more melanophores near or along the margin of one or both preopercles.
40. Melanophores on ventral surface of heart region [pr-ej]
 1. absent.
 2. present.

(continued)

Table 62. Continued.

41. Ventral midline from shortly behind heart region to near vent [pr-ej]
 1. without melanophore pigment.
 2. with 1 to 6 melanophores.
 3. with 7 to 20 melanophores.
 4. with greater than 20 melanophores in a short or a distinctly discontinuous line or narrow band (two or more well-separated segments).
 5. with greater than 20 melanophores in a continuous or nearly continuous full-length line or narrow band.
45. Pigmentation in developing dorsal fin [pm]
 1. absent or sparse with 5 or fewer melanophores.
 2. at least moderate with 6 or more melanophores.
46. Pigmentation in developing anal fin [pm]
 1. absent.
 2. present.
47. Pigmentation in developing pectoral fins [pm]
 1. absent.
 2. present.
48. Pigmentation in dorsal fin [mt-ej]
 1. present to extensive along principal fin rays with few, if any, melanophores on membranes between rays (but might be present on membranes between branches of rays).
 2. extensive along principal fin rays and notably present (more than just a few melanophores) to extensive on at least a portion of membranes between some or all principal rays (might also be present on membranes between branches of rays).
49. Pigmentation in anal fin [mt-ej]
 1. absent.
 2. present but very light with 5 or fewer melanophores.
 3. present but more prominent with 6 or more melanophores.
(Melanophores are sometimes very linear along margins of fin rays and easily overlooked.)
50. Pigmentation in caudal fin [mt-ej]
 1. present to extensive along principal fin rays with few, if any, melanophores on membranes between principal rays (but might be present on membranes between branches of rays).
 2. extensive along principal fin rays and notably present (more than just a few melanophores) to extensive on most or at least the middle or distal portions of membranes between some or all principal rays (might also be present on membranes between branches of rays).
 3. extensive along principal fin rays and notably present (more than just a few melanophores) to extensive only on proximal portions of membranes between at least some principal rays.
51. Pigmentation in pectoral fins [mt-ej]
 1. absent.
 2. present but very light with up to 5 melanophores.
 3. present but more prominent with greater than 5 melanophores.
52. Pigmentation in pelvic fins [mt-ej]
 1. absent.
 2. present (but seldom with more than a few melanophores).
53. Pigmentation along and in horizontal myosepta [pm-ej]
 1. not notably more intense than other lateral pigmentation or the only lateral pigmentation.
 2. notably more intense than other lateral pigmentation.
54. Melanophores on ventral surface anterior to heart in branchial (gular) region (between opercles or branchiostegal membranes) [all]
 1. absent.
 2. present.
55. Pigmentation over dorsal surface of gut under air bladder as apparent from lateral view [fm-pm]
 1. absent.
 2. present covering less than a quarter of distance.
 3. present covering a quarter to three-quarters of distance.
 4. present covering greater than three-quarters of distance.

Table 63. Comparison of size (mm SL) relative to mouth position and lower lip lobe separation for metalarvae (M) and juveniles (J, ≤ 40 mm SL) of native catostomids of the Gila River Basin. (Size is preceded by initials for the applicable developmental intervals. Rare values are given in parentheses.)

Character	<i>Catostomus clarkii</i>	<i>Catostomus insignis</i>	<i>Catostomus latipinnis</i>	<i>Xyrauchen texanus</i>
Mouth position				
Terminal, above bottom of eye	–	–	–	MJ ≤ 25
Low terminal, at or below bottom of eye	M ≤ 17	M ≤ 23	MJ all	MJ all
Subterminal, low, and not most anterior portion of snout	MJ $\geq (16)17$	MJ ≥ 20	MJ ≥ 20	J ≥ 32
Lower lip lobes, median separation				
Indistinct	M ≤ 17	M ≤ 20	–	–
Well separated	M ≥ 17	M 21	M ≤ 20	MJ ≤ 37
Slightly separated	MJ 18-27	M 21-24	MJ all	MJ 20-37
None, adjacent	J $\geq (23-)28$	MJ ≥ 22	MJ ≥ 22	MJ ≥ 20

Table 64. Comparison of frontoparietal fontanelle size for selected larval and juvenile length groups of native catostomids of the Gila River Basin. (*Catostomus clarkii* not analyzed. N = number of specimens examined.)

Size group Character	<i>Catostomus insignis</i>	<i>Catostomus latipinnis</i>	<i>Xyrauchen texanus</i>
17-19 mm SL, N	1	3	3
Width, mm	1.5	0.8-1.2	1.0-1.2
Length, mm	1.8	1.2-2.0	1.7-1.9
Width/length, %	83	50-67	59-63
20-21 mm SL, N	1	3	5
Width, mm	1.8	0.6-0.7	1.0-1.3
Length, mm	2.2	1.8-2.0	1.8-2.1
Width/length, %	82	33-35	52-68
22-25 mm SL, N	2	3	2
Width, mm	0.8-1.6	0.8-0.8	1.0-1.3
Length, mm	2.1-2.2	1.8-2.1	1.9-2.1
Width/length, %	38-73	38-44	53-62
26-34 mm SL, N	4	2	2
Width, mm	0.6-0.9	0.7-0.8	0.9-1.3
Length, mm	2.2-2.6	2.2-2.3	2.1-2.3
Width/length, %	26-41	30-36	43-57
35-46 mm SL, N	–	1	3
Width, mm	–	0.7	1.1-1.7
Length, mm	–	2.3	2.3-3.4
Width/length, %	–	30	48-50
76-81 mm SL, N	–	1	1
Width, mm	–	1.0	2.3
Length, mm	–	4.0	5.1
Width/length, %	–	25	45

Native Cyprinids

Table 65. Comparison of size (mm SL) at onset of or transition to developmental intervals, gut phases, and other developmental events for larvae and early juveniles of native cyprinids of the Gila River Basin. (Rare values in parentheses. NA = not applicable.)

Character	<i>Agosia chrysogaster</i>	<i>Gila elegans</i>	<i>Gila robusta</i>	<i>Meda fulgida</i>	<i>Ptychocheilus lucius</i>	<i>Rhinichthys cobitis</i>	<i>Rhinichthys osculus</i>
Egg diameter	2.2-2.8	2.0-2.4	2.7-3.1	1.7-2.1	1.9-2.2	1.8-2.3	est. 1.6-2.2
Phase/period transitions							
Embryo to larva	5(6)	5-6	7(8)	5	(5)6-7	(5)6	5-6
Proto- to mesolarva	7	(7)8	(8)9-10	7(8)	7-8(9)	(6)7-8	6-7
Flexion to postflexion mesolarva	9	(8)9	10-11	9(-11)	(7)8-9	8(9)	8-9
Meso- to metalarva	11-12	11(12)	12-13(14)	12(13)	(10)11-12	(9)10	9-10(11)
Larva to juvenile	(15)16(17)	22(23)	(18)19-20(-22)	(25-)27->41	19-20(21)	14(15)	15-16(17)
Gut phase transitions							
1 to 2 (90° bend)	10-11	(11)12-15	12-14	12-18	11-17	12(-14)	10-11
2 to 3 (full loop)	13-14	(19)20-22	28-34	(18-)25->41	31-38	>20,<42	18-26
3 to 4 (partial crossover)	(15)16-19(20)	NA	NA	NA,(25)	NA	NA	NA
4 to 5 (full crossover)	(19-)24-25	NA	NA	NA	NA	NA	NA
Onset of selected events							
Eyes pigmented	5(6)	6 ^c	^c	^c	^c	5(6) ^c	5? ^c
Yolk assimilated	(6)7	8-9	9-10(11)	(6)7(8)	(7)8(9)	(7)8	6-8(9)
Finfold absorbed	(15)16(17)	22(23)	(18)19-20(-22)	(25-)27->41	19-20(21)	14(15)	15-16(17)
Pectoral-fin buds	^c	6 ^c	^c	^c	6 ^c	^c	^c
Pelvic-fin buds	(9)10	10-11 ^d	(10)11-12	11	10-11	9	9-10
Pelvic fins adnate ^a	NA	NA	NA	21-22	NA	NA	NA
Dorsal spine formation ^b	NA	NA	NA	(19-)22-24	NA	NA	NA
Maxillary barbels	19-20(21)	NA	NA	NA	NA	NA	16-17
Fin rays first observed							
Dorsal, principal	(8)9(10)	9	10	9-10	8	8(9)	7-8
Anal, principal	9-10	9	10(11)	10	9-10	9	8
Caudal, principal	7	(7)8	(8)9-10	7(8)	7-8(9)	(6)7-8	6-7
Caudal, rudimentary	9	9-10	(10)11	9-10	(7)8-9(10)	9(10)	9-10
Pectoral	(9)10	9-10	11-13	9-10	11-12	9(10)	9-10
Pelvic	12(13)	10-11	12-14	13(14)	11-12	11(12)	11-12
Full fin-ray counts first observed							
Dorsal, principal	(10)11-12	11(12)	(10-)12-13(14)	(11)12	(10)11-12	(9)10	9-10(11)
Anal, principal	11-12	11(12)	12-13(14)	12(13)	11-12	(9)10	9-10(11)
Caudal, principal	9	(8)9	10-11	9(-11)	(7)8-9	8(9)	8-9
Caudal, rudimentary	(14)15(16)	<22(23)	16-19	(16-)21-24	17	14	15-16
Pectoral	14(15)	14	14-16	(15-)18(-21)	16-17	(13)14	13-15(16)
Pelvic	14-15	15	14-17	(14)15(16)	15	13-14	(12)13-14
Scales, lateral series							
First observed	22-25(-31)	≤25	≤24	NA	~27-31	20-21	17-18
Full series first observed	(23-)25(-31)	–	–	NA	35-40	21-24	19-24

^a Medial margin of fin at least partially connected to body.

^b Transformation (thickening and elongation) of second (last) rudimentary to a distinctive spine as indicated by length greater than three-quarters that of the first principal dorsal-fin ray.

^c (Or) before hatching.

^d Pelvic-fin bud formation reported as 11 mm SL by Muth (1990); extended range to 10 mm to accommodate Muth's report of first pelvic-fin ray formation at 10-11 mm SL.

Table 66. Comparison of selected meristics for larvae and early juveniles of native cyprinids of the Gila River Basin. (Character range is followed by the mean, mode, or more typical range. See Figure 4 for methods of counting myomeres and fin rays. ODF = origin of dorsal finfold, OD = origin of dorsal fin, OP2 = origin of pelvic buds or fins, and PV = posterior margin of the vent. Vertebra counts include four for the Weberian complex; dorsal- and anal-fin-ray counts are of principal rays; scale counts are of the lateral line or series. Data previously published by other authors are given in parentheses; sources are listed in corresponding species accounts.)

Character	<i>Agosia chrysogaster</i>	<i>Gila elegans</i>	<i>Gila robusta</i>	<i>Meda fulgida</i>	<i>Ptychocheilus lucius</i>	<i>Rhinichthys cobitis</i>	<i>Rhinichthys osculus</i>
Myomeres to ODF							
Protolarvae	9-15, 13	–	11-12, 12	12-17, 15	10-17, 16	11-16, 14	12-15, 14
Flexion mesolarvae	11-14, 13	–	–	16-18, 17	17-18, 18	12-16, 14	13-16, 15
Postflexion mesolarvae	11-15, 13	–	–	16-19, 17	15-19, 18	12-17, 15	14 (N=1)
Myomeres to OD							
Postflexion mesolarvae	16-18, 17	19-21, 20	19-21, 20	18-20, 19	21-25, 23	17-19, 18	17-21, 18
Metalarvae	16-18, 17	19-22, 20	17-20, 19	17-19, 18 ^a	21-24, 23	16-20, 18	16-20, 19
Myomeres to OP2							
Postflexion mesolarvae	15-17, 16	17-17 ^c	15-18, 16	16-18, 17	–	16-18, 17	16-17 ^c
Metalarvae	15-18, 17	16-18, 17	15-17, 16	16-17, 17 ^a	18-21, 19	16-18, 17	14-17, 16
Myomeres to PV							
Proto- & mesolarvae	24-28, 26-27	29-32, 30	26-32, 29	25-29, 27-28	31-35, 33-34	23-27, 25-26	23-26, 25
Metalarvae	25-27, 26	29-32, 30	25-30, 28	27-28, 28 ^a	31-34, 33	25-27, 26	23-27, 24
All larvae	24-28, 26-27	29-32, 30	25-32, 28-29	25-29, 27-28 ^a	31-35, 33-34	23-27, 25-26	23-27, 24-25
Myomeres after PV							
Proto- & mesolarvae	10-14, 11-12	19-21, 21	13-19, 17-18	11-14, 13	14-17, 15-17	10-12, 10-11	10-14, 12-13
Metalarvae	11-13, 12	19-21, 20	16-19, 18	12-14, 13 ^a	15-18, 16	10-13, 11	11-16, 14
All larvae	10-14, 11-12	19-21, 20-21	13-19, 17-18	11-14, 13 ^a	14-18, 15-17	10-13, 10-11	10-16, 12-14
Myomeres, total							
Proto- & mesolarvae	36-39, 37-38	49-52, 51	43-48, 46-47	39-42, 40-41	48-51, 49-50	34-38, 36-37	34-40, 37-38
Metalarvae	37-39, 38	49-52, 50	44-48, 46	40-41, 41 ^a	48-50, 49	36-39, 38	36-40, 38
All larvae	36-39, 37-38	49-52, 50-51	43-48, 46-47	39-42, 40-41 ^a	48-51, 49-50	34-39, 36-38	34-40, 37-38
Vertebrae							
	38	49-51, 50	44-47, 46	39	47-49, 48-49	38	38-40
	–	(46-51, 49)	(42-49, 46)	(39-42, 40)	(47-49, 48-49)	–	(37-38)
Dorsal-fin rays							
	7-9, 8	10-11, 10	9	7 ^b	9-10, 9	8	7-8, 8
	(7-10, 8)	(9-11, 10)	(8-10, 9)	(7-8, 7)	(9-10, 9)	(8-9, 8)	(6-9, 8)
Anal-fin rays							
	7	10-11, 10	8-10, 9	8-10, 9	8-10, 9	6-7, 7	6-8, 7
	(6-8, 7)	(9-11, 10)	(7-10, 9)	(8-10, 9)	(8-10, 9)	(6-7, 7)	(6-8, 7)
Lateral-line scales							
	77-93, 81-93	–	–	not applicable	–	65-73, 65-71	–
	(60-95, 73-90)	(75-110, 88-99)	(71-99, 79-86)		(76-98, 84-93)	(61-70, 61-65)	(47-90, 55-80)

^a Metalarvae > 25 mm SL excluded.

^b First principal dorsal-fin ray preceded and partially enveloped by a slightly shorter, stout spine which is derived from a rudimentary (secondary) ray and well formed by transition to the juvenile period resulting in dorsal fin formula of I,7 or i,I,7 (lower-case Roman numerals refer to normal rudimentary rays, in this case a very tiny splint at or incorporated in the anterior base of the spine). The first principal dorsal-fin ray sometimes has itself been considered as second spine in adults, which would result in a formula of II,6 or i,II,6.

^c N = 2.

Table 67. Comparison of the more diagnostic differences in morphometrics for larvae and juveniles (≤ 40 mm SL) of native cyprinids of the Gila River Basin. (Except as indicated, all data are percentages of standard length, % SL, presented as ranges followed by means. HL = head length measured to the origin of the pectoral fin, AS to OP1; see Figure 4 for other abbreviations and methods of measurement.)

