Computer-Interactive Key to Sucker Larvae and Early Juveniles of the Upper Colorado River Basin with Description of Longnose Sucker

(Supplemental Update to Colorado Division of Wildlife Technical Publication 38 which together constitute Part 1 of a Comprehensive Guide to the Cypriniform Fish Larvae and Early Juveniles of Western Colorado and the Upper Colorado River Basin)

Recovery Program Project 112

Draft Final Report
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to

Upper Colorado River Endangered Fish Recovery Program

U.S. Department of the Interior Fish and Wildlife Service
Lakewood, Colorado 80225

by

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Larval Fish Laboratory
Contribution
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Aquatic Toxicology/Behavior	Shortcourses/Guest Lectures	Descriptions/Keys/Illustrations

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Except for replacement and new figures listed below, figures referenced in this supplemental update, including the computer-interactive key, are those in Snyder and Muth (1990). Numbers for new figures continue the series from that publication.

List of Key Words

Computer-interactive key, descriptions, identification, larval fish, juvenile fish, bluehead sucker *Catostomus discobolus*, flannelmouth sucker *Catostomus latipinnis*, longnose sucker *Catostomus catostomus*, mountain sucker *Catostomus platyrhynchus*, razorback sucker *Xyrauchen texanus*, Utah sucker *Catostomus ardens*, white sucker *Catostomus commersoni*, Upper Colorado River Basin.

Preface

This project was jointly sponsored. It was initiated with support by Colorado Division of Wildlife (CDOW) through its GO-CO Program and completed with support by the Upper Colorado River Endangered Fish Recovery Program. Under CDOW sponsorship, development of longnose sucker *Catostomus catostomus* larvae and early juveniles was studied and described and illustrated in an initial version of the descriptive species account using a previously preserved developmental series and selected wild-caught specimens in the Larval Fish Laboratory (LFL) Collection (Snyder 2001). Also, ripe adults were acquired and artificially spawned, and culture and preservation of new developmental series was begun for additional study and description. Under Recovery Program sponsorship, culture and preservation of the new developmental series was completed and, as presented in this final report, descriptive data and an additional illustration from the new series have been incorporated in the longnose sucker species account, corrections and new data and illustrations for existing descriptions of other suckers in Snyder and Muth (1990) have been documented, the "Comparative Summary" therein has been updated and expanded, and the keys therein have been replaced with an updated and expanded computer-interactive key. This final report to the Recovery Program, with appropriate modification of format (to that required by the chosen publication outlet), the cover page, this preface, and recommendations, constitutes a manuscript for supplemental update of Snyder and Muth (1990).

Executive Summary

Collections of the early life stages of fish are essential to research on and monitoring of fish spawning sites and seasons, larval production, transport, distribution, nursery habitat, and survival, as well as other aspects of early life history. Such research cannot proceed effectively without accurate identification of at least the target species. However, morphological identification requires knowledge of the appearance of not only the target species, but all similar species in the waters sampled and the diagnostic criteria for segregating them.

For the early life stages of most species, morphological criteria for identification change dramatically as the fish grow and develop, and when species are closely related or otherwise very similar in appearance, as in the case of catostomids (suckers) and many cyprinids (minnows) in the Upper Colorado River Basin (UCRB), diagnosis becomes especially difficult and complicated. Still, the 1990 Colorado Division of Wildlife (CDOW) guide to the larvae and early juveniles of six of seven catostomids in the UCRB (Snyder and Muth 1990) has served CDOW, the Upper Colorado River Endangered Fish Recovery Program, and other regional researchers well. But species coverage is incomplete, some descriptive data needs to be updated, and users have found its very long and intricate set of printed keys formidable, inflexible, and occasionally in error.

The goal of this project was to facilitate more accurate identification of larval and early juvenile suckers collected in western Colorado and the UCRB. The primary objective was to update and complete the 1990 guide to catostomids (Snyder and Muth 1990) as Part 1 of a comprehensive guide to the larvae and early juveniles of cypriniform fishes in the region. This was accomplished by preparation of a manuscript (this final report) for subsequent publication as

a supplement to the 1990 guide. Included in this manuscript are updated descriptive information for the species covered in the guide, a comparable descriptive species account for longnose sucker, an updated and expanded comparative summary, and a new computer-interactive key (program and files on compact disk) to correct, update, and expand upon the existing printed keys. A secondary objective of the project was to provide proof-of-concept for the effective application of a relatively new taxonomic tool for larval-fish identification, the computer-interactive key. Both objectives were successfully accomplished.

In an associated investigation sponsored by CDOW, an interim descriptive species account with detailed drawings was prepared and an effort to rear a new developmental-study series was begun for longnose sucker (Snyder 2001). The species account was based on a previously reared, but abbreviated, series of larvae from an east-slope population and positively identified juveniles collected from the Gunnison River. The new culture effort, also from east-slope populations, and description of the species was completed with this project. In addition to the completed species account, descriptive data for longnose sucker also were used in the updated and expanded "Comparative Summary" and "Computer-Interactive Key." With some adjustments for use of computer imaging technology, methods for developmental study of longnose sucker, including analysis of morphometric, meristic, pigment, and developmental-state characters; clearing and alizarin-red staining of whole specimens for skeletal study; illustration; and data analysis and summarization generally followed Snyder and Muth (1990).

Through the years since publication of the 1990 guide (Snyder and Muth 1990), mistakes in that guide were noted by the authors, reviewers, and users; character-range extensions for most described species were recorded by Larval Fish Laboratory (LFL) and other researchers; and for white sucker *C. commersoni*, better drawings for two larval stages became available. These, with

appropriate amendments, were compiled in a list of errata and updated descriptive data for the affected sections of the guide and incorporated in the revised "Comparative Summary" and new "Computer-Interactive Key."

Based on prior experience and comparison with several alternatives, the DELTA program for computer-interactive keys, *Intkey* (Dallwitz et al.1993 onwards, 1995 onwards), which operates under Microsoft *Windows 95* or later, was selected as the host program for the new key. *DELTA Editor* (Dallwitz et al. 1999 onwards) was used to develop and refine a progressive series of data sets for UCRB suckers and the derived data files required by *Intkey*. Like the printed keys, a set of preliminary keys prepared prior to this project and early interim versions developed during this project consisted of six keys, one for each developmental period or phase. These early interim-version keys were demonstrated and discussed with opportunities for hands-on experimentation at three technical meetings. Based on participant feedback, the separate data sets and keys were combined into one for later versions. Late-interim and near-final versions of the key were subjected to in-house testing.

The final key, provided on the enclosed CD-ROM and over the Internet, consists of a data set for 110 characters and 234 taxon items (species subdivided by developmental interval and size) with associated image, text, and controlling files for use by *Intkey*. Instructions for installation and general use are provided in this report; detailed user and help files are built into the program. Although *Intkey* can make extensive use of taxon and character-state-selection images, preparation and inclusion of such was neither critical for operation of the key nor logistically and budgetarily feasible for this project. Instead, the key is intended to be used along with descriptions in the 1990 guide and this supplemental update, and, except for three character-state images included mostly as examples, it refers extensively to figures in these documents.

Whether the goal of facilitating more accurate identification of collected razorback and other sucker larvae in the basin is realized beyond LFL staff depends on the extent to which other regional biologists become familiar with and utilize the updated descriptive information, new species account, and key. In addition to limited distribution of the new, revised, and supplemental information and the new key through this final report, more formal publication and broader distribution as either a supplemental update to the 1990 guide or the updated and expanded material in a new edition of the guide is proposed.

The usefulness of the updated and expanded guide and the new key can extend well beyond the UCRB. Allowing for potential differences in developmental morphology exhibited by remote populations, they can be used for identification wherever two or more of the covered species may occur.

Future updates, expansions, or adaptations of the computer-interactive key provided herein could be made more convenient, especially for new and less experienced users, by incorporating extensive illustration of character states and taxa rather than referring users to illustrations in published descriptions. But even without extensive illustration, this key has great potential for future expansion or adaptation to cover catostomid fishes in other regions and cyprinid fishes in the UCRB and elsewhere.

Except for formal publication, Part 1 of a comprehensive guide to cypriniform fishes in the UCRB is now complete. It is recommended that the Recovery Program and CDOW proceed with support for Part 2–a comparable guide and key to the cyprinid fishes, including three of the four endangered species in the basin.

Introduction

Collections of the early life stages of fish are essential to research on and monitoring of fish spawning sites and seasons, larval production, transport, distribution, nursery habitat, and survival, as well as other aspects of early life history. Such research cannot proceed effectively without accurate identification of at least the target species. However, morphological identification requires knowledge of the appearance of not only the target species, but all similar species in the waters sampled and the diagnostic criteria for segregating them. For the early life stages of many species, including the suckers and minnows of the Upper Colorado River Basin (UCRB, Fig. 97), morphological criteria for identification change dramatically as the fish grow and develop, making diagnosis especially difficult and complicated. This is exemplified by the 60-page set of keys in the Colorado Division of Wildlife (CDOW) guide by Snyder and Muth (1990) which covers the larvae and early juveniles of just six of seven catostomids (suckers) in the UCRB. Descriptive information and diagnostic criteria must be well founded, sufficiently detailed, and documented in such a way that they are retrievable, usable, and verifiable by any interested researcher.

Covering the larvae and early juveniles of native-endangered razorback sucker *Xyrauchen texanus*, native bluehead sucker *Catostomus discobolus*, mountain sucker *C. platyrhynchus*, and flannelmouth sucker *C. latipinnis*, and non-native (introduced) Utah sucker *C. ardens* and white sucker *C. commersoni*, the 1990 guide (Snyder and Muth 1990) has served CDOW, the Upper Colorado River Endangered Fish Recovery Program, and other regional researchers well. But species coverage of the document is incomplete, some descriptive data needs to be updated, and

users have found its very long and intricate set of polychotomous keys formidable, inflexible, and occasionally in error.

Longnose sucker *C. catostomus* was not included in the 1990 guide (Snyder and Muth 1990) because of budgetary limitations and the improbability of encountering its larvae or early juveniles in Recovery Program collections. However, with collection of a significant number of juvenile longnose sucker and many larvae suspected to be longnose sucker or hybrids in the lower Gunnison River in 1993, confidence in identification of those and other suckers, was compromised, and the need to comparably describe and incorporate the last of the UCRB suckers in the keys became evident. Existing descriptions of longnose sucker larvae by Fuiman and Witman (1979; partially reproduced in Auer 1982 and Kay et al. 1994) and Sturm (1988) lack much of the descriptive data and detail needed to directly compare them with potentially sympatric species described by Snyder and Muth (1990).

Intricate printed keys, such as the one in Snyder and Muth (1990), are very difficult to prepare, correct, update, or expand, in part because each change cascades through most subsequent portions of the key. As a modern alternative, computer-interactive keys are much easier to prepare and modify, and users find them much more flexible and user-friendly (Dallwitz et al. 2000 onwards). Among other features, users can limit consideration to only likely candidate species, elect to have available characters listed in most diagnostic order, and select from that list in any desired sequence, bypassing characters that are unfamiliar, difficult to assess, or based on structures that are damaged or missing.

The goal of this project was to facilitate more accurate identification of the larvae and early juveniles of endangered razorback sucker and other suckers collected in the UCRB, including longnose sucker in the lower Gunnison River or wherever else it might occur in the

basin. The primary objective was to update and complete the 1990 guide to suckers (Snyder and Muth 1990) as Part 1 of a comprehensive guide to the larvae and early juveniles of cypriniform fishes in the region. This was to be accomplished by preparation of a manuscript (this final report) for subsequent publication as a supplement to the 1990 guide. The supplement would include updated descriptive information for the species covered in that guide, a comparable descriptive species account for longnose sucker, an updated and expanded comparative summary, and a new computer-interactive key or keys (program and files on diskette or compact disk) to correct, update, and expand upon the existing printed keys. A secondary objective of the project was to provide proof-of-concept for the effective application of a relatively new taxonomic tool to larval-fish identification, the computer-interactive key.

Methods

Specimens Examined

Description of the larvae and early juveniles of longnose sucker was based on specially assembled developmental series that were laboratory-reared in 1979 and 2001 from eastern-slope, north-central Colorado populations and selected collections of wild early juveniles (young-of-the-year) from the lower Gunnison River in 1993 and 1995. Ninety-eight (98) specimens were examined and analyzed in detail, 57 specimens were cleared and stained with alizarin red for examination of skeletal features, and still others were cursorily examined for extremes in developmental state or pigmentation. Specimens were either fixed in 10% formalin and

subsequently preserved in phosphate-buffered 3% formalin or preserved directly in 95% ethanol without formalin fixation. All specimens are maintained as part of the LFL Collection.

Specimens analyzed, examined, or illustrated in detail were individually cataloged as:

LFL# 6690 (1 specimen; 37.0 mm TL, total length) — Collected 7 September 1993 from Gunnison River km 96.1, Delta County, CO, by USFWS; formalin.

LFL# 6837 (1 specimen; 38.5 mm TL) — Collected 7 September 1993 from Gunnison River km 83.7 by USFWS; formalin.

LFL# 26446 (1 specimen; 34.7 mm TL) — Collected 19 September 1995 from Gunnison River km 55.7 by USFWS (Burdick, et al.); formalin.

LFL# 67261-67263, 67265, 67274-67275, 67277-67278 (8 of 166 specimens from LFL# 26647; 21.1-38.0 mm TL) — Collected 21 September 1995 from Gunnison River km 94.0 by USFWS (Burdick, et al.); formalin.

LFL# 67264, 67273, 67276 (3 of 10 specimens from LFL# 26520; 25.1-30.6 mm TL) — Collected 19 September 1995 from Gunnison River km 80.0 by USFWS (Burdick, et al.); formalin.

LFL# 67266-67267 (2 of 7 specimens from LFL# 6799; 42.5-46.0 mm TL) — Collected 7 September 1993 from Gunnison River km 84.0 by USFWS; formalin.

LFL# 67268, 67272 (2 of 4 specimens from LFL# 6703; 32.8-48.8 mm TL) — Collected 7 September 1993 from Gunnison River km 95.5 by USFWS; formalin.

LFL# 67269-67270 (2 of 39 specimens from LFL# 6758; 46.2-50.2 mm TL) — Collected 7 September 1993 from Gunnison River km 89.5 by USFWS; formalin.

LFL# 67271 (1 of 10 specimens from LFL# 6899; 42.8 mm TL) — Collected 7 September 1993 from Gunnison River km 83.1 by USFWS; formalin.

LFL# 67220-67260 (41 specimens, 7.6-19.9 mm TL) — From developmental series that was laboratory-reared in 1979 by LFL (E. Wick, et al.) from Parvin Lake stock, Larimer County, CO; formalin.

LFL# 81460-81495 (36 specimens, 8.9-47.2 mm TL) — From developmental series that was laboratory-reared in 2001by LFL (S. Seal, et al.) from Upper Big Creek Lake stock, Jackson County, CO (brood 1); formalin.

LFL# 81496-81526 (57 specimens, 15.0-77.3 mm TL) — From developmental series that was laboratory-reared in 2001by LFL (S. Seal, et al.) from Upper Big Creek Lake stock, Jackson County, CO; originally in formalin or ethanol, cleared and stained with alizarin red for skeletal study, and since preserved in 100% glycerol.

Of the above, specimens specifically used for drawings were cataloged as:

LFL# 67223 (8.5 mm TL) — recently hatched protolarva, primary drawing specimen.

LFL# 67222 (7.6 mm TL) — recently hatched protolarva, secondary drawing specimen.

LFL# 67229 (10.6 mm TL) — later protolarva, primary drawing specimen.

LFL# 67228, 67230 (10.2-11.1 mm TL) — later protolarva, secondary drawing specimens.

LFL# 67235 (12.5 mm TL) — recently transformed flexion mesolarva, primary drawing specmen.

LFL# 67236-67237 (12.5-12.7 mm TL) — recently transformed flexion mesolarva, secondary drawing specimens.

LFL# 67245 (15.1 mm TL) — recently transformed postflexion mesolarva, primary drawing specimen.

LFL# 67243-67244 (14.8-14.9 mm TL) — recently transformed postflexion mesolarva, secondary drawing specimens.

LFL# 67253 (17.5 mm TL) — recently transformed metalarva, primary drawing specimen.

LFL# 67254-67257(17.5-18.5 mm TL) — recently transformed metalarva, secondary drawing specimens.

LFL# 81460 (22.5mm TL) — later metalarva, primary drawing specimen.

LFL# 81461-81462 (21.2-21.7 mm TL) — later metalarva, secondary drawing specimens.

LFL# 67263 (27.8 mm TL) — recently transformed juvenile, primary drawing specimen.

LFL# 67261-67262, 67264-67265 (26.7-27.8 mm TL) — recently transformed juvenile, secondary drawing specimens.

LFL# 6990 (37.0 mm TL) — later juvenile, primary drawing specimen.

LFL# 6837, 67265 (38.0-38.5 mm TL) — later juvenile, secondary drawing specimens.

Additional specimens in the reared series, including eggs, were cursorily examined or measured and returned to the lot of specimens with which they were preserved. The source developmental series for these specimens were cataloged as:

LFL# 67168-67219 (104 embryos, 2.3-3.0 mm dia.; 917 larvae-juveniles, 7.5-19.4 mm TL) — reared in 1979; formalin.

LFL# 81190-81279 (154 embryos, 2.4-2.6 mm dia.; 508 larvae-juveniles, 7.0-53 mm TL) — reared in 2001, brood 1; formalin.

LFL# 81336-81406 (8 embryos, 2.2-2.6 mm dia.; 417 larvae-juveniles, 7.4-43 mm TL) — reared in 2001, brood 1; ethanol.

LFL# 81280-81335 (36 embryos, 2.4-2.8 mm dia.; 165 larvae-juveniles, 7.5-25.5 mm TL) — reared in 2001, brood 2; formalin.

LFL# 81407-81459 (19 embryos, 2.2-2.6 mm dia.; 163 larvae-juveniles, 5.0 (abnormal) -29 mm TL) — reared in 2001, brood 2; ethanol.

The source or location of specimens upon which selected character range extensions are based are documented in with those updates in the results section "Errata and Updated Descriptive Data for the guide by Snyder and Muth (1990)."

Culture and Developmental Study

As indicated in the above list, many study specimens were part of a developmental series of longnose sucker that had been reared in 1979 from Parvin Lake (Larimer County, Colorado) stock by E. Wick and other LFL staff. Unfortunately, that rearing effort was terminated before many specimens became metalarvae.

To supplement the 1979 series and collected early juveniles used for this description, and to provide better representation of morphological diversity in the description, additional series of embryos, larvae, and early juveniles were reared from two artificially spawned broods in 2001. Like the earlier 1979 series, both broods were the progeny of captures from eastern-slope populations in north-central Colorado; attempts to secure ripe adults from western Colorado populations were unsuccessful. One brood was the progeny of a single pair of un-injected fish from among several adults captured and transported for this purpose by CDOW biologist K. Kehmeier and crew from Upper Big Creek Lake in Jackson County. The other brood consisted of the offspring from a much less successful fertilization using hormone-injected (HCG) fish--another female from among the Upper Big Creek Lake captures and a small male captured by S. Seal from the Spring Creek drainage in Fort Collins, Larimer County. The collection, holding,

and use of longnose suckers in or near spawning condition was permitted under Colorado State (scientific-collection) License 01-AQ902.

Adult fish were held, hormone injected if necessary, stripped of gametes, and euthanized, and artificially fertilized eggs and subsequent progeny reared, euthanized, and preserved in Colorado State University's indoor Aquatic Research Laboratory (Department of Fishery and Wildlife Biology) with the approval of the university's Animal Care and Use Committee (Animal Welfare Assurance Number A3572-01, Protocol Number 00-313A-01). The eggs for both broods were maintained in a flow-through Heath incubator, and upon hatching, the larvae were transferred for subsequent rearing to small net boxes suspended in partially shaded flow-through troughs and later directly into the troughs themselves. The incubator and troughs were served with filtered well water at about 18 °C. Eggs were treated once with malachite green for fungus and the larvae were fed live, and later frozen, brine shrimp as well as dry flake and semi-moist particulate food. Parallel developmental series of specimens from each brood were either fixed in 10% formalin and preserved in phosphate-buffered 3% formalin or preserved directly in 95% ethanol without prior formalin fixation. Additional details of collecting trips, adult longnose sucker captures, artificial fertilization of eggs, culture, and preservation are provided by Snyder (2001).

Methods for developmental study of longnose sucker larvae and early juveniles, including analysis of morphometric, meristic, pigment, and developmental-state characters; clearing and alizarin-red staining of whole specimens for skeletal study; illustration; and data analysis and summarization generally followed Snyder and Muth (1990). However, most morphometric measurements were made using multiple digital images of the specimens and a computer image-analysis and measurement program (Optimas 5.1, Optimas Corp., Seattle). Also, digital images,

rather than photographs, were enlarged and traced for major outlines and features in drawings and to illustrate selected skeletal characters. Images were captured by computer through a digital camera attached to a low-power stereo-zoom microscope or macro-zoom lens. Drawings were professionally scanned as TIFF files at resolutions suitable for publication and subsequent reduction, manipulation, and conversion for other print and computer-display purposes. Developmental intervals referenced herein and used as a framework for description and the key (embryonic, protolarval, flexion mesolarval, postflexion mesolarval, metalarval, and early juvenile) are also discussed and defined by Snyder and Muth (1990). Common and scientific names follow Robins et al. (1991).

All descriptive data for longnose sucker are summarized in a descriptive species account comparable to those in Snyder and Muth (1990) or an update and expansion of the "Comparative Summary" in that guide. Most of those data are also used and accessible in the computer-interactive key. The illustrations of longnose sucker larvae and early juveniles are presented as part of the species account. Illustrations and much or the tabulated descriptive data in the species account were presented as a poster at the 2002 meeting of Recovery Program Researchers in Moab, Utah, 16-17 January, and American Fisheries Society Colorado-Wyoming Chapter in Laramie, Wyoming, 26-27 February.

Corrections and Updates

Through the years since publication of Snyder and Muth (1990), mistakes in that guide have been noted by the authors, reviewers, and users; character-range extensions for most described species have been recorded based on atypical specimens examined or processed by

LFL or other researchers; and for one species, better drawings for two larval stages have become available. Unfortunately, some records connecting character-range extensions to specific LFL-cataloged or client-maintained specimens have been lost. Appropriate amendments to the affected sections of the guide are listed in results or incorporated, with descriptive data for longnose sucker, in the revised "Comparative Summary" and new "Computer-Interactive Key." New drawings representing recently hatched protolarvae and mid-phase metalarvae of white sucker were prepared for a comparative description of Rio Grande sucker *C. plebeius* by Snyder (1998). Those drawings are reproduced in results as substitutes for the corresponding illustrations in the 1990 guide.

Computer-Interactive Key

Most computer-interactive keys are data sets designed to be used with specific commercial, public-domain, or proprietary programs for that purpose. The features and flexibility of several computer-interactive key programs were compared. Upon deciding to stay with the DELTA program *Intkey* (Dallwitz et al.1993 onwards, 1995 onwards), with which I had some prior experience, I downloaded the latest versions of *Intkey*, *DELTA Editor* (Dallwitz et al. 1999 onwards), and associated programs and files from the Internet (http://biodiversity.uno.edu/delta/). *DELTA Editor* was used to develop and refine a progressive series of data sets for UCRB suckers and the derived data files required by *Intkey*. Rich-text files accessed by *Intkey* were prepared or modified with a word-processor program (Corel *WordPerfect* or Microsoft *Word*). Image files used by *Intkey* were created or modified from

scanned files with a computer drawing or presentation programs (Microsoft *PhotoDraw* or *PowerPoint*).