Developmental Phase Character	<i>Agosia chrysogaster</i>	<i>Gila elegans</i>	<i>Gila robusta</i>	<i>Meda fulgida</i>	<i>Ptychocheilus lucius</i>	<i>Rhinichthys cobitis</i>	<i>Rhinichthys osculus</i>
Protolarvae							
Eye diameter ^a	7-9, 8	5-7, 6	5-7, 6	6-8, 7	6-8, 7	6-9, 7	6-9, 8
AS-to-PE length	9-12, 10	7-10, 9	8-11, 9	9-11, 10	8-11, 9	8-12, 10	8-12, 10
AS-to-ODF length	31-44, 40	39-42	26-39	42-46, 44	32-44, 42	40-48, 44	41-45, 43
AS-to-PV length	64-68, 66	62-70, 65	67-72, 69	64-68, 65	67-69, 68	64-71, 67	63-69, 66
Yolk length ^b	0-50, 29	–	49-62	0-56, 37	42-55, 49	33-56, 47	0-56, 39
Pectoral-fin length ^c	10-14, 12	4-12	4-10	9-15, 13	4-10, 7	5-13, 9	6-12, 9
Depth at OD ^b	10-14, 11	9-15, 12	13-15, 14	10-17, 12	12-15, 14	11-19, 15	10-16, 13
Width at OD ^b	5-7, 6	5-8, 6	7-8, 8	5-9, 6	5-10, 7	6-10, 8	5-9, 7
Max. yolk depth ^b	0-13, 5	–	10-18	0-20, 9	9-15, 13	2-17, 11	0-16, 8
Max. yolk width ^b	0-12, 7	–	12-23	0-22, 11	9-18, 12	3-23, 13	0-20, 10
Flexion mesolarvae							
Eye diameter, % HL ^a	34-47, 37	24-33, 29	27-36, 32	32-36, 34	34-37, 36	33-41, 35	36-40, 38
AS-to-PE length	10-12, 11	8-10, 9	9-12, 11	10-12, 11	10-10, 10	10-12, 11	11-13, 12
AS-to-OPAF length	25-33, 30	29-32	28-37	27-32, 30	25-28, 27	27-39, 32	30-44, 36
AS-to-ODF length	37-47, 42	42-45	40-48	43-48, 46	44-45, 45	37-48, 43	37-55, 47
AS-to-PV length	66-70, 68	63-70, 67	65-71, 68	64-69, 66	67-68, 67	63-70, 67	63-70, 66
Yolk length	0	0-26	0-45	0-13, 1	0-48, 23	0-42, 21	0-43, 9
Pectoral-fin length	12-16, 14	12-13	10-13	12-15, 14	11-12, 12	12-16, 13	12-14, 13
Depth at OP1	15-17, 16	12-17, 14	12-18, 16	13-17, 15	13-14, 13	14-18, 16	12-18, 14
Depth at OD ^d	11-13, 12	8-14, 11	10-16, 12	9-13, 11	11-11, 11	11-14, 13	10-13, 11
Depth at BPV	7-9, 8	6-9, 8	8-11, 9	7-8, 8	8-8, 8	9-10, 9	8-10, 9
Width at BPE	13-17, 15	11-14, 13	10-14, 13	14-16, 15	12-13, 12	13-16, 15	13-14, 13
Width at OP1	10-12, 11	7-11, 10	10-13, 11	9-14, 12	9-10, 10	11-14, 11	8-14, 10
Width at OD ^d	6-7, 6	4-7, 5	6-9, 7	5-7, 6	6-6, 6	6-8, 7	6-8, 7
Max. yolk depth	0	0-4	0-9	0-1, 0	0-8, 3	0-8, 2	0-6, 1
Max. yolk width	0	0-8	0-9	0-2, 0	0-11, 6	0-12, 4	0-10, 2
Postflexion mesolarvae							
Eye diameter, % HL ^a	30-46, 34	27-36	29-38, 33	30-37, 33	22-37, 33	31-36, 33	31-38, 34
AS-to-OP1 length	20-26, 24	22-24, 22	22-26, 24	20-24, 22	20-25, 22	20-26, 23	22-27, 24
AS-to-OP2 length	48-52, 49	44-46	45-50, 47	46-50, 48	–	49-51, 50	48-51, 49
AS-to-OPAF length	31-39, 34	29-31	33-41	28-35, 32	27-34, 29	28-40, 33	30-53, 41
AS-to-PV length	69-74, 71	66-69, 67	67-72, 70	66-71, 69	67-74, 70	67-72, 70	65-71, 68
Yolk length	0	0	0-32	0	0	0	0
Pectoral-fin length	13-21, 15	12-13	12-14	13-16, 14	11-15, 13	12-16, 15	11-15, 13
Dorsal-fin-base length ^{ef}	10-14, 12	–	10-12, 11	9-13, 11	–	10-13, 11	8-16, 11
Depth at OP1	16-21, 19	12-17, 14	12-18, 16	16-18, 17	13-17, 14	16-19, 18	15-21, 17
Depth at OD	12-16, 14	8-14, 11	10-16, 12	11-14, 12	10-14, 11	13-15, 14	12-15, 13
Depth at BPV	8-11, 10	6-9, 8	8-11, 9	7-10, 9	7-10, 8	9-11, 10	9-12, 10
Width at BPE	14-19, 17	13-14, 13	14-16, 15	15-17, 16	13-14, 13	16-17, 16	14-16, 15
Width at OP1	12-16, 14	7-11, 10	10-13, 11	13-17, 15	9-12, 10	13-17, 14	10-18, 12
Width at OD	7-11, 9	4-7, 5	6-9, 7	6-9, 8	5-8, 6	7-8, 7	6-9, 7
Max. yolk depth	0	0	0-2	0	0	0	0
Max. yolk width	0	0	0-9	0	0	0	0
Metalarvae							
Eye diameter, % HL ^a	28-35, 32	28-36, 32	21-29, 25	< 25 mm SL ^h 26-36, 31	25-32, 29	24-34, 28	26-38, 33
AS-to-AE length	4-6, 5	3-6, 4	4-9, 6	4-7, 6	5-9, 6	4-8, 6	4-6, 5
AS-to-PE length	12-14, 13	11-14, 12	11-16, 13	12-14, 13	12-18, 14	11-15, 13	11-15, 13
AS-to-OP1 length	24-27, 26	23-28, 25	23-31, 28	22-26, 23	24-29, 26	23-28, 26	23-28, 25
AS-to-OP2 length	48-54, 52	44-49, 47	47-54, 51	47-50, 48	49-54, 52	49-54, 51	48-54, 51
AS-to-OD length	49-54, 51	50-57, 52	51-58, 55	49-53, 50	51-57, 55	50-54, 52	51-58, 55
AS-to-ID length	63-67, 65	62-69, 65	63-69, 66	63-66, 64	63-68, 66	63-69, 65	65-70, 67
AS-to-PV length	68-71, 69	62-70, 65	63-73, 68	64-70, 67	65-69, 68	68-73, 69	63-69, 65
AS-to-IA length	76-80, 78	75-82, 77	75-81, 78	76-79, 78	75-82, 79	75-79, 77	72-77, 75

(continued)

Table 67. Continued.

Developmental Phase Character	<i>Agosia chrysgaster</i>	<i>Gila elegans</i>	<i>Gila robusta</i>	<i>Meda fulgida</i>	<i>Ptychocheilus lucius</i>	<i>Rhinichthys cobitis</i>	<i>Rhinichthys osculus</i>
Caudal-fin length ^g	15-21, 18	16-26, 23	16-28, 23	16-22, 19	20-30, 24	15-22, 19	14-24, 19
Pectoral-fin length	14-18, 16	12-15, 14	12-17, 15	14-18, 16	13-16, 15	15-20, 18	11-18, 14
Pelvic-fin length	5-13, 9	5-16, 10	3-13, 6	4-12, 9	7-14, 10	4-17, 10	2-13, 7
Dorsal-fin-base length ^f	11-17, 14	11-15, 13	10-12, 11	12-16, 14	10-12, 11	11-15, 13	9-17, 11
Depth at BPE	17-20, 18	15-17, 16	14-18, 16	13-16, 15	14-18, 16	15-18, 17	15-18, 17
Depth at OP1	20-25, 22	16-24, 20	17-22, 20	17-20, 19	16-19, 18	17-22, 20	15-23, 20
Depth at OD	15-25, 20	9-24, 19	13-21, 17	12-19, 16	15-18, 16	13-20, 16	13-21, 17
Depth at BPV	11-14, 12	9-18, 14	10-15, 13	9-13, 11	11-15, 13	10-14, 12	10-16, 13
Depth at AMPM	8-10, 9	6-7, 7	6-9, 7	7-9, 8	7-9, 8	7-10, 9	6-10, 8
Width at BPE	16-19, 18	14-16, 15	13-19, 16	15-18, 16	13-16, 15	17-20, 18	15-19, 17
Width at OP1	15-20, 17	14-18, 16	12-17, 14	15-18, 17	10-15, 13	13-20, 17	12-18, 14
Width at OD	9-17, 13	7-18, 12	8-13, 10	9-14, 11	8-12, 10	8-13, 10	7-13, 10
Width at BPV	7-9, 8	6-13, 10	6-11, 8	6-10, 8	7-11, 8	6-9, 7	6-11, 9
Width at AMPM	4-5, 5	2-4, 3	2-5, 4	3-5, 4	3-5, 4	3-5, 4	2-5, 4
Juveniles <40 mm SL				& metalarvae 25-39 mm SL^h			
Eye diameter, % HL ^a	25-32, 28	25-33, 29	26-33, 30	29-35, 32	23-31, 27	20-27, 25	25-33, 29
AS-to-AE length	4-8, 6	5-6, 5	5-8, 6	4-7, 6	5-8, 6	7-9, 8	4-8, 6
AS-to-PE length	11-15, 14	11-13, 12	12-16, 14	12-15, 14	12-16, 14	13-15, 14	11-15, 13
AS-to-OP1 length	23-28, 26	22-26, 24	24-29, 27	21-26, 24	24-30, 26	24-28, 26	21-28, 24
AS-to-OP2 length	50-54, 52	44-47, 45	46-52, 50	45-50, 48	49-54, 52	50-55, 53	45-53, 50
AS-to-OD length	49-53, 51	49-54, 51	49-57, 54	48-52, 50	53-56, 55	52-55, 53	50-57, 53
AS-to-ID length	63-66, 65	62-66, 65	61-69, 66	63-68, 65	63-68, 66	64-68, 67	62-69, 65
AS-to-PV length	67-71, 69	60-65, 63	61-68, 66	64-69, 65	64-69, 67	66-71, 68	57-65, 63
AS-to-IA length	76-79, 77	74-78, 76	74-80, 77	76-80, 78	76-82, 79	75-80, 77	70-77, 73
AS-to-AFC length	111-115, 113	111-114, 112	109-116, 115	112-117, 114	110-116, 113	113-119, 116	109-115, 112
Caudal-fin length ^g	18-24, 20	23-28, 25	18-29, 26	19-26, 22	22-34, 28	18-27, 22	17-26, 21
Pectoral-fin length	16-21, 18	15-19, 17	14-20, 17	15-21, 19	13-18, 16	18-23, 21	14-20, 17
Pelvic-fin length	11-24, 15	15-18, 16	9-15, 12	12-15, 14	11-17, 15	11-19, 16	10-16, 13
Dorsal-fin length	20-27, 22	20-24, 22	18-24, 20	19-26, 22	18-25, 22	21-25, 23	18-24, 21
Anal-fin length	15-22, 18	17-23, 21	16-21, 18	17-21, 19	15-20, 18	17-23, 21	16-22, 19
Dorsal-fin-base length ^f	11-16, 14	12-15, 14	11-13, 12	13-18, 14	10-14, 11	12-15, 14	10-14, 12
Depth at BPE	16-20, 18	15-17, 16	14-19, 17	13-16, 14	13-16, 15	12-18, 15	13-18, 16
Depth at OP1	21-25, 23	20-24, 22	19-23, 20	16-20, 18	17-20, 18	16-22, 19	18-24, 21
Depth at OD	18-25, 22	20-26, 23	18-22, 20	16-22, 18	17-21, 19	16-22, 18	18-23, 20
Depth at BPV	12-17, 14	11-15, 13	13-18, 15	12-14, 14	14-17, 15	11-17, 13	13-19, 16
Depth at AMPM	9-11, 10	6-7, 6	7-10, 8	7-8, 8	8-9, 9	9-11, 10	9-12, 10
Width at BPE	15-19, 17	14-16, 15	13-18, 16	13-17, 15	13-16, 14	13-20, 16	12-18, 15
Width at OP1	15-20, 18	16-21, 18	13-17, 14	14-16, 15	13-17, 15	15-21, 18	13-21, 16
Width at OD	12-20, 15	15-21, 17	10-15, 12	11-16, 13	10-16, 13	10-16, 13	11-18, 14
Width at BPV	8-14, 10	11-15, 13	8-12, 10	8-11, 9	8-14, 11	7-11, 9	9-16, 12
Width at AMPM	4-6, 5	3-4, 4	2-5, 4	3-5, 4	2-5, 4	4-5, 4	3-7, 6

^a Eye diameter = (AS to PE)-(AS to AE); approximated for *Gila* species by difference between mean, minimum and maximum values in species accounts with range extended by the greater standard deviation, and then, for all but protolarvae, dividing those results by HL.

^b Ignore differences in maximum values because they may be affected by developmental state at hatching.

^c Ignore differences in minimum values because they may be affected by developmental state at hatching.

^d OD for protolarvae and early flexion mesolarvae is approximated at one-half of standard length (AS to PHP).

^e Applicable only to specimens with a full complement of dorsal-fin pterygiophores or principal rays.

^f Dorsal-fin base = (AS to ID)-(AS to OD); approximated for *Gila* species by difference between mean, minimum and maximum values in species accounts with range extended by the greater standard deviation.

^g Caudal-fin length = (AS to PC)-(AS to PHP), total length minus standard length.

^h Some *Meda fulgida* measuring well beyond 25 mm SL retain preanal finfold and thereby remain metalarvae at size for which most other cyprinids are defined as juveniles. Accordingly, for comparative purposes, morphometric data for metalarvae of this species greater than 24 mm SL are included with data for juveniles.

Table 68. Comparison of size (mm SL) relative to melanophore pigmentation of the eyes and bodies for protolarvae and lateral to ventral peritoneum for metalarvae (M) and early juveniles (J, ≤ 40 mm SL) of native cyprinids of the Gila River Basin. (For peritoneal pigmentation, size is preceded by initials for the applicable developmental intervals. Rare values are given in parentheses.)

Character	<i>Agosia chrysogaster</i>	<i>Gila elegans</i>	<i>Gila robusta</i>	<i>Meda fulgida</i>	<i>Ptychocheilus lucius</i>	<i>Rhinichthys cobitis</i>	<i>Rhinichthys osculus</i>
Eye pigmentation, protolarvae							
Unpigmented	5(6)	6 ^a	^a	^a	^a	5(6) ^a	5? ^a
Light to moderate	5-6	6 ^a	7-9 ^a	5 ^a	6?-7 ^a	5-7(8) ^a	5? ^a
Dark	$\geq 5?$ or 6	≥ 7	≥ 9	$\geq 5^a$	$\geq 6?$ or 7 ^a	≥ 6	$\geq 5?$ ^a or 6
Body pigmentation, protolarvae							
Unpigmented	5(6)	5-7	7-8	^a	7 ^a	5(6) ^a	5? ^a
1-12 melanophores on dorsum	5(6)	7	8	^a	7(-9)	5(6) ^a	5? ^a
≥ 13 melanophores on dorsum	$\geq (5)6$	$\geq (7)8$	$\geq (8)9$	$\geq 5^a$	$\geq 7^a$	$\geq (5)6$	$\geq 5?$ ^a or 6
Peritoneal pigmentation^b							
Lateral							
Absent	–	–	–	–	–	MJ (12-) ≥ 16	–
Sparse or patchy	MJ ≤ 24	M all	M all	MJ all	M all	MJ $\leq 16^c$	MJ $\leq 17(-23)$
Uniformly speckled	–	M all	–	MJ $\leq 24(-40)$	–	–	–
Uniformly light	MJ 15-25(-31)	–	–	–	–	–	–
Uniformly dark	MJ (17-) ≥ 22	–	–	–	–	–	–
Obscured by overlying tissues	(J ≥ 38)	MJ ≥ 20	MJ ≥ 18	MJ ≥ 25	MJ ≥ 21	J ≥ 21	J ≥ 20
Ventrolateral surfaces							
Absent	MJ $\leq 14(-19)$	–	MJ ≤ 24	–	MJ $\leq 21(23?)$	MJ all	MJ $\leq 17(all?)$
Sparse or patchy	MJ 12-25	MJ ≤ 23	–	MJ all	–	(M 12) ^c	–
Uniformly light	(MJ 17-31)	–	–	–	–	–	–
Uniformly dark	J ≥ 22	–	–	–	–	–	–
Obscured by overlying tissues	(J ≥ 38)	MJ ≥ 22	J ≥ 25	MJ ≥ 25	J ≥ 24	–	J ≥ 20
Ventral surface							
Absent	MJ $\leq 24(-38)$	MJ ≤ 32	MJ ≤ 34	M ≤ 25	MJ all	MJ all	MJ $\leq 24(all?)$
Sparse or patchy	MJ 14-27(-36)	–	–	MJ all	–	–	–
Uniformly light	J (22-) ≥ 24	–	–	–	–	–	–
Uniformly dark	(J ≥ 33)	–	–	–	–	–	–
Obscured by overlying tissues	–	J ≥ 33	J ≥ 35	MJ ≥ 25	–	–	J ≥ 28

^a (Or) before hatching.

^b Pigmentation of the peritoneum is subsurface and should not be confused with surface or cutaneous pigmentation; some near-surface pigmentation in protolarvae and mesolarvae becomes distinguishable as peritoneal pigment in metalarvae. Also, pigment is usually apparent in the dorsal and dorsolateral aspects of the peritoneum of smaller metalarvae (and earlier larvae) and should not be interpreted as pigment in the lateral region. In juveniles (and the larger metalarvae of *Meda*), possibly including specimens smaller than recorded, melanophore pigmentation in the peritoneum may be obscured by overlying muscle or, especially in living and alcohol-preserved specimens, integument with a silvery lining of iridophores.

^c In many metalarvae of this species, lateral peritoneal pigment begins as a broad, internal band of rather larger melanophores below or after the air bladder that continues over the lateral (to ventrolateral) surface of the posterior gut (only rarely does the band begin on the ventrolateral aspect of the peritoneum).

Table 69. Comparison of selected melanophore pigmentation patterns for larvae and juveniles (≤ 40 SL) of native cyprinids of the Gila River Basin. (Key to characters and their states is given below; character numbers correspond to those used in the computer-interactive key. Rare character states are enclosed in parentheses. NA = not applicable.)

Character number	<i>Agosia chrysogaster</i>	<i>Gila elegans</i>	<i>Gila robusta</i>	<i>Meda fulgida</i>	<i>Ptychocheilus lucius</i>	<i>Rhinichthys cobitis</i>	<i>Rhinichthys osculus</i>
Protolarvae (after pigment is well established)							
25.	(1),2,(3),4	1	1	(1),2-4	1	1,(3)	1
26.	2	1	1	2	1	(1),2	2
27.	(1),2-3	1	1	2-3	1	(2),3	2
28.	NA,2-3	2	1	NA,(3,5)	1	NA,(4)	3
29.	NA,2-3,(4)	3	3	NA,2	3	NA,(2)	3
35.	1-3	1	2	(1),2-3	1-2	1-2	1,3
38.	(1),2,(3),5	1-2	2	(1),2,4,(5)	1,4	1,(4),5	2,4
39.	(1,3),6	6	6	3,6	1,3,6	1,6	3,6
43.	(1),3,(4)	1	1-2	3,(4-5)	1-2	1,(2-3)	1-2
51.	1,(2)	1	1	1	1	1	1
52.	1-2	1	1	1	1	1	1
53.	1-2	1	1	1,(2)	1	1	1
54.	1-2	1	1	1,(2)	1	1	1
55.	(1),2,(3),4	1-2	1-2	1,3,(4-5)	1-2	1,(2-4)	1,3-4
56.	1-2,(3)	2	1	1,(2-3,6)	1	1-2	1
57.	NA,1,(2-3)	1	NA	NA,(1-3)	NA	NA,1	NA
58.	NA,(2)	NA	NA	NA,(2,6)	NA	NA	NA
59.	NA	NA	NA	NA,(4)	NA	NA	NA
Flexion mesolarvae							
24.	(1),2-3	1-3	1-3	3	1	1-3	1-3
25.	3-4	1-2	1-2	(2),3	1-2	1-2	1-2
26.	2	1-2	2	2	1-2	2	2
27.	(1),2-3	1	1	2-3	1	(1-2),3	1-2
28.	NA,(2),3,(4)	1,3	2-3	NA,5	1,3	NA,(1)	2-3
29.	NA,2-3,(4)	1,3	3-4	NA,2	3-4	NA,(3-4)	3-4
35.	2-3	2-3,5	2-3	2-3	2,4	1-2	2,(3)
37.	2-3	1-3	1-3	(2),3	1	2-3	(1),2
38.	5	2,4	3-4	(2),4	2,4	(1,4),5	4-5
39.	6	6	6	6	1,6	6	6
40.	(1),2,(3)	1	1	(1),2-3	1-2	1,(2)	(1),2
41.	2-3	1	1-2	(2),3	1	(1),2-3	3
42.	2-3	1	1-2	(2),3	1	(1),2,(3)	2-3
43.	3-4	1-2,5	2-3	3-4	2	1-3	(1),2,(3)
44.	1	1-2	1-3	1-2,(3)	1-2	1,(2)	1
51.	1,(2)	1	1	1	1	1	1
52.	1	1	1	1	1	1	1
53.	1-2	1	1	1,(2)	1	1	1
54.	1-2	1	1	1-2	1	1	1
55.	2-3,(4-5)	2-3	2-3	4,(5)	1-3	(2),3,(4)	2-3
56.	1-3	1-2	1-2	(1),2	1	1	1
57.	NA,(1),3	NA,1	NA,1	(NA),1	NA	NA	NA
58.	NA,6	NA	NA	NA	NA	NA	NA
59.	NA	NA	NA	NA	NA	NA	NA
Postflexion mesolarvae							
24.	(2),3	3	(1),3	3	3	2-3	2-3
25.	(2-3),4	1-2	1-2	3	1-2,4	3	2
27.	(1),2,(3)	1	1-2	2-3	1-2	3	2-3
28.	(NA,2),3-5	2-3	3	NA,5	3,5	NA	NA,2
29.	(NA),2,(3-4)	3-4	4	NA,2	3-4	NA	NA,3
35.	1-2,(3)	1-2	1-2,(3)	2-3	2,4	1	1-2
37.	(2),3	2-3	2-3	3	2-3	3	2-3
38.	5	4	4	(2),4	4	(4),5	4
39.	1,6-7	4,6-7	6	6-7	3,6	6	1,6
40.	1-2	1-2	1-2	2-3	1,3	1-2	2
41.	3	1-2	1-2,(3)	3	1,3	3	3

(continued)

Table 69. Continued.