Like the printed keys, a set of preliminary keys prepared prior to this project and each set of early interim versions developed during this project consisted of six keys, one for each developmental period or phase (including a single-character key for embryos based on egg diameter). These early interim-version keys were demonstrated and discussed with opportunities for hands-on experimentation at three technical meetings in 2002–the 23rd Annual Recovery Program Researchers Meeting in Moab, Utah, 16-17 January; the annual meeting of the Colorado-Wyoming Chapter of the American Fisheries Society in Laramie, Wyoming, 26-27 February; and the 26th annual Larval Fish Conference in Bergen, Norway, 22-26 July. The interest generated in the keys, and computer-interactive keys in general, during these presentations and hands-on sessions was encouraging. Participant feedback, however, suggested that keys could be best improved by combining them into one key covering all developmental intervals.

Accordingly, the separate data sets and keys were combined into one for later interim versions with either characters or taxa subdivided according to developmental interval and size. Near final versions of the data set and key were prepared with subdivided taxa, mostly because subdivided characters incurred more character-dependency problems (availability of certain characters depending on the character state selected for a controlling character–e.g., if yolk is not present, yolk-related characters should be made unavailable).

Although *Intkey* can make extensive use of taxon and character-state-selection images, preparation and inclusion of such was neither critical for operation of the key nor logistically and budgetarily feasible for this project (if desired, they can be prepared and incorporated at some

future date). 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, I extensively referenced illustrations in Snyder and Muth (1990) and this report, which means that both documents should be handy when using the key. However, as examples of how character-state-selection images function, I did prepare and include such for three characters–developmental phase, standard length (SL), and phases of gut development.

Interim and near final versions of the key were subjected to in-house testing, mostly in the routine processing of UCRB collections, and refined accordingly. Although additional testing by outside researchers was originally planned, such was precluded by delays in completing the latest versions of the key. However, a near-final version was sent to M. Dallwitz for review. Further refinements of the key, beyond this project, will likely be implemented as needed based on reviews and user feedback, also as the key is further expanded or adapted for other regions and species. An introduction to and instructions for installing and using the key were also prepared and reviewed in house.

Results and Discussion

These results amend, update, and complete the descriptions and keys for UCRB sucker larvae and early juveniles in the CDOW guide by Snyder and Muth (1990). Specific corrections and updates (due mostly to character range extensions) are listed immediately below. Based on those corrections and updates, as well as study of reared and collected longnose sucker, expanded updates of the "Comparative Summary" and "Keys" sections of that guide follow. A species

account for longnose sucker comparable to those at the end of the guide is similarly provided at the end of this section, in part to maintain an internal sequence of tables and figures consistent with the guide. Except for replacement tables in the updated "Comparative Summary" and additional tables in the new species account, all table and figure references are to those in Snyder and Muth (1990).

Errata and Updated Descriptive Data for the guide by Snyder and Muth (1990)

All working copies of the guide should be manually amended with the following changes, except those listed for the "Results and Conclusions–Comparative Summary" and "Results and Conclusion–Keys" which, except for the figures in or referenced therein, are to be replaced by the new "Comparative Summary" and "Computer-Interactive Key" provided later in this supplemental update.

A combined developmental interval terminology. —

Page 6, text box, mesolarva: correct from "in all median (dorsal, anal, and caudal) fins" to "in at least one median (dorsal, anal, or caudal) fin."

Characteristics useful in identification of cypriniform fish larvae. —

Page 10, paragraph 2, sentence 4: correct from "preanal to postanal myomere proportion" to "postanal to preanal myomere proportion" (Error identified by Fuiman 1991.)

Page 12, paragraph 1, sentence 4: correct from "used to diagnosis" to "used to diagnose." (Error identified by Fuiman 1991.)

Comparative summary. —

Page 24, Table 1, *C. ardens*: update onset of pelvic fin buds to "13-14(15)" mm SL.

Page 24, Table 1, *C. discobolus*: update phase transition meso- to metalarva to "(15-)17" mm SL, yolk assimilated to "(10-)12-13(14)," fin rays first observed in dorsal fin to "(11-)13(14)" (based on 13.6 mm SL postflexion mesolarva in LFL# 80454), fin rays first observed in pelvic fin to "(15)16" mm SL, and full fin-ray count first observed in anal fin (principal rays) to "(15-)17" mm SL.

Page 24, Table 1, *C. latipinnis*: update phase transition flexion to postflexion mesolarva to "(14)15(16)" mm SL, yolk assimilated to "(14)15(16)" mm SL, and full counts first observed for principal caudal fin rays to "(14)15(16)" mm SL. (Based in part on mesolarvae collected from the Yampa River in 1976 and 1977–LFL# 69949, 69951, 69952, 69975.)

Page 24, Table 1, *C. platyrhynchus*: correct fin rays first observed in anal fin to "14-15" mm SL and full series of lateral series scales first observed to "32-38."

Page 24, Table 1, *X. texanus*: correct principal caudal fin rays first observed to "(10)11(12)" mm SL and full count of principal caudal first observed to "(11)12-13" mm SL.

Page 24, Table 1, *X. texanus*: update onset of pelvic fin buds to "(13)14" mm SL, dorsal fin rays first observed to "13-14" mm SL, anal fin rays first observed to "(13-)15" mm SL, pectoral fin rays first observed to "(13-)15" mm SL, and pelvic fin rays first observed to "(13-)15-17" mm SL." (Based on observations by Martinez 1996 and, for pelvic fin buds and dorsal fin rays first observed, a specimen collected from the San Juan River in 2001–Museum of Southwestern Biology Accession# 2001-IV:17, Collection# WJB01-134.)

Page 25, Table 2 caption, last sentence: correct from "Data ... is given" to "Data ... are given." (Error identified by Fuiman 1991.)

Page 25, Table 2, vertebrae: correct by shifting “(44-48)” from under *C. latipinnis* to under *C. commersoni*, “(45-50, 47-49)” from under *C. platyrhynchus* to under *C. discobolus*, and “(42-48, 44-47)” from under *X. texanus* to under *C. platyrhynchus*.

Page 26, Table 3 caption, sentence 2: correct from "all data is given as a percentage of standard length." to "all data are given as percentages of standard length." (Error identified by Fuiman 1991.)

Page 28, Table 4, *X. Texanus*, Body pigmentation, protolarvae: update unpigmented to “≤11" mm SL and 1-12 spots on dorsum to “8-12" mm SL. (Based on observation of 0-12 melanophores on the dorsum of 10.5-11.4 mm SL protolarvae and flexion mesolarvae collected from the Green River at River kilometer 302.9, Cliff Creek, Utah on 23-30 May 2001–LFL# 80501-80504, 80506, 80508-80509, 80513, and 80515-80516.)

Page 29, Table 5, Key to pigment characters and states, characters 1, 7, and 8: update for consistency (states in ascending order) by reversing numbering and order of states with corresponding changes to taxon states in the table.

Page 29, Table 5, Key to pigment characters and states, character 2, pigment over ventral to ventro-lateral surfaces of gill covers: update state 2 to “consisting of or including a distinct . . . along margin of one or both preopercles” and state 3 to“present but not consisting of or including a distinct . . . along margin of either preopercle,” then reverse the order and number of those two states (2 to 3 and vice versa), with corresponding changes to taxon states in the table.

Page 29, Table 5, Key to pigment characters and states, character 5, dorsal body pigmentation between head and last myomere: update character to append "(for specimens with 13 or more melanophores on dorsal surface)" and state 2 to replace "including" with "not scattered or scattered with. . . .," then reverse state order and numbers (1 to 2 and vice versa) and change taxon states in the table accordingly. (Changes necessitated for clarity and in part by observation of 0-12 melanophores on the dorsum of 10.5-11.4 mm SL protolarvae and flexion mesolarvae collected from the Green River at River kilometer 302.9, Cliff Creek, Utah on 23-30 May 2001–LFL# 80501-80504, 80506, 80508-80509, 80513, and 80515-80516.)

Page 29, Table 5, Key to pigment characters and states, character 9, state 2: update to ". . . resulting in a herringbone pattern."

Page 29, Table 5, Key to pigment characters and states, character 16: update character to "Mid-lateral surface of body" and all states by replacing "large, distinct, mid-lateral body spots" with "distinct, near-eye-size spots of pigment," then state numbers 3 to 4 and 2 to 3 and insert new state 2 "with 1 distinct, near-eye-size spot of pigment on caudal peduncle near base of caudal fin."

Page 29, Table 5, Key to pigment characters and states, character 19, pigment in dorsal fin: update state 1 to "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)" and state 2 to "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 fin rays."

Page 29, Table 5, Key to pigment characters and states, character 22, pigment in caudal fin: update state 1 to “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),” state 2 to “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 fin rays, ” and add new state 3 “extensive along principal fin rays and notably present (more than just a few melanophores) to extensive only on proximal portions of membranes between some or all principal fin rays.”

Page 29, Table 5, Protolarvae: update with addition of character 5, character state “1/ 2(r)” for *C. discobolus*, and character state “1" for all other taxa.

Page 29, Table 5, Flexion Mesolarvae, character 5: update character states to “1/ 2” for *C. discobolus*, “1/ 2(r)” for *C. platyrhynchus*, and “1" for all other taxa.

Page 29, Table 5, Postflexion Mesolarvae: update with addition of character 5, character state “1/ 2(r)” for *X. texanus*, and character state “1-2" for all other taxa.

Page 29, Table 5,: update with addition of character 7 and character states “1/ 2(r)” for *C. ardens* and *C. latipinnis*, “1(r)/2/3(r)” for *C. commersoni*, “1/ 2-3(r)” for *C. discobolus*, “1(r)/2" *C. platyrhynchus*, and “1/ 2 for *X. texanus*.

Page 29, Table 5, Metalarvae: update with addition of character 22, character state “1-2" for *X. texanus*, and character state “1" for all other species.

Page 29, Table 5, *C. ardens*: update flexion mesolarva character 1 to “1-3/4-5(r)” and postflexion mesolarva character 1 to “1(r)/2/3-5(r)” (based on specimens in LFL# 13 from Strawberry

Reservoir, Utah, and following reordering of character states as specified above), and juvenile character 16 to “1 /3(r)” in accord with above changes in defined character states.

Page 29, Table 5, *C. discobolus*: update metalarva character 21 to “1-2/3(r)."

Page 29, Table 5, *C. commersoni*: update juvenile character 16 to “1 /2(r)/4" in accord with above changes in defined character states for the character.

Page 29, Table 5, *C. latipinnis*: update flexion mesolarva character 1 and postflexion mesolarva character 1 to “3-4/5(r)” and metalarva character 21 to “1 /2(r).”

Page 29, Table 5, *C. platyrhynchus*: update flexion mesolarva character 1 to “1-2/3(r), ” postflexion mesolarva character 1 to “1 /2-4(r),” and metalarva character 1 to “1-3/4(r).” (Based on postflexion mesolarvae in the LFL Collection from Strawberry Reservoir, Utah, and interpolation between observations for bounding phases.)

Page 29, Table 5, *X. texanus*: update juvenile character 22 to “1(r)/2."

Page 31, paragraph 3, sentence 2: correct from “flannelmouth” to “mountain.”

Page 34, Fig. 8 caption: correct from “inter-neurals” to “interneurals.”

Page 34, Fig. 8 caption: update from “subgenus *Catostomus*” to “subgenus *Catostomus* (except *C. catostomus*).”

Page 35, Fig. 9 caption: correct from “only juveniles” to “early juveniles.”

Keys. — Corrections or updates that are too complex to implement without a complete rewrite of the affected sequences in the printed key are indicated with an asterisk (*); however, all corrections and updates are effectively incorporated in the new computer-interactive key.

Page 47, Flexion Mesolarvae, Step 1: update to include option "g. 16 mm . . . . *C. latipinnis*." (Based in part on mesolarvae collected from the Yampa River in 1976 and 1977–LFL# 69952 and 69975.)

Page 47, Flexion Mesolarvae, Step 2: correct option b from "absent . . . . . *C. commersoni*" to "absent . . . . . 6" and add back reference to Step 2 in Step 6.

Page 47, Flexion Mesolarvae, Steps 4-6: update Step 4 option b to "≤4% SL . . . .6," delete Step 5, and update back reference in Step 6 from "5" to "4" to account for rare possibility of 14-mm-SL *C. latipinnis*" having a yolk depth less than 4% SL. (Based in part on mesolarvae collected from the Yampa River in 1976–LFL# 69949.)

Pages 47-53, Flexion Mesolarvae, sequences of steps following option b (absent) in Step 3 (page 47): update to include the rare possibility of 14-mm-SL *C. latipinnis* without yolk.* (Based in part on mesolarvae collected from the Yampa River in 1976–LFL# 69949.)

Pages 47-53, Flexion Mesolarvae, sequences of steps following option a (≥21 melanophores) in Step 7 (page 47) and options a and b (both ≥21 melanophores) of Steps 22, 25, and 44 (pages 48 and 50): update to include the rare possibility of *C. ardens* with greater than 20 melanophores in a midventral line between heart and vent.*

Pages 47-53, Flexion Mesolarvae, sequences of steps following option b (≤20 melanophores) in Step 7 (page 47) and option c (7-20 melanophores) in Steps 22 and 44 (pages 48 and 50): update to include the rare possibility of *C. platyrhynchus* with 7-20 melanophores in a midventral line between heart and vent.*

Pages 48 and 50, Flexion Mesolarvae, Steps 16 and 48: update options a and b to begin "with > 12 melanophores . . . ." and add option c "with ≤12 melanophores . . . . *X. texanus*." (Based on observation of 0-12 melanophores on the dorsum of 10.5-11.4 mm SL

protolarvae and flexion mesolarvae collected from the Green River at River kilometer 302.9, Cliff Creek, Utah on 23-30 May 2001–LFL# 80501-80504, 80506, 80508-80509, 80513, and 80515-80516.)

Page 48, Flexion Mesolarvae, Step 22: update option 22c to "1-20 melanophores or without pigment (Figs. 16, 58) . . . . . 27" and delete option 80e and back references to Step 22 in Step 47 on page 50 (allows for rare occurrence of *C. latipinnis* postflexion mesolarvae without ventral midline pigmentation).

Page 53, Flexion Mesolarvae, Step 89: correct from "(lateral midline below" to "(lateral midline) and below."

Page 54, Flexion Mesolarvae, Step 109: add blank line before this step to separate from Step 108.

Page 54, Postflexion mesolarvae, Step 1, option f: update to "16 mm . . . . 2C" and insert new Step "2C (1). Yolk" with options "a. present . . . . *C. latipinnis*" and "b. absent . . . . 80" to provide for rare possibility of 16-mm-SL *C. latipinnis* still bearing some yolk. (Based in part on mesolarvae collected from the Yampa River in 1976–LFL# 69952.)

Pages 55-72, Postflexion Mesolarvae, sequences of steps following options a and b (both ≥21 melanophores) of Steps 10, 27, 44, 80, and 101: update to include the rare possibility of *C. ardens* with greater than 20 melanophores in a midventral line between heart and vent.*

Pages 55-72, Postflexion Mesolarvae, sequences of steps following options c (7-20 melanophores) and d (1-6 melanophores) in Steps 10, 27, 44, 80, and 101: update to include the rare possibility of *C. platyrhynchus* with 6-20 melanophores in a midventral line between heart and vent, including new options 10e and 27e for species from former 10d and 27d with no midventral melanophores.*

Pages 56-72, Postflexion Mesolarvae, sequences of steps following option b (present) of Steps 24 and 26: update to include the possibility of 13-mm-SL *X. texanus* having some dorsal fin rays.*

Pages 56-72, Postflexion Mesolarvae, sequences of steps following options c (7-20 melanophores) and d (1-6 melanophores or without pigment) of Step 27: update to include the possibility of 14-mm-SL *C. latipinnis*.*

Page 57, Postflexion Mesolarvae, Steps 41 and 42: update by deleting option a, changing option b to a and option c to b, and beginning the new option a (old b) with "absent or . . . ," and deleting back reference to Step 41 in Step 282. (Based on observation of 14-mm-SL *C. discobolus* in 2001 Green River Collection# 81, LFL# 80454, without distinct principal dorsal fin rays.)

Pages 57-60, Postflexion Mesolarvae, Step 44: update option 44d to "1-6 melanophores or without pigment (Figs. 59, 87) . . . . . 65" and delete option 44e, Steps 75, 77, and 78, back-reference to Step 75 in Step 76, and back reference to Step 78 in Step 79 (allows for rare occurrence of *C. latipinnis* postflexion mesolarvae without ventral midline pigmentation).

Page 60, Postflexion Mesolarvae, Step 80: update option 80d to "1-6 melanophores or without pigment (Figs. 59, 87) . . . . . 93" and delete option 80e, Step 96, and back-references to Step 96 in Steps 97 and 98 (allows for rare occurrence of *C. latipinnis* postflexion mesolarvae without ventral midline pigmentation).

Page 60, Postflexion Mesolarvae, Step 82: correct by moving "or with no distinct lines of melanophores along either side of dorsal midline" from option b to a new option c with the "or" deleted and ". . . . 84" appended (also add back reference to Step 82 in Step 84).

Page 62, Postflexion Mesolarvae, Step 101: update option 101d to “1-6 melanophores or without pigment (Figs. 59, 87) . . . . 111" and delete option 101e, Step 114 on page 62, and back-references to Step 114 in Step 115 (allows for rare occurrence of *C. latipinnis* postflexion mesolarvae without ventral midline pigmentation).

Pages 66-73, Postflexion Mesolarvae, sequences of steps following option a (absence) of odd-numbered Steps 185 to 207 (pelvic fin buds): correct to account for specimens which may key to a species that according to descriptive data should have pelvic fin buds at the size of the specimen being identified.*

Page 71, Postflexion Mesolarvae, Step 285: correct from “c. 41" to “c. 39-41."

Page 75, Metalarvae, Step 23, option b: correct misprint by ending with “. . . . 60."

Page 76, Metalarvae, Step 51, option b: correct from “Fig. 33" to “Fig. 75.”

Pages 78-82, Metalarvae, sequences of steps following option c (≤6 melanophores) in Steps 78, 81 and option b (≤6 melanophores) in Step 88: update to include the rare possibility of *C. platyrhynchus* with as few as 6 melanophores in a midventral line between heart and vent.* Also update Step 85 option b on page 78 to ”1-20 melanophores (Fig 47)” for same reason.

Species accounts —

Page 100, *C. ardens*, Table 9: update onset or formation of pelvic fin buds to “13-14(15)” mm SL and “14-15(16)" mm TL.

Page 110, *C. commersoni*, Fig. 29: update with corresponding replacement below from Snyder (1998).

Page 112, *C. commersoni*, Fig. 33: update with corresponding replacement below from Snyder (1998).

Page 116, *C. discobolus*, Table 19: update yolk assimilated to "(10-)12-13(14)" mm SL (no change for mm TL), dorsal fin rays first formed to "(11-)13(14)" mm SL and (12-)14(15) mm TL (based on 13.6 mm SL, 14.8 mm TL postflexion mesolarva in LFL# 80454), anal fin rays last formed to "(15-)17" mm SL and "(18-)20" mm TL, and pelvic fin rays first formed to "(15)16" mm SL (no change for mm TL).

Page 117, *C. discobolus*, Table 20: update transition to metalarva to "(15-)17" mm SL and "(18-)20" mm TL.

Page 117, *C. discobolus*, Table 21, Postflexion Mesolarvae: update all yolk-related characters with "[i]" (superscript i) in column for mean values, and add footnote "[i]Rare 14-mm-SL specimens have been observed with some remnant yolk." below table.

Page 119, *C. discobolus*, Fig. 45, ventral view: correct to indicate presence of beginning pelvic fin buds located as per lateral view.

Page 120, *C. discobolus*, figures: correct by reversing drawings such that the lower drawing becomes Fig. 46 and the upper drawing becomes Fig. 47.

Page 124, *C. latipinnis*, Table 24: update yolk assimilated to "(14)15(16)" mm SL and "(15)16-17" mm TL and principal caudal fin rays last formed to "(14)15(16)" mm SL and "(15)16(17)" mm TL. (Based on mesolarvae collected from the Yampa River in 1976 and 1977–LFL# 69949, 69951, 69952, 69975.)

Page 125, *C. latipinnis*, Table 25: update transition to postflexion mesolarva to "(14)15(16)" mm SL and "(15)16(17)" mm TL. (Based on mesolarvae phase collected from the Yampa River in 1976 and 1977–LFL# 69949, 69951, 69952, 69975.)

Page 125, *C. latipinnis*, Table 26, Flexion Mesolarva: update minimum values for yolk length and maximum yolk depth and width with "[l]"(superscript letter l) and add footnote "[l]actual minimum is zero based on observation of specimens as small as 14-mm SL without yolk" to bottom of table.

Page 127, *C. latipinnis*, Fig. 59, ventral view: correct to indicate presence of beginning pelvic fin buds located as per lateral view.

Page 133, *C. platyrhynchus*, Table 3, Flexion mesolarvae: correct missing data by adding "54±1[c] 53-54" for Length (%SL) AS to OP2, "50±0[c] 50-50" for Length (%SL) AS to OD, "0±0[c] 0->0" for Length (%SL) P2, "21±1[c] 20-21" for Myomeres to OP2, and "19±1[c] 18-19" for Myomeres to OD.

Page 138, *C. platyrhynchus*, figures, middle and bottom photographs: correct by reversing left-right locations such that those on right become corresponding parts of Fig. 78 and those on left become corresponding parts of Fig. 79.

Page 140, *X. texanus*,Table 34: update formation of pelvic fin buds to "(13)14" mm SL, dorsal fin rays first formed to "13-14" mm SL and "(14)15" mm TL, anal fin rays first formed to "(13-)15" mm SL and "(14-)17" mm TL, pectoral fin rays first formed to "(13-)15" mm SL and "(15-)17" mm TL, and pelvic fin rays first formed to "(13-)15-17" mm SL and "(15-)18-20." (Based on observations by Martinez 1996 and, for pelvic fin buds and dorsal fin rays first formed, on a specimen collected from the San Juan River in 2001and maintained by the Museum of Southwestern Biology–Accession# 2001-IV:17, Collection# WJB01-134.)

Page 141, *X. texanus*, Table 35: correct transition to flexion mesolarva to "(10)11(12)" mm SL and transition to postflexion mesolarva to "(11)12-13" mm SL.

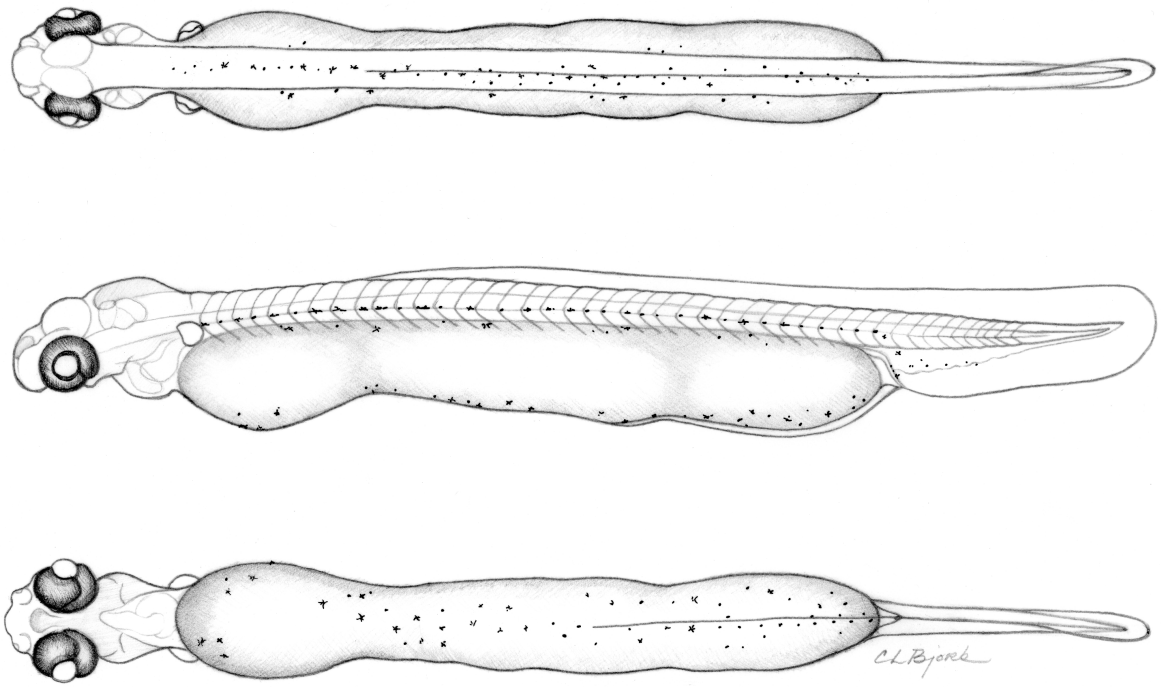


Fig. 28. *Catostomus commersoni* protolarva, recently hatched (day 1), 9.3 mm SL, 9.6 mm TL. Cultured in 1979 with stock from a private pond (Louis Swift), Fort Collins, CO (from Snyder 1998).

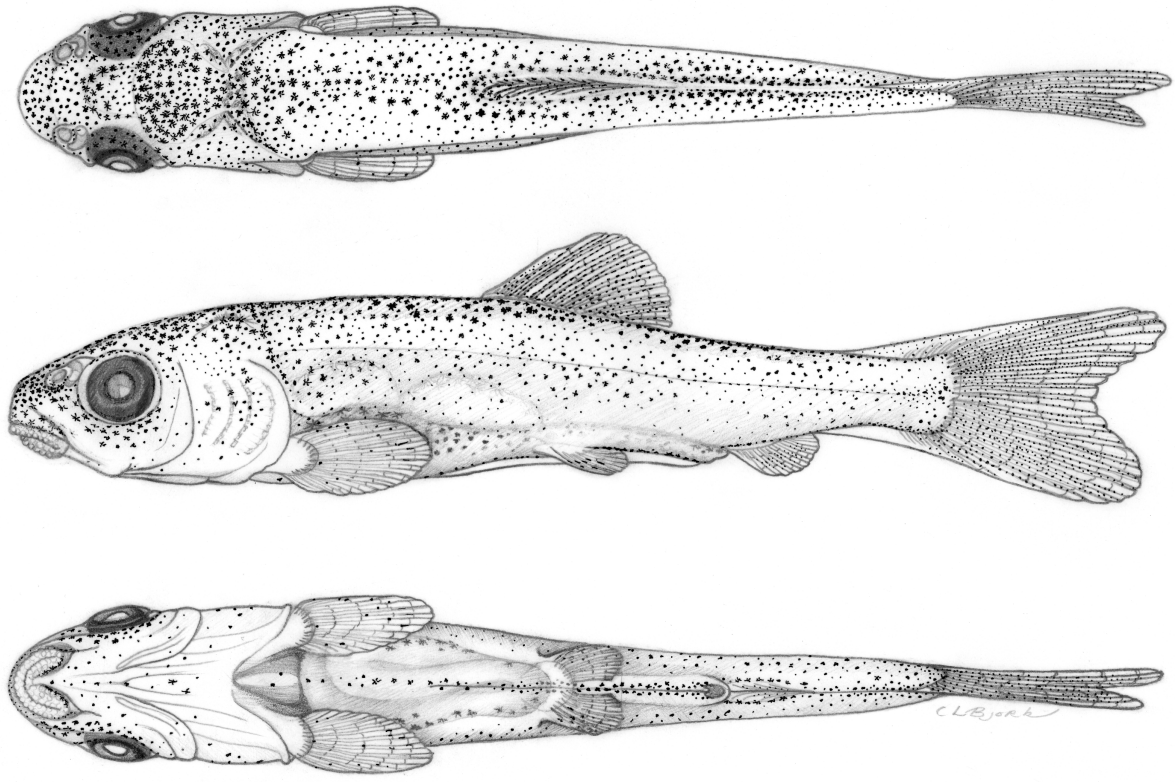


Fig. 33. *Catostomus commersoni* metalarva, 19.2 mm SL, 23.1 mm TL. Collected in 1977 from the Yampa River, Colorado (from Snyder 1998).

Comparative Summary

The diagnostic criteria that follow are included in the computer-interactive key, but are provided here, along with the descriptive species accounts here and in Snyder and Muth (1990), to help confirm identities determined through the key or for use as an alternative to the key. Since extremes in character states beyond those reported here are likely to occur, identifications should be based on as many criteria as possible.

Size relative to state of development. — Flannelmouth sucker eggs are the largest of UCRB suckers (3.8-3.9 mm diameter versus 3.3-3.5 for bluehead sucker and 2.3-3.3 for the others) and larvae hatching from them are usually much larger as well. This relative size difference is characteristic of flannelmouth sucker throughout its early development (Table 1). In contrast, razorback, mountain, and some white and longnose sucker eggs are notably smaller (2.3-2.8 mm diameter) than other species and their recently hatched protolarvae and recently transformed mesolarvae tend to be correspondingly small. These species also complete yolk absorption at a much smaller size, usually by 12 mm SL; flannelmouth sucker larvae finish their yolk at 15 mm SL (occasionally 16 mm SL).

Size relative to state of development for all species but flannelmouth sucker is nearly the same by the beginning of the metalarval phase. In general, fin development proceeds fastest (at smaller sizes) for white sucker and slowest (at larger sizes) for flannelmouth sucker. However, pelvic fins develop earliest in longnose sucker. White and Utah suckers acquire the adult complement of all fin rays, lose their preanal finfolds, and become juveniles at the smallest sizes

(19-20 mm SL) whereas transformation to the juvenile period for some razorback sucker occurs at sizes nearly as large as for flannelmouth sucker (22-23 and 23-24 mm SL, respectively).

Gut folding or coiling proceeds at a faster rate for most bluehead sucker than for other species and at a much slower rate for nearly all flannelmouth sucker. Although gut folding begins only a little later in razorback larvae than in bluehead larvae, it slows during the metalarval phase. As a result, the upper end of the size range for razorback sucker at transition to gut phase 4 overlaps the lower end of the range for flannelmouth sucker.

The size at first appearance of the full series of lateral scales roughly correlates with scale size. The full lateral series of scales appears as early as 24 mm SL for Utah sucker and 29 mm SL for white sucker, both of which have large scales. But it appears no earlier than 39 mm SL for flannelmouth sucker which has very fine scales.

Meristics and morphometrics. — Some character differences determined by comparison of species account summaries of meristics and morphometrics are not included in Tables 2 and 3 because corresponding data for an adjacent phase indicate that the differences might not hold up if additional specimens in the size range of concern are analyzed. When comparing morphometric characters, be aware that some characters, especially depths and widths at OD and OP2, are affected by the amount of yolk in early larvae and by health or condition in later larvae and juveniles. Juvenile morphometric data are applicable to only specimens up to about 40 mm SL.

The more useful meristics are counts of lateral line (or series) scales for juveniles in which scales are sufficiently formed; principal dorsal fin rays (and corresponding pterygiophores) and vertebrae for late postflexion mesolarvae, metalarvae, and juveniles; and myomeres, both

total and to the posterior margin of the vent (often referred to as preanal myomeres), for all larval phases (Table 2). White and Utah suckers usually have fewer than 75 lateral rows of scales whereas longnose, bluehead, and flannelmouth suckers usually have over 85, and mountain and razorback suckers typically have counts between 75 and 85. Typical counts of principal dorsal fin rays are highest for razorback sucker with 14-15, and lowest for longnose and mountain suckers with 10; the other species have typical counts within the 11-13 range. However, when considering observed extremes in these counts, three species have ranges that include the count of 14 and five species include the count of 10.

As would be expected, vertebra counts (based on specimens on cleared and stained for cartilage or bone) nearly match or fall within the range of total myomere counts (all larval phases combined). The one notable exception, an upper extreme of 50 vertebrae for the mountain sucker is based on one verified observation over 48. The greater range in values for myomere counts, especially at the lower end, is due to the far greater number of specimens examined for myomere counts (vertebra counts are based on only a few to several observations per species) and the difficulty in observing first and last myomeres in some specimens, especially metalarvae for which polarizing filters are no longer useful. Probably for the latter reason, both total and to-the-vent myomere counts for metalarvae tend to range one or two myomeres less than for protolarvae and mesolarvae. A slightly more anterior vent position in metalarvae (and juveniles) than in earlier larvae might also account for some of the difference in myomere counts to the posterior margin of the vent (preanal myomere counts). Combined total vertebrae and myomere counts are greatest for bluehead and flannelmouth suckers (typically 47 or greater) and least for Utah, longnose, white, and mountain suckers (typically 47 or less); razorback sucker larvae typically have 46 to 48 total vertebrae or myomeres. The number of myomeres to the vent is

typically 37 or greater for bluehead, flannelmouth, and razorback sucker and 36 or fewer for mountain sucker; typical ranges for Utah, white, and longnose suckers are intermediate and overlap with 35 or 36 to 37 or 38 myomeres to the vent. Unfortunately, the full ranges of myomere counts for these species generally overlap to a greater degree, making myomere counts less useful for diagnostic purposes.

For protolarvae and flexion mesolarvae most diagnostically useful measures relate to the amount of yolk remaining as the fish grow (Table 3). By the end of the protolarva phase, longnose, mountain and razorback suckers consume most or all of their yolk. White and Utah suckers also consume most but not all of their yolk, whereas bluehead and especially flannelmouth suckers still retain about half of their original yolk supply by the end of the protolarva phase. All suckers except flannelmouth complete yolk absorption by the end of the flexion mesolarva phase.

For late postflexion mesolarvae, metalarvae, and juveniles most diagnostic measures relate to the size and position of the dorsal fin. The length of the dorsal fin (from origin of the fin to its most distal margin) and length of the base of the fin correlate well with the number of principal fin rays discussed above. As would be expected, these measures are greatest for razorback sucker and least for mountain sucker, but not much less than for longnose, white, and bluehead suckers. Length to the insertion of the dorsal fin is also greatest (farthest back) for razorback and least for mountain sucker , whereas length to the origin of the fin is least (most forward) for flannelmouth and razorback suckers and greatest (farthest back) for white, bluehead, and mountain suckers.

Among the remaining measures, only eye diameter is useful for all developmental intervals. As protolarvae, mountain sucker generally have the greatest eye diameters and

mountain and longnose suckers the greatest head lengths (measured to the origin of the pectoral fin bud) relative to standard (notochord) length. Bluehead and flannelmouth protolarvae typically have the smallest eyes and heads. For subsequent developmental intervals, differences in eye diameter are best considered as a percentage of head length. For these later stages Utah sucker usually have the largest eyes whereas flannelmouth sucker continue to average the smallest eyes, although not by much. Head length among juveniles is often greatest for razorback and white suckers and least for bluehead, flannelmouth, and mountain suckers.

In addition to dorsal fin lengths discussed above, pectoral and caudal fin lengths are also useful for specific developmental intervals. Pectoral fin length is sufficiently diagnostic only for protolarvae, and then only with respect to the maximum values which are greatest for white, longnose, mountain, and razorback suckers and least for Utah and bluehead suckers. Caudal fin length is sufficiently diagnostic only for metalarvae and juveniles. Among metalarvae, caudal fin length is greatest for razorback sucker and least for mountain sucker. Among juveniles, it is greatest for razorback and Utah suckers and least for mountain and longnose suckers.

Lengths from snout to pelvic fin origin and posterior margin of the vent are the only remaining length characters considered sufficiently diagnostic to include in Table 3. Snout to pelvic fin origin lengths, like lengths to the origin of the dorsal fin, are typically greatest (farthest back) for bluehead sucker and least for flannelmouth sucker metalarvae and juveniles, thereby maintaining the pelvic fin origins at a more-or-less similar horizontal distance behind dorsal fin origins. For postflexion mesolarvae, length to origin of the pelvic fin is also greatest for bluehead sucker but least for Utah, longnose and razorback suckers. Snout to vent lengths are greatest for Utah and razorback sucker postflexion mesolarvae and razorback sucker juveniles.

As noted above, body depth measured at the origin of the dorsal fin reflects the amount of yolk remaining in protolarvae and mesolarvae and the health or condition of the fish in later stages, but especially for larger juveniles, it also represents differences in structural depth. The upper end of the range for this measure is notably greater for razorback sucker juveniles than other species and is probably due, at least in part, to enlarging interneural bones behind the head which will eventually form the distinctive predorsal "razor" or keel of older juveniles and adults.

Pigmentation. — Capture of these suckers prior to initial eye and body pigmentation is rare. If not pigmented at hatching, at least the eyes and some body pigmentation is usually evident by emergence from the spawning substrate. Longnose, white, and mountain suckers are usually well pigmented by 9 mm SL and Utah, bluehead, and flannelmouth suckers by 11 mm SL (Table 4). Pigmentation throughout early development is generally lightest for flannelmouth sucker and especially razorback sucker.

Of all pigment characters, the most diagnostic for later larvae and early juveniles of bluehead and mountain suckers is the extent of peritoneal pigmentation (Table 4). In the ventro-lateral region of the peritoneum, pigmentation is sparse to patchy pigment in some postflexion mesolarvae as early as 14 or 15 mm SL and uniformly dark pigmentation in metalarvae by 20 to 22 mm SL (Figs. 45-49 and 74-77). On the ventral aspects of the peritoneum, pigmentation is uniformly dark in all bluehead sucker greater than 25 mm SL and all mountain sucker greater than 34 mm SL. In contrast, uniform peritoneal pigmentation (light or dark) in either ventro-lateral or ventral regions was not observed at all in any Utah sucker (Figs. 17-21) and only rarely in white or flannelmouth suckers greater than 34 mm SL. In longnose sucker greater than 17 mm SL, the ventro-lateral peritoneal pigmentation was occasionally uniformly light (Fig. 105), but

not uniformly dark until 32 mm SL, and then only rarely; on the ventral surface it was rarely uniformly light in specimens greater than 34 mm SL and never uniformly dark. Although ventro-lateral peritoneal pigmentation in razorback sucker was rarely uniformly light or dark and then only in specimens greater than 25 mm or 34 mm SL, respectively, such uniform pigmentation on the ventral aspects of the peritoneum was, unexpectedly, a bit more common in specimens as small as 29 mm SL for light pigmentation or 32 mm SL for dark pigmentation. However, uniformly light or dark pigmentation of the ventral peritoneum was not observed in some other razorback sucker juveniles as large as 40 mm SL (as viewed through surface tissues without dissection).

Once melanophore pigmentation is sufficiently established, one of the more useful surface pigment characters is the extent of pigmentation on the ventral midline between the heart region and the vent (Table 5). Longnose, white, and mountain suckers typically have a continuous line of midventral pigment with over 20 melanophores (Figs. 30-32, 34,72-73, 98-101,103), at least through the larval period. Extension of this pigment line into the branchial region anterior to the heart is common in longnose and white suckers but rare in mountain sucker. Among the others, only bluehead sucker occasional have as many melanophores along the ventral midline, but the line is either shorter or distinctly discontinuous (Figs. 44-45). Complete absence of melanophores along the ventral midline is rare among Utah, bluehead, and flannelmouth larvae but common for razorback sucker larvae. Unlike the other species, razorback sucker larvae have not been observed to have more than 6 melanophores along the ventral midline (Figs. 85-89).

Presence and pattern of melanophores on the ventral to ventro-lateral surfaces of the gill covers can also be diagnostic throughout the early development of these fishes. Such pigment is

present on some larvae of all developmental intervals for all species except bluehead and flannelmouth sucker. It is rarely present on bluehead flexion mesolarvae and metalarvae or on flannelmouth flexion mesolarvae. This pigmentation is sometimes present as a distinctive oblique row of three or more melanophores along or near the ventral margin of one or both preopercles in longnose, white, and mountain suckers (Figs. 31 and 74).

Another obvious diagnostic character for protolarvae and mesolarvae is the melanophore pattern on the dorsal surface from behind the head to about two-thirds of the distance to the last myomeres. Pigment here is scattered with no distinct lines parallel to the dorsal midline in most mesolarvae of bluehead and mountain suckers (Figs. 44-45 and 72-73). Many flannelmouth sucker and some white sucker mesolarvae have lines of melanophores lateral to the dorsal midline in which the melanophores tend to be in obliquely oriented pairs or groups resulting in a distinctive "herring bone" or "tractor tread" pattern (Figs. 30 and 58).

Extent of lateral body pigmentation is useful for mesolarvae through juveniles. Among flexion mesolarvae, for example, at least a couple melanophores are sometimes present between dorsolateral surface and the horizontal myoseptum of all but mountain and razorback suckers. Even by the metalarval phase, rare specimens of longnose and razorback suckers are still without pigment in this region (Fig. 88). Among juveniles, only white sucker often have three large, distinct, mid-lateral spots on the body, one anteriorly between the head and dorsal fin, one under the dorsal fin, and one near the end of the caudal peduncle (Fig. 35). Longnose sucker occasionally have a similarly large and distinct caudal-peduncle spot and Utah sucker rarely two comparable spots anterior to the vent (possibly with a faint or indistinct caudal spot). The large, distinct, caudal-peduncle spots observed on many white and some longnose suckers should not be confused with the small but sometimes prominent concentration of pigment sometimes

present in the same location on these and most other species. The scales of most white and longnose suckers and some Utah and mountain suckers greater than 30 mm SL are well outlined with pigment (Fig. 35).

Distribution of pigment in various fins can be diagnostic for later larvae and juveniles. Pigment along the rays of the dorsal and caudal fins is typical of all suckers considered herein. In addition, notable pigmentation (more than just a few melanophores, sparsely scattered to abundant) on the membranes between principal dorsal-fin and caudal-fin rays is characteristic of most metalarval and nearly all juvenile razorback suckers (Fig. 91). In contrast, the membranes between principal dorsal-fin and caudal-fin rays of all other metalarvae, except rarely in the dorsal fins of white and flannelmouth suckers, are never pigmented with more than a few incidental melanophores. Among other juveniles up to 40 mm SL, the membranes between dorsal-fin and caudal-fin rays of all bluehead sucker and caudal-fin rays of all mountain sucker and nearly all white and longnose suckers are similarly unpigmented.

Mouth characters. — Mouth characters are important in the diagnosis of adult catostomids. Unfortunately the mouths are insufficiently developed in all but the latest larvae and certain characters remain indistinct in the earliest juveniles (e.g., the lower lip lobes of some bluehead sucker up to 25 mm SL, Table 6).

Mouth position remains terminal for some metalarvae and juveniles of mountain and razorback suckers up to 25 mm SL, but changes to low terminal before the metalarval phase of longnose and flannelmouth suckers and becomes low terminal or subterminal by 19 mm SL for metalarvae of the remaining species. Some white, flannelmouth, and razorback suckers have low terminal mouths throughout the metalarval phase and early juvenile period, at least up to 40 mm

SL (Figs. 90-91). The first subterminal mouths appear as early as 18 mm SL for longnose and bluehead sucker metalarvae and as late as 32 mm SL for razorback sucker juveniles. All bluehead sucker juveniles and metalarvae over 19 mm SL have subterminal mouths (Figs. 47-49). Likewise for all mountain sucker greater than 25 mm SL, Utah sucker greater than 31 mm SL, and longnose sucker greater than 34 mm SL.

The median cleft of the lower lip divides the lip of these suckers into two distinct lobes. The cleft is deep in most suckers but is shallow in bluehead and mountain suckers in which it is bridged by a few rows of papillae. Once the lower lips are sufficiently formed to distinguish two lobes, the lower lip lobes of most metalarvae and some juveniles of all species are well separated. This separation continues for some Utah, white, and bluehead suckers up to 25 to 31 mm SL (Figs. 47 and 48), some razorback sucker up to at least 37 mm SL, and many mountain sucker to at least 40 mm SL (Figs. 75-77). The gap between lip lobes closes much more rapidly in longnose and flannelmouth suckers with all specimens over 18 or 20 mm SL, respectively, having either slightly separated or adjacent lip lobes (Figs. 61-63, 104-105).

The presence or absence of notches at the corners of the mouth is diagnostic for juveniles as well as adults. For bluehead and mountain suckers, the notches are present and distinctly separate the upper and lower lips (Figs. 48 and 49). For the other species, distinct notches do not develop and the upper and lower lips are more-or-less smoothly joined (Figs. 62 and 63).

Osteological features. — Osteological features can be conclusively diagnostic for late metalarvae and juveniles of razorback sucker, subgenus *Pantosteus*, and subgenus *Catostomus*. Unfortunately these characters, as well as vertebra counts discussed under meristics, 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 more external characters for which special preparation is not required. The frontoparietal fontanelle (opening between the frontal and parietal bones–covered with connective tissue) and first interneural bone are observable in some late postflexion mesolarvae whereas the remaining skeletal characters considered herein are applicable only to larger metalarvae and juveniles (Fig. 6). Adult descriptions suggest that more detailed study of larval and early juvenile skeletons might reveal additional skeletal differences, but these are probably the more obvious differences.

As the bones of the skull form, an oval to rectangular fontanelle approximately half as wide as long forms in postflexion mesolarvae and small metalarvae. By 20 mm SL, the fontanelle narrows to a more rectangular shape and maximum width is less than 45% of maximum length for all but razorback and longnose suckers (Table 7, Fig. 7). Beyond 20 mm SL, fontanelle length increases proportionately with body length, but width and shape vary with species. Width generally increases in razorback sucker and maintains a more-or-less oval shape, decreases in mountain sucker, and remains relatively constant in the others (greatest in longnose sucker and least in bluehead sucker). For specimens 35-46 mm SL, fontanelle width remains greater than 45% of length in most razorback sucker (rarely as low as 43%), drops to less than 25% in mountain sucker, and ranges between 25 and 45% in the others (generally greatest in longnose and Utah suckers and least in bluehead sucker). Observations for Utah sucker may be suspect due to poor culture conditions and growth rates (Appendix C, Snyder and Muth 1988).

Adult descriptions of the subject species reveal that the fontanelle is significantly reduced or lost only in bluehead and mountain suckers. Smith (1966) reported that the fontanelle of bluehead sucker is usually reduced in juveniles and closed in adults, whereas that of mountain sucker adults is usually reduced to a narrow slit and only occasionally obliterated. To

preliminarily document changes in fontanelle shape and size toward the adult condition, we cleared and stained one 76 to 81 mm SL yearling for each species except Utah sucker (specimen not available). Based on these solitary observations (Table 7), the fontanelle continues to grow in both length and width in razorback sucker and maintains its larger width-to-length ratio (45%). The fontanelle increases significantly only in length for all other species except mountain sucker, resulting in decreased width-to-length ratios (31% for longnose sucker, 25-26% for white and flannelmouth suckers, and 19% for bluehead sucker). Only in mountain sucker was the fontanelle closed. More yearling and older specimens must be examined to determine if fontanelle closure is typical of mountain sucker populations in the UCRB.