Character number	<i>Agosia chrysogaster</i>	<i>Gila elegans</i>	<i>Gila robusta</i>	<i>Meda fulgida</i>	<i>Ptychocheilus lucius</i>	<i>Rhinichthys cobitis</i>	<i>Rhinichthys osculus</i>
42.	2-3	1	1,(2-3)	3	1,3	2-3	2-3
43.	3-4	5-6	(1),2,(3),5	3-4	1,5	2-3	2-3,5
44.	1	1-3	2-3	1-2,(3)	3	1	1-2
51.	1-2	1	1	1,(2)	1-2	1	1
52.	1,(2)	1	1	1,(2)	1-2	1	1
53.	1-2	1	1	1-2	1-2	1	1
54.	1-2	1	1	1,(2)	1	1	1
55.	1,(2)	1-3	1-2,(3)	4	1-2	1-2	1,5
56.	(1),2-3	1-2	1,(2)	1-2	1	1	1
57.	NA,1-2,(3)	NA,1	NA,(1)	NA,(1),2,(3)	NA	NA	NA
58.	NA,(2,6)	NA	NA	NA	NA	NA	NA
59.	NA	NA	NA	NA	NA	NA	NA
63.	1-3	1-2	1,3	1-3	1,3	1,(2-3)	1,3
64.	1-2	1	1	1,(2)	1	1	1
65.	1	1-2	1-2	(1),2	1	1,(2)	1-2
Metalarvae				≤ 25 mm SL			
30.	1	1	1	1	1	1	1
31.	1	1	1	1	1	1	1
32.	2-3	2	1-2,4	1-2	1-2	(1),2,4	2-4
33.	4-5	5-6	1,5-6	5	5	5	1,3
34.	(3),4-5	5	5	5	5	(1),5	3-4
36.	1	1	1	1	1	1	1-2
37.	3	3	3	3	2-3	3	3
38.	4-5	4	4	4	4-5	(1),4,(5)	4
41.	3	2-3	1,3	(2),3	1,3	3	3
42.	3	1-3	1,3	(2),3	1-3	(2),3	3
44.	1	2-3	1-3	1-3	2-3	1	1
45.	1-2,(3)	1-2	1	1-2,(3)	1-3	1-2,(3)	1-3
46.	1	1	1	1-2	1	1	1
47.	1-2,(3)	1	1	1-2,(3)	1	1,3	1,3,5
51.	1-2	1	1	1,(2)	1	1	1
52.	1,(2)	1	1	1,(2)	1	1	1
53.	1-2	1	1	1,(2)	1	1	1
54.	1-2	1	1	1,(2)	1	1	1-2
55.	1	1	1	1,(3),4	1	1	1,5
56.	1-3	1-2	1	1-2,(3)	1	1,(2)	1
57.	NA,(2),3	NA,1,3	NA	NA,(1-3)	NA	NA,(3)	NA
58.	NA,(2),6	NA	NA	NA,(6)	NA	NA	NA
66.	1	1	1	1,(2)	1	1	1
67.	(1-2),3	1,3	1-2	1,(2),3	1,3	1,(2-3)	1-3
68.	1,5	1-2	1	1,(2),5	1-2	5	1,5
69.	(1),2-3	1-3	1-3	(1),3	1-3	1-3	1-3
70.	1,(2)	1-2	1	1	1-2	1	1
Juveniles				(& metalarvae 25-40 mm SL)			
30.	1	1	1	1-2	1	1	1
31.	1,(2)	1	1	1	1	1,(2)	1
32.	3	2	2	2	2	4	3-4
33.	4	5	5	5	5	5	3,5
34.	(3),4,6	1,5	1,3,5-6	1,(2),5	5	3,5	3-4
36.	1	1	1	1	1	1	2
45.	(2),3	1	1-2	2-3	2-3	2-3	1,3
46.	1	1	1	2	1	1	1
47.	(1),2-3	1-2	1-2	2,5	1	1-3	4-5
48.	2-3	3	3	2-3	3	3	2-3
49.	1-2,(3)	1,3	1,3	(2),3	1,3	(1),3	2-3
50.	1,(2-4)	1-2	1	1	1,3	1-2	1
51.	1,(2)	1	1	1	2	1	1
52.	1	1	1	1	1	1	1
53.	1	1	1	1	1	1	1

(continued)

Table 69. Continued.

Character number	<i>Agosia chrysogaster</i>	<i>Gila elegans</i>	<i>Gila robusta</i>	<i>Meda fulgida</i>	<i>Ptychocheilus lucius</i>	<i>Rhinichthys cobitis</i>	<i>Rhinichthys osculus</i>
54.	1-2	1	1-2	1	1	1	1-2
55.	1	1	1,5	1	1	1	1,5
56.	1-3	1-2	1	1,(3)	1	1	1
57.	NA,(1,3)	NA,3	NA	NA	NA	NA	NA
58.	NA,(2,6)	NA	NA	NA,(6)	NA	NA	NA
66.	1-2	1	1	1-2	1	1-2	1
67.	1-3	3	1-3	1,(3)	3	1,(2),3	1
68.	5	1	1	5	1	5	5
69.	(1-2),3	3	1-3	1,(2),3	3	1,3	1,3
70.	1-2	1-2	1	1	2	1-2	1

Key to pigment characters and states (applicable developmental phases in brackets – pr = protolarvae, fm = flexion mesolarvae, pm = postflexion mesolarvae, mt = metalarvae, ej = early juveniles):

24. Snout (above upper lip or margin of upper jaw and exclusive of nares) [fm-pm]
 1. unpigmented.
 2. pigmented with 1–5 melanophores.
 3. pigmented with 6 or more melanophores.
25. Pigmentation in and along margin of nares (nasal pits) [pr-pm]
 1. absent.
 2. sparse to moderate.
 3. extensive without strong emphasis on anterior and medial margins.
 4. extensive with strong emphasis on anterior and medial margins.
26. Dorsal surface of head [pr-fm]
 1. unpigmented or pigmented only over hindbrain (posterior to middle of eyes).
 2. pigmented over both mid- and hindbrain (anterior and posterior to middle of eyes).
27. Pigmentation across dorsal surface of body between head and last myomere (for specimens with greater than 12 melanophores on dorsal surface) [pr-pm]
 1. not scattered or sparsely scattered with at least a partial, distinct, lengthwise line or narrow band of melanophores on or lateral to dorsal midline.
 2. densely scattered over all or most of back with at least a partial, distinct, lengthwise line or narrow band of melanophores on or lateral to dorsal midline.
 3. densely scattered over all or most of back with no distinct, lengthwise lines or narrow bands of melanophores [characters 28 and 29 NA].
28. Pigmentation on dorsal midline behind head to origin of the dorsal fin (first pterygiophore) or its approximate future origin (about half of standard length) [pr-pm; NA if character 27 is state 3]
 1. absent.
 2. present but sparse—just a few scattered melanophores not forming a distinct line of any length.
 3. present in a short but distinct, continuous or discontinuous line or series of several well-spaced melanophores extending to no more than half the distance.
 4. present in a distinct but discontinuous line or series of at least several well-spaced melanophores extending to or nearly to full length.
 5. present in a distinct continuous or nearly continuous line to or nearly to full length.
29. Pigmentation on dorsal surfaces lateral to midline from shortly behind head to about 2/3 distance to last myomeres [pr-pm; NA if character 27 is state 3]
 1. absent.
 2. sparsely to densely scattered with no distinct, lengthwise lines or narrow bands of melanophores on either side.
 3. scattered or not but with a distinct, short or discontinuous (well separated segments) line or narrow band of melanophores along one or both sides of dorsal midline.
 4. scattered or not but with a distinct, continuous or nearly continuous, full-length line or narrow band of melanophores along each side.
30. Pigmentation on dorsal surface of body between head and last myomere [mt-ej]
 1. scattered more or less evenly (with or without emphasis on distinct lines of melanophores or melanophore clusters on or lateral and parallel to dorsal midline).
 2. scattered in a blotchy or mottled pattern (with or without emphasis on distinct lines of melanophores or melanophore clusters on or lateral and parallel to dorsal midline).
31. Distinct spot or aggregation of pigment at origin of dorsal fin [mt-ej]
 1. absent (or indistinct).
 2. prominent.

(continued)

Table 69. Continued.

32. Pigment on or between pterygiophores of dorsal fin [mt-ej]
 1. absent or not obvious (essentially white).
 2. obvious (light to strong) without a distinct spot.
 3. with an obvious spot over posterior two-thirds to half of pterygiophores with some scattered pigment before and/or after.
 4. with an obvious spot over posterior two-thirds to half of pterygiophores with obvious unpigmented spot or area immediately before and/or after.
33. Pigmentation under or immediately along base of dorsal fin [mt-ej]
 1. absent.
 2. present only under or along middle portion, often forming a distinctive "dash" of pigment.
 3. present only under or along middle and posterior portions.
 4. present under or along posterior two-thirds to full length of base with greater intensity and concentration at posterior end.
 5. present full length.
 6. otherwise.
34. Pigmentation under or immediately along base of anal fin [mt-ej]
 1. absent.
 2. present only under or along middle portion, often forming a distinctive "dash" of pigment.
 3. present only under or along middle and posterior portion.
 4. present under or along posterior two-thirds to full length of base with greater intensity and concentration at posterior end.
 5. present full length.
 6. otherwise.
35. Pigmentation around end of notochord or urostyle (uroneural) [pr-pm]
 1. absent.
 2. present but sparse--just a few melanophores.
 3. moderate but not prominent--does not stand out.
 4. present with a prominent series of melanophores along dorsal side only.
 5. present with a prominent series of melanophores along dorsal side, around end, and ventral side.
36. Dark bar of pigment on lateral surface of snout anterior to eye [mt-ej]
 1. absent.
 2. present (usually as a continuation of an intense lateral band from eye to tail).
37. Lateral surface of head posterior to eyes [fm-mt]
 1. unpigmented.
 2. pigmented with 1–5 melanophores.
 3. pigmented with more than 5 melanophores.
38. Pigmentation of horizontal myosepta [pr-mt]
 1. absent.
 2. sparse.
 3. moderate to strong line only along middle of body.
 4. moderate to strong line only along middle and posterior body.
 5. moderate to strong line along entire body (except sometimes immediately behind head).
 6. moderate to strong narrow band along entire body (except sometimes immediately behind head; precursor of a broader lateral band).
39. Line of internal to near-surface pigment over dorsal and dorsolateral surfaces of posterior gut and air bladder, as visible from lateral view [pr-pm]
 1. absent, obscure, or indistinct (can't tell).
 2. does not extend anteriorly to head.
 3. continues anteriorly to head but not beyond.
 4. continues anteriorly in head to or towards anterior margin of auditory vesicle behind eye and has obvious horizontal-y-forming branch extending down behind base of pectoral fin or bud then forward to throat region.
 5. continues anteriorly in head beyond anterior margin of auditory vesicle towards eye and has obvious horizontal-y-forming branch.
 6. continues anteriorly in head to or towards anterior margin of auditory vesicle behind eye but without obvious horizontal-y-forming branch.
 7. continues anteriorly in head beyond anterior margin of auditory vesicle towards eye but without obvious horizontal-y-forming branch.
40. Internal to near-surface pigmentation over dorsal to dorsolateral surfaces of gut or visceral cavity under air bladder as visible from lateral view [fm-pm]
 1. absent.
 2. sparse, up to several melanophores.
 3. moderate in coverage or intensity.
 4. continuous and dark.
41. Lateral surface of body above horizontal myosepta (lateral midline) and below dorsolateral surface (exclusive of pigmentation associated with horizontal myosepta) [fm-mt]
 1. unpigmented.
 2. pigmented with 1–5 melanophores.
 3. pigmented with more than 5 melanophores.

(continued)

Table 69. Continued.

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42. Lateral surface of body below horizontal myosepta (or lateral midline) but anteriorly above gut and visceral cavity (exclusive of pigmentation associated with horizontal myosepta and air bladder) [fm-mt]
1. unpigmented.
 2. pigmented with 1–5 melanophores.
 3. pigmented with more than 5 melanophores.
43. Pigmentation on lateral surface of visceral cavity (exclusive of internal near-surface pigment on dorsal and dorsolateral surfaces of gut) [pr-pm]
1. absent.
 2. sparsely scattered, up to 5 melanophores not forming a line.
 3. moderately scattered with no line or band.
 4. scattered anterior and ventral of mid air bladder with a line extending from mid-air bladder posteriorly to along dorsolateral surface of posterior gut.
 5. scattered or not, but with a continuous or discontinuous line or series of melanophores extending nearly horizontally between pectoral fin and line of pigment above the posterior gut.
 6. scattered or not, but with a continuous or discontinuous line or series of melanophores extending diagonally between heart on ventral or ventrolateral surface and line of pigment above the posterior gut.
 7. otherwise.
44. Basicaudal spot (distinctive pigment spot on lower hypural bones) [fm-mt]
1. absent.
 2. faint, or light.
 3. dark and prominent.
45. Caudal spot (distinctive spot of pigment at the middle base of the caudal fin, about the size of the pupil or larger, sometimes present as the enlarged end of the lateral band, sometimes extending onto the base of the middle caudal rays) [mt-ej]
1. absent.
 2. faint, or light.
 3. dark and prominent.
46. Distinctive, large, square melanophores on lateral surface of body [mt-ej]
1. absent.
 2. present (coverage few to extensive).
47. Lateral band of pigment from head to tail [mt-ej]
1. absent.
 2. faint to dark and narrow on posteriorly, absent anteriorly.
 3. faint to moderate intensity, sometimes broadening anteriorly, not continuing on lateral surface of head.
 4. dark and narrow posteriorly, becoming much broader (diffuse) and slightly lighter to faint (dusky) anteriorly.
 5. dark and consistently wide for full body length, beginning on lateral surface of head, sometimes ending posteriorly in a slightly wider or disjunct caudal spot.
48. 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) [ej]
1. scattered only partially down to the horizontal myoseptum (lateral midline) or lateral band if present, leaving an unpigmented zone above all or most of the horizontal myosepta or lateral band.
 2. scattered fully and evenly down to the horizontal myoseptum or lateral band with few if any melanophores below the myoseptum or band.
 3. scattered evenly or in mottled pattern (continuous with dorsal and dorsolateral surface pattern) down to horizontal myoseptum or lateral band and at least partially below horizontal myoseptum to bottom-of-eye level.
49. Pigmentation on lateral to ventrolateral surfaces of body below bottom-of-eye level (exclusive of melanophores associated with horizontal myosepta, air bladder, visceral cavity peritoneum, or gut) [ej]
1. absent including caudal peduncle.
 2. absent except on caudal peduncle.
 3. present.
50. Pigmentation outlining scales [presence -- ej]
1. absent.
 2. light (barely evident).
 3. moderate.
 4. bold.
51. Pigmentation under chin (anterior ventral surface of lower jaw) [pr-ej]
1. absent.
 2. present with one melanophore or more but not in a midline row.
 3. present with two or more melanophores in a midline row.
52. Melanophores on ventral to ventrolateral surfaces or margins of preopercles (below to behind posterior half of eyes) [pr-ej]
1. absent.
 2. present, but not consisting of or including a distinct oblique row of 3 or more melanophores near or along the margin of either preopercle.
 3. consisting of or including a distinct oblique row of 3 or more melanophores near or along the margin of one or both preopercles.

(continued)

Table 69. Continued.