The large, fan-shaped, first interneural bone of razorback sucker metalarvae and juveniles over 16 mm SL readily distinguishes it from the other species (Fig. 8). By late in the metalarval phase, the smaller interneurals posterior to the first also develop enlarged or flared tops. The interneurals eventually form the skeletal basis for the unique predorsal keel or "razor" of the razorback sucker (Fig. 94). By 20 mm SL, the first interneural generally segregates the remaining species according to subgenera. Most members of subgenus *Catostomus* (at least Utah, white, and flannelmouth suckers) have moderate to large anvil-shaped first interneurals with moderate to long posterior extensions (especially long in flannelmouth sucker). Subgenus *Pantosteus* (bluehead and mountain suckers) have smaller, somewhat blocky first interneurals with short to moderate posterior extensions. The interneurals for similar-size longnose sucker (also subgenus *Catostomus*) examined for this study are less well defined and appear to develop more slowly than for the other species. The small size and abbreviated shape of the first interneural in longnose sucker juveniles about 40 mm SL (Fig. 107) appears more like those of subgenus *Pantosteus* metalarvae or juveniles about 21-22 mm SL (Figs. 8, 52, and 80) and is

perhaps associated with the more cylindrical anterior body shape of longnose sucker than the other members of subgenus *Catostomus*.

The position of mandibles relative to maxillae is also diagnostic for subgenus *Pantosteus*. For juveniles and metalarvae greater than 22 mm SL, the anterior margins of the mandibles are closer to the posterior than anterior ends of the maxillae in bluehead sucker and mountain sucker (Fig. 9). For the other species, they are closer to the anterior ends of the maxillae. However, by about 40 mm SL, at least some flannelmouth suckers have anterior margins of the mandibles positioned about midway between anterior and posterior ends of the maxillae.

Shape and size of anterior-dorsal projections on the maxillae are diagnostic for razorback sucker and subgenus *Pantosteus* greater than 22 mm SL, sometimes smaller. The anterior-dorsal projections of the maxillae are very shallow to almost absent in razorback sucker, relatively long and pointed (at least as deep as wide at the base) in bluehead and mountain suckers, and intermediate (prominent but blunt and less deep than wide at the base) in subgenus *Catostomus* (Fig. 10). By 40 mm SL, these projections grow but relative differences in size and form continue with those of *Pantosteus* and most *Catostomus* projecting forward (Fig. 51) or even a bit outward (Fig. 37). In contrast, the anterior-dorsal projections of the maxillae of longnose sucker grow a bit larger than other members of subgenus *Catostomus* and project forward and uniquely inward or medially (Fig. 107), perhaps facilitating development of a somewhat longer, more conical snout.

The angle at which the postcleithrum extends from the cleithrum was initially suspected to be diagnostic for subgenus *Pantosteus*, about 90° for bluehead and mountain suckers and variable, but usually much less angled for the others (Fig. 11). However, the differences in this

character are not always distinct, and perceived postcleithral angle can be affected strongly by angle of view.

Table 1. Comparison of size (mm standard length) at onset or transition of developmental intervals, gut phases, and other developmental events for larvae and early juveniles of Upper Colorado River Basin catostomids. Rare extremes in parentheses. * = "or before hatching."

Character	*Catostomus ardens*	*Catostomus catostomus*	*Catostomus commersoni*	*Catostomus discobolus*	*Catostomus latipinnis*	*Catostomus platyrhynchus*	*Xyrauchen texanus*
Egg diameter:	2.9-3.2	(2.2)2.4-3.0	2.6-3.3	3.3-3.5	3.8-3.9	2.3-2.7	2.5-2.8
Phase/period transitions							
Embryo to larva:	(7)8-11	(7)8-10	(7)8-10	(8)9-10(11)	(8-)10-11	(7)8	7-9
Proto- to mesolarva:	12-13	11	10-12	10-12	13	11	(10)11(12)
Flexion to postflexion mesolarva:	13-14	12-13	(12)13-15	(11)12-13	(14)15(16)	13-14	(11)12-13
Meso- to metalarva:	15-17	15-16(17)	15-16(17)	(15-)17	19-20(21)	16-17	15-17
Larva to juvenile:	19-20	21-22	(17-)19-20	21-22(23)	23-24(25)	21-22	(21)22-23(24)
Gut phase transitions							
1 to 2 (90° bend):	14-17	14	14-15(16)	14(15)	(17)18(-20)	14-17	(14)15(-17)
2 to 3 (full loop):	18-19	16-17	(16)17-18	15(16)	(19-)21-25(-27)	16-17	17
3 to 4 (partial crossover):	20-22	18-21(22)	19-20(21)	(16)17	(22)23-32(-37)	18-20	18-25(26)
4 to 5 (full cross over):	27-28	(19)20-23(-25)	(20)21-25	(16)17-19(-21)	(29-)35-42	21-23	(22-)26-28(-31)
Onset of selected events							
Eyes Pigmented:	9-10 *	(7)8 *	(7)8 *	9-10 *	(9)10 *	8	(7)8(9) *
Yolk Assimilated:	12-13	10-11(12)	10-12(-14)	(10-)12-13(14)	(14)15(16)	(10)11	(9)10-11
Finfold Absorbed:	19	21-22	(17-)19-20	21-22(23)	23-24(25)	21-22	(21)22-23(24)
Pectoral Fin Buds:	(7) *	*	(7)8 *	(8) *	(9) *	(7) *	7 *
Pelvic Fin Buds:	13-14(15)	12	13-15	14	(15)16(17)	13	(13)14
Fin rays first observed							
Dorsal, principal:	13-15	13-14	12-13	(11-)13(14)	15	13	13-14
Anal, principal:	14-15	(13)14(15)	14-16	14-15	17	14-15	(13-)15
Caudal, principal:	12-13	11	10-12	10-12	13	11	(10)11(12)
Caudal, rudimentary:	14-15	13-14	13-15	14	(16)17	14	14
Pectoral:	14-15	13-14	14-16	14-15	17	13-15	(13-)15
Pelvic:	14-17	14(15)	15-16	(15)16	17-18	16	(13-)15-17
Full fin ray counts first observed							
Dorsal, principal:	14-16	(13)14(15)	14-16	(14)15	17-18	14-17	15(-17)
Anal, principal:	15-17	15-16(17)	15-16(17)	(15-)17	19-20(21)	16-17	15-17
Caudal, principal:	13-14	12-13	(12)13-15	(11)12-13	(14)15(16)	13-14	(11)12-13
Caudal, rudimentary:	19-20	21	(17)18	19-20	23	20-21	19-20(-24)
Pectoral:	15-18	20-21	16(-20)	16-18(19)	19-22	18-20	16-18
Pelvic:	18-19	(16-)18-19(-21)	16-18	19-20	23	18-20	16-17
Scales, lateral series							
First observed:	21-23	27-28	22(23)	28-34	(36)37-39	23-24	24-28
Full series first observed:	24-28	(30)31	29-31	30-39	39-42	32-38	33-36(37)

Table 2. Comparison of the more diagnostic differences in meristics for larvae and early juveniles of Upper Colorado River Basin catostomids. Character range is followed by the mean or more typical range. See Fig. 4 for methods of counting myomeres and fin rays. 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 (cited in species accounts) are given in parentheses.

Character	*Catostomus ardens*	*Catostomus catostomus*	*Catostomus commersoni*	*Catostomus discobolus*	*Catostomus latipinnis*	*Catostomus platyrhynchus*	*Xyrauchen texanus*
Myomeres to PV							
Proto- & mesolarvae:	35-38, 36-37	36-39, 37-38	34-40, 37-38	37-40, 39	37-40, 39	34-37, 36	37-41, 38-39
Metalarvae:	34-37, 36	34-38, 36	34-37, 35	35-38, 37	36-38, 37	32-36, 35	36-39, 37
All larvae:	34-38, 36-37	34-39, 36-38	34-40, 35-38	35-40, 37-39	36-40, 37-39	32-37, 35-36	36-41, 37-39
Myomeres, total							
Proto- & mesolarvae:	45-48, 46	45-49, 47	43-49, 46-47	47-49, 48	47-49, 48	43-47, 45-46	46-49, 47-48
Metalarvae:	43-47, 45	44-48, 46	44-47, 45	47-48, 47	46-48, 47	43-45, 45	44-48, 46
All larvae:	43-48, 45-46	44-49, 46-47	43-49, 45-47	47-49, 47-48	46-49, 47-48	43-47, 45-46	44-49, 46-48
Vertebrae:	47-48	46-47 (45-48, 45-47)	45-48, 46 (44-48)	47-49 (45-50, 47-49)	47-50	46-50, 46-48 (42-48, 44-47)	45-47, 46
Dorsal fin rays:	10-14, 11-13 (11-13)	9-11, 10 (9-12, 10)	10-13, 11-12 (9-15, 10-13)	9-12, 11 (9-12, 10-11)	11-14, 12-13 (10-15, 12-13)	9-11, 10 (8-13, 10)	12-16, 14-15 (12-16,14-15)
Lateral line scales:	57-68, 62-68 (54-79, 60-70)	103-116, 105 (85-120,95-115)	56-72, 59-68 (53-85, 56-76)	(78-122,86-115)	(89-120,98-105)	76-86 (60-108,75-97)	(68-95,76-87)

Table 3. Comparison of the more diagnostic differences in morphometrics for larvae and juveniles (≤40 mm SL) of Upper Colorado River Basin catostomids. Except as otherwise noted for most eye diameters, all data are given as percentages of standard length. The full range for each character is followed by the mean or more typical range. See Fig. 4 for abbreviations and methods of measurement. HL = head length measured to origin of the pectoral fin (AS to OP1).

Developmental Phase Character	*Catostomus ardens*	*Catostomus catostomus*	*Catostomus commersoni*	*Catostomus discobolus*	*Catostomus latipinnis*	*Catostomus platyrhynchus*	*Xyrauchen texanus*
Protolarvae							
Eye diameter:[a]	5-7, 6	5-7, 6	5-7, 6	5-6, 5	5-6, 5	6-8, 7	5-6, 6
AS to PE length:	7-9, 8	8-10, 9	8-9, 8	6-7, 7	6-9, 7	8-10, 9	7-8, 8
AS to OP1 length:	12-17, 15	15-18, 16	13-19, 16	13-15, 14	12-16, 14	16-18, 17	14-17, 16
Yolk length:[b]	49-64, 57	0-64, 52	26-63, 51	61-67, 63	54-67, 61	0-67, 47	0-68, 44
Pectoral fin length:[c]	1-8, 5	4-11, 7	2-12, 7	3-6, 5	3-9, 6	2-11, 9	3-11, 7
Depth at OD:[b,d]	10-12, 11	8-15, 12	8-13, 10	12-17, 14	13-15, 14	10-14, 12	7-13, 10
Width at OD:[b,d]	5-9, 7	5-12, 7	5-9, 6	8-12, 10	7-11, 10	6-11, 8	4-9, 6
Max. yolk depth:[b]	3-11, 7	0-13, 7	1-11, 6	7-12, 10	9-16, 12	0-13, 5	0-9, 5
Max. yolk width:[b]	5-14, 8	0-14, 8	1-10, 6	10-15, 12	9-18, 13	0-14, 6	0-9, 5
Flexion mesolarvae							
Eye diameter, % HL:[a]	34-38, 36	32-35, 34	28-38, 34	32-38, 35	32-37, 34	31-38, 35	28-39, 34
AS to PV length:	75-77, 76	75-79, 78	76-81, 79	74-79, 77	75-78, 77	75-78, 77	78-81, 79
Yolk length:	0-43, 16	0-34, 3	0-50, 18	0-53, 26	23-54, 46	0-14, 3	0-50, 4
Depth at OD:[d]	8-9, 9	8-11, 10	8-10, 9	9-12, 10	9-13, 11	10-12, 11	6-11, 9
Max. yolk depth:	0-2, 0	0-2, 0	0-3, 1	0-7, 3	2-8, 5	0-1, 1	0-2, 0
Max. yolk width:	0-2, 1	0-3, 0	0-4, 1	0-8, 4	1-9, 6	0-2, 0	0-5, 0
Postflexion mesolarvae							
Eye diameter, % HL:[a]	31-38, 34	29-35, 32	24-34, 31	24-34, 28	24-35, 27	26-35, 30	27-33, 30
AS to OP2 length:	50-53, 52	50-54, 52	52-54, 53	53-57, 55	50-54, 53	52-56, 54	50-54, 52
AS to ID length:[e,f]	60-63, 62	60-63, 62	61-64, 63	61-64, 62	62-67, 64	61-64, 62	65-67, 66
AS to PV length:	76-80, 79	77-80, 78	78-81, 80	76-81, 79	76-80, 78	77-80, 79	78-84, 81
Dorsal fin (D) length:[f,g]	14-16, 15	14-18, 16	16-17, 17	11-17, 15	15-21, 18	11-15, 13	18-21, 19
Dorsal fin base length:[e,f,h]	12-15, 13	12-14, 13	12-14, 13	11-14, 12	12-17, 15	11-13, 12	16-18, 17
Yolk length:	0	0	0	0	0-7, 0	0	0
Metalarvae							
Eye diameter, % HL:[a]	28-33, 30	26-34, 29	25-34, 30	22-27, 25	22-25, 24	25-28, 26	24-32, 27
AS to OP2 length:	53-57, 56	53-59, 56	54-59, 56	55-61, 58	52-57, 55	53-58, 56	51-58, 56
AS to OD length:	49-52, 50	47-52, 49	48-53, 51	49-54, 52	47-51, 49	50-53, 51	47-51, 49
AS to ID length:[f]	64-67, 65	60-66, 63	61-67, 65	63-66, 64	62-67, 65	62-65, 63	65-69, 67
Caudal fin length:[i]	18-22, 20	17-22, 20	16-26, 21	16-24, 21	17-25, 22	15-20, 18	20-28, 23
Dorsal fin (D) length:[f]	18-20, 19	17-21, 19	15-22, 19	17-21, 19	20-24, 22	15-19, 17	21-29, 24
Dorsal fin base length:[f,h]	14-16, 15	12-15, 13	12-15, 14	11-15, 13	14-17, 16	11-14, 12	16-21, 18
Juveniles <40 mm SL							
Eye diameter, % HL:[a]	27-32, 30	20-29, 25	22-28, 25	21-28, 24	19-26, 23	22-25, 24	21-30, 25
AS to OP1 length:	25-28, 26	24-30, 27	24-29, 28	23-27, 25	24-28, 25	24-26, 25	25-31, 28
AS to OP2 length:	55-58, 56	55-59, 57	52-59, 57	56-60, 58	52-57, 55	55-60, 57	54-60, 57
AS to OD length:	48-51, 49	49-53, 50	48-53, 51	47-54, 51	46-49, 48	48-52, 50	46-52, 49
AS to ID length:[f]	64-66, 65	62-65, 64	61-68, 65	62-66, 64	61-66, 65	60-64, 63	65-70, 67
AS to PV length:	73-76, 75	74-78, 76	72-78, 76	72-76, 75	72-76, 74	74-78, 75	75-80, 77
Caudal fin length:[i]	23-28, 25	19-23, 21	19-24, 22	20-24, 23	21-25, 23	19-23, 21	23-28, 25
Dorsal fin (D) length:[f]	21-26, 24	18-22, 20	18-24, 20	19-23, 21	23-26, 24	18-21, 20	23-29, 27
Dorsal fin base length:[f,h]	14-17, 16	11-16, 13	13-16, 14	11-16, 13	14-18, 16	12-14, 13	16-20, 18
Depth at OD:	16-22, 20	19-22, 20	17-22, 19	16-21, 19	17-22, 19	18-21, 20	18-27, 23

[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] Ignore differences in minimum values since 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] 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).

[g] Applicable only to specimens with most principal dorsal fin rays formed; ignore differences in minimum values since some data represent specimens with a few fin rays less than the adult count.

[h] Dorsal fin base = (AS to ID)-(AS to OD).

[i] Caudal fin length = (AS to PC)-(AS to PHP), total length minus standard length.

Table 4. Comparison of size (mm SL) relative to pigmental state (melanin) of eyes and bodies for protolarvae and lateral to ventral regions of the peritoneum for postflexion mesolarvae (P), metalarvae (M), and early juveniles (J, ≤40 mm SL) of Upper Colorado River Basin catostomids. For peritoneal pigmentation, size is preceded by initials for the applicable developmental intervals. The letter "r" indicates that the condition is rare.

Character	*Catostomus ardens*	*Catostomus catostomus*	*Catostomus commersoni*	*Catostomus discobolus*	*Catostomus latipinnis*	*Catostomus platyrhynchus*	*Xyrauchen texanus*
Eye pigmentation, protolarvae[a]							
Unpigmented	≤10	7	7	≤10	≤10	≤8	≤9
Light to moderate	9-11	7-10	7-9	9-11	9-11	8-9	7-10
Dark	≥10	≥9	≥8	≥10	≥11	≥8	≥9
Body pigmentation, protolarvae[a]							
Unpigmented	≤11	7	≤9	≤10	≤10	≤8	≤11
1-12 melanophores on dorsum	9-12	7-8	7-9	9-10	9-11	8-9	8-12
≥13 melanophores on dorsum	≥11	≥7	≥8	≥10	≥11	≥8	≥9
Peritoneal pigmentation[b]							
Lateral, P and M only[c]							
Absent	PM all	PM ≤15	PM ≤18	P ≤17	PM ≤22	P ≤14	PM ≤24
Sparse or patchy	PM ≥15	PM ≥14	PM ≥14	PM ≤17	PM ≥19	PM ≤22	PM ≥14
Uniformly light	-	M ≥18	-	M 17-19	-	M ≥21	-
Uniformly dark	-	M ≥18	-	M ≥17	-	M ≥21	-
Ventro-lateral surfaces							
Absent (or obscured in J)	PMJ all	PM ≤17	PMJ all	P ≤17	PMJ all	PM ≤16	PMJ all
Sparse or patchy	J ≥19	MJ ≥16,r-15	PMJ 16-37	PM 15-17	MJ ≥23	PM 14-18	MJ 20-37
Uniformly light	-	MJ ≥18,r-15	r-J 35-37	M 17-19	r-J ≥35	M 19-21	r-J 26-37
Uniformly dark	-	r-J ≥ 32	-	MJ ≥17	r-J ≥38	MJ ≥20	r-J 35-37
Ventral surface							
Absent	PMJ all	PM ≤17	PMJ all	PM ≤17	PMJ all	PM ≤21	PMJ all
Sparse or patchy	-	MJ ≥17	J 22-37	MJ 17-25	MJ ≥22	MJ 17-34	J 23-37
Uniformly light	-	r-J ≥35	r-J 35-37	MJ 18-25	r-J ≥38	J 26-34	J ≥29
Uniformly dark	-	-	-	MJ ≥18	r-J ≥38	J ≥26	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 dorso-lateral 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 5. Comparison of the more diagnostic melanophore pigmentation patterns for larvae and juveniles (≤40 SL) of Upper Colorado River Basin catostomids. Key to characters and their states is given below. Rare or questionable data are enclosed in parentheses. NA = not applicable.

Character number	*Catostomus ardens*	*Catostomus catostomus*	*Catostomus commersoni*	*Catostomus discobolus*	*Catostomus latipinnis*	*Catostomus platyrhynchus*	*Xyrauchen texanus*
Protolarvae (after pigment is well established)							
1.	1-3	3-5	4-5	1-4	1-3	3-5	1-2
2.	1-2	1,(2-3)	1-2,(3)	1	1	1-2,(3)	1-2,(3)
5.	1	1	1	1,(2)	1	1	1
7.	1-2	(2),3	2-3	1-3	1-3	2-3	1-3
8.	1-2	1-2	2-3	1-2	2-3	1-2	2-3
Flexion Mesolarvae							
1.	1-3,(4-5)	3-5	4-5	1-4	(1),2-3	(3),4-5	1-2
2.	1-2	1-3	1-3	1	1	1-3	1-3
3.	1-2	2	2	1-2	1-2	2	1-2
4.	1-2	(1),2	1-2	1-2	1	1-2	1-2
5.	1	1	1	1-2	1	1,(2)	1
7.	1-2	2-3	1-3	2-3	1-2	2-3	1-3
8.	2-3	(1),2	1-3	1-3	2-3	1-2	2-3
9.	1	1	1-2	1	1-2	1	1
10.	2	2	2	2	2	2	1-2
11.	1-2	1-2	1-2	1-3	1-2	1	1
12.	1-2	1-2	1-2	1-2	1	1	1
13.	2-3	2-3	2-3	1-3	2-3	2-3	1-3
Postflexion Mesolarvae							
1.	(1),2,(3-5)	3-5	(4),5	(1-2),3-4	(1),2-3	(2-4),5	1-2
2.	1-2,(3)	1-3	(1),2-3	1,(2)	1,(2-3)	(1),2-3	1-2,(3)
3.	2	2	2	(1),2	1-2	2	(1),2
5.	1-2	1	1-2	1-2	1-2	1-2	1,(2)
7.	1,(2)	(1),2,(3)	(1),2,(3)	1,(2-3)	1,(2)	(1),2	1-2
8.	1-3	1-2,(3)	1,(2-3)	1-2	1-3	1,(2)	1-2,(3)
9.	1	1	(1-2)	1	(1),2	(1)	1
12.	1-2	1-3	1-3	1-2,(3)	1-2	1-3	1-2
13.	(2),3	(2),3	3	2-3	2-3	2-3	(2),3
18.	1,(2)	1-2	2	1,(2)	1-2	(1),2	(1-2)
Metalarvae							
1.	(1),2,(3)	(2),3-5	4-5	(1-2),3-4	(1),2,(3)	(2),3-5	1,(2)
2.	(1),2	1-2,(3)	1-3	1,(2)	1	1-3	1
3.	(1),2	2	2	1-2	1-2	(1),2	1,(2)
6.	1	1-2	1	1,(2)	1	1	1
11.	3	(1-2),3	3	3	(2),3	3	(1),2-3
12.	(2),3	1-3	(1-2),3	3	(1),2-3	(1-2),3	1-2
19.	1	1	1,(2)	1	1,(2)	1	(1),2
20.	1-2,(3)	1-3	1-2,(3)	1-2	1,(2-3)	1,(2)	(1),2
21.	(1),2-3	1-3	1-2,(3)	1-2,(3)	1,(2)	(1),2-3	1,(2)
22.	1	1	1	1	1	1	1-2
Juveniles							
1.	1-2,(3)	1-3,(4),5	(1-2),3-5	1-3	1-2,(3)	1,(2),3,(4-5)	1-2
2.	1,(2)	1,(2)	1-2,(3)	1	1	1,(2)	1,(2)
14.	3	3	(2),3	3	2-3	2-3	1-3
15.	2-3	1-2,(3)	1-2,(3)	1-2	1-2	(1),2-3	1-2,(3)
16.	1,(3)	1-2	1,(2),4	1	1	1	1
17.	1,(2)	1-2	1-2	1	1	1,(2)	1
19.	1-2	1-2	1-2	1	(1),2	1-2	2
20.	1-2,(3)	1-3	1-2,(3)	(1),2	1,(2-3)	1-2	1-2,(3)
22.	1-2	1,(2)	1,(2)	1	1-2	1	(1),2

Table 5. Continued

Key to pigment characters and states:

1. Ventral midline from shortly behind heart region to near vent
    1. without melanophore pigment.
    2. with 1-6 melanophores.
    3. with 7-20 melanophores.
    4. with ≥21 melanophores in a short or distinctly discontinuous line.
    5. with ≥21 melanophores in a continuous or nearly continuous, full-length line or narrow band.
2. Pigment over ventral to ventro-lateral surfaces of gill covers (opercula)
    1. absent.
    2. present but not consisting of or including a distinct oblique row of 3 or more melanophores near or along margin of either preopercle.
    3. consisting of or including a distinct oblique row of 3 or more melanophores near or along margin of one or both preopercles.
3. Pigment on ventral surface of heart region
    1. absent.
    2. present.
4. Pigment under chin (anterior ventral surface of lower jaw)
    1. absent.
    2. present.
5. Dorsal body pigmentation between head and last myomere (for specimens with >12 melanophores on dorsal surface)
    1. not scattered or scattered with at least a partial distinct line of melanophores on or lateral (and parallel) to dorsal midline.
    2. scattered with no distinct lines of melanophores on or lateral (and parallel) to dorsal midline.
6. Dorsal body pigmentation between head and last myomere
    1. scattered more or less evenly (with or without emphasis on distinct lines of melanophores on or lateral and parallel to dorsal midline).
    2. scattered but in a blotchy pattern (with or without emphasis on distinct lines of melanophores on or lateral and parallel to dorsal midline).
7. Dorsal midline from shortly behind head to near last myomeres
    1. with ≤24 melanophores in a short, discontinuous, or well-spaced line, or (rarely) with no distinct line of melanophores.
    2. with ≥25 melanophores but in a short or distinctly discontinuous line.
    3. with ≥25 melanophores in a distinct continuous or nearly continuous, full-length line.
8. Dorsal surface lateral to midline from shortly behind head to about 2/3 distance to last myomeres
    1. without distinct lines of melanophores along either side of dorsal midline.
    2. with distinctly short or discontinuous lines of melanophores along one or both sides of dorsal midline.
    3. with distinct continuous or nearly continuous, full-length lines of melanophores along (parallel to) each side of dorsal midline.
9. Melanophores in lines lateral (and parallel) to dorsal midline between head and 2/3 distance to last myomeres mostly
    1. in single file.
    2. in obliquely oriented pairs or groups resulting in a herringbone pattern.
10. Dorsal surface of head pigmented
    1. only over hindbrain (posterior to middle of eyes).
    2. over both mid- and hindbrain (anterior and posterior to middle of eyes).
11. Lateral surface of body above horizontal myosepta (or lateral midline), exclusive of melanophores associated with horizontal myosepta, air bladder, visceral cavity (peritoneum), or gut,
    1. unpigmented.
    2. with 1-5 melanophores.
    3. with ≥6 melanophores.
12. Lateral surface of body below horizontal myosepta (or lateral midline), exclusive of melanophores associated with horizontal myosepta, air bladder, visceral cavity (peritoneum), or gut,
    1. unpigmented.
    2. with 1-5 melanophores.
    3. with ≥6 melanophores.
13. Lateral surface of head posterior to eyes
    1. unpigmented.
    2. with 1-5 melanophores.
    3. pigmented with ≥6 melanophores.
14. Pigmentation on lateral surfaces of body above bottom-of-eye level and anterior to vent, exclusive of melanophores associated with horizontal myosepta, air bladder, visceral cavity (peritoneum), or gut,
    1. scattered only partially down to the horizontal myoseptum (lateral midline).
    2. scattered fully and evenly down to the horizontal myoseptum with few if any melanophores below the myoseptum.
    3. scattered evenly or in blotchy pattern (continuous with dorsal and dorso-lateral surface pattern) down to horizontal myoseptum and at least partially to bottom- of-eye level below.
15. Pigmentation on lateral to ventro-lateral surfaces of body below bottom-of-eye level, exclusive of melanophores associated with horizontal myosepta, air bladder, visceral cavity (peritoneum), or gut,
    1. absent including caudal peduncle.
    2. absent except on caudal peduncle.
    3. present.

Table 5. Continued

16. Mid-lateral surface of body
    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.
    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.
17. Pigment outlining scales
    1. absent or light.
    2. bold.
18. Developing dorsal fin
    1. with few (≤5) or no melanophores.
    2. with many (≥6) melanophores.
19. Pigment in dorsal fin
    1. 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 at least a portion of membranes between some or all principal fin rays.
20. Pigment in anal fin
    1. absent.
    2. present but very light with only a few (≤5) melanophores (sometimes very linear along margins of rays and easily overlooked).
    3. present but more prominent with many (≥6) melanophores (sometimes very linear along margins of rays and easily overlooked).
21. Pigment in pectoral fin
    1. absent.
    2. present but very light with only a few (≤5) melanophores.
    3. present but more prominent with many (≥6) melanophores.
22. Pigment in caudal fin
    1. 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 portion of membranes between some or all principal fin 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 some or all principal fin rays.

Table 6. Comparison of size (mm SL) relative to mouth position and lower lip lobe separation for metalarvae (M) and juveniles (J, ≤40 mm SL) of Upper Colorado River Basin catostomids. Size is preceded by initials for the applicable developmental intervals; "r" indicates that the condition is rare.

Character	*Catostomus ardens*	*Catostomus catostomus*	*Catostomus commersoni*	*Catostomus discobolus*	*Catostomus latipinnis*	*Catostomus platyrhynchus*	*Xyrauchen texanus*
Mouth position							
Terminal, above bottom of eye	M ≤19	-	M ≤18	M ≤17	-	MJ ≤25	MJ ≤25
Low terminal, at or below bottom of eye	MJ ≤31	MJ ≤34	MJ all	M ≤19	MJ all	MJ ≤25	MJ all
Subterminal, low and not most anterior portion of snout	J ≥23	MJ ≥18	J ≥19	MJ ≥18	MJ ≥22	J ≥23	J ≥32
Lower lip lobes, median separation							
Indistinct	M ≤18	M ≤15	M ≤18	MJ ≤25	-	M ≤22	-
Well separated	MJ ≤25	M 15-18	MJ ≤31	MJ ≤28	M ≤20	MJ all	MJ ≤37
Slightly separated	MJ ≥18	MJ 18-37	MJ 17-31	J ≥22	MJ all	J ≥23	MJ 20-37
None, adjacent	J ≥22(r)	MJ ≥18	MJ ≥17	J ≥22	MJ ≥22	J ≥26(r)	MJ ≥20

Table 7. Comparison of frontoparietal fontanelle size for selected length groups of larval and juvenile catostomids of the Upper Colorado River Basin. "N" is number of specimens examined.

Size group Character	*Catostomus ardens*	*Catostomus catostomus*	*Catostomus commersoni*	*Catostomus discobolus*	*Catostomus latipinnis*	*Catostomus platyrhynchus*	*Xyrauchen texanus*
17-19 mm SL, n	2	2	2	4	3	0	3
Width, mm	1.0-1.2	1.5-1.5	0.8-1.0	0.6-0.9	0.8-1.2		1.0-1.2
Length, mm	2.0-2.2	1.8-2.1	2.0-2.2	1.4-1.8	1.2-2.0		1.7-1.9
Width/length, %	45-60	71-83	40-45	41-50	50-67		59-63
20-21 mm SL, n	1	2	2	2	3	2	5
Width, mm	0.9	1.5-1.7	0.6-0.8	0.5-0.9	0.6-0.7	0.6-0.8	1.0-1.3
Length, mm	2.1	2.0-2.1	1.9-2.1	1.7-1.7	1.8-2.0	2.2-2.2	1.8-2.1
Width/length, %	43	75-79	32-38	29-35	33-35	27-36	52-68
22-25 mm SL, n	2	3	1	3	3	1	2
Width, mm	0.9-0.9	0.9-1.5	0.8	0.5-0.8	0.8-0.8	0.7	1.0-1.3
Length, mm	2.3-2.4	2.1-2.3	2.0	1.3-2.8	1.8-2.1	2.2	1.9-2.1
Width/length, %	38-39	39-68	40	29-38	38-44	32	53-62
26-34 mm SL, n	3	3	2	2	2	1	2
Width, mm	1.0-1.0	1.1-1.4	0.8-0.8	0.6-0.7	0.7-0.8	0.5	0.9-1.3
Length, mm	2.3-2.4	2.7-3.0	2.3-2.6	2.0-2.2	2.2-2.3	2.1	2.1-2.3
Width/length, %	42-43	40-47	31-35	27-35	30-36	24	43-57
35-46 mm SL, n	1	2	1	1	1	2	3
Width, mm	1.1	1.1-1.4	0.9	0.7	0.7	0.4-0.5	1.1-1.7
Length, mm	2.7	3.2-3.8	3.0	2.7	2.3	2.5-2.7	2.3-3.4
Width/length, %	41	29-44	30	26	30	15-20	48-50
All 22-46 mm SL, n	6	8	4	6	6	4	7
Width, mm	0.9-1.1	0.9-1.5	0.8-0.9	0.5-0.8	0.7-0.8	0.4-0.7	0.9-1.7
Length, mm	2.3-2.7	2.1-3.8	2.0-3.0	1.3-2.8	1.8-2.3	2.1-2.7	1.9-3.4
Width/length, %	38-43	29-68	30-40	26-38	30-44	15-32	43-62
47-75 mm SL, n		2					
Width, mm		1.1-1.4					
Length, mm		3.8-4.5					
Width/length, %		29-31					
76-81 mm SL, n		1	1	1	1	1	1
Width, mm		1.5	0.8	0.7	1.0	0.0	2.3
Length, mm		4.8	3.1	3.7	4.0	0.0	5.1
Width/length, %		31	26	19	25	0	45

Computer-Interactive Key

Introduction. — Covering bluehead, flannelmouth, longnose, mountain, razorback, Utah, and white suckers, the "Computer-Interactive Key to Eggs, Larvae, and Early Juveniles of Catostomid Fishes in the Upper Colorado River Basin" provided herein (on CD-ROM in a pocket on the inside rear cover), and over the Internet (see instructions below), is an updated and expanded replacement for the printed keys in the 1990 guide (Snyder and Muth 1990). It is a data set of 110 characters and 234 taxon items (species subdivided by developmental interval and size) with associated image, text, and controlling files for use with the DELTA program, *Intkey* (Dallwitz et al. 1993 onwards, 1995 onwards, and 2000 onwards). The current version of the host program, *Intkey5*, runs under Microsoft *Windows 95* and later *Windows* operating systems. A color display with at least 800 x 600 pixel resolution (SVGA) is recommended and higher resolutions are preferred, but 640 x 480 pixel resolution (VGA) will work (less text displayed without scrolling). The key is intended to be used along with descriptions in the 1990 guide and this supplemental update. Figures cited in the key refer to illustrations in these publications (Figs. 3-95 in Snyder and Muth 1990, Figs. 96-109 in this document).

Intkey is one of the longer-standing, highly evolved, and more widely used programs for interactive keys on personal computers (Dallwitz 1993). I first became familiar with an earlier DOS version of *Intkey* when I used the DELTA format (DEscriptive Language for TAxonomy–a powerful, flexible, and widely accepted method for recording descriptive taxonomic data for computer processing) and a suite of DELTA programs (Dallwitz 1980; Dallwitz and Paine 1986) to prepare the printed keys in the 1990 guide (Snyder and Muth 1990). I even considered preparing data sets for use with that earlier DOS version of *Intkey* rather than printed keys for the

1990 guide, but, at the time, conventional printed keys were deemed more appropriate for publication and general use. However, in 1993, it became clear that the guide and keys needed to be expanded to include longnose sucker, and to facilitate easier preparation of the expanded key and future corrections, updates, and expansions, I proposed a more user-friendly and flexible interactive key alternative. In anticipation of this update project in 1995, I visited with M. Dallwitz (Commonwealth Scientific and Industrial Research Organization Department of Entomology, Canberra, Australia), the senior author of *Intkey* and other DELTA programs, for assistance with preparation of preliminary *Intkey* data sets, one for each developmental interval. Through this project, those data sets were further developed and most recently combined into one covering all developmental intervals through juveniles up to 40 mm SL.

Many other programs are available for interactive keys (e.g., *IdentifyIt, LucID, MEKA, Navikey, ONLINE, PollyClave,* and *XID*–Dallwitz 1996 onwards), and some may have worked as well for this project. However, after comparing features and flexibility (in part via Dallwitz 2000 onwards), I decided to stay with *Intkey* 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 now 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 set provided herein for early life stages of suckers; it can be used with a wide array of data sets for other taxa (e.g., salamanders, crustaceans, beetles, butterflies, polycheates, flowering plants, grasses, viruses) that are available as part of published guides, on

CDs, or over the Internet (go to http://biodiversity.bio.uno.edu/delta/ and select “data” or “references” for listed applications).

Installation. — The key can be used directly from the “Delta” directory (folder) on the enclosed CD-ROM or installed on your computer’s hard-drive using the compressed *Intkey* program (Intk32.exe) and data set (cat-ucrb.zip) distribution files on the CD or downloaded from the Internet. 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 (World-Wide) Web (http://biodiversity.uno.edu/delta/ – select “Programs and Documentation,” then under the programs listing, select *Intkey*). “Cat-ucrb.zip” can be similarly downloaded from the Colorado State University College of Natural Resources FTP site for LFL (using your web browser, go to “ftp://ftp.cnr.colostate.edu/pub/lfl/cik-data/” and select the distribution file). Future updates of the data set will probably be available only over the Internet. Users should periodically check the download site for subsequently updated copies of the file with a later date or sequence number in the name.

Install *Intkey* by double clicking on "Intk32.exe" from the CD or its downloaded location and following on-screen instructions. Installation in a directory 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 in a "doc" subdirectory for the user's guide (intkey.doc, a Microsoft *Word* document which is reproduced in part herein as Appendix A) 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 file "Cat-ucrb.zip" and using *WINZIP*, or another suitable decompression program, expand the distribution file into the directory in which you've installed *Intkey*. It will expand as a subdirectory called "cat-ucrb" and include five files and two further subdirectories ("images" and "rtf"). The current data set and associated files require about 0.9 Mb of storage memory.

Use. — The *User's Guide to Intkey* (Dallwitz, et al. 1995 onwards) is reproduced herein as Appendix A (without the lengthy section on commands–in addition to inclusion in the *Intkey* distribution package, the full document, intkey.doc, is also provided on the enclosed CD under delta/doc). 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 enclosed CD, open the "Delta" directory and double click on "intkey5.exe." *Intkey* will open with the data-set name highlighted in an index window (startup dialog box); just click on "OK" to open the data set.

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 is listed and highlighted, 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 and select "intkey-ucrb.ink" in subdirectory "cat-ucrb" (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 the 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 it’s 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 a description of specific 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 .

Before beginning identification, limit taxon possibilities (candidate species) by selecting the pertinent subset of taxa. 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 by river reach (e.g, Yampa River

above Cross Mountain Canyon, Colorado and lower Green Rivers in Utah, San Juan River) or individually from the list of taxa. 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 directed in the general instructions ("introduction" under "help" in main menu).

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

Pigmentation characters used in this key 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 key is generally limited to specimens 40 mm or less in standard length (SL). However, some larger early (young-of-the-year) juveniles can be successfully identified with this key by treating them as 40-mm-SL juveniles. Meristic characters such as fin-ray and scale counts in this key are also applicable to all later juveniles and adults but may not be sufficient for definitive identification of these larger fish.

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 this key, even with its extensive character set, the identity of closely related fish larvae of similar developmental state and size cannot always be resolved to a single species, and even then, 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. 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. Users should critically compare the specimen in question with descriptive information and illustrations in the associated publications to confirm the identity suggested by the key. If available, comparison with preserved reference specimens is also recommended. 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, perhaps with an explanatory footnote) or identified conservatively only to genus or family (e.g., *Catostomus* sp., unidentified catostomid).

Please report any problems, discrepancies, errors, or observed character-range extensions for future updates of this computer-interactive-key data set directly to: Darrel E. Snyder, Larval Fish Laboratory, Colorado State University, 1474 Campus Delivery, Fort Collins, Colorado 80521-1474 (Phone: 970-491-5295, Fax: 970-491-5091, E-mail: Darrel.Snyder@ColoState.edu)

If this key is to be referenced aside from its inclusion in this supplemental update, the suggested citation is:

> Snyder, D. E. 2003 onwards. Computer-interactive key to eggs, larvae, and early juveniles of catostomid fishes of the Upper Colorado 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-ucrb.zip. (If following American Fisheries Society citation format, replace the text in these parentheses with the date you last accessed the site and downloaded or checked on presence of the distribution file.)

Future development. — *Intkey* allows for extensive illustration of taxa and character states. However, such is not critical for operation of the program and for logistical and budgetary reasons, the computer-interactive key herein is largely text-based with extensive references to figures in the 1990 guide (Snyder and Muth 1990) and this supplemental update and only a few character-state illustrations in the key itself. Still, extensive illustration of the key, perhaps with links to files of tabulated species-account and comparative-summary data, would make future versions of the key more self-contained and convenient for users. Moderate-resolution, jpeg-compressed, digital scans (e.g., 0.5-1.0 Mb) of the 56 drawings used to illustrate sucker larvae and juveniles in Snyder and Muth (1990) and this supplemental update could be easily

incorporated in the key, but would require some time to prepare and about 28-56 Mb of storage memory. Illustrations of states for many characters, especially pigmentation characters, might be especially useful and convenient for new and less experienced users, but would require considerably more time to prepare. Most could be prepared as modified composites from selected portions of taxon illustrations.

Once a computer-interactive key is established for a particular set of taxa (e.g., catostomid fish larvae of UCRB), data can be easily corrected or updated and the revised data set made readily available to most users via the Internet. Adaptation or expansion to include additional characters or cover other, similar taxa, requires more effort and, of course, comparable data for all taxon-items or characters, respectively, but is still much easier than adapting or expanding a complex printed key.

The computer-interactive key provided with this supplemental update has great potential for future adaptation or expansion to cover other regions and cypriniform fishes. With comparable data for Rio Grande sucker (mostly already provided by Snyder 1998), the key could be expanded or adapted using portions of the data set for white and longnose suckers to cover the catostomid fishes of the Rio Grande Basin in Colorado. Likewise, for June sucker *Chasmistes liorus mictus* (similarly described by Snyder and Muth 1988) with Utah and mountain suckers for the Utah Lake Basin. With comparable descriptive information for the remaining catostomid species, the key could eventually be expanded to cover all of Colorado or all of the Colorado River Basin. Adaptation of the key for comparably described cyprinid fishes of the UCRB, or elsewhere, would likely require some additional or modified characters, but is certainly feasible.

Species Account–Catostomus catostomus

This descriptive species account for the larvae and early juveniles of longnose sucker follows the format of species accounts published for six other suckers by Snyder and Muth (1990) and completes comparable description of all catostomid species in the UCRB.

Species Account – *Catostomus catostomus*

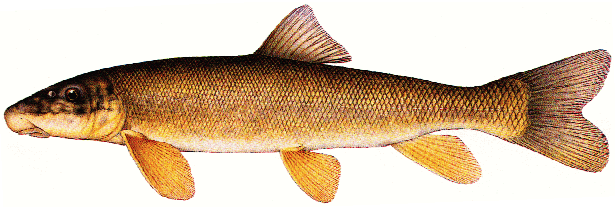


Fig. 96. *Catostomus catostomus* (from Tomelleri and Eberle 1990).

Adult Diagnosis: Elongate, cylindrical body with deep caudal peduncle and no predorsal keel. Long, bulbous, somewhat pointed snout extending well beyond ventral mouth. Cartilaginous ridge along lower jaw but not hard and prominent. Mouth moderate in size but with large, fleshy, coarsely papillous lips, not notched at corners; lower lips flaring widely well behind mouth, medially divided to base or single row of papillae. Dorsal fin short, not falcate. Pelvic axillary process present but small. Scales small. Gill rakers relatively few, short, and fleshy. Fontanelle long and relatively narrow. Peritoneum variable, silvery or dusky with silvery areas to uniformly black. TL usually 30-43 cm, up to 64, possibly 76 cm. (Also, Table 1).

Reproduction: Non-guarding, open-substrate lithophil. April through July, probably May to early July in Upper Colorado River Basin. Migrate at >5 °C. Spawn mostly at 10-15 °C for 1-3 weeks, usually <10 d. Spawn primarily in small tributary or inlet streams at depths of 15-30 cm over gravel with a current of 30-45 cm/sec; occasionally in lakes over sand, gravel, or rocks at depths of 1.5-76 cm. Eggs (2.2-) 2.4-3.0 mm diameter, demersal, initially adhesive.

Young: Hatch in 5-14 days at 18-10°C, remain in gravel 1-2 weeks, then emerge and begin drifting downstream at 10-12 mm TL, usually at night. Young occupy low velocity shoreline areas in streams or lakes, often with aquatic vegetation. Aggregate in top 15 cm of water within 2 m of shore. Those 11-18 mm TL feed on plankton, 20-90 mm graze on weeds and solid surfaces and feed on larger organisms.

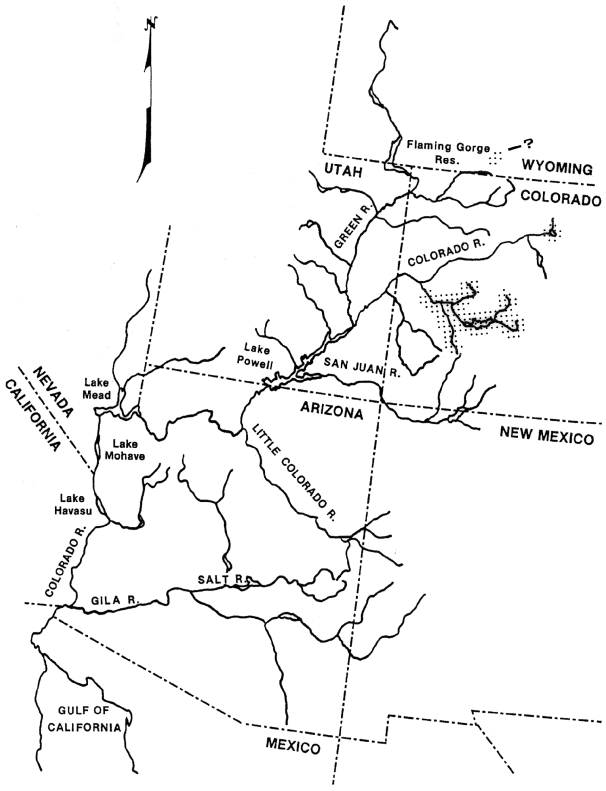


Fig. 97. Regional distribution of *Catostomus catostomus*.

Table 38. Selected juvenile and adult meristics for *Catostomus catostomus*. P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Gill rakers for exterior row of first arch, specimens >70 mm SL. Mean or modal values underlined if known and noteworthy; rare or questionable extremes in parentheses.

Character	Original	Literature	Character	Original	Literature
Dorsal Fin Rays - P:	(9)10-11	9-10-11(12)	Dorsal Fin Rays - R:	2-3	
Anal Fin Rays - P:	7(8)	7(-9)	Anal Fin Rays - R:	2-3	
Caudal Fin Rays - P:	18(-20)	18	Caudal Fin Rays - RD:	10-11-12(-14)	
Pectoral Fin Rays:	15-16-17(18)	16-18	Caudal Fin Rays - RV:	9-10(-12)	
Pelvic Fin Rays:	9-10(11)	9-11	Lateral Scales:	103-105-110(116)	(85-)90-95-115-120
Vertebrae:	46-47	45-47(48)	Gill Rakers:		23-30

Table 39. Size at apparent onset of selected developmental events for *Catostomus catostomus*, as observed under low power magnification. P = principal rays; R = rudimentary rays; Scales are lateral series. Rare or questionable extremes in parentheses.

Event or Structure	Onset or Formation mm SL	mm TL	Fin Rays or Scales	First Formed mm SL	mm TL	Last Formed mm SL	mm TL
Hatched:	(7)8-10	(7)8-10	Dorsal - P:	13-14	(14)15	(13)14(15)	(15)16
Eyes Pigmented:	(7)8 or *	8 or *	Anal - P:	(13)14(15)	(15)16	15-16(17)	(17)18-19(20)
Yolk Assimilated:	10-11(12)	10-12(13)	Caudal - P:	11	11-12	12-13	13-14
Finfold Absorbed:	21-22	26-27	Caudal - R:	13-14	15	21	25-26
Pectoral Fin Buds:	*	*	Pectoral:	13-14	15-16	20-21	24-25
Pelvic Fin Buds:	12	13	Pelvic:	14(15)	16-17	(16-)18-19(-21)	(19-)22-23(-25)
* before hatching			Scales:	27-28	33-34	(30)31	37-38

References: Auer 1982, Baxter and Simon 1970, Baxter and Stone 1995, Becker 1983Beckman 1952, Brauch PC, Carlander 1969, Eddy and Underhill 1974, Everhart and Seaman 1971, Fuiman and Witman 1979, Geen et al. 1966, Harris 1962, Hubbs et al. 1943, Jordan and Evermann 1896, Kay et al. 1994, Lee et al. 1980, Nelson and Paetz 1992, Martinez PC, Morrow 1980, Radant PC, Rahel PC, Remmick PC, Scarola (1973), Schneidervin PC, Scott and Crossman 1973, Simpson and Wallace 1978, Smith 1979, Smith 1985, Snyder 1981, Sturm 1988, Tomelleri and Eberle 1990, Tyus et al. 1982, Wheeler 1997, Wiltzius 1978, Woodling 1985, Wydoski and Whitney 1979.