53. Melanophores on ventral surface anterior to heart in branchial (gular) region (between opercles and branchiostegal membranes) [pr-ej]
1. absent.
2. present.
54. Melanophores on ventral surface of heart region exclusive of outer margins [pr-ej]
1. absent.
2. present.
55. Pigmentation outlining heart cavity [pr-ej]
1. absent (or obscured).
2. sparse, or light with ≤ 5 melanophores.
3. moderate, at least laterally.
4. bold along lateral margins only.
5. bold along lateral and posterior margins.
56. Pigmentation on ventral surface between heart and vent [pr-ej]
1. absent [characters 57, 58, and 59 NA].
2. present only as scattered melanophores over all or part of surface [characters 58 and 59 NA].
3. present only as a partial to continuous line, narrow band, or series of well spaced melanophores along the ventral midline [characters 57 and 59 NA].
4. present only as partial to continuous lines, narrow bands, or linear series of well-spaced melanophores laterally outlining at least the anterior visceral cavity from behind or lateral to the heart and extending posteriorly onto ventrolateral to lateral surfaces [characters 57 and 58 NA].
5. present only as partial to continuous lines, narrow bands, or linear series of well-spaced melanophores both on the ventral midline and laterally outlining the anterior visceral cavity [character 57 NA].
6. present as combination of scattered melanophores with a partial to continuous line, narrow band, or well-spaced linear series of melanophores on the ventral midline and/or outlining the anterior visceral cavity.
57. Scattered pigmentation on ventral surface between heart and vent [pr-ej; NA if character 56 is state 1, 3, 4, or 5]
1. restricted to anterior region behind heart.
2. widely spaced and covering most of ventral surface.
3. otherwise.
58. Pigmentation along ventral midline from shortly behind heart region to near vent [pr-ej; NA if character 56 is state 1, 3, 4, or 5]
1. absent [potentially applicable only if character 56 is state 6].
2. present only as a full or partial series of widely spaced melanophores.
3. present as a full length (or nearly so) continuous or nearly continuous line or narrow band of melanophores.
4. present as a continuous or nearly continuous line or narrow band of melanophores only under all or most of the preanal finfold.
5. present as a short continuous or nearly continuous line or narrow band of melanophores extending from the heart towards the origin of the preanal finfold (sometimes in combination with oblique lines of pigment to each side forming a trident-like pattern).
6. otherwise.
59. Lines, narrow bands, or linear series of well-spaced melanophores laterally outlining at least the anterior visceral cavity from behind or lateral to the heart and extending posteriorly onto ventrolateral to lateral surfaces [pr-pm (generally obscured or lost in mt-ej); NA if character 56 is state 1, 3, 4, or 5]
1. absent [potentially applicable only if character 56 is state 6].
2. present but continue only a short distance onto ventrolateral surfaces.
3. continue onto ventrolateral and lateral surfaces and then along gut to vent.
4. otherwise.
63. Pigmentation in developing dorsal fin [pm]
1. absent.
2. sparse with 5 or fewer melanophores.
3. at least moderate with 6 or more melanophores.
64. Pigmentation in developing anal fin [pm]
1. absent.
2. present.
65. Pigmentation in developing pectoral fins [pm]
1. absent.
2. present.
66. Pigmentation in dorsal fin [mt-ej]
1. present to extensive along principal fin rays with few, if any, melanophores on membranes between rays (but might be present on membranes between branches of rays).
2. extensive along principal fin rays and notably present (more than just a few melanophores) to extensive on at least a portion of membranes between some or all principal rays (might also be present on membranes between branches of rays).
67. Pigmentation in anal fin (melanophores are sometimes very linear along margins of fin rays and easily overlooked) [mt-ej]
1. absent.
2. present but very light with 5 or fewer melanophores.
3. present but more prominent with 6 or more melanophores.

(continued)

Table 69. Continued.

68. Pigmentation in caudal fin [mt-ej]
1. present to extensive along principal fin rays with few, if any, melanophores on membranes between principal rays (but might be present on membranes between branches of rays).
 2. extensive along principal fin rays and notably present (more than just a few melanophores) to extensive only on proximal portions of membranes between at least some principal rays.
 3. extensive along principal fin rays and notably present (more than just a few melanophores) to extensive on middle or (and) distal portions of membranes between some or all principal rays (might also be present on membranes between branches).
 4. extensive along principal fin rays and notably present (more than just a few melanophores) to extensive over most of membranes (proximal to distal portions) between at least some principal rays.
 5. extensive along entire middle rays, and sometimes on membranes between, but only along, and sometimes between, middle to distal portions of principal rays above and below (proximal portions of these mostly unpigmented).
69. Pigmentation in pectoral fins [mt-ej]
1. absent.
 2. present but very light with up to 5 melanophores.
 3. present but more prominent with greater than 5 melanophores.
70. Pigmentation in pelvic fins [mt-ej]
1. absent.
 2. present (but seldom with more than a few melanophores).

Table 70. Comparison of diagnostic eye, mouth, and fin position characters for larvae and juveniles (≤ 40 SL) of native cyprinids of the Gila River Basin. (Key to characters and their states is given below. Rare character states are enclosed in parentheses. NA = not applicable.)

Character	<i>Agosia chrysogaster</i>	<i>Gila elegans</i>	<i>Gila robusta</i>	<i>Meda fulgida</i>	<i>Ptychocheilus lucius</i>	<i>Rhinichthys cobitis</i>	<i>Rhinichthys osculus</i>
Eye Shape							
Protolarvae	2-3	1-2	1-3	(1-2),3	1-2	2-3	1-2
Flexion Mesolarvae	3	1-2	2-3	3	1-2	(1),2-3	1-2
Postflexion Mesolarvae	3	2-3	2-3	3	2-3	2-3	2-3
Mouth Position							
Protolarvae	3-4	2,4-5	4-5	1-2,(4)	2,4-5	4-5	3-4
Flexion Mesolarvae	3	2	2	1	2,4	(3),4	3-4
Postflexion Mesolarvae	3	2	2	1,(2)	2	4	3-4
Metalarvae	3	2	2-3	1-2	2-3	4	4
Juveniles	3-4	2	2	2-3	3	3-4	4
Posterior Corner of Mouth							
Protolarvae	3-4	3-4	3-4	2,(3-4)	3-4	3-4	3-4
Flexion Mesolarvae	(2),3	3	2-3	2	3	(2),3	3
Postflexion Mesolarvae	2-3	3	2-3	2	3	2-3	3
Metalarvae	(2),3	3	2-3	2-3	3	2-3	3
Juveniles	3	3	3	3,(4)	3	1-2	3
Frenum							
Postflexion Mesolarvae	1-3	1,2	2	(1),2	2-3	2	2
Metalarvae	3	2-3	2-3	2-3	3	2	2-3
Juveniles	3	3	(2),3	3	3	2	3
Origin of Dorsal Fin							
Metalarvae	1-3	3	(2),3	(2),3	(2),3	(1),2-3	3
Juveniles	1-2,(3)	3	(2),3	(2),3	(2),3	(1),2,(3)	3
Insertion of Dorsal Fin							
Metalarvae	1,(2)	1-3	(1),2	1-2,(3)	1-2	1,(2)	2-3
Juveniles	1,(2)	2,(3)	2,(3)	(1),2	(1),2	1-2	3

Key to special characters and states (applicable developmental phases in brackets – pr = protolarvae, fm = flexion mesolarvae, pm = postflexion mesolarvae, mt = metalarvae, ej = early juveniles):

Eye shape [pr-pm]

1. Strongly to moderately oval (dorsoventrally flattened).
2. Slightly but distinctly oval.
3. Round (or very nearly so).

Mouth position [all]

1. Superior–strongly oblique with anterior end of upper lip above middle-of-eye level, lower jaw usually most anterior margin of snout (portion of head anterior to eyes).
2. Terminal–moderately oblique with anterior end of upper lip above bottom- to middle-of-eye level, lips usually even with or the most anterior margin of snout (sometimes slightly behind anterior margin of snout).
3. Low terminal–slightly oblique to horizontal with anterior end of upper lip at or below bottom-of-eye level and either even with or the most anterior margin of snout.
4. Subterminal–slightly oblique to horizontal with anterior margin of upper lip at or below bottom-of-eye level and lips preceded or overhung by anterior margin of snout.
5. Inferior–horizontal (or nearly so) and distinctly on underside of head with lips well behind anterior margin of snout.

Posterior corner of mouth (including lips) relative to eye [all]

1. Distinctly anterior to anterior margin of eye.
2. Below anterior margin of eye, or nearly so.
3. Distinctly posterior of anterior margin of eye but anterior to pupil.
4. Below at least anterior margin of pupil.

Frenum (bridge of tissue between anterior upper lip and rest of snout, no crease between anterior portion of upper lip and portion of snout above, upper lip not protrusible) [pm-jv]

1. Lip not sufficiently developed to assess.
2. Present.
3. Absent (lip completely separated from snout above).

Origin of dorsal fin relative to origin of pelvic fins [mt-jv]

1. Distinctly anterior.
2. Over or very nearly so (difference no more than $\pm 2\%$ SL).
3. Distinctly posterior.

Insertion (posterior end of base) of dorsal fin relative to posterior margin of vent [mt-jv]

1. Distinctly anterior.
2. Over or very nearly so.
3. Distinctly posterior.

Non-native -Cyprinids

Table 71. Comparison of size (mm SL) at onset of or transition to developmental intervals, gut phases, and other developmental events for larvae and early juveniles of non-native cyprinids of the Gila River Basin. (Rare values in parentheses. NA = not applicable.)

Character	<i>Cyprinus carpio</i>	<i>Cyprinella lutrensis</i>	<i>Pimephales promelas</i>
Egg diameter	1.3-2.1	1.0-1.3	1.2-1.6
Phase/period transitions			
Embryo to larva	(3)4-5(6)	3-4	4(5)
Proto- to mesolarva	7-8	5	6-7
Flexion to postflexion mesolarva	(8)9(10)	6	7-8
Meso- to metalarva	(12)13-16(-18)	(7)8	8-9
Larva to juvenile	16-19(-21)	10(-12)	13-15
Gut phase transitions			
1 to 2 (90° bend)	8-12(-15)	8-10	8-11
2 to 3 (full loop)	12-15	26	11(12)
3 to 4 (partial crossover)	16-21	NA	15-19
4 to 5 (full crossover)	≥(16-)20	NA	19-20
Onset of selected events			
Eyes pigmented	^c	3 ^c	^c
Yolk assimilated	6-7(8)	(4)5	4-5(6)
Finfold absorbed	16-19(-21)	(9)10(-12)	13-15
Pectoral-fin buds	^c	^c	^c
Pelvic-fin buds	9-11(12)	7-8	8-9
Pelvic fins adnate ^a	NA	NA	NA
Dorsal spine formation ^b	20-21 (with serrations)	NA	NA
Maxillary barbels	13-15 (corner pair) >32, <41 (anterior pair)	NA	NA
Fin rays first observed			
Dorsal, principal	(8)9-11	6	–
Anal, principal	10-11	(6)7	–
Caudal, principal	7-8	5	6-7
Caudal, rudimentary	9-11	7	–
Pectoral	11-12	(5)6	–
Pelvic	12	9	–
Full fin-ray counts first observed			
Dorsal, principal	(12)13-16(-18)	7-8	8-9
Anal, principal	12-13	(7)8	8-9
Caudal, principal	(8)9(10)	6	7-8
Caudal, rudimentary	15-16(17)	10(11)	13-15
Pectoral	(14-)16-17	9-10	–
Pelvic	(15-)17-19	10	–
Scales, lateral series			
First observed	13-16	12-13	–
Full series first observed	18-21	(15)16	16-<23

^a Medial margin of fin at least partially connected to body.

^b Transformation (thickening and elongation) of second (last) rudimentary to a distinctive spine as indicated by length greater than three-quarters that of the first principal dorsal-fin ray.

^c (Or) before hatching.

Table 72. Comparison of selected meristics for larvae and early juveniles of non-native cyprinids of the Gila River Basin. (Character range is followed by the mean, mode, or more typical range. See Figure 4 for methods of counting myomeres and fin rays. ODF = origin of dorsal finfold, OD = origin of dorsal fin, OP2 = origin of pelvic buds or fins, and PV = posterior margin of the vent. Vertebra counts include four for the Weberian complex; dorsal- and anal-fin-ray counts are of principal rays; scale counts are of the lateral line or series. Most data are from Snyder, 1981, and references listed in species accounts there and herein.)

Character	<i>Cyprinus carpio</i>	<i>Cyprinella lutrensis</i>	<i>Pimephales promelas</i>
Myomeres to ODF			
Protolarvae	–	9-9, 9	–
Flexion mesolarvae	10-12, 11	7-13, 9	10-13, 12
Postflexion mesolarvae	10-12, 11	7-11, 9	10-13, 12
Myomeres to OD			
Postflexion mesolarvae	11-13, 12	15-16, 16	–
Metalarvae	10-12, 11	13-19, 16	12-16, 15
Myomeres to OP2			
Postflexion mesolarvae	13-15, 14	–	–
Metalarvae	11-14, 13	12-16, 14	12-15, 14
Myomeres to PV			
Proto- & mesolarvae	26-28, 26-28	20-24, 21-23	21-25, 23-24
Metalarvae	25-26, 25	19-24, 21	22-25, 23
All larvae	25-28, 25-28	19-24, 21-23	21-25, 23-24
Myomeres after PV			
Proto- & mesolarvae	10-12, 11-12	12-15, 13-14	12-15, 13
Metalarvae	11-13, 12	12-17, 14	11-13, 12
All larvae	10-13, 11-12	12-17, 13-14	11-15, 12-13
Myomeres, total			
Proto- & mesolarvae	37-39, 38	34-37, 35-36	34-38, 36-37
Metalarvae	36-37, 37	34-37, 36	34-36, 35
All larvae	36-39, 37-38	34-37, 35-36	34-38, 35-37
Vertebrae	32-39, 35-38	32-36, 35-36	35-38, 36-37
Dorsal-fin rays	16-24, 18-22 ^a	6-9, 8	7-9, 8
Anal-fin rays	5-8, 6 ^a	7-13, 9	7
Lateral-line scales	32-41, 35-38	30-40, 32-37	40-60, 44-48

^a Spines are hardened lepidotrichia and not separated by use of Roman numerals.

Table 73. Comparison of the more diagnostic differences in morphometrics for larvae and juveniles (≤ 40 mm SL) of non-native cyprinids of the Gila River Basin. (Except as indicated, all data are percentages of standard length, % SL, presented as ranges followed by means. HL = head length measured to the origin of the pectoral fin, AS to OP1. See Figure 4 for other abbreviations and methods of measurement.)

Developmental Phase Character	<i>Cyprinus carpio</i>	<i>Cyprinella lutrensis</i>	<i>Pimephales promelas</i>
Protolarvae			
Eye diameter ^a	6-9, 7	6-7, 7	7-8, 7
AS-to-PE length	10-13, 11	8-9, 9	8-10, 9
AS-to-ODF length	37-47	44-49, 47	39-45, 42
AS-to-PV length	70-75, 72	62-64, 63	61-64, 62
Yolk length ^b	0-44	0-58	0-53
Pectoral-fin length ^c	4-13, 10	10-13, 11	5-14, 12
Depth at OD ^b	12-16, 14	–	–
Width at OD ^b	5-10, 7	–	–
Max. yolk depth ^b	0-17	0-21	0-22
Max. yolk width ^b	0-8	0-24	0-20
Flexion mesolarvae			
Eye diameter, % HL ^a	29-32, 30	32-35, 33	38-47, 40 ¹
AS-to-PE length	12-15, 13	9-13, 11	12-14, 12 ¹
AS-to-OPAF length	37-45, 39	34-38, 37	–
AS-to-ODF length	46-49, 48	42-49, 46	41-50, 46 ¹
AS-to-PV length	74-75, 75	61-67, 65	65-72, 69 ¹
Yolk length	0	0	0
Pectoral-fin length	12-15, 13	11-15, 13	12-14, 12 ¹
Depth at OP1	16-20, 18	11-14, 13	13-16, 15 ^{ij}
Depth at OD ^d	11-16, 13	–	–
Depth at BPV	7-8, 7	8-13, 10	–
Width at BPE	13-14, 14	12-14, 13	–
Width at OP1	10-12, 11	9-13, 10	10-13, 10 ^{ij}
Width at OD ^d	7-8, 7	–	–
Max. yolk depth	0	0	0
Max. yolk width	0	0	0
Postflexion mesolarvae			
Eye diameter, % HL ^a	25-38, 29	23-38, 32	38-47, 40 ¹
AS-to-OP1 length	13-18, 15	11-13, 12	21-24, 22 ¹
AS-to-OP2 length	26-33, 30	21-24, 23	–
AS-to-OPAF length	29-57, 43	37-38, 38	–
AS-to-PV length	74-77, 76	65-67, 66	65-72, 69 ¹
Pectoral-fin length	11-16, 13	13-16, 14	12-14, 12 ¹
Dorsal-fin-base length ^{e,f}	–	14-15, 14	–
Depth at OP1	19-27, 23	14-16, 15	13-16, 15 ^{ij}
Depth at OD	13-25, 20	14-15, 14	–
Depth at BPV	7-15, 12	10-12, 11	–
Width at BPE	15-20, 18	12-14, 13	–
Width at OP1	11-16, 14	10-11, 10	10-13, 10 ^{ij}
Width at OD	7-20, 12	7-8, 7	–
Metalarvae			
Eye diameter, % HL ^a	19-34, 25	25-36, 32	29-43, 36
AS-to-AE length	6-8, 7	5-7, 5	5-5, 5
AS-to-PE length	13-18, 15	12-15, 13	13-16, 14
AS-to-OP1 length	29-35, 32	22-28, 25	24-30, 27
AS-to-OP2 length	50-54, 52	47-51, 49	51-57, 54
AS-to-OD length	47-51, 49	49-54, 52	50-57, 54
AS-to-ID length	79-83, 81	63-67, 66	–
AS-to-PV length	72-77, 74	61-67, 64	65-75, 71
AS-to-IA length	80-84, 82	74-78, 77	–
Caudal-fin length ^g	19-25, 22	16-26, 19	16-23, 20
Pectoral-fin length	12-15, 13	11-18, 13	12-15, 13
Pelvic-fin length	8-10, 9	3-12, 8	2-10, 6
Dorsal-fin-base length ^f	31-33, 32	13-15, 14	–

(continued)

Table 73. Continued.