Table 40. Size at developmental interval (left) and gut phase (right) transitions for *Catostomus catostomus*. See Figure 2 for phases of gut folding. Rare or questionable extremes in parentheses.

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion Mesolarva:	11	11-12	2 - 90° bend:	14	16
Postflexion Mesolarva:	12-13	13-14	3 - Full loop:	16-17	20-21
Metalarva:	15-16(17)	(17)18-19(20)	4 - Partial crossover:	18-21(22)	22-25(-27)
Juvenile:	21-22	26-27	5 - Full cross over:	(19)20-23(-25)	(23)24-28(-31)

Table 41. Summary of morphometrics and myomere counts by developmental phase for *Catostomus catostomus*. See Figure 1 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded.

	Protolarvae (N=16)				Flexion Mesolarvae (N=11)				Postflexion Mesolarvae (N=19)				Metalarvae (N=26)				Juveniles (N=26)			
	$\bar{x}$	±SD	Range		$\bar{x}$	±SD	Range		$\bar{x}$	±SD	Range		$\bar{x}$	±SD	Range		$\bar{x}$	±SD	Range	
SL, mm:	9	1	7	11	12	1	11	13	14	1	12	17	18	2	15	21	30	6	22	41
TL, mm:	10	1	8	12	13	1	11	14	16	2	13	20	21	3	17	26	36	8	27	50
Lengths %SL:																				
AS to AE	3	1	2	4	3	1	3	4	4	1	3	6	6	1	4	9	8	1	6	11
PE	9	1	8	10	9	1	8	11	12	2	9	14	13	1	11	16	15	1	13	18
OP1	16	1	15	18	18	1	16	21	23	2	19	26	25	2	22	28	27	1	24	30
OP2					51	1[a]	50	52	52	1	50	54	56	2	53	59	57	1	55	59
PY	76	2[b]	71	80	71	[c]	71	71												
OPAF	39	19	22	72	27	2	23	31	32	4	25	40	49	9	35	66				
ODF	43	3	39	49	42	1	39	44	45	1	42	47	46	0[d]	46	47				
OD					48	0[a]	48	49	48	1[e]	47	49	49	1	47	52	50	1	49	53
ID									62	1[f]	60	63	63	1	60	66	64	1	62	65
PV	79	1	76	81	78	1	75	79	78	1	77	80	77	1	75	79	76	1	74	78
OA									78	1[g]	76	78	76	1	74	78	76	1	75	77
IA									84	1[h]	82	85	84	1	83	85	84	1	82	85
AFC					106	1[e]	105	107	112	2[e]	107	115	116	1	114	119	116	1	115	118
PC	104	1	103	106	106	1	105	109	114	3	108	118	120	1	117	122	121	1	119	123
Y	52	15	0	64	3	10	0	34												
P1	7	2	4	11	11	1	11	12	13	1	11	15	16	2	13	19	17	1	15	19
P2					1	2	0	4	6	2	3	11	11	2	6	13	13	1	11	15
D									16	1[f]	14	18	19	1	17	21	20	1	18	22
A									8	1[i]	7	9	11	1	9	13	14	1	12	16
Depths %SL:																				
at BPE	9	1	8	11	11	1	9	13	14	2	11	18	17	2	14	19	17	1	16	19
OP1	11	1	10	12	12	1	10	14	16	2	11	19	19	2	16	22	20	1	18	22
OD	12	2[b]	8	15	10	1	8	11	14	2	11	19	18	3	13	22	20	1	19	22
BPV	6	1	3	7	6	1	5	7	7	1	6	10	10	2	7	13	12	1	11	13
AMPM	3	1	2	4	4	1	3	5	6	1	5	8	7	1	5	9	9	1	7	10
Max. Yolk	7	4	0	13	0	1	0	2												
Widths %SL:																				
at BPE	9	1	7	11	11	1	10	13	14	1	12	16	16	1	14	17	17	1	15	19
OP1	6	1	6	8	8	1	6	10	11	2	9	15	15	2	11	18	17	1	16	18
OD	7	2[b]	5	12	6	1	5	7	9	3	6	14	13	3	8	18	16	2	13	19
BPV	4	0	3	4	4	0	4	5	5	1	4	7	7	2	4	10	9	1	7	10
AMPM	2	0	2	3	2	0	2	3	3	1	2	5	4	1	2	5	4	1	3	6
Max. Yolk	8	4	0	14	0	1	0	3												
Myomeres:																				
to PY	35	1[b]	33	37	33	[c]	33	33												
OPAF	14	10	5	31	6	1	6	7	8	1	6	11	16	6	9	27				
OP2					21	1[a]	20	22	21	1	19	22	22	1	19	25				
ODF	15	1	13	17	16	1	14	17	16	1	13	18	16	0[d]	16	16				
OD					19	0[a]	19	19	18	1[e]	16	20	17	1	15	19				
PV	37	1	36	39	38	1	37	39	38	1	36	39	36	1	34	38				
Total	47	2	45	49	47	1	45	49	47	1	45	49	46	1	44	48				
After PV	10	1	8	11	9	1	8	11	9	1	8	10	10	1	9	11				

[a]N = 3; [b]N = 15; [c]N = 1; [d]N = 4; [e]N = 18; [f]N = 11, [g]N = 16, [h]N = 9, [i]N = 8.

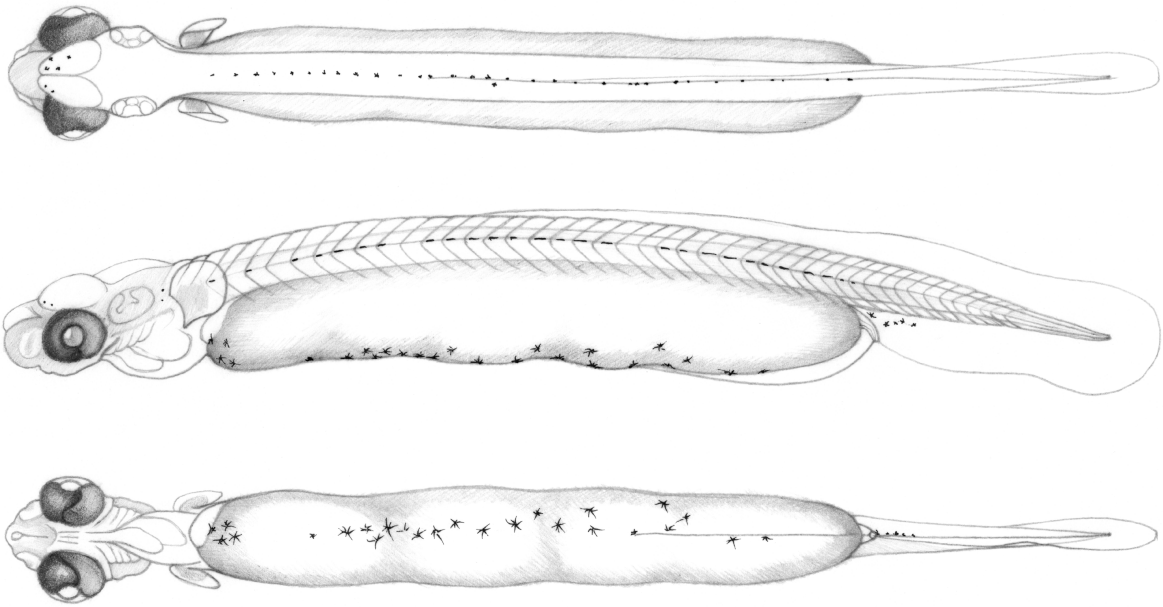


Fig. 98. *Catostomus catostomus* protolarva, recently hatched (day 1), 8.2 mm SL, 8.5 mm TL. Cultured in 1979 with stock from Parvin Lake, Larimer County, Colorado.

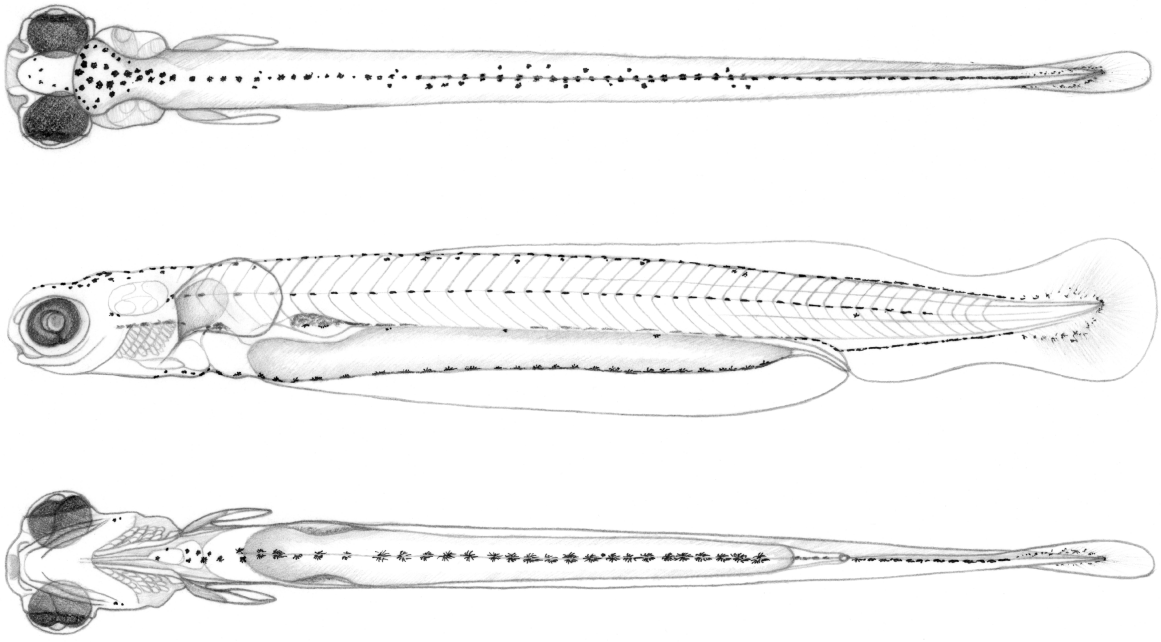


Fig. 99. *Catostomus catostomus* protolarva, 10.2 mm SL, 10.6 mm TL. Cultured in 1979 with stock from Parvin Lake, Larimer County, Colorado.

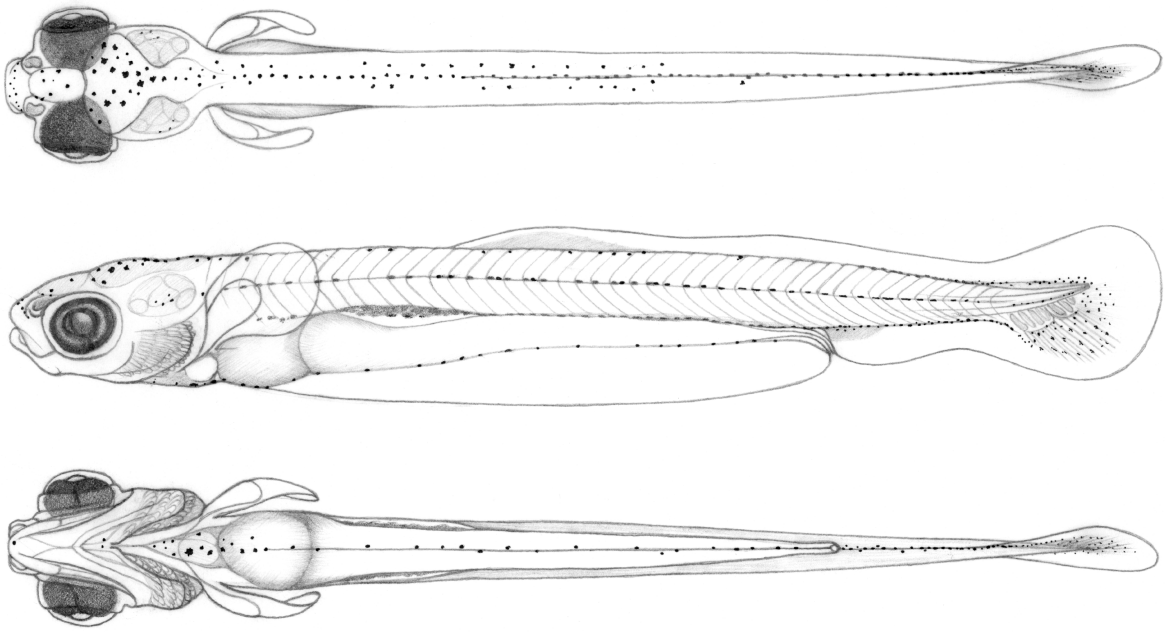


Fig. 100. *Catostomus catostomus* flexion mesolarva, recently transformed, 11.9 mm SL, 12.5 mm TL. Cultured in 1979 with stock from Parvin Lake, Larimer County, Colorado.

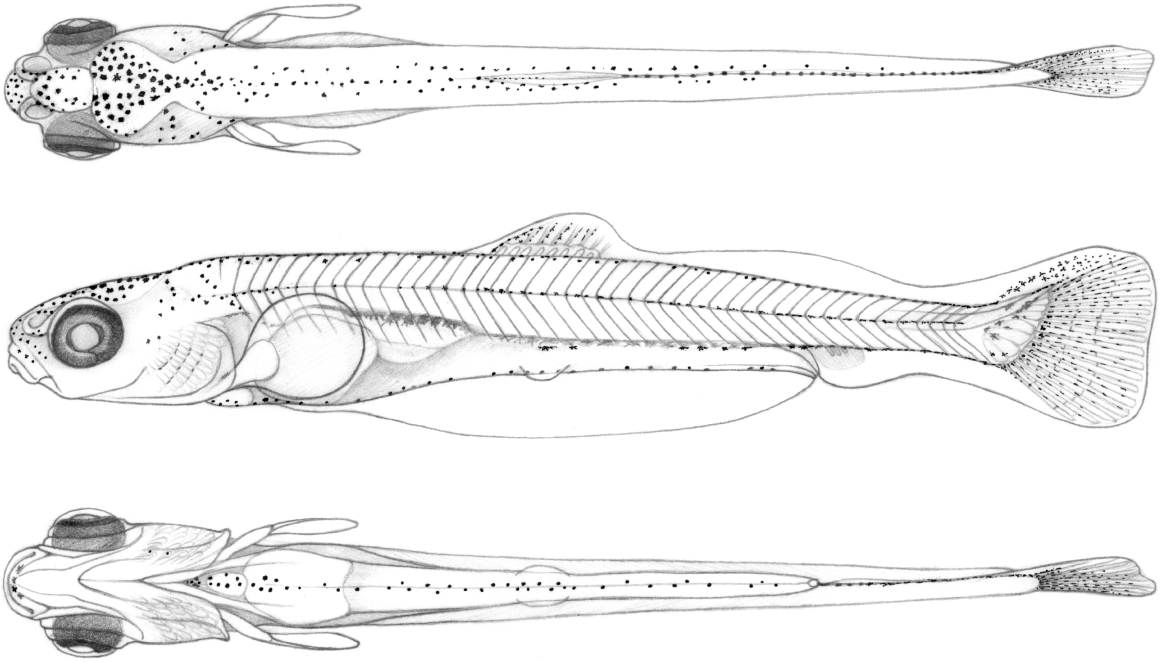


Fig. 101. *Catostomus catostomus* postflexion mesolarva, 13.5 mm SL, 15.1 mm TL. Cultured in 1979 with stock from Parvin Lake, Larimer County, Colorado.

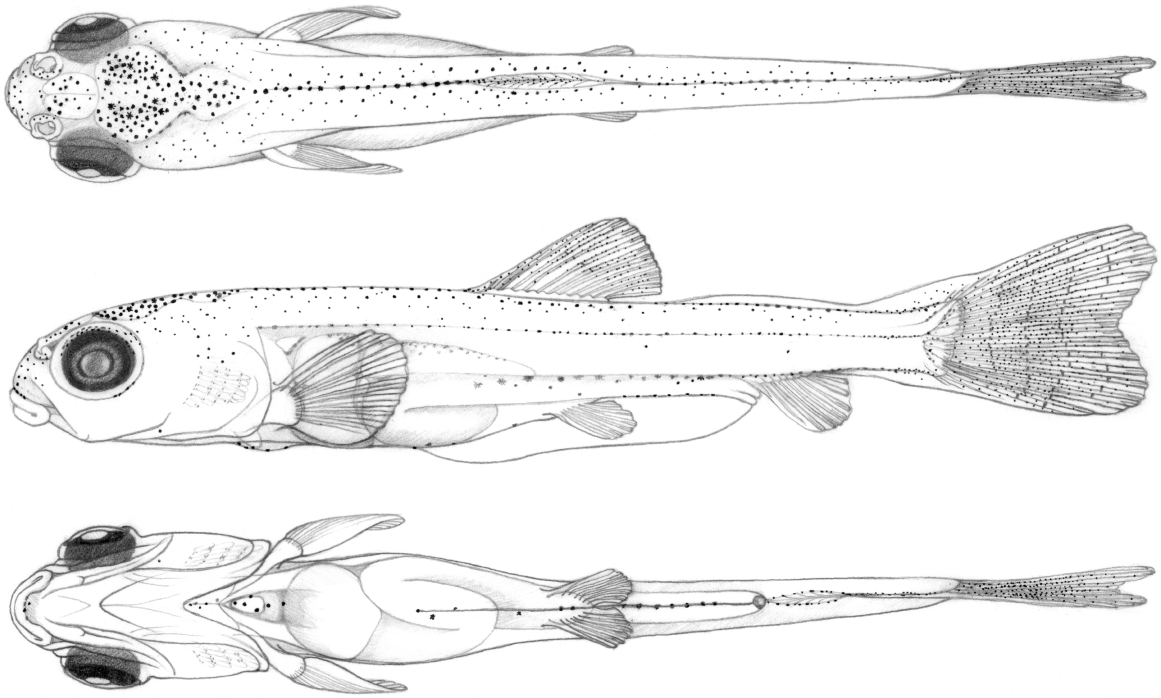


Fig. 102. *Catostomus catostomus* metalarva, recently transformed, 14.6 mm SL, 17.5 mm TL. Cultured in 1979 with stock from Parvin Lake, Larimer County, Colorado.

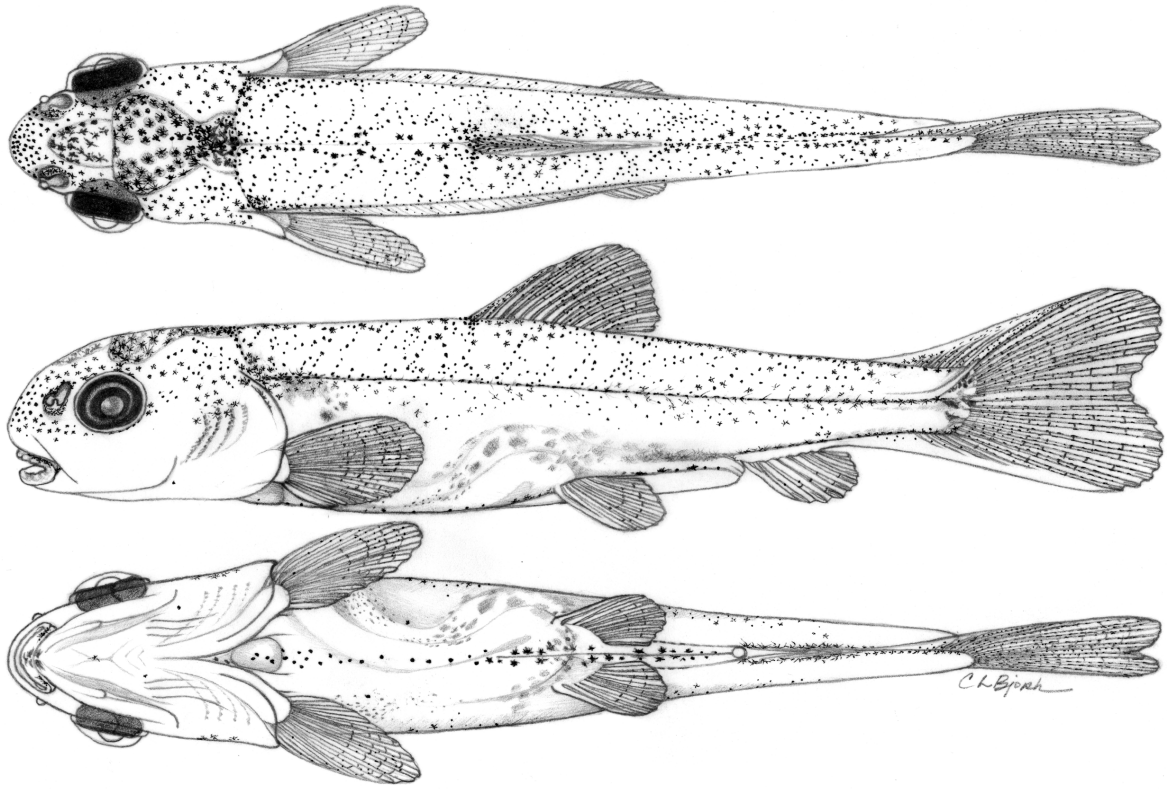


Fig. 103. *Catostomus catostomus* metalarva, 18.7 mm SL, 22.5 mm TL. Cultured in 2001 with stock from Upper Big Creek Lake, Jackson County, Colorado.

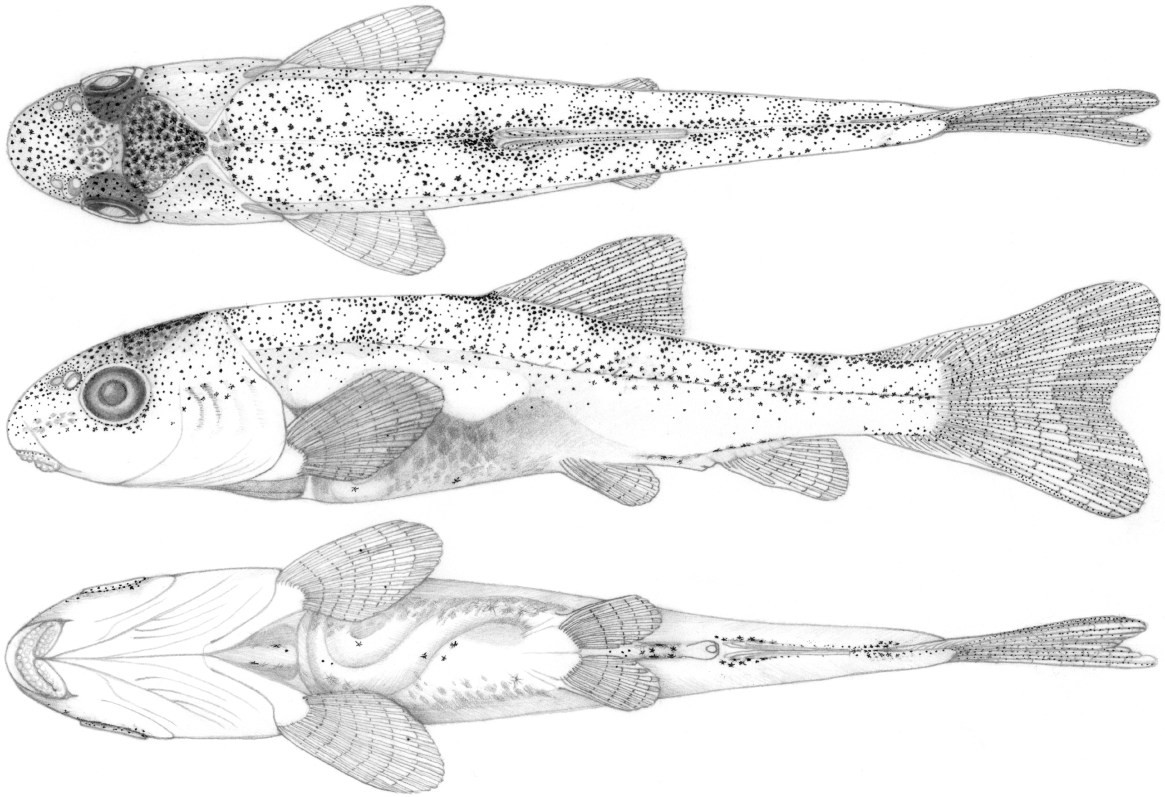


Fig. 104. *Catostomus catostomus* juvenile, recently transformed, 22.9 mm SL, 27.8 mm TL. Collected 21 September 1995 from Gunnison R., Kilometer 94.0, near Escalante, Delta County, CO.

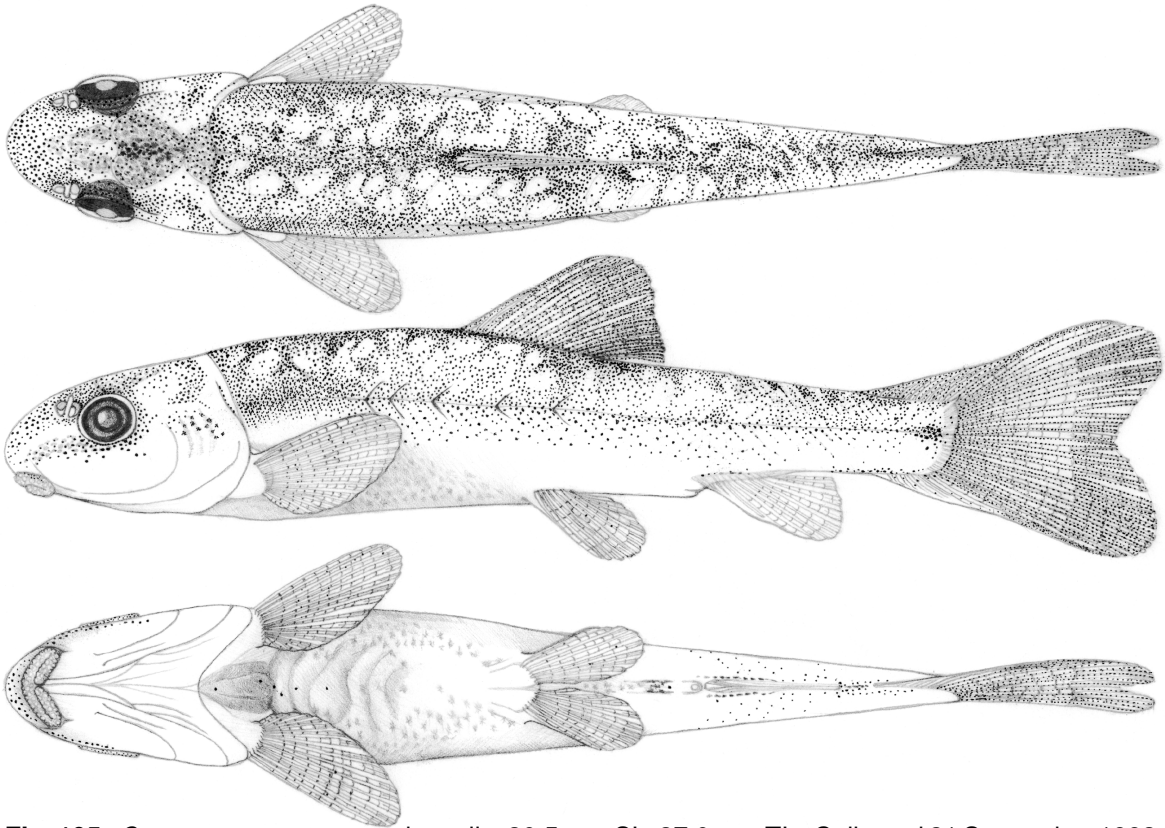
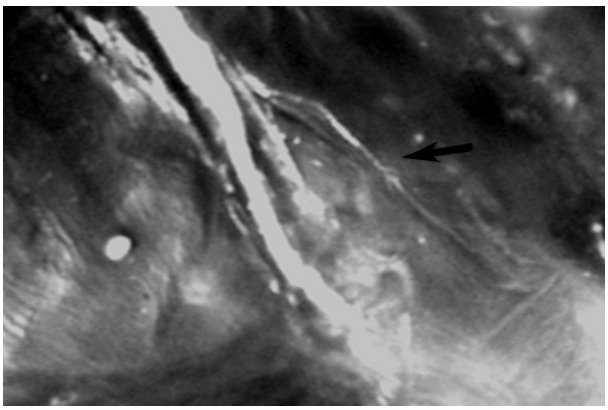
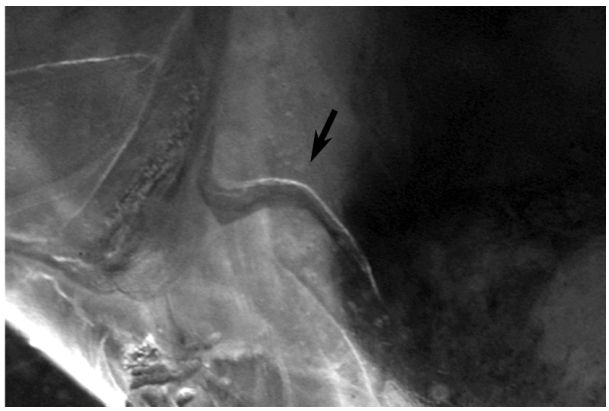
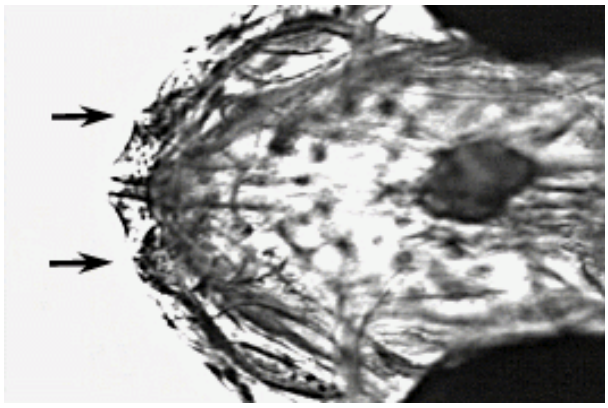
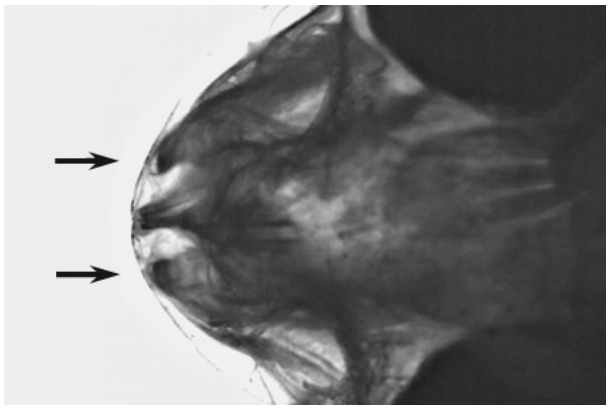


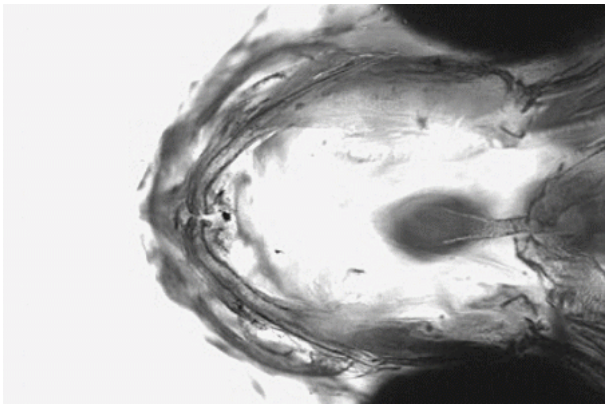
Fig. 105. *Catostomus catostomus* juvenile, 30.5 mm SL, 37.0 mm TL. Collected 21 September 1993 from Gunnison River, Kilometer 96.1, near Escalante, Delta County, Colorado.











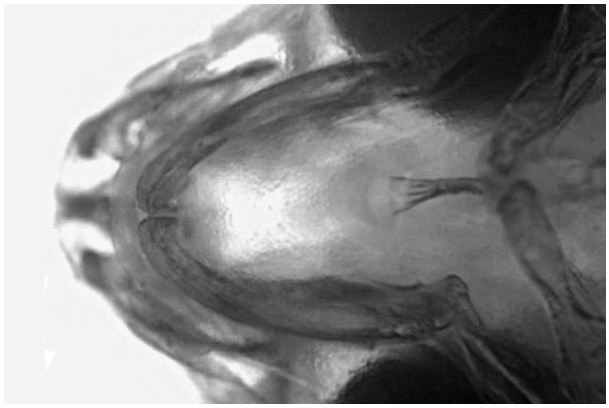
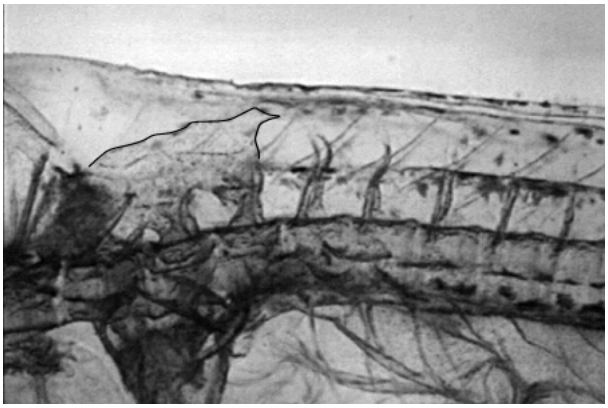
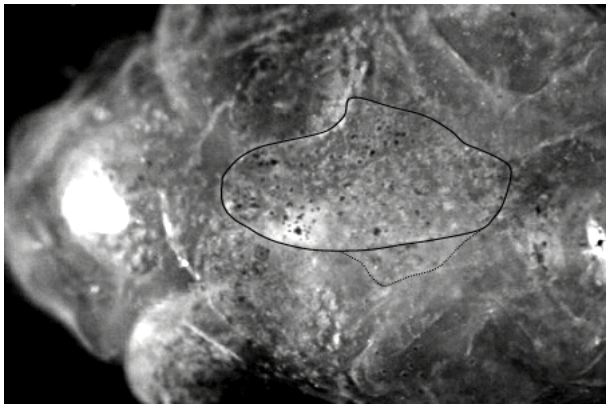
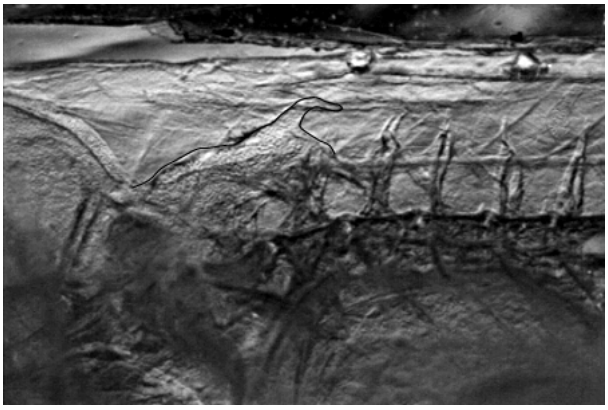


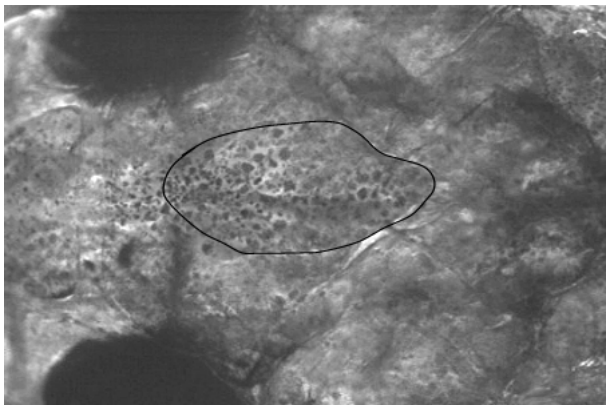
Fig. 106. Selected skeletal features of *Catostomus catostomus*, metalarva, 20 mm SL, 24 mm TL. Top – postcleithrum. Middle – anterior-dorsal maxillary projections. Bottom – mandible position.

Fig. 107. Selected skeletal features of *Catostomus catostomus*, juvenile, 41 mm SL, 49 mm TL. Top – postcleithrum. Middle – anterior-dorsal maxillary projections. Bottom – mandible position.









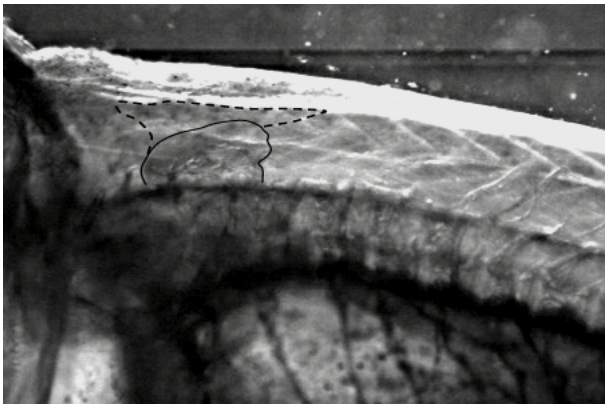


Fig. 108. Interneurals of *Catostomus catostomus*. Top – postflexion mesolarva, 15 mm SL, 18.0 mm TL. Middle – metalarva, 20.5 mm SL, 24.4 mm TL. Bottom – juvenile, 41 mm SL, 49 mm TL (dashed line–possible unstained portion).

Fig. 109. Frontoparietal fontanelle of *Catostomus catostomus*. Top – metalarva, 22 mm SL, 26 mm TL (head angled downward giving false impression that fontanelle is more anterior than it should be). Bottom – juvenile, 29 mm SL, 35 mm TL.

Table 42. Dimensions of frontoparietal fontanelle for *Catostomus catostomus* larvae >16 mm SL., early juveniles, and yearling..

Specimens mm SL	n	Max. width (mm)	Max. length (mm)	Width as % of length
17-19	2	1.5-1.5	1.8-2.1	71-83
20-21	2	1.5-1.7	2.0-2.1	75-79
22-25	3	0.9-1.5	2.1-2.3	39-68
26-34	3	1.1-1.4	2.7-3.0	40-47
35-46	2	1.1-1.4	3.2-3.8	29-44
47-75	2	1.1-1.4	3.8-4.5	29-31
76-87	1	1.5	4.8	31

Conclusions

This project has successfully completed its primary objective of updating and completing the 1990 CDOW guide to catostomid larvae and early juveniles in western Colorado and the UCRB. It has also successfully met its second objective of providing proof-of-concept for the effective application of computer-interactive keys to larval fish identification. Whether the goal of facilitating more accurate identification of collected razorback and other sucker larvae in the basin is realized beyond LFL staff depends on the extent to which other regional biologists become familiar with and utilize the updated descriptive information, new species account, and key.

The usefulness of these taxonomic tools can extend well beyond the UCRB. Allowing for potential differences in developmental morphology exhibited by remote populations, these descriptions and the key can be used for identification of covered species wherever they may occur. For example, white and longnose sucker are common throughout much of Colorado (the only *Catostomus* species in eastern-slope drainages), and indeed much of North America. And bluehead, flannelmouth, and razorback sucker occur in portions of the Lower Colorado River Basin. Where two or more of these species occur exclusive of other closely related species (or where similar sympatric species can be eliminated otherwise as candidates for the specimen to be identified), the key has the flexibility of being limited to just those species and effectively becoming a key for that region, site, or circumstance.

Future updates, adaptations, or expansions of the computer-interactive key provided herein could be made more convenient, especially for new and less experienced users, by incorporating extensive illustration of states for at least some types of characters (e.g.,

pigmentation patterns) and of taxa rather than referring users to illustrations in published descriptions. But even without extensive illustration, this key has great potential for future adaptation or expansion to cover catostomid fishes in other regions and cypriniform fishes in the UCRB and elsewhere.

Recommendations

In addition to limited distribution of this supplemental update as a final report to the Recovery Program, I recommend more formal publication and broader distribution of an appropriately modified version of this report (e.g., removal of this recommendation and Appendix B) with a second printing of the long out-of-print 1990 CDOW guide (Snyder and Muth 1990) that it supplements and updates. Alternatively, and perhaps preferably, this supplemental update could be integrated and published in a revised and expanded edition of the 1990 guide (prospectively entitled *Catostomid Fish Larvae and Early Juveniles of the Upper Colorado River Basin–Morphological Description, Comparison, and Computer-Interactive Key*). A draft Recovery Program proposal considering both options is provided in Appendix B.

Over 20 years ago the LFL published *Contributions to a Guide to the Cypriniform Fish Larvae of the Upper Colorado River System in Colorado* through the U.S. Bureau of Land Management (Snyder 1981). Based on descriptive information and illustrations from the literature and several developmental studies, funded in part by CDOW, that document was intended to serve as the foundation for a comprehensive guide. With this supplemental update and proof-of-concept that computer-interactive keys can be effectively prepared for and applied to identification of sets of very similar-appearing fish larvae, Part 1 of a comprehensive guide to

the cypriniform fish larvae and early juveniles of western Colorado and the UCRB is now complete, except for formal publication. I recommend that the Recovery Program and CDOW proceed with support for Part 2, a comparable and long-proposed guide with a computer-interactive key to the cyprinid larvae and early juveniles, including three of the four endangered fishes in the basin.

Although enhancement of the computer-interactive key with extensive illustration would be desirable, I recommend that such be deferred for future updates or included in support for Part 2 of the comprehensive cypriniform guide. Some illustration of the key might be gradually accomplished as a byproduct of other computer-interactive key projects.

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Rahel, F. J. University of Wyoming, Laramie.

Remmick, R. Wyoming Game and Fish Department, Green River.

Schneidervin, R. Utah Division of Wildlife Resources, Dutch John.

Appendix A – User's Guide to *Intkey*

Reprint of:

Dallwitz, M. J., T. A. Paine, and E. J. Zurcher. 1995 (onwards). User's guide to Intkey: a program for interactive identification and information retrieval, 1st edition. Commonwealth Scientific and Industrial Research Organization Department of Entomology. Available: biodiversity.uno.edu/delta/. (April 2003).

This reprint excludes the front cover and last section which pertains to *Intkey* commands. The full document is also available on the enclosed CD as a *Word* file (delta/doc/intkey.doc).

User's Guide to Intkey

A Program for Interactive Identification and Information Retrieval

Edition 1.09

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CSIRO Entomology
Australia

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Edition 1.09 December 2000

This manual is included in the full DELTA program package
available at http://biodiversity.uno.edu/delta/

M.J. Dallwitz, T.A. Paine, and E.J. Zurcher (1995 onwards).
'User's Guide to Intkey: A Program for Interactive Identification and Information Retrieval.'
Edition 1.09 (December 2000).
http://biodiversity.uno.edu/delta/

Abstract

Intkey is an interactive program for identifying a specimen by comparing it with stored descriptions. The program can also be used to interrogate the stored data.

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Introduction

Introduction

Intkey is an interactive program for identifying a specimen by comparing it with stored descriptions. The program can also be used to interrogate the stored data.

Intkey has two modes of operation: Normal and Advanced. We recommend that you start with Normal mode, even if you know how to use conventional identification keys.

In Normal mode, the program is operated via the toolbars. Most of the menu system, many dialog-box buttons, and the command line are disabled.

In Advanced mode, which is set by the 'Advanced Mode' option of the 'File' menu, the program can be operated via the toolbars, the menu system, or the command line. Before using this mode, you should become thoroughly familiar with Normal mode, and read the 'Introduction' which becomes available upon entering Advanced mode.

To display the Help for an active toolbar button (one that is not grey), first press the '?' button at the right of the main toolbar (which is just below the menu bar), then click on the button for which help is required. Basic instructions for using the program for identification are in the help for the 'Restart identification' button. The author of a data set may also have supplied other help accessible via the leftmost button of the main toolbar.

This documentation is intended for users of Advanced mode. It is not available in Normal mode, for which the Help provided with the toolbar buttons should be adequate.

Identification

To identify a specimen:

1. In the 'Characters' toolbar (top-left pane), press the 'Restart identification' button.
2. The top-left pane shows a list of characters. Normally, the pane is headed 'Best Characters' and the best characters are at the top (if not, you can restore this setting by pressing the 'Best order' button). Click on a character.
3. The program displays a list of character states, or a box for entering values such as lengths. If there is an illustration for the character, it will be normally be displayed automatically (if not, press the 'Images' button). Most characters have explanatory notes, which may be viewed by pressing the 'Notes' button. Click on the state, or enter the value, that applies to your specimen, and press 'OK'. *If you are not sure, do not guess a single state or value* . Instead, click on more than one state, enter a range of values, or press 'Cancel' and try another character. To deselect a previously selected state, click on it again.
4. The 'Taxa Remaining' (top-right) pane shows the taxa that match the information that you have entered. The 'Taxa Eliminated' (bottom-right) pane shows the taxa that do not match, with the number of mismatches in parentheses. Repeat from step 2 until 'Identification complete' or some other message is displayed in the top-left pane. A 'Help' button is also displayed; press this to obtain information on how to proceed (for example, how to confirm the identification).

If, at any stage, you think you have made a mistake and want to correct it, click on the appropriate character in the 'Used Characters' (bottom-left) pane. The program again displays the box for selecting character states or entering values, and you can change the information you previously entered. You can remove the character from the identification by clearing all the information.

Checking an Identification

You should check your identification against the information that can be obtained by pressing the 'Information' button, in the 'Taxa' toolbar (top-right pane). The information usually includes full and diagnostic descriptions. A diagnostic description aims to distinguish the taxon from all the others, using only characters that have not already been used in the identification. Illustrations may also be available.

If the descriptions or illustrations are inconsistent with the tentative identification, you can increase the 'error tolerance', by means of the 'Error tolerance' button in the 'Characters' toolbar (in the top-left pane). This allows a greater number of mismatches before taxa are eliminated, so some taxa that were previously in the 'Eliminated Taxa' pane move to the 'Remaining Taxa' pane. The identification process can then be continued exactly as before, until only a single taxon remains.

Increasing the error tolerance may also be used directly to confirm or increase your confidence in a tentative identification. Continuing the identification after increasing the error tolerance should again lead to a single remaining taxon. This may or may not be the same as the original remaining taxon, but, in either case, it will be more strongly separated from the eliminated taxa, and so you can have more confidence in the result. The advantage of this method over using a diagnostic description is that you have full control over the extra characters used.

In Advanced mode (see 'Help' menu), an increased error tolerance can be used in conjunction with the 'Separate a given taxon' button, which orders the available characters according to how well they separate a given taxon from the other remaining taxa. This can lead to a quicker confirmation or rejection of the tentative identification. If the extra information that you enter is inconsistent with the original identification, you should switch back to using the 'Best' order.