Developmental Phase Character	<i>Cyprinus carpio</i>	<i>Cyprinella lutrensis</i>	<i>Pimephales promelas</i>
Depth at BPE	21-24, 22	12-18, 15	16-22, 19
Depth at OP1	25-30, 27	14-21, 18	16-23, 19 ⁱ
Depth at OD	23-30, 27	15-19, 17	–
Depth at BPV	14-17, 15	11-15, 13	–
Depth at AMPM	8-11, 10	8-10, 9	–
Width at BPE	19-20, 20	12-16, 14	–
Width at OP1	16-19, 18	11-13, 12	12-20, 16 ^j
Width at OD	14-17, 16	8-11, 10	–
Width at BPV	9-12, 10	7-9, 8	–
Width at AMPM	3-6, 5	2-5, 4	–
Juveniles <40 mm SL			
Eye diameter, % HL ^a	19-26, 24	25-36, 32	–
AS-to-AE length	8-11, 9	4-8, 6	–
AS-to-PE length	15-18, 17	12-15, 14	–
AS-to-OP1 length	27-33, 31	22-28, 25	–
AS-to-OP2 length	50-56, 53	46-52, 49	–
AS-to-OD length	46-49, 48	47-52, 50	–
AS-to-ID length	80-84, 82	60-67, 63	–
AS-to-PV length	73-77, 75	60-64, 62	–
AS-to-IA length	81-85, 84	73-78, 76	–
AS-to-AFC length	109-115, 111	111-118, 114	–
Caudal-fin length ^g	18-27, 22	20-29, 25	–
Pectoral-fin length	12-18, 15	15-22, 19	–
Pelvic-fin length	11-17, 14	11-17, 14	–
Dorsal-fin length	37-41, 38	20-24, 22	–
Anal-fin length	14-19, 17	17-23, 20	–
Dorsal-fin-base length ^f	33-36, 34	12-15, 13	–
Depth at BPE	21-24, 23	14-18, 16	–
Depth at OP1	29-35, 32	17-24, 21	–
Depth at OD	31-36, 34	17-25, 20	–
Depth at BPV	18-23, 21	13-20, 17	–
Depth at AMPM	11-13, 12	8-12, 10	–
Width at BPE	18-21, 20	12-16, 14	–
Width at OP1	19-23, 21	11-16, 14	–
Width at OD	18-22, 20	9-16, 12	–
Width at BPV	10-17, 14	8-14, 10	–
Width at AMPM	4-9, 6	3-7, 4	–

^a Eye diameter = (AS to PE)-(AS to AE); approximated for protolarvae, metalarvae, and juveniles of *Cyprinus carpio* and *Cyprinella lutrensis* by difference between mean, minimum and maximum values in species accounts with range extended by the greater standard deviation, and then, for all but protolarvae, dividing those results by mean HL.

^b Ignore differences in maximum values because they may be affected by developmental state at hatching.

^c Ignore differences in minimum values because they may be affected by developmental state at hatching.

^d OD for protolarvae and early flexion mesolarvae is approximated at one-half of standard length (AS to PHP).

^e Applicable only to specimens with a full complement of dorsal-fin pterygiophores or principal rays.

^f Dorsal-fin base = (AS to ID)-(AS to OD); approximated for protolarvae, metalarvae, and juveniles of *Cyprinus carpio* and *Cyprinella lutrensis* by difference between mean, minimum and maximum values in species accounts with range extended by the greater standard deviation.

^g Caudal-fin length = (AS to PC)-(AS to PHP), total length minus standard length.

^h Maximum yolk values are approximated using measurements from the largest protolarva with yolk that was analyzed (although found, no flexion mesolarvae with yolk were analyzed for morphometrics).

ⁱ Data for mesolarvae as whole, not analyzed separately for flexion and postflexion phases.

^j Maximum body depth or width, probably near or somewhat behind OP1.

Table 74. Comparison of size (mm SL) relative to melanophore pigmentation of the eyes and bodies for protolarvae and lateral to ventral peritoneum for metalarvae (M) and early juveniles (J, ≤ 40 mm SL) of non-native cyprinids of the Gila River Basin. (For peritoneal pigmentation, size is preceded by initials for the applicable developmental intervals. Rare values are given in parentheses.)

Character	<i>Cyprinus carpio</i>	<i>Cyprinella lutrensis</i>	<i>Pimephales promelas</i>
Eye pigmentation, protolarvae			
Unpigmented	^a	3? ^a	^a
Light to moderate	(3)4-5 ^a	3 ^a	4 ^a
Dark	$\geq 5^a$	≥ 4	$\geq 5^a$
Body pigmentation, protolarvae			
Unpigmented	(3-4) ^a	3 ^a	^a
1-12 melanophores on dorsum	(3-5) ^a	4-6	(4) ^a
≥ 13 melanophores on dorsum	$\geq 4^a$	≥ 5	$\geq 4^a$
Peritoneal pigmentation^b			
Lateral			
Absent	–	M ≤ 9	MJ (≤ 15)
Sparse or patchy	–	M(J) $\geq (9)10$	M all
Uniformly speckled	M all	M(J) ≥ 12	M ≥ 11
Uniformly light	–	–	M ≥ 11
Uniformly dark	–	M(J) $\geq (9)10$	J ≥ 15
Obscured by overlying tissues	MJ ≥ 15	J ≥ 12	J ≥ 19
Ventrolateral surfaces			
Absent	M ≤ 24	MJ ≤ 12	MJ 11-15
Sparse or patchy	MJ (12-24)	MJ $\geq (9)10$	MJ 11-19
Uniformly light	–	J ≥ 11	MJ (11-15)
Uniformly dark	–	–	J ≥ 19
Obscured by overlying tissues	J ≥ 25	J ≥ 26	J $\geq (24)25$
Ventral surface			
Absent	M ≤ 24	MJ ≤ 25	MJ ≤ 15
Sparse or patchy	–	MJ ≥ 13	MJ ≤ 24
Uniformly light	–	–	J (24-25)
Uniformly dark	–	–	J ≥ 25
Obscured by overlying tissues	J ≥ 25	J ≥ 26	J ≥ 39

^a (Or) before hatching.

^b Pigmentation of the peritoneum is subsurface and should not be confused with surface or cutaneous pigmentation; some near-surface pigmentation in protolarvae and mesolarvae becomes distinguishable as peritoneal pigment in metalarvae. Also, pigment is usually apparent in the dorsal and dorsolateral aspects of the peritoneum of smaller metalarvae (and earlier larvae) and should not be interpreted as pigment in the lateral region. In juveniles, possibly including specimens smaller than recorded, melanophore pigmentation in the peritoneum may be obscured by overlying muscle or, especially in living and alcohol-preserved specimens, integument with a silvery lining of iridophores.

Table 75. Comparison of selected melanophore pigmentation patterns for larvae and juveniles (≤ 40 SL) of non-native cyprinids of the Gila River Basin. (See Table 69 for key to characters and their states; character numbers are those used in the computer-interactive key. Rare character states are enclosed in parentheses. NA = not applicable.)

Character number	<i>Cyprinus carpio</i>	<i>Cyprinella lutrensis</i>	<i>Pimephales promelas</i>
Protolarvae (after pigment is well established)			
25.	1-2	1-2	1
26.	1-2	1-2	1-2
27.	2	1	1
28.	1-2	1	1
29.	1-2	1	4
35.	1,3,5	1	2,5
38.	1-2	1,3	2,5
39.	4,6	1	1
43.	2-3,5	1,6	3
51.	1-2	1	1
52.	1	1	3
53.	1	1-2	1
54.	1	1	2
55.	1	2	1
56.	1-2	1,4	2,4
57.	NA,2	NA	NA,3
58.	NA	NA	NA
59.	NA	NA,2	NA,4
Flexion mesolarvae			
24.	3	1	2-3
25.	2-3	1	1-2
26.	2	1	1-2
27.	2-3	1	1,3
28.	NA,2	1,3	1,3
29.	NA,2-3	1,4	1,4
35.	2-3	1	1,4
37.	2-3	1	2-3
38.	2	1,4	4-5
39.	4,7	1,6	4,6
40.	1-2	1	1
41.	3	1	1-2
42.	2-3	1	1-2
43.	2-3	1	3,6
44.	1,3	1	1
51.	2	1-2	1-2
52.	1	1-2	3
53.	1	1-2	2
54.	1	1	1
55.	1	2,4	4
56.	2	1,4	2
57.	2	NA	2
58.	NA	NA	NA
59.	NA	NA,3	NA
Postflexion mesolarvae			
24.	3	1	3
25.	2-3	1	1
27.	2-3	1	2-3
28.	NA,5	1,3	5
29.	NA,2	2-3	3
35.	1,4	1	1
37.	3	1	3
38.	2,4	4	5
39.	1	6	6
40.	1	1-2	1
41.	3	1	3
42.	3	1	2-3
43.	1,3	1,6	6
44.	3	1-2	1,3
51.	2	1	2

(continued)

Table 75. Continued.

52.	1	1	3
53.	1	1	2
54.	1	1	1-2
55.	1	2	4
56.	1-2	1-2	2
57.	NA,2	NA, 1	2-3
58.	NA	NA	NA
59.	NA	NA	NA
63.	3	1	2-3
64.	1-2	1	2
65.	1-2	1	1-2
Metalarvae			
30.	1	1	1
31.	1	1	1
32.	1-2	1-2	1-2
33.	2,5	5-6	2,5-6
34.	5	5	5
36.	1	1	1
37.	3	1-2	3
38.	4	3-4	4-5
41.	3	1	2-3
42.	3	1	1-3
44.	3	1-3	1-2
45.	1-3	1	1
46.	1	1	1
47.	1	1	1
51.	1-2	1	1-2
52.	1-2	1	1-3
53.	1	1	1-2
54.	1	1	1-2
55.	1	1	1
56.	1-2	1	1-2,4
57.	NA,2	NA	NA,1-2
58.	NA	NA	NA
66.	1-2	1	1
67.	3	1	1,3
68.	1	1	1
69.	1,3	1	1,3
70.	1	1	1
Juveniles			
30.	1	1	1
31.	1	1	1
32.	2	1-2	2
33.	5	1,5	2,5
34.	1,5	1,3,5	1,3,5
36.	1	1	1
45.	1-3	1	1,(2),3
46.	1	1	1
47.	1	1-2	1-3,5
48.	3	1-3	1-3
49.	2-3	1,3	1,3
50.	1-3	1,3-4	1,3-4
51.	1	1-2	1-2
52.	1	1	1
53.	1	1-2	1,(2)
54.	1	1	1
55.	1	1	1
56.	1	1	1
57.	NA	NA	NA
58.	NA	NA	NA
66.	2	1-2	1
67.	1,3	1,3	1,3
68.	1,4	1	1
69.	1,3	1-3	(1),3
70.	1-2	1	1-2

Table 76. Comparison of diagnostic eye, mouth, and fin position characters for larvae and juveniles (≤ 40 SL) of non-native cyprinids of the Gila River Basin. (Key to characters and their states is given below. Rare character states are enclosed in parentheses. NA = not applicable.)

Character	<i>Cyprinus carpio</i>	<i>Cyprinella lutrensis</i>	<i>Pimephales promelas</i>
Eye Shape			
Protolarvae	2-3	1-2	2-3
Flexion Mesolarvae	3	1,(2)	(1),2-3
Postflexion Mesolarvae	3	1,(2)	3
Mouth Position			
Protolarvae	2-3,5	2,5	3,5
Flexion Mesolarvae	2	2	2
Postflexion Mesolarvae	2-3	2	(1),2
Metalarvae	3	1-2	2
Juveniles	2-3	1-2	2
Posterior Corner of Mouth			
Protolarvae	2-4	3-4	3-4
Flexion Mesolarvae	2	3	2
Postflexion Mesolarvae	2	2-3	2
Metalarvae	1-3	2	1-2
Juveniles	1-2	2	1,(2)
Frenum			
Postflexion Mesolarvae	3	2	3
Metalarvae	3	2-3	(2),3
Juveniles	3	3	3
Origin of Dorsal Fin			
Metalarvae	1	3	2-3
Juveniles	1-2	3	(1),2
Insertion of Dorsal Fin			
Metalarvae	3	1-2	1,(2)
Juveniles	3	2	1,(2)

Key to special characters and states (applicable developmental phases in brackets – pr = protolarvae, fm = flexion mesolarvae, pm = postflexion mesolarvae, mt = metalarvae, ej = early juveniles):

Eye shape [pr-pm]

1. Strongly to moderately oval (dorsoventrally flattened).
2. Slightly but distinctly oval.
3. Round (or very nearly so).

Mouth position [all]

1. Superior–strongly oblique with anterior end of upper lip above middle-of-eye level, lower jaw usually most anterior margin of snout (portion of head anterior to eyes).
2. Terminal–moderately oblique with anterior end of upper lip above bottom- to middle-of-eye level, lips usually even with or the most anterior margin of snout (sometimes slightly behind anterior margin of snout).
3. Low terminal–slightly oblique to horizontal with anterior end of upper lip at or below bottom-of-eye level and either even with or the most anterior margin of snout.
4. Subterminal–slightly oblique to horizontal with anterior margin of upper lip at or below bottom-of-eye level and lips preceded or overhung by anterior margin of snout.
5. Inferior–horizontal (or nearly so) and distinctly on underside of head with lips well behind anterior margin of snout.

Posterior corner of mouth (including lips) relative to eye [all]

1. Distinctly anterior to anterior margin of eye.
2. Below anterior margin of eye, or nearly so.
3. Distinctly posterior of anterior margin of eye but anterior to pupil.
4. Below at least anterior margin of pupil.

Frenum (bridge of tissue between anterior upper lip and rest of snout, no crease between anterior portion of upper lip and portion of snout above, upper lip not protrusible) [pm-jv]

1. Lip not sufficiently developed to assess.
2. Present.
3. Absent (lip completely separated from snout above).

Origin of dorsal fin relative to origin of pelvic fins [mt-jv]

1. Distinctly anterior.
2. Over or very nearly so (difference no more than $\pm 2\%$ SL).
3. Distinctly posterior.

Insertion (posterior end of base) of dorsal fin relative to posterior margin of vent [mt-jv]

1. Distinctly anterior.
2. Over or very nearly so.
3. Distinctly posterior.

Computer-Interactive Keys

Computer-interactive keys to the eggs, larvae, and early juveniles of catostomid and cyprinid Gila River Basin fishes covered herein, and a family-level key to the larvae of all Gila River Basin fishes can be accessed from the compact disk (CD) in the pocket on the inside rear cover of this guide or downloaded from the Internet as instructed below. These keys consist of data sets with associated image, text, and controlling files for use with the DELTA program, *Intkey* (Dallwitz et al. 1993 et seq., 1995 et seq.). The current version of the host program, *Intkey5* (also provided on the CD or downloadable from the Internet) runs under Microsoft *Windows 95* and later *Windows* operating systems. A color display with at least 800 x 600 pixel resolution (SVGA) is recommended (higher resolutions are preferred), but 640 x 480 pixel resolution (VGA) will work (less text is displayed without scrolling).

Intkey is one of the longer-standing, more highly evolved, and more widely used programs for interactive keys on personal computers (Dallwitz 1993). Many other interactive-key programs are available (e.g., *IdentifyIt*, *LucID*, *MEKA*, *Navkey*, *ONLINE*, *PollyClave*, and *XID*—Dallwitz 1996 et seq.), and some may have worked as well for these keys. However, the catostomid key prepared for Snyder and Muth (2004), the first ever published for fish larvae, used *Intkey* and it was decided to stay with that program rather than start over with a new program and system for storing and formatting data. Also, on the condition that it is not used or distributed for financial gain, *Intkey* is available free over the Internet—an important consideration for potential users of this key. In addition to its function as an interactive key, *Intkey* has a vast array of other options for information retrieval, including output of full or partial "natural-language" descriptions of, or differential comparisons among, selected taxon-items. Once installed, use of *Intkey* is not limited to the data sets provided herein for early life stages of Gila River Basin fishes, or the data set for catostomid fish larvae of the Upper Colorado River Basin (Snyder 2003 et seq., Snyder and Muth 2004); it can be used also with a wide array of data sets for other taxa (e.g., salamanders, crustaceans, beetles, butterflies, polychaetes, flowering plants, grasses, viruses) that are available as part of published guides, on CDs, or over the Internet (go to <http://delta-intkey.com/> and select "data" or "references" for listed applications).

Installation

The keys can be used directly from the "Delta" directory (folder) on the CD or installed on your computer's hard-drive using the compressed *Intkey* program (*Intk32.exe*) and data set (*Cat-grb.zip*, *Cyp-grb.zip*, *Fam-grb.zip*) distribution files on the CD. Installation of *Intkey* on your hard drive is required if (or when) you anticipate downloading and using future updates of this data set or using *Intkey* with data sets for other taxa. The "Delta" directory on the CD can be copied to and used on your hard drive (or elsewhere), but without installation from the program distribution file, *Intkey* would not be registered within the *Windows* operating system, listed in your start menu under programs, or set up as a helper file for your Internet browser.

In the absence of the CD, "*Intk32.exe*" can be downloaded from the DELTA Home Page on the Internet (<http://delta-intkey.com/>—select "Programs, documentation, and methodology" then under the programs listing, select *Intkey*). "*Cat-grb.zip*," "*Cyp-grb.zip*," and "*Fam-grb.zip*" can be similarly downloaded from the Colorado State University College of Natural Resources FTP site for LFL (go to "<ftp://ftp.cnr.colostate.edu/pub/lfl/cik-data/>" using your web browser and select the distribution file). Future updates of the data sets will likely be available only over the

Internet. Users should periodically check the download site for subsequently updated copies of the file, as indicated by a later date.

Install *Intkey* by double clicking on "Intk32.exe" from the CD or its downloaded location and following on-screen instructions. Installation in a directory (folder) named "Delta" under either the root directory or "Program Files" is recommended. In addition to the program and an array of bitmap and other files used by *Intkey*, the distribution file also includes and installs a "doc" subdirectory for the user's guide (intkey.doc, a Microsoft *Word* document but readable by most other word processors) and separate text files regarding installation (install.txt), conditions of use (use.txt), and registration (register.txt—*Intkey* can be used without registration, but remains subject to other conditions of use). The full set of program and related files will require about 2.2 Mb of storage memory.

Once *Intkey* is installed, select the data-set distribution files "Cat-grb.zip," "Cyp-grb.zip," and "Fam-grb.zip," one at a time, and using *WINZIP*, or another suitable decompression program, expand the distribution files into the directory in which you've installed *Intkey*. They will expand as subdirectories called "Cat-grb," "Cyp-grb," and "Fam-grb," respectively, and each includes five files and two further subdirectories ("images" and "rtf"). The current data sets and associated files require less than 3 Mb of storage memory.

Use

As noted above, the *User's Guide to Intkey* (Dallwitz, et al. 1995 et seq.) is included as "intkey.doc" in the folder "delta/doc" on the CD included with this guide, as well as in the *Intkey* distribution package on the CD or the Internet. Although all information needed for use of *Intkey* is included in program help files, first-time users are encouraged to read the user's guide, at least the first few pages through "Information Retrieval."

To start the program and use the key directly from the provided CD, open the "Delta" directory and double click on "intkey5.exe." *Intkey* will open with one of the three data-set names highlighted in an index window (startup dialog box). If your CD drive is designated as drive "D," just select (highlight) the key data set you want (if not already highlighted) and click on "OK" to open that data set; if your CD drive is not designated as drive "D" or the data set you want is not listed, click on Browse and in the appropriate subdirectory (Cat-grb, Cyp-grb, or Fam-grb) click on and open the corresponding startup file, "intkey-cat-grb.ink," "intkey-cyp-grb.ink," or "intkey-fam-grb.ink."

To run *Intkey* after it is installed on your computer's hard drive, press the *Windows* "Start" button, then select "Programs," "Delta," and "*Intkey*" (for convenience, a startup icon can be placed on your *Windows* desktop). The startup index window will be displayed. If the data-set name you want is listed, select it if not already highlighted, and click on "OK" to open the data set. If the data-set name is not yet listed in the index window (as upon first use after installation), browse for the appropriate subdirectory (e.g., Cat-grb) and select and open the corresponding startup file (e.g., intkey-cat-grb.ink); upon closing the data set or program, you will be given to the opportunity to add the data set to the startup index.

Upon opening a data set, a startup image with the name of the key and author will be displayed. Press enter or click on the screen to close the image and start the key. The standard interactive-key screen will be initially overlaid with introductory and instructional text windows. After reading their contents, close or minimize the text windows (if closed, they can be redisplayed by selecting the desired text file from the "information" index—click on the book icon

in the top left corner of the screen beneath "File"). Upon closing the text files, the standard screen will be revealed with its main menu, character and taxon-item toolbars, and four integral windows (available or best-remaining characters in upper left, used characters in lower left, remaining taxon items in upper right, and eliminated or non-matching taxon items in lower right). The relative size of the four windows can be changed at any time by moving the dividers between them.

For general instructions on use of the *Intkey* program, select or click on "Introduction" under the "Help" menu (upper left, main menu). As directed therein, for description of the various toolbar buttons and their use, click on the "↵?" help button in the upper right corner of the screen, above the end of the taxon-item toolbar, then on the desired toolbar button. Doing so for the "restart button" (curved arrow, left-most button in the upper right toolbar of "Best Characters" window) reveals the basic steps for proceeding with the key.

Before beginning identification, limit taxon possibilities (candidate species) by selecting only those species (for families) likely in your collection. Click on the "use subset of taxa" button (green oval icon, second from the right in the "Remaining Taxa" toolbar, upper right window), then in the special window brought up by that button, select the appropriate subset of taxa individually from the list of taxa (e.g., in the catostomid key, if only desert sucker and Sonora sucker are known to be the only covered catostomids in the river reach you have sampled, select just those species). Taxa to be considered in the key can be changed at any time.

Inappropriate or unfamiliar characters can be simply ignored and skipped over, but if desired, specific subsets of characters can also be selected (e.g., a subset without skeletal characters if the specimen to be identified has not been cleared, or a subset without morphometric characters if the user is unable to make such measurements). To select or deselect subsets of characters, click on the "use subset of characters" button (yellow oval icon, second from right in the "Best Characters" or "Available Characters" toolbar, upper left window). Proceed with identification as per basic instructions (click on the "help" (↵?), then "restart" buttons).

With the exception of internal skeletal characters in the catostomid key (and the circumstance mentioned in the next paragraph), all characters in these keys are based on external or externally visible morphology and pigmentation and can be assessed without dissection or destructive treatment. Internal skeletal characters included for catostomid metalarvae and early juveniles are intended for cleared and, preferably, bone-stained specimens, although careful dissection might also reveal the state of those characters.

Pigmentation characters used in these keys (and referenced in catostomid and cyprinid comparative summary tables) refer only to the black or brown pigment of melanophores (melanin-bearing cells). The pigment of most other chromatophores is difficult to preserve and has not been assessed. However, in living, freshly euthanized, and alcohol-preserved metalarvae and juveniles (not first fixed in formalin), melanophore pigmentation of the peritoneum (membrane lining the visceral cavity), as well as the degree of gut coiling, is often obscured by a layer of silvery iridophores. In such cases, it may be necessary to cut open the visceral cavity to examine the inner surface of the peritoneum and folds of the gut.

The catostomid and cyprinid keys are generally limited to specimens 40 mm or less in SL. However, some larger early (young-of-the-year) juveniles can be successfully identified with these keys by treating them as 40-mm-SL juveniles. Meristic characters such as fin-ray and scale counts in these keys are also applicable to all later juveniles and adults but may not be sufficient for definitive identification of these larger fish. The family key covers only the larval period.

As noted in the "Introduction" under the "Help" menu, the program opens in "normal mode" which limits users to preset options and is generally recommended for beginning or less-experienced users. However, depending on screen resolution, text for some character-state options might not be fully displayed. Increasing the width of the "Best Characters" or "Available Characters" window will increase the amount of text displayed in each line, but sometimes not enough. In these few cases, the user's only option is to cancel the selected character, switch to "advanced mode" under the "File" menu, again select the desired character, and in the character display box, click on the button for "Full Text" which is then displayed in a separate window. Unfortunately, this option is not currently available in "normal mode."

Taxonomic keys are tools for specimen identification, but the responsibility for accurate determinations remains with the user. Computer-interactive keys are simply easier-to-use and much more flexible tools than traditional printed keys, but as such they should facilitate more accurate identifications by the user. In the case of these keys, even with their extensive character sets, the identity of closely related fish larvae of similar developmental state and size cannot always be resolved to a single species; and even when it is, because true character ranges may extend beyond those observed for description, and because of possible errors by the author or user, the results are not necessarily conclusive. As discussed earlier in this guide, the possibility of hybrids among candidate taxa can further confound or reduce confidence in the resulting identification. Upon resolution of identity to a single taxon or if no matches are found, *Intkey* provides a help file with suggestions for confirming identity or allowing for some mismatches (increasing error tolerance) and continuing with the key. By allowing a couple of mismatches, even when identity is resolved to a single species, the user can base his or her identification on more characters and be more confident of the results. To further confirm the identity suggested by the key, users should also critically compare the specimen in question with descriptive information and illustrations in the species accounts and comparative summary tables and, if available, with preserved reference specimens. As noted earlier, identities that cannot be resolved with reasonable certainty should be either treated tentatively as the most likely species with a question mark following the determination (and perhaps with an explanatory footnote) or identified conservatively only to genus or family (e.g., *Catostomus* sp. or unidentified catostomid).

Please report any problems, discrepancies, errors, or observed character-range extensions for future updates of these computer-interactive-key data sets directly to:

Darrel E. Snyder
Larval Fish Laboratory
Colorado State University
1474 Campus Delivery
Fort Collins, Colorado 80523-1474
Phone: 970-491-5295
Fax: 970-491-5091,
E-mail: DESnyder@CNR.ColoState.edu).

If these keys are to be referenced separately from their inclusion in this guide, the suggested citations are, using Transactions of the American Fisheries Society journal format for Internet sources:

Snyder, D. E., and S. C. Seal. 2004 et seq. Computer-interactive key to eggs, larvae, and early juveniles of native catostomid fishes in the Gila River Basin (data set for use with DELTA *Intkey*). Larval Fish Laboratory, Colorado State University, Fort Collins. Available: <ftp://ftp.cnr.colostate.edu/pub/lfl/cik-data/>, select distribution file cat-grb.zip (January 2005).

Snyder, D. E., and S. C. Seal. 2004 et seq. Computer-interactive key to eggs, larvae, and early juveniles of selected cyprinid fishes in the Gila River Basin (data set for use with DELTA *Intkey*). Larval Fish Laboratory, Colorado State University, Fort Collins. Available: <ftp://ftp.cnr.colostate.edu/pub/lfl/cik-data/>, select distribution file cyp-grb.zip (January 2005).

Seal, S. C., and D. E. Snyder. 2004 et seq. Computer-interactive key to families of fish larvae of fishes in the Gila River Basin (data set for use with DELTA *Intkey*). Larval Fish Laboratory, Colorado State University, Fort Collins. Available: <ftp://ftp.cnr.colostate.edu/pub/lfl/cik-data/>, select distribution file fam-grb.zip (January 2005).

Replace the date in parentheses at the end of each citation with the date you personally last accessed the site and verified presence of the file.

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APPENDIX I

Pictorial Guide to Families of Fish Larvae in the Gila River Basin

Pictorial Guide to Families of Fish Larvae in the Gila River Basin

This is a modification of the pictorial guide to families of fish larvae in the Ohio River drainage by Wallus et al. (1990) for only those families found in the Gila River Basin. It is supplemented at the end with a comparable account for the family Cichlidae with representative illustrations of yolk-bearing and later larvae from Fryer and Iles (1972) and McGowan (1988), respectively.

Larvae with yolk

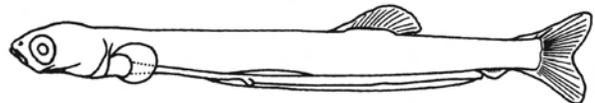
CLUPEIDAE—herrings

- slender, little pigment, transparent
- oil may or may not be visible
- large oil globule, if present, will be located posteriorly
- posterior vent
- less than 10 postanal myomeres
- dorsal finfold origin anterior, at mid-yolk sac early and just behind head later



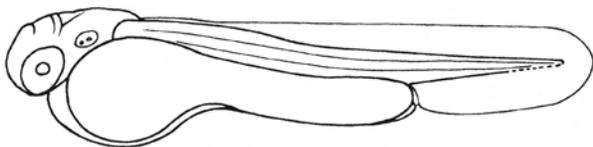
Larvae without yolk

- slender, little pigment
- posterior vent
- anal fin posterior to dorsal fin

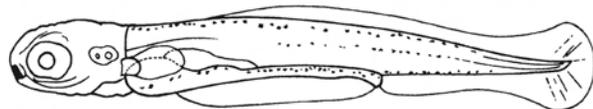


CYPRINIDAE—carps and minnows

- yolk long, cylindrical, initially bulbous anteriorly
- pigmentation varies from light to heavy
- vent usually slightly beyond midbody



- pigmentation often in rows; dorsolaterally, midlaterally, along ventral margin of myomeres, and midventrally
- air bladder obvious, becoming two-chambered, usually pigmented dorsally
- single dorsal fin



Larvae with yolk

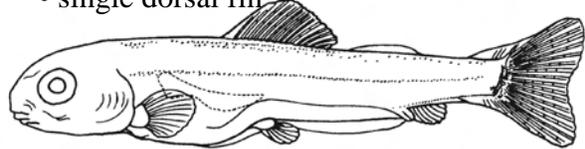
CATOSTOMIDAE—suckers

- yolk long, cylindrical, initially more bulbous anteriorly
- vent posterior, two-thirds to three fourths back on body



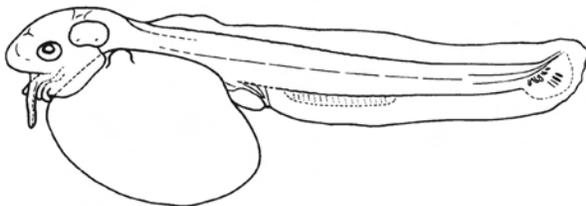
Larvae without yolk

- mouth shape and position varies from inferior (later in development) to terminal and oblique
- pigment variable but often in three rows, dorsally, ventrally, and midlaterally; dorsal pigment may also be in 1-3 rows
- air bladder obvious
- single dorsal fin



ICTALURIDAE—catfishes

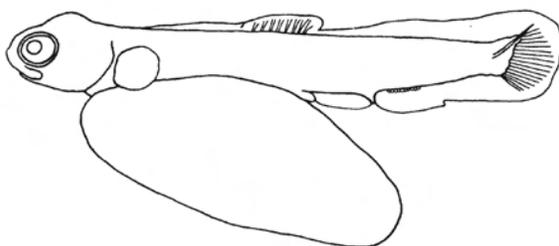
- large bulbous yolk
- barbels evident at hatching
- advanced fin development before complete yolk absorption



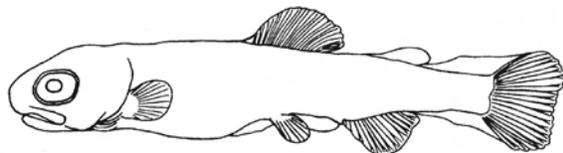
- some juveniles still have yolk, others absorb yolk as larvae before adipose fin is fully differentiated from remnant finfold or all rudimentary caudal-fin rays are formed

SALMONIDAE—trouts

- large, greater than 11 mm TL at hatching
- large yolk, initially pendulous
- advanced fin development prior to complete yolk absorption
- vent about two-thirds back on body



- robust
- large, rounded head
- adipose fin



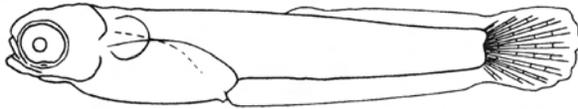
Larvae with yolk

Larvae without yolk

CYPRINODONTIDAE—killifishes

- stubby, robust
- caudal fin with rays at hatching
- vent anterior, near posterior margin of yolk

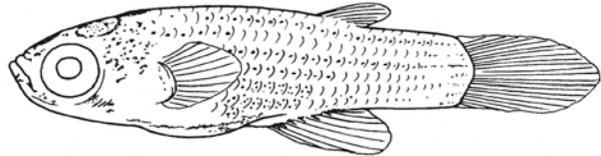
- large head
- superior mouth
- rounded caudal fin
- stocky caudal peduncle
- 10 or more dorsal rays (later larvae)



POECILIIDAE—livebearers

- inside female

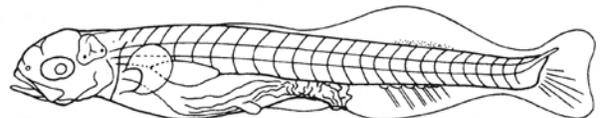
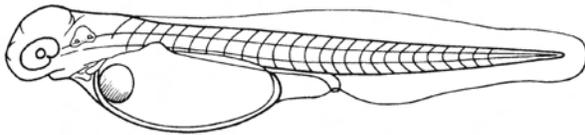
- scales present at birth
- rays in all fins at birth
- superior mouth
- dorsal fin short, 7-8 rays



MORONIDAE—temperate basses

- vent slightly posterior to midbody
- single, large, anterior oil globule
- low total myomere count, 25-26 or less

- "s" shaped gut
- low myomere count
- late larvae with well developed mouth with teeth
- spinous dorsal fin develops secondarily (later larvae)

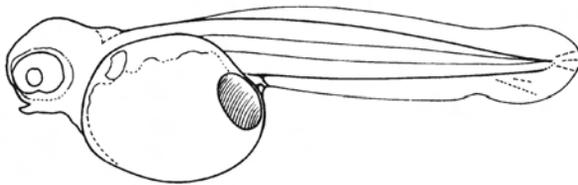


Larvae with yolk

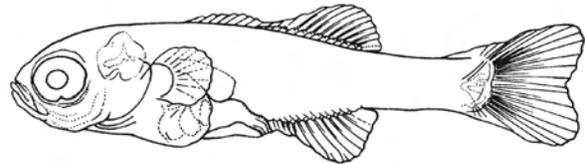
Larvae without yolk

CENTRARCHIDAE—sunfishes

- large, oval yolk sac at hatching
- position of oil globule variable, but usually posterior
- vent anterior to midbody

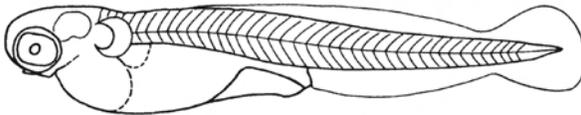


- usually robust with large head
- air bladder distinct
- gut short, coils with growth
- spinous and soft dorsal fins continuous (later larvae)

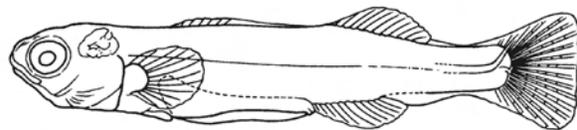


PERCIDAE—perches

- vent near midbody
- large anterior oil globule
- pectoral fins usually well developed at hatching
- total myomere counts higher than in moronids or centrarchids

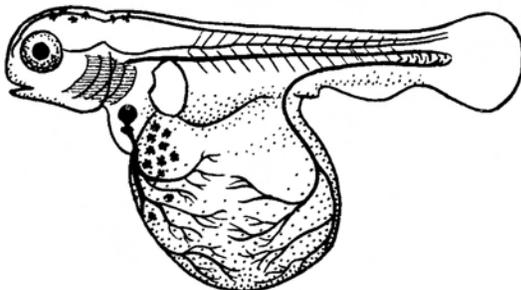


- large pectoral fins
- spinous dorsal separate from soft dorsal fin (later larvae)

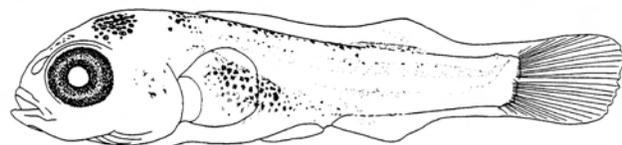


CICHLIDAE—cichlids

- small, 4-10 mm TL
- oil globules spread throughout large yolk sac



- stout body
- head with large eyes and terminal mouth
- continuous dorsal fin with 15-17 spiny rays, 10-13 soft rays (later larvae)



APPENDIX II

Glossary

GLOSSARY

This glossary is a supplemented combination of most glossary terms and definitions listed by Hardy et al. (1978, including volume 1 by Jones et al. 1978), Auer (1982), and Simon and Wallus (2004; mostly from Wallus et al. 1990) as indicated by superscript numbers 1, 2, and 3, respectively. Terms and definitions from other sources end with a corresponding citation. Author modifications, definitions, and comments on usage in this guide are enclosed in brackets. Many terms included in this glossary are not used in this guide, but are provided for more general reference. For developmental-interval terminology used herein, see discussion and definitions provided in the introduction. For a review of other developmental-interval terminologies, including terms not included in this glossary, see Snyder (1976b). Terms for many anatomical features, methods and abbreviations for morphometrics and fin-ray and myomere counts, and definitions for phases of gut coil development are illustrated in Figures 2-5.

A – Abbreviation for anal fin.¹

Abbreviate heterocercal – Tail in which the vertebral axis is prominently flexed upward, only partly invading upper lobe of caudal fin; fin fairly symmetrical externally.^{1,3}

Actinotrichia – Fin supports which are precursors of fin rays or spines; also [mistakenly] called lepidotrichia.^{2,3} Spiny fin rays; horny rays in the form of spines, which develop, embryonically at least, in all bony fish fins, and may persist as the spines in the spiny-rayed fishes (Acanthopterygii) [or are replaced by, or transformed into, scaly or soft rays called lepidotrichia in soft-rayed fishes (Malacopterygii) or the soft-rayed fins or parts of fins of spiny-rayed fishes] (Lagler et al. 1962, pp. 59 and 186).

Adherent – Attached or joined together, at least at one point.^{1,3}

Adhesive egg – An egg which adheres on contact to substrate material or other eggs; adhesiveness of entire egg capsule may or may not persist after attachment.^{1,3}

Adipose fin – A fleshy rayless median dorsal structure, located behind the true dorsal fin.^{1,3}

Adnate – Congenitally united; conjoined.^{1,3} Joined to; grown together.² Keel-like.³

Adnexed – Flaglike.³

Adult – Sexually mature as indicated by production of gametes.^{1,3}

Air bladder – See gas bladder; swim bladder.

Alevin – A term applied to juvenile catfish, trout, and salmon after yolk absorption; exhibiting no post yolk-sac larval phase.³ [However, if loss of finfold and acquisition of the minimum adult count of rays in all fins, including rudimentary rays, are required for transition to the juvenile period, most, if not all, of these fish do indeed have a post yolk-sac larval phase and the term is no longer useful as defined.]

Allopatric – Having separate and mutually exclusive areas of geographical distribution.³

Anadromous – Fishes which ascend rivers from the sea to spawn.^{1,3}

Anal – Pertaining to the anus or vent.^{1,3}

Anal fin – Unpaired median fin immediately behind anus or vent.^{1,3}

Anal fin origin – Anterior-most point at which the anal fin attaches to the body.¹

Anlage – Rudimentary form of an anatomical structure;^{1,2,3} primordium.^{1,3} Incipient.³

Antero-hyal – Anterior bone to which branchiostegal rays attach; formerly ceratohyal.^{2,3}

Anus – External orifice of the intestine; vent [when opening also includes the end of the urogenital duct].^{1,3}

Auditory vesicle – Sensory anlage from which the ear develops; clearly visible during early development.^{1,3}

Axillary process – Enlarged accessory scale attached to the upper or anterior base of pectoral or pelvic fins.^{1,3}

Barbel – Tactile process arising from the head of various fishes.^{1,3}

Basibranchials – Three median bones on the floor of the gill chamber, joined to the ventral ends of the five gill arches.^{2,3}

Bicuspid – Having or ending in two points; a tooth with two points.²

BL – Abbreviation for body length.¹

Blastocoel – Cavity of the blastula; segmentation cavity.¹

Blastoderm – *Sensu strictu*, early embryonic tissue composed of blastomeres; more generally, embryonic tissue prior to formation of embryonic axis.¹

Blastodisc – Embryo-forming area of egg prior to cleavage.¹

Blastomeres – Individual cells formed during cleavage.¹

Blastopore – Opening formed by and bordered by the germ ring as it extends over the yolk.¹

Blastula – Stage in embryonic development which represents the final product of cleavage stages, characterized by formation of the blastocoel.¹ A hollow ball of cells formed early in embryonic development.³

Body depth at anus – Vertical depth of body at anus,^{2,3} not including finfolds.³

Body length – A specialized method of measuring, generally applied only to billfishes, and defined by Rivas (1956) as the distance from the tip of the mandible (with jaws closed) to the middle point on the posterior margin of the middle caudal rays.¹

Branched ray – Soft ray with two or more branches distally.^{1,3}

Branchial arches – Bony or cartilaginous structures supporting the gills, filaments, and rakers.^{1,3} gill arches.³

Branchial region – In petromyzontids, area between the anterior margin of the first gill opening and the posterior margin of the last.² The pharyngeal region where branchial arches and gills develop.³

Branchiostegal rays, branchiostegals – Struts of bone inserting on the hyoid arch and supporting, in a fanwise fashion, the branchiostegal membrane.^{1,3} Bony rays supporting the membranes which close the gill (branchial) cavity under the head.²

Buoyant egg – An egg which floats free within the water column; pelagic.^{1,3}

C – Abbreviation for caudal fin.¹

Caeca – Finger-like outpouchings at boundary of stomach and intestine.^{1,3}

Calcareous – Composed of, containing, or characteristic of calcium carbonate.³

Cardiform – Brush-like; referring to teeth of uniform length in patches or bands.²

Catadromous – Fishes which go to sea from rivers to spawn.^{1,3}

Caudal fin – Tail fin.^{1,3}

Caudal peduncle – Area lying between posterior end of anal fin base and base of caudal fin.^{1,3}

Cement glands – Discrete or diffuse structures which permit a larva to adhere to a substrate.^{2,3}

Cephalic – Pertaining to the head.^{2,3}

Ceratohyal – See antero-hyal.³

Cheek – Lateral surface of head between eye and opercle, usually excluding preopercle.^{1,3}

Chevron-shaped – The earliest developmental form of myomeres in larvae; describing the angle formed by the epaxial and hypaxial portions of the myosepta.²

Choroid fissure – Line of juncture of invaginating borders of optic cup; apparent in young fish as a trough-like area below lens.^{1,3} A cleft in outer layers of the eye visible in early larvae.²

Chorion – Outer covering of egg; egg capsule.^{1,3} After water hardening, the outermost membrane of a fish egg.²

Chromatophores – Pigment-bearing cells;^{1,2,3} frequently capable of expansions and contractions which change their size, shape, and color.^{1,3}

Cirrus – Generally small, dermal, flap-like or tentacle-like process on the head or body.¹

Cleavage stages – Initial stages in embryonic development where divisions of blastomeres are clearly marked; usually include 1st through 6th cleavages (2-64 cells).^{1,3}

Cleithrum – Prominent bone of pectoral girdle, clearly visible in many fish larvae.^{1,3} Large bone of support for the pectoral fins.²

Coelomic – Pertaining (belonging) to the body cavity.^{2,3}

Confluent – Coming together to form one.^{2,3}

Ctenoid scale – Scales with comb-like margin; bearing cteni.^{1,3} Scales having small, needle-like projections on the posterior margin.²

Cycloid scale – Scales with evenly curved free border, without cteni.^{1,3}

D – Abbreviation for dorsal fin.¹

Deciduous – Referring to scales that are easily rubbed off and thus not firmly attached.²

Demersal – Refers to aquatic organisms living on or in close association with the substrate (bottom) (Bond 1996).

Demersal egg – An egg which remains on the bottom, either free or attached to substrate.^{1,3} An egg which rests upon the substrate as a result of deposition or settling.² [An egg which sinks to the bottom in still water (negatively buoyant); in currents, unattached demersal eggs may be buoyed upward and carried down current.]

Dentary – Major bony element of the lower jaw, usually bearing teeth.^{2,3}

Dorsal fins – Median, longitudinal, vertical fins located on the back.^{1,3}

Dorsal fin origin – [Anterior-most] point where first dorsal ray or spine attaches to body.¹

Early embryo – Stage in embryonic development characterized by formation of embryonic axis.^{1,3}

Egg capsule – Outer-most encapsulating structure of the egg, consisting of one or more membranes; the protective shell.^{1,3}

Egg diameter – In nearly spherical eggs, greatest diameter; in elliptical eggs given as two measurements, the greatest diameter or major axis and the least diameter or minor axis.^{1,3}

Egg pit – The pit or pocket in a redd (nest) into which a trout female deposits one batch of eggs.³

Emarginate – Notched but not definitely forked, as in the shallowly notched caudal fin of some fishes.^{1,3} Caudal fin possessing a slight notch or indentation.²

Embryonic axis – Primitive differentiation of the embryo; an elongate thickening of blastodermal tissue.¹

Embryonic shield – Thickened shield-like area of the blastoderm at caudal edge of the germ ring.¹

Emergence – The act of leaving the substrate and beginning to swim; swim-up.^{2,3}

Epaxial – Portion of the body dorsal to the horizontal or median myoseptum.^{2,3}

Epihyal – See postero-hyal.

Epurals – Modified vertebrae elements which lie above the vertebrae and support part of the caudal fin.^{2,3}

Erythrophores – Red or orange chromatophores.^{1,3}

Esophagus – Alimentary tract between pharynx and stomach.^{1,3}

Eye diameter – Horizontal measurement (distance) of the iris of the eye.^{2,3} [Horizontal diameter of the externally visible eye.]

Falcate – Deeply concave as a fin with middle rays much shorter than anterior and posterior rays.^{1,3} Scythe-shaped; referring to an anal fin.²

Fin insertion – [As used herein,] posterior-most point at which the fin attaches to the body.³ [More generally refers to entire margin of fin attachment to the body, the fin base.]

Fin origin – Anterior-most point at which the fin attaches to the body.³

Finfold – Median fold of integument which extends along body of developing fishes and from which median fins arise.^{1,3}

FL – Abbreviation for fork length.¹

Flexion larva – Phase between hatching and upward flexing of the tip of the notochord [or appearance of first caudal fin rays] (Ahlstrom et al. 1976).

Flexion mesolarva – Among fishes with homocercal tails, subphase of mesolarval development characterized by an incomplete adult complement of principal caudal-fin rays (posterior portion of notochord flexes upward and standard length measured to end of notochord) (Snyder and Muth 1988, 1990, 2004; see discussion on developmental interval terminology in introduction; presence of yolk indicated by an appropriate modifier).

Focal point – Location of a fish maintaining a stationary position on or off the substrate for at least a 10-second period.³

Fontanelle – A gap or space between bones in the roof of the skull covered only by a membrane.²

Foramen – An opening through a bone.²

Fork length – Distance measured from the anterior-most point of the head to the end of the central caudal rays.^{1,3} Distance from the most anterior point on the snout to the end of the shortest central caudal fin ray.²

Frenum – A fold of skin that limits movement of the upper jaw.^{2,3} [Bridge of tissue tightly connecting anterior portion of upper lip to fleshy portion of snout above (rather than being fully separated by a crease or groove between) and making premaxillaries non-protractile (upper lip not protrusible).]

Ganoid scales – Diamond- or rhombic-shaped scales consisting of bone covered with enamel.^{1,3}

Gape – The border of the mouth.² Distance between the tips of the open jaws of vertebrates (Pennak 1964). Width of gape is the greatest transverse distance across the opening of the mouth (Hubbs and Lagler 1958).

Gas bladder – Membranous, gas-filled organ located between the kidneys and alimentary canal in teleosts; air bladder or swim bladder.^{1,3}

Gastrula – Stage in embryonic development between blastula and embryonic axis.^{1,3}

Germ ring – The thickened rim of the blastoderm evident during late blastula and gastrula stages.¹

Germinal disc – The blastodisc.¹

Gill arches – See branchial arches.^{1,3}

Gill rakers – Various-shaped bony projections on anterior edge of the gill arches.^{1,3} Unless otherwise stated, counts are for all rakers on the first arch [external row] (Hubbs and Lagler 1958).

Glossohyal – A median bone of the tongue.²

Granular yolk – Yolk consisting of discrete units of finely to coarsely granular material.^{1,3}

Greatest body depth – Greatest vertical depth of the body excluding fins and finfolds.^{2,3}

Guanophores – White chromatophores; characterized by presence of iridescent crystals of guanine.^{1,3} [= iridophores.]

Gular fold – Transverse membrane across throat.^{1,3}

Gular plate – Ventral bony plate between anterior third of lower jaws, as in *Amia calva*.¹
Ventral bony plate on throat, as in *Amia calva*.³ Median ventral bony plate or plates located behind the chin and between the sides of the lower jaw.²

Gular region – Throat.³

Haemal – Relating to or situated on the side of the spinal cord where the heart and chief blood vessels are placed.³

Head length – Distance from anterior-most tip of head to posterior-most part of opercular membrane, excluding spine; prior to development of operculum, measured to posterior end of auditory vesicle.^{1,3} Distance from the most anterior point on the snout [including mouth] to the posterior edge of the auditory vesicle, cleithrum or opercle as each develop.² [As used herein, measured instead to the origin of the pectoral fin, or prior to formation of the pectoral fin buds, to the cleithrum.]

Head width – Greatest dimension between opercles.^{2,3} [Unless measured, as herein, at other specified locations such as middle of eye or just behind posterior margin of eye.]

Heterocercal – Tail in which the vertebral axis is flexed upward and extends nearly to tip of upper lobe of caudal fin; fin typically asymmetrical externally, upper lobe much longer than lower.^{1,3}

HL – Abbreviation for head length.¹

Holoblastic – Type of cleavage in which the entire egg, including the yolk, undergoes division.¹

Homocercal – Tail in which the vertebral axis terminates in a penultimate vertebra followed by a urostyle (the fusion product of several vertebral elements); fin perfectly symmetrical externally.^{1,3}

Horizontal myoseptum – Connective tissue dividing epaxial and hypaxial regions of the body;^{2,3} median myoseptum.³

Hypaxial – That portion of the body ventral to the horizontal myoseptum.^{2,3}

Hypochord – A transitional rod of cells which develops under the notochord in the trunk region of some embryos.^{1,3}

Hypochordal – Below the notochord; referring to the lower lobe of the caudal fin.^{2,3}

Hypurals – Expanded, fused, haemal spines of last few vertebrae which support the caudal fin.^{1,3}
The expanded hemal spines of the posterior vertebrae which support most of the caudal fin.²

Incipient – Becoming apparent.^{2,3}

Incubation period – Time from fertilization of egg to hatching.^{1,3}

Inferior mouth – Snout projecting beyond the lower jaw.^{2,3} [As used herein, mouth that is horizontal (or nearly so) and distinctly on underside of head with lips well behind anterior margin of snout.]

Insertion (of fin) – See fin insertion.

Integument – An enveloping layer or membrane.³ Coating or external skin (Pennak 1964).

Internarial – Area between the nares on one side of the head or the other.²

Interorbital – Space between eyes over top of head.^{1,3}

Interorbital width – Least distance between the orbits across dorsum of head.²

Interradial – Area between the fin rays.^{2,3}

Interspaces – Spaces between parr marks of salmonids.^{2,3}

Iridocytes – Crystals of guanine having reflective and iridescent qualities.^{1,3}

Iridophores – See guanophores.

Isocercal – Tail in which vertebral axis terminates in median line of fin, as in Gadiformes,^{1,2,3} caudal fin rays arising symmetrically from it.²

Isthmus – The narrow area of flesh in the jugular region between gill openings.^{1,3} Fleshy space beneath the head and between the gill openings.²

Jugular – Pertaining to the throat.^{1,3} Gular.³

Juvenile – Young fish after attainment of minimum adult fin-ray counts and before sexual maturation.¹ Young fish after attainment of minimum adult fin-ray counts and complete absorption of the median finfold and before sexual maturation.³ [Latter definition used herein—see discussion on developmental interval terminology in introduction].

Keeled – With a ridge or ridges.^{1,3}

Kupffer's vesicle – A small, vesicular, ventro-caudal pocketing which forms as blastopore narrows.¹

Lanceolate – Slightly broad at the base and tapering to a point.²

Larva – Young fish between time of hatching and attainment of minimum adult fin ray counts.¹ Young fish between time of hatching and attainment of juvenile characteristics.³ Encompasses both yolk-sac and post yolk-sac phases of development (Wallus et al. 1990). As used herein, 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 (Snyder and Muth 1988, 1990, 2004; see discussion on developmental interval terminology in introduction; presence of yolk indicated by an appropriate modifier).

Late embryo – Stage prior to hatching in which the embryo has developed external characteristics of its hatching stage.^{1,3}

Lateral line – Series of sensory pores and/or tubes extending backward from head along sides.^{1,3}

Lateral-line scales – Pored or notched scales associated with the lateral line.^{1,3} Count of pores in the lateral line, or the number of scales along the line in the position which would normally be occupied by a typical lateral line from the shoulder girdle to the structural base of the caudal fin (scales wholly on the caudal fin base not included in the count,

even when well developed and pored) (Hubbs and Lagler 1958). [Second definition: lateral-series scales.]

Lateral-series scales – [Number of rows of scales crossing the midlateral surface or lateral line if complete; see second definition by Hubbs and Lagler (1958) for lateral-line scales.]

Lateral teeth – In petromyzontids, teeth of oral disc lateral to esophageal opening.²

Lepidotrichia – Replacements of actinotrichia; soft fin rays or spines.² See actinotrichia.³ Scaly or soft fin rays [typically branched and jointed or segmented, always biserial (laterally divided or paired)]; replacements of [embryonic or larval] actinotrichia in the soft-rayed fishes or the soft-rayed fins or parts of fins of spiny-rayed fishes (Lagler et al. 1962, pp. 59 and 186).

Low-terminal mouth – [As used herein, mouth that is slightly oblique to horizontal with anterior end of upper lip at or below bottom-of-eye level and either even with or the most anterior margin of snout.]

Mandible – Lower jaw, comprised of three bones: dentary, angular and articular.^{1,3}

Maxilla – The posterior, lateral bones of the upper jaw.²

Maxillary – The dorsal-most of the two bones in the upper jaw.^{1,3}

Meckel's cartilage – Embryonic cartilaginous axis of the lower jaw in bony fishes,^{1,3} forms the area of jaw articulation in adults.³

Melanophores – Black chromatophores.^{1,3} [Also brown.] Melanin-bearing pigment cell.²

Mental – Pertaining to the chin.^{1,3}

Meroblastic – Type of cleavage in which only the blastodisc undergoes division.¹

Mesencephalon – Midbrain; serves optic functions.²

Mesolarva – Phase of larval development characterized by presence of at least one dorsal, anal, or caudal-fin spine or ray but either lacking the adult complement of principal soft rays in at least one median (dorsal, anal, or caudal) fin or lacking pelvic-fin buds or pelvic fins (if present in adult) (Snyder and Muth 1988, 1990, 2004; see discussion on developmental interval terminology in introduction; presence of yolk indicated by an appropriate modifier; standard length measured to end of notochord or, when sufficiently developed, axial skeleton).

Mesopterygoid – Middle of three dermal bones of the upper jaw.²

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 pelvic fins (if present in adult) (Snyder and Muth 1988, 1990, 2004; see discussion on developmental interval terminology in introduction; presence of yolk indicated by an appropriate modifier; standard length measured to posterior end of axial skeleton, hypural elements or plates in fishes with homocercal tails).

Metencephalon – Portion of the brain immediately behind the mesencephalon.² [Hind brain.]

Micropyle – Opening in egg capsule through which spermatozoa enter.¹ Principle path of sperm entry through the chorion (vitelline membrane) of an egg.²

Molariform – Referring to a tooth with a flat grinding surface.²

Morula – Stage in development of egg in which blastomeres form a mulberry-like cluster.¹

Myomeres – Serial muscle bundles of the body.^{1,3} [Total myomere count is sum of preanal (to posterior margin of vent) and postanal (post vent) counts and should approximate the number of vertebrae (including Weberian vertebrae in ostariophysian fishes such as cyprinids, catostomids, and ictalurids).]

Myoseptum(a) – Connective tissue partition(s) separating myomeres.^{1,3} Thin partition of connective tissue which joins myomeres.²

Nape – Area immediately posterior to occipital region.¹

Nares – Nostrils, openings leading to the olfactory organs.^{2,3}

Narial – Pertaining to the nares.^{2,3}

Nasal – Pertaining to region of the nostrils, or to the specific bone in that region.^{1,3}

NL – Abbreviation of notochord length.¹

Notochord – Longitudinal supporting axis of body which is eventually replaced by the vertebral column in teleostean fishes.¹

Notochord length – Straight-line distance from anterior-most part of head to posterior tip of notochord; used [as standard length] prior to and during notochord flexion.^{1,3}

Obtuse – With a blunt or rounded end; an angle greater than 90 degrees.^{2,3}

Occipital region – Area on dorsal surface of head, beginning above or immediately behind eyes and extending backwards to end of head;^{1,3} occiput.³

Oil globule(s) – Discrete sphere(s) of fatty material with-in the yolk.^{1,3}

Olfactory buds – Incipient olfactory organs.^{1,3}

Ontogeny – Developmental history of an organism from zygote to maturity (Pennak 1964).

Opercle – Large posterior bone of the operculum.³

Operculum – Gill cover.³

Optic vesicles – Embryonic vesicular structures which give rise to the eyes.^{1,3}

Origin (or fin) – See fin origin.

Otoliths – Small, calcareous, secreted bodies within the inner ear.^{1,3}

Over yearling – Fish having spent at least one winter in a stream; applies to trout and salmon.³

P [or P1] – Abbreviation for pectoral fin.¹

P2 [or V] – [Abbreviation for the ventral or pelvic fin.]

Palatine teeth – Teeth on the paired palatine bones in the roof of the mouth of some fishes.^{1,3}

Palatines – Paired bones on the roof of the mouth, often bearing teeth.²

Parapatric – Distribution of species or other taxa that meet in a very narrow zone of overlap.³

Paravertebral – Along the same plane as the spinal column.²

Parietal – Paired bones of the roof of the skull.²

Pectoral [fin] bud – Swelling at site of future pectoral fin; anlage of pectoral fin.¹

Pectoral fin length – Distance from base to farthest tip of fin.²

Pectoral fins – Paired fins behind head, articulating with pectoral girdle.^{1,3}

Peduncle – Portion of body between anal and caudal fins.^{2,3} [Caudal peduncle.]

Pelagic – Floating free in water column; not necessarily near the surface.^{1,3} Living in the open water habitat, as opposed to bottom living or inshore inhabitants.²

Pelvic bud – Swelling at site of future pelvic (ventral) fins; anlage of pelvic fin.^{1,3}

Pelvic fins – Paired fins articulating with pelvic girdle; ventral fins.^{1,3}

- Periblast** – A layer of tissue between the yolk and cells of blastoderm which is observed as a thin border around blastula.¹
- Pericardium** – Cavity in which the heart lies.^{2,3}
- Peritoneum** – Membranous lining of abdominal cavity.^{1,2,3}
- Perivitelline space** – Fluid-filled space between egg proper and egg capsule.^{1,3} Fluid-filled space between the chorion and yolk material.²
- Pharyngeal teeth** – Teeth on the pharyngeal bones of the branchial skeleton.^{1,3} Bony tooth-like projections derived from the fifth (pharyngeal) gill arch.² In cyprinids, both left and right arches bear 1-3 rows of teeth; counts for each row and arch are given in a formula in order from left to right [rows separated by commas, arches by a dash] (Hubbs and Lagler 1958).
- Physoclistic** – Having no connection between the esophagus and the pneumatic duct [of the swim (air or gas) bladder]; typical of perciform fishes.³
- Physostomus** – Having the swim bladder connected to the esophagus by the pneumatic duct;^{2,3} typical of cypriniform fishes.³
- Plicae** – Wrinkle-like folds found on the lips of some catostomids.^{2,3}
- Post yolk-sac larva** – Phase beginning with complete absorption of the yolk and ending when a minimum adult complement of rays is present in all fins and the median finfold is completely absorbed (Wallus et al. 1990).
- Postanal length** – Distance from posterior margin of anus [or vent] to the tip of the caudal fin,^{2,3} or median finfold.²
- Postanal myomeres** – The number of myomeres between posterior margin of anus and the most posterior myoseptums.¹ Number of whole myomeres posterior to an imaginary vertical line at the most posterior point of the anus [vent],^{2,3} including one urostylar element; the first postanal myomere is the first myomere behind and not touched by the imaginary line.³ [The last myomere lies immediately anterior to the most posterior complete myoseptum.]
- Postero-hyal** – Posterior bone to which branchiostegal rays attach, formerly epihyal.^{2,3}
- Postflexion larva** – Phase following upward flexion of the tip of the notochord [more precisely considered to begin with formation of all principal caudal fin rays] (Ahlstrom et al. 1976).
- Postflexion mesolarva** – Among fishes with homocercal tails, subphase 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) (Snyder and Muth 1988, 1990, 2004; see discussion on developmental interval terminology in introduction; presence of yolk indicated by an appropriate modifier).
- Postorbital length** – Distance from posterior margin of eye to posterior edge of opercular membrane.^{2,3} [Or to origin of pectoral fin, depending on criteria for head length.]
- Preanal length** – Method of measuring often not stated, assumed to be about equivalent to snout to vent length in larvae.¹ Distance from anterior-most part of head to posterior margin of anus.^{2,3} [Snout-to-vent length, herein measured to posterior margin of vent.]

- Preanal myomeres** – The number of myomeres between the anterior-most myoseptum^{1,3} and the posterior margin of anus¹ or an imaginary vertical line drawn at the posterior margin of anus, including any bisected by the line.³ Number of myomeres from the nape to, and including any myomeres bisected by an imaginary vertical line at the most posterior point of the anus.² [As used herein, the most anterior myomere, which is mostly an epaxial unit, is located immediately behind the occiput and often deltoid in shape (somewhat wider at the top), and the last is the most posterior myomere transected by a vertical line from the posterior margin of the vent.]
- Prebranchial length** – In petromyzontids, distance between the tip of the snout and the anterior margin of the first gill opening.²
- Predorsal length** – Distance from the most anterior point on the snout to the anterior margin of the base [origin] of the first dorsal fin ray when formed.²
- Predorsal myomeres** – Number of myomeres from nape to dorsal origin of median finfold.² [Or, to origin of the dorsal fin once anterior-most pterygiophores or fin rays are formed.]
- Predorsal scales** – Scales along dorsal ridge from occiput to origin of dorsal fin.^{1,3}
- Preflexion larva** – Phase between hatching and upward flexing of the tip of the notochord [or appearance of first caudal fin rays] (Ahlstrom et al. 1976).
- Preflexion mesolarva** – Among fishes with homocercal tails, subphase 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 first median-fin ray is a caudal ray, as in most fishes, larva progresses directly from protolarva to flexion mesolarva) (Snyder and Muth 1988, 1990, 2004; see discussion on developmental interval terminology in introduction; presence of yolk indicated by an appropriate modifier).
- Prejuvenile** – Developmental stage [phase] immediately following acquisition of minimum fin ray complement of adult and before assumption of adult-like body form; used only where strikingly different from juvenile^{1,3} (*cf.* Hubbs, 1958; *Tholichthys* stage of butterflyfishes, *querimana* stage of mullets, etc.).¹ [Transitional phase.]
- Premaxilla, premaxillary** – The ventral-most of the two bones included in the upper jaw.^{1,3} Primary bone of the upper jaw in most fish, usually bearing teeth.²
- Preorbital** – Large bone anterior to the eye.²
- Primordium** – Rudimentary form of an anatomical structure; anlage.^{1,3}
- Principal anal- and dorsal-fin rays** – In certain fishes, particularly the Cyprinidae and Catostomidae, . . . the principal rays include the branched rays plus one unbranched ray [the anteriorly adjacent, usually longest, unbranched ray]; . . . the last two bases [branched rays, both of which articulate with the most posterior pterygiophore] are counted as one ray (Hubbs and Lagler 1958). [In traditional fin-ray count formulas, represented by Arabic numerals.]
- Principal caudal [-fin] rays** – Caudal rays inserting on hypural elements; the number of principal rays is generally defined as the number of branched rays plus two [adjacent unbranched rays, one above and one below the branched rays].^{1,3} [In traditional fin-ray count formulas, represented by Arabic numerals.]

Procurrent caudal rays – A series of much shorter rays anterior to the principal caudal rays, dorsally and ventrally, not typically included in the margin of the caudal fin.^{1,3}
[Rudimentary or secondary rays of the caudal-fin; in traditional fin-ray count formulas, represented by lower case Roman numerals (dorsal before and ventral after principal ray count, separated by commas.)]

Pronephric ducts – Ducts of pronephric kidney of early developmental stages.^{1,3}

Protolarva – Phase of larval development characterized by absence of dorsal-, anal-, and caudal-fin spines and rays (Snyder and Muth 1988, 1990, 2004; see discussion on developmental interval terminology in introduction; presence of yolk indicated by an appropriate modifier; standard length measured to end of notochord).

Protractile – Describing premaxillae which can be extended.² [Protrusible.]

Pterygoid – Dermal bone of the upper jaw.²

Pterygiophores – Bones of the internal skeleton supporting the dorsal and anal fins.^{2,3}

Redd – An excavated area or nest into which trout spawn.³

Retrorse – Pointing backward.³

Rostrum – Snout.³

Rudimentary fin rays – [In certain fishes, particularly the Cyprinidae and Catostomidae, size-graded series of shorter, unbranched soft rays anterior to the principal rays of the dorsal, anal, and caudal fins; also called secondary rays or, in the case of the caudal fin, procurrent rays; in traditional fin-ray count formulas, represented by lower case Roman numerals and separated from the principal ray count, in Arabic, by commas.]

Saddle markings – Pigment patterns which cover the dorsal and lateral aspects and give an overall appearance of a saddle.²

Secondary fin rays – See rudimentary fin rays, and with respect to the caudal fin, procurrent rays.

Scute – A modified, thickened scale, often spiny or keeled.^{1,3}

Semibuoyant – Referring to eggs which neither float nor sink, but remain suspended in the water column.^{2,3}

Sigmoid heart – The S-shaped heart which develops from the primitive heart tube.^{1,3}

SL – Abbreviation for standard length.¹

Snout – [Portion of head anterior to eyes and, as used herein, including the portion of the mouth anterior to the eyes (often used in reference only to the fleshy anterior extension of the head above the mouth including the nares).]

Snout-to-vent length – Distance from anterior-most part of head to posterior margin of anus [vent]; the precise method of measurement often not stated.¹ [See preanal length.]

Soft rays – Bilaterally paired, usually segmented, fin supports.^{1,3} [See lepidotrichia; in traditional fin-ray count formulas, principal soft rays of median fins or all rays of paired fins represented by Arabic numerals.]

Somites – Primitive, segmented, mesodermal tissue along each side of notochord.¹ [Consists in part of future myomeres.]

Spatulate – Having a rounded apex and tapering to a base; spoon-shaped.²

Spines – Unpaired [uniseriate, not bilaterally divided], unsegmented, unbranched fin supports, usually (but not always) stiff and pungent.^{1,3} [In traditional fin-ray count formulas, represented by upper case Roman numerals, and if part of a fin with both spines and soft rays, separated from such by a comma, or if in a fully separated section of the fin (e.g., first dorsal fin of some perciform fishes), separated by a dash.]

Spinous rays – [In certain otherwise soft-rayed fish, soft rays that during embryonic or larval development are thickened, fused, and hardened into spine-like structures, sometimes with moderate to strong serrations or barbs along their posterior margins (e.g., spines at the anterior margins of the dorsal and pectoral fins in catfishes, order Siluriformes, dorsal and anal fins in goldfish *Carassius auratus* and carp *Cyprinus carpio*, and dorsal fins of the spiny-rayed cyprinids, tribe Plagopterini, for which the basal portions of certain other dorsal, pelvic, and pectoral fin rays also exhibit spine-like modifications—Hubbs and Lagler 1958, Lagler et al. 1962, and Miller and Hubbs 1960). In formulas for fin-ray counts, fully spinous rays may be designated by Roman numerals like true spines.]

Squamation – Covering of scales.^{2,3}

Standard length – In larvae, straight-line distance from anterior-most part of head to end of hypural elements; not applicable to larvae prior to [or during] notochord flexion (in juveniles and adults measured from most anterior point of snout or upper lip.)¹ In larvae, straight-line distance from anterior-most part of head to the most posterior point of the notochord or hypural complex.^{2,3} [As used herein for fish with homocercal tails, includes notochord length prior to formation of all principal caudal fin rays which signals the end of notochord flexion.]

Stellate – Referring to a melanophore [with pigment] which is expanded into a starlike shape.^{2,3}

Stomodeum – Primitive invagination of the ectoderm which eventually gives rise to the mouth.^{1,3} Primordial mouth; the anterior pitted portion of the embryonic gut.²

Submandibular – Beneath the lower jaw; along the edge of the lower jaw.²

Subterminal mouth – [As used herein, mouth that is slightly oblique to horizontal with anterior margin of upper lip at or below bottom-of-eye level and lips slightly to moderately preceded or overhung by anterior margin of snout; between low-terminal and inferior positions.]

Superior mouth – Condition when the lower jaw extends upward and the mouth opens dorsally.^{2,3} [As used herein, mouth that is strongly oblique with anterior end of upper lip above middle-of-eye level and lower jaw usually the most anterior margin of snout.]

Supramaxilla – Small dermal bone attached posterior and dorsal to the maxilla.²

Supraoral – Above the mouth; referring to the teeth of the oral disc in lampreys which are anterior to the mouth opening.²

Supraoral tooth plate – In petromyzontids, tooth plate immediately anterior to esophageal opening.²

Swim bladder – See gas bladder.

Sympatric – Species inhabiting the same or overlapping geographic areas.³

Tail-bud stage – Stage of embryonic development characterized by a prominent caudal bulge and marked development of cephalic region.¹

Tail-free stage – Stage of embryonic development characterized by separation of the tail from the yolk.¹

Tail length – In petromyzontids, distance from cloacal slit to tip of caudal fin.²

Teleosts – Bony fishes.³

Terminal mouth – Condition when lower and upper jaws are equal in length and the mouth opens terminally.^{2,3} [As used herein, mouth that is moderately oblique with anterior end of upper lip above bottom-of-eye to middle-of-eye level, lips usually even with or the most anterior margin of snout (sometimes slightly behind anterior margin of snout).]

Tessellated – Markings or colors arranged into squares.²

TL – Abbreviation for total length.¹

Total length – Straight-line distance from anterior-most part of head to tip of tail.^{1,3} Distance from the most anterior point on the snout to the most posterior point on the caudal fin or finfold.²

Truncate – Ending abruptly along a vertical line.² Terminate abruptly as if the end were cut off.³

Trunk length – In petromyzontids, distance between posterior margin of last gill opening and cloacal slit.²

Trunk myomeres – In petromyzontids, myomeres between the most posterior gill opening and the cloacal slit.²

Urostyle – Terminal vertebral element in higher teleosts, derived from the fusion and loss of several of the most posterior centra of the more primitive forms;^{1,3} usually modified for caudal fin support.³ Final vertebral segment usually modified for caudal fin support.²

V [or P2] – Abbreviation for the ventral or pelvic fin.¹

Vent – Anus.^{1,3} [Cloacal aperture, includes both anus and end of the uro-genital duct.]

Ventral fins – Paired fins articulating with the pelvic girdle; pelvic fins.¹

Vermiculate – Having wormlike markings.^{2,3}

Villiform – In the form of finger-like projections.²

Vitelline membrane – After water hardening, the membrane surrounding the egg proper (animal and vegetal material).²

Vitelline vessels – Arteries and veins of yolk region.^{1,3}

Vomer – Anterior, median bone of the roof of the mouth (= prevomer).²

Water-hardening – Expansion and toughening of egg capsule due to absorption of water into the perivitelline space.^{1,3} Process of membrane delamination and fluid formation which forms the perivitelline space bordered by the chorion and vitelline membrane.²

Weberian vertebrae – First four vertebrae in cyprinids, catostomids, and ictalurids which are modified to connect the swim bladder to the inner ear.²

Width of perivitelline space – Distance between yolk and egg capsule expressed either as direct measurement or a ratio of the egg diameter.¹ Distance between yolk and outer margin of egg capsule.³ [Technically, measured instead to the inner surface of the chorion.]

Xanthophores – Yellow chromatophores.^{1,2,3}

Yearling – A fish in its second year.³

Yolk – Food reserve of embryonic and early larval stages, usually seen as a yellowish sphere diminishing in size as development proceeds.^{1,3}

Yolk diameter – Greatest diameter of yolk; more accurately measurable prior to embryo formation.^{1,3}

Yolk plug – Yolk within the blastopore.¹

Yolk sac – A bag-like ventral extension of the primitive gut containing the yolk.^{1,3}

Yolk-sac larva – A larval fish characterized by the presence of a yolk-sac.^{1,3} Phase of development from the moment of hatching to complete absorption of the yolk (Wallus et al. 1990).

Yolk-sac length – Horizontal distance from most anterior to most posterior margin of yolk sac.^{2,3}

Yolk-sac depth – Vertical distance from dorsum to venter of yolk sac.²

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Computer-Interactive Key
[Inside back cover]