Not Enough Characters to Complete an Identification

In some circumstances, you may be unable to use any of the available characters (for example, if your specimen is incomplete), or the program may report that there are no characters that separate the remaining taxa.

If you have used the 'Use subsets of the characters' button to exclude some characters, you could try using the button again to include all the characters. Other possibilities are as follows.

If you have used the 'Error tolerance' button to allow mismatches between the specimen and the remaining taxa, you could try reviewing the information you have entered, which is displayed in the 'Used Characters' (bottom-left) pane. If you can see an obvious error, click on the relevant character. The program displays the box for selecting character states or entering values, and you can change the information you previously entered.

(1) The specimen information that you have entered may be too broad. You can find out which characters separate the remaining taxa by selecting all the remaining taxa, and pressing the 'Differences' button in the 'Taxa' toolbar. These differences may include characters that you have

already used. If so, you may be able to separate the taxa by selecting fewer states or entering smaller ranges for those characters. To do this, click on the required character in the 'Used Characters' (bottom-left) pane. The program displays the box for selecting character states or entering values, and you can change the information you previously entered.

(2) The author may have set 'reliabilities' of zero for some characters that were considered to be generally inappropriate for use in identification (for example, number of chromosomes). This prevents the characters appearing in the 'Best Characters' pane. You can find out whether such characters separate the remaining taxa by selecting all the remaining taxa, and pressing the 'Differences' button in the 'Taxa' toolbar. If a useful character is found, you can access it by first pressing the 'Natural order' button in the 'Characters' toolbar.

(3) It may be that the taxa really cannot be separated by the comparative information in the database. Information available via the 'Information' button in the 'Taxa' toolbar, may help to distinguish them. The information may include descriptions, illustrations, and links to Web pages. The descriptions may contain supplementary free-text information and/or references, in addition to the comparative information from the database.

Selecting Taxa

The taxa on which an operation is to be carried out (for example, displaying the differences between taxa) may be selected in the 'Taxa' (right-hand) panes of the main window before specifying the operation. In Advanced mode, other selection methods are also available (see 'Dialog Boxes and List Boxes').

The 'Remaining Taxa' and 'Eliminated Taxa' lists behave as a single list when taxa are being selected. Clicking on a taxon selects that taxon and deselects all others. Multiple taxa can be selected in the usual ways, that is, by holding down the Shift and/or Ctrl keys while clicking.

The 'Find text in taxon names' button in the 'Taxa' toolbar allows you to search for text in the taxon names in the 'Taxa' panes. The authorities are also searched, although they are not normally displayed in these panes. The names found are selected, allowing them to be used in subsequent operations (for example, in requesting information about the taxa). By default, all the matching names are selected; 'Next' and 'Previous' buttons allow all the selections to be seen, if they cannot all be displayed together. Clicking the radio button 'Select one' cause the names to be selected one by one; the 'Next' and 'Previous' buttons then move the selection to the next or previous matching name.

By default, only the names in the 'Remaining Taxa' (top-right) pane) are searched. Check boxes allow the search to be extended to the 'Eliminated Taxa' (bottom-right) pane and to the synonyms (if available).

Information retrieval

The 'Remaining Taxa' and 'Eliminated Taxa' lists behave as a single list when taxa are being selected. Clicking on a taxon selects that taxon and deselects all others. Multiple taxa can be selected in the usual ways, that is, by holding down the Shift and/or Ctrl keys while clicking.

The ‘Information’ button in the ‘Taxa’ toolbar (top-right pane) provides access to descriptions and illustrations of taxa. Before pressing the button, you may select the required taxon or taxa in either or both of the ‘Taxa’ panes; if no taxa are selected, the ‘Remaining’ taxa are used.

When the button is pressed, the ‘Information’ dialog box is displayed. This initially shows the name of the first (or only) selected taxon, and lists the descriptions and/or images that are available for it. Any or all of these can be selected and displayed. The information for the other selected taxa (if any) can be shown by navigating the list of taxa by means of ‘Back’ and ‘Forward’ buttons, or by selecting from a drop-down list. A completely new selection of taxa can be made by means of the ‘Select new taxa’ button.

The information usually includes a diagnostic description, which aims to distinguish the taxon from all the others in at least a certain number of characters. This number is called the ‘diagnostic level’. Intkey gives it a default value of 1, but a larger value may have been set by the author of a particular data set. The diagnostic description includes messages showing the diagnostic levels that were actually attained. If an identification is in progress, the diagnostic description uses only characters that have not already been used in the identification.

Images are scaled to fit the available area; to turn scaling off or on, click ‘Scaled’ in the image’s ‘Window’ menu. To view an image or description at the maximum possible size, press its ‘maximize’ button.

The ‘Differences between taxa’ button in the ‘Taxa’ toolbar (top-right pane) displays the differences between selected taxa. Two or more taxa must be selected in either or both of the ‘Taxa’ panes before pressing the button. Differences in free-text characters are not shown, and unrecorded or inapplicable attributes are not treated as being different from recorded attributes.

Taxa having a specified set of attributes can be found by using the ordinary identification procedure to specify the attributes. The natural order of the character list (obtained by pressing the ‘Natural order’ button in the ‘Characters’ toolbar) should be used. The ‘Match’ setting used for identification is usually inappropriate, because taxa for which the specified characters are unrecorded or inapplicable are not eliminated. The setting can be changed by means of the ‘Set match’ button, which is in the ‘Characters’ toolbar in Advanced mode. For details, see the help for the ‘Set Match’ command, which is available via the main ‘Help’ menu, or by pressing the ‘Help’ button in the ‘Set Match’ dialog box.

To find the taxa for which a given character is unrecorded, set ‘Match’ to ‘Overlap Inapplicables’, and select all the states of the character; the taxa for which the character is unrecorded are displayed in the ‘Eliminated Taxa’ pane.

The Queries menu contains other commands useful for information retrieval: Describe, Diagnose, Differences, Similarities, and Summary. Using the Differences command from this menu instead of from the ‘Taxa’ toolbar allows more flexibility — free-text attributes may be compared, and matching is defined by the current ‘Match’ setting.

Modes of Operation

Intkey has two modes of operation: Normal and Advanced.

In Normal mode, the program is operated via the toolbars. Most of the menu system, many dialog-box buttons, and the command line are disabled. There are three toolbars: the main toolbar, just under the menu bar; the 'Characters' toolbar, at the top of the 'Best/Available Characters' (top-left) pane; and the 'Taxa' toolbar, at the top of the 'Remaining Taxa' (top-right) pane. The main toolbar is usually defined by the author of a data set, and invoked in the program's initialization file (usually INTKEY.INI or INTKEY.INK).Advanced mode, which is set by the 'Advanced Mode' option of the 'File' menu, the program can be operated via the toolbars, the menu system, or the command line.

The program works the same in both modes, with the following exceptions.

1. Different main-toolbar buttons may be available in the two modes, and buttons which look the same may have been defined differently (see 'Define').
2. In Normal mode, there are no 'Separate' and 'Set match' buttons in the 'Characters' toolbar (top-left pane).
3. In Normal mode, the following keywords are not shown in keyword-selection dialogs: remaining, eliminated, selected, available, used.
4. In Normal mode, character images are automatically displayed during identification. In Advanced mode, you must press the 'Images' button to display images. See 'Display Images'.
5. In Normal mode, Autotolerance is off; in Advanced mode, it is on. See 'Set Autotolerance'.

Keywords

A keyword is a word or phrase associated with a group of characters or taxa. The keyword can be used to refer to those characters or taxa (instead of using a list of character or taxon numbers).

The set of characters or taxa denoted by a keyword is normally restricted to the 'included' characters or taxa. See the 'Include' command for details and an example.

Keywords are defined by means of the 'Define' command. Most sets of data will incorporate keywords defined by the person who prepared the data. You can add further definitions for your own convenience.

Several keywords are predefined by the program itself. The actual sets of characters and taxa defined by these may change as you use certain commands.

Four character keywords are predefined:
all – all the (included) characters;
none – none of the characters;
used – the characters used in the current identification;
available – the characters still usable in the current identification (characters which have not been used, and which are not inapplicable because of a dependency on used characters).

Five taxon keywords are predefined:
all – all the (included) taxa;
none – none of the taxa;
remaining – the taxa remaining in the current identification;
eliminated – the taxa eliminated from the current identification.

selected – the taxa currently selected in the 'Taxa' panes of the main window..

Dialog Boxes and List Boxes

Many commands require you to specify the taxa and/or characters upon which the command is to act, and some also require you to specify character states. These commands automatically display a 'dialog box' from which you can make your selection. Inside the dialog box are various buttons, and a 'list box' containing taxa, characters, or states. Clicking on an item in the list selects the item (or deselects it if it was already selected). You can also drag the cursor to select or deselect multiple items. Some dialog boxes contain 'SelectAll' and 'DeselectAll' buttons, which select or deselect all the items in the list.

The item currently at the 'focus' of a list box is enclosed in a dotted rectangle, and is also indicated by an arrow. If you press the 'OK' button (or its equivalent) without having selected any items from the list, then the item at the focus is automatically selected.

Taxa and characters may be selected in groups from 'keyword' dialog boxes, or individually from taxon and character dialog boxes. To switch between these dialog boxes, use the 'Keywords' and 'List' buttons.

Using the keyboard in list boxes

You can move the focus in list boxes by pressing the up-arrow, down-arrow, PageUp, PageDown, Home, and End keys, or by typing the number of the required item. The space bar selects or deselects the item at the focus.

Advanced selection methods

A set of taxa or characters may be built up by repeated selections or deselections in the keyword and taxon or character dialog boxes. The rules governing the process are as follows.

1. When a keyword dialog box is deactivated by pressing an 'OK' or 'List' button, the taxa or characters corresponding to the selected keywords are added to the set.
2. When a taxon or character dialog box is deactivated by pressing an 'OK' or 'Keywords' button, the selected taxa or characters are added to the set, and the deselected taxa or characters are removed from the set.

Note that taxa or characters cannot be *removed* from the set via the keyword dialog box. As control passes to and fro between the keyword and taxon or character dialog boxes, the keywords and taxa or characters that are currently in the set are automatically marked as selected. The fact that a keyword is *not* automatically marked as selected implies only that at least one of its taxa or characters is not in the set.

Buttons in Dialog Boxes

All Images. Select all the images in the list.
Cancel. Cancel the command (or the current part of a repetitive command).
Change. Equivalent to 'OK' in 'Change' dialog box.
Delete. Equivalent to 'OK' in 'Delete' dialog box.
Deselect All. Deselect all the items in a list.

Display. Display the selected information.
*Done.*Close the dialog box.
Full Text. Display the full text of a character or taxon name.
Help. Obtain information about using the program.
Images. Display image(s) for the character currently being used, or for the taxon or character at the focus.
Keywords. Open or return to the keyword dialog box.
List. Open a dialog box containing the taxa or characters corresponding to the keyword at the focus.
Notes. Display notes about the character currently being used or at the focus.
OK. Proceed with the command.
Search. Search for text in a list.
Select All. Select all the items in a list.
Stop. Stop a repetitive command.

The Command Line

Intkey commands may be typed in on the 'command line' at the bottom of the screen. Commands consist of a command word, or a command word followed by parameters. You can learn to use the command line by observing the commands which are built up by the program when you use the menu system.

Command words and parameters may be abbreviated, as long as the abbreviations are not ambiguous (the program will tell you if they are).

You can edit the command line by using the left and right arrow keys, and the Backspace, Delete, and Insert keys.

If a keyword (q.v.) containing blanks is used on the command line, it must be enclosed in quotation marks ("), or the blanks must be omitted. All taxon names can be used as keywords on the command line.

Commands may also be read from a file. See the 'File Input' command for details.

Saving Output

Program output can be saved in files, or copied to the clipboard and pasted into other applications.

Output from commands such as 'Describe', 'Diagnose', and 'Differences' is normally displayed in separate windows. The contents of these windows can be printed, saved, or copied to the clipboard by the usual Windows mechanisms.

The contents of the 'log', which can be displayed by means of the command 'Display Log On' in the 'Settings' menu, can also be printed, saved, or copied to the clipboard by the usual Windows mechanisms; they can also be saved via the 'File Log' command in the 'File' menu.

The 'File Output' and 'Output' commands in the 'File' menu produce output in special formats for input to other programs.

Data-Sets Index and Startup Parameters

Data sets are normally selected from a dialog box, which the program displays on startup or when the New Data Set option of the 'File' menu is invoked. The program generates this dialog box from a file INTKEY.IND which is normally in the same directory as the program. Entries in this file can be added or removed using Intkey dialog boxes which are automatically displayed at appropriate times. Also, the file can be edited with any text editor (e.g. Notepad, which is supplied with Windows).

If there is a file INTKEY_.IND in the same directory as the program, the name of a data-set initialization file (usually INTKEY.INI or INTKEY.INK) is read from this file, and the data set is immediately loaded. This feature can be used to simplify the starting of an Intkey package on a CD-ROM.

Some aspects of the program's behaviour on startup can be controlled by adding parameters to the shortcut target line, as follows. Press the Windows 'Start' button. Select 'Settings'. Select 'Taskbar'; the 'Taskbar Properties' dialog box appears. Select the 'Start Menu Programs' tab. Press the 'Advanced' button; an 'Exploring ...' window appears. In the right-hand part of the window, double click on Programs, then double click on DELTA. Click the right mouse button on 'Intkey'; a menu appears. Click on 'Properties'; the 'Intkey Properties' dialog box appears. Click on the 'Shortcut' tab. Click near the end of the 'Target' text box, and type in the required parameters, separated by blanks.

The available parameters are as follows.

filename
: Specifies the name of an initialization file (for example, C:\ANGIO\INTKEY.INI). The corresponding data set is then automatically loaded when the program starts, and the data-set selection box is not displayed.

–A
: Sets Advanced mode.

–G=*filename*
: Specifies the name of the (global) index file. The default is INTKEY.IND in the same directory as the program. You will need to use this option if Intkey is on a network drive for which you do not have write permission.

–H=*filename*
: Specifies the name of the 'Help' file. The default is INTKEN.HIN in the same directory as the program.

–I
: Suppresses display of startup images.

–P=*filename*
: Specifies the name of a preferences file — see help for the 'Preferences' command. The default directory is the one containing the program.

–R=*filename*
: Specifies the name of the DELTA registration file. The default is DELTA.INI in the same directory as the program.

Hardware and Operating-System Requirements

Intkey requires Windows 95, NT, or later.

The program will work on any hardware capable of running Windows. However, for good image quality, we recommend a display card with at least 32768 colours at 800x600 or 1024x768 resolution, and a refresh rate of at least 70Hz.

Conditions of Use

If the use of the program leads to a publication, you must include appropriate citations (see below), and send a copy of the publication to the authors.

Use or distribution of the program for financial gain is prohibited unless you have entered into a License Agreement for such use or distribution.

Details of the conditions of use are contained in the file USE.TXT, which accompanies the the DELTA program suite (see http://biodiversity.uno.edu/delta/).

References

Dallwitz, M. J. (1980). A general system for coding taxonomic descriptions. Taxon 29, 41–6.

Dallwitz, M. J., Paine, T. A., and Zurcher, E. J. (1993 onwards). User's guide to the DELTA System: a general system for processing taxonomic descriptions. 4th edition. http://biodiversity.uno.edu/delta/

Dallwitz, M. J., Paine, T. A., and Zurcher, E. J. (1995 onwards). User's guide to Intkey: a program for interactive identification and information retrieval. 1st edition. http://biodiversity.uno.edu/delta/

Dallwitz, M. J., Paine, T. A., and Zurcher, E. J. (2000 onwards). Principles of interactive keys. http://biodiversity.uno.edu/delta/

Appendix B – Proposal for Publication

Computer-Interactive Key to the Eggs, Larvae, and Early Juveniles of Catostomid Fishes of the Upper Colorado River Basin with Description of Longnose Sucker.

Supplemental update to CDOW guide by Snyder and Muth (1990),
Colorado Division of Wildlife Technical Publication 38

Publication options and estimated costs

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1. Publication of this Supplemental Update without a reprint of the 1990 guide.

This would provide for formal publication and much broader distribution of this document, possibly as a CDOW Special Report, with the computer program and files on CD in a back cover pocket (approximately 64 pages plus covers). Users would be expected to already have and manually update their own copies of the 1990 guide except for substitution of the comparative summary, two illustrations for white sucker, and keys, and addition of the species account for longnose sucker. Since the 1990 guide has been out-of-print since the mid-90s, new users would need to locate and buy used copies of the 1990 guide or obtain photocopies (e.g., via Fish and Wildlife Reference Service, Bethesda, MD; MIN# 059140020). Unfortunately, depending on source, critical illustrations in the guide may not photocopy well. The new computer-interactive key is intended to be used with both the manually updated 1990 guide and the Supplemental Update for illustration of the covered taxa and to help confirm the results of the key.

Estimated costs –	Supplemental update, 500 copies, printer*	$1,967	
	Optional color rather than b&w covers, printer	300	
	Reproduction of CDs	300	
	CDOW costs, editor, etc. (contributed as needed)	0	
	Salary, PI/author (0.25 month)	1,250	
	Total		$3,817**
	Supplemental update, 1,000 copies, printer*	$3,080	
	Optional color rather than b&w covers, printer	400	
	Reproduction of CDs	600	
	CDOW costs, editor, etc. (contributed as needed)	0	
	Salary, PI/author (0.25 month)	1,250	
	Total		$5,330**
	Supplemental update, 1,500 copies, printer*	$4,193	
	Optional color rather than b&w covers, printer	500	
	Reproduction of CDs	900	
	CDOW costs, editor, etc. (contributed as needed)	0	
	Salary, PI/author (0.25 month)	1,250	
	Total		$6,843**

*Includes B&W covers and CD pocket **Plus CSU indirect costs.

2. Publication of Supplemental Update with a limited reprint of the 1990 guide.

As above for Option 1, but newly reprinted copies of the 1990 guide (160 pages plus covers) would be available for new users and prior users who might need to replace lost or tattered copies.

Estimated additional costs to above –

Reprint of 1990 guide, 200 copies, printer	$3,000
Reprint of 1990 guide, 500 copies, printer	$3,750

Combined with Option 1, reprint run of 500 copies would bring totals to:

500 Supplemental updates plus 500 1990 guides	$7,567**
1,000 Supplemental updates plus 500 1990 guides	$9,080**
1,500 Supplemental updates plus 500 1990 guides	$10,593**

**Plus CSU indirect costs.

3. Integration of the Supplemental Update in the 1990 guide and publication as a new updated and expanded edition.

Preparation and publication of a new, updated, and expanded edition of the 1990 guide (approximately 124 pages plus covers), with the computer program and files on CD in a back cover pocket, would be the cleanest, most convenient, and most desirable publication option for the user–they would not need to manually update the old guide and would need only one volume to use in association with the computer-interactive key.

Estimated costs –

Updated edition of guide, 500 copies, printer*	$3,397	
Optional color rather than b&w covers, printer	300	
Reproduction of CDs	300	
CDOW costs, editor, etc. (contributed as needed)	0	
Salary, PI/author (0.75 month)	3,750	
Total		$7,747**
Updated edition of guide, 1,000 copies, printer*	$5,296	
Optional color rather than b&w covers, printer	400	
Reproduction of CDs	600	
CDOW costs, editor, etc. (contributed as needed)	0	
Salary, PI/author (0.75 month)	3,750	
Total		$10,046**
Updated edition of guide, 1,500 copies, printer*	$7,195	
Optional color rather than b&w covers, printer	500	
Reproduction of CDs	900	
CDOW costs, editor, etc. (contributed as needed)	0	
Salary, PI/author (0.75 month)	3,750	
Total		$12,345**

*Includes B&W covers and CD pocket, plus $300 allowance for stripping charges for changes to old negatives.

**Plus CSU indirect costs.

From the author's point of view, either Option 2 or 3 would be preferable to Option 1, but Option 1 would be better than no formal publication at all. Without a reprint of the 1990 guide for new users, I would recommend a print run of 500 or 1,000 copies (cost differential is not great). With a limited reprint run of the 1990 guide (500 copies recommended since not much more than 200 copies) as in Option 2, I would recommend a print run of 500 or 1,000. However, the costs for Option 3 is not much greater (printing costs actually much less) than for Option 2, and a new updated, and expanded edition of the guide itself would be much more convenient for the user. If sufficient funds can be made available, I (and I believe most users) would strongly prefer Option 3 with a print run of 1,000 or 1,500 copies.

COLORADO RIVER RECOVERY PROGRAM Project No.:_____
FY-2004–2005 PROPOSED SCOPE OF WORK for:
Publication of Supplemental Update to Larval Sucker Guide

Lead Agency: Larval Fish Laboratory, Colorado State University
Submitted by: Darrel E. Snyder, Principal Investigator
Larval Fish Laboratory
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Date: 30 April 2003

Category:
_ Ongoing project
_ Ongoing-revised project
_ Requested new project
x Unsolicited proposal

Expected Funding Source:
x Annual funds
_ Capital funds
x Other (explain)

I. Title of Proposal:
Publication of Supplemental Update to Larval and Early Juvenile Sucker Guide by Snyder and Muth, CDOW Technical Publication 38, 1990.

II. Relationship to RIPRAP:
General Recovery Program Support Action Plan item V.C–develop and enhance scientific techniques required to complete recovery actions.

III. Study Background/Rationale and Hypotheses:
Collections of the early life stages of fish are essential to research on and monitoring of razorback sucker (or other sucker) spawning sites and seasons, larval production, transport, distribution, nursery habitat, and survival, and other aspects of early life history. Such research cannot proceed effectively without accurate identification of at least razorback sucker or other target species among collected specimens. Morphological identification requires knowledge of the appearance of not only the target species but all similar species in the waters sampled and the diagnostic criteria for segregating them. For the early life stages of many species, including the suckers and minnows of the Upper Colorado River Basin (UCRB), morphological criteria for identification change dramatically as the fish grow and develop, making diagnosis especially difficult and complicated. Descriptive information and diagnostic criteria must be well founded, sufficiently detailed, and documented in such a way that they are retrievable, usable, and verifiable by any interested researcher.

The (draft) final report for Recovery Project 112 constitutes, with minor modifications, a manuscript for publication of a supplemental update and expansion of the descriptions and keys in the Colorado Division of Wildlife (CDOW) guide to UCRB sucker larvae and early juveniles (Snyder and Muth 1990). The manuscript includes a listing of corrections and descriptive updates (character range extensions, replacement drawings), description of longnose sucker larvae and juveniles (only sucker not covered by the 1990 publication, an updated and expanded comparative summary, and an updated and expanded replacement for the printed keys–a computer-interactive key on CD and available over the internet.

This proposed scope of work provides for formal publication of the manuscript as either a supplemental update to the 1990 guide with a limited reprint of that guide or, preferably, an integrated portion of a new edition of the guide. The former option would necessitate manual update of the user's copy of the 1990 guide and use of both it and the supplement with the interactive key. The latter option would be a much nicer product and more convenient and desirable for the user (updates, the revised comparative summary, the introduction and instructions for the computer-interactive key, and the new species account for longnose sucker would be cleanly integrated with the old guide and the former 60-page printed key deleted). The supplemental update could be published without a reprint of the 1990 guide, but that publication's original print run of 1,200 copies has been exhausted (out-of-print) since the mid-1990's. Accordingly, that less costly option has been dismissed.

Although unpublished copies of the final report and key for Recovery Project 112, when used with existing copies of the 1990 guide, will facilitate more certain identification of razorback sucker and other larval and early juvenile suckers collected in the UCRB, formal publication will provide for much broader recognition, distribution, and use of the descriptive information and computer-interactive key. In addition to the UCRB, the proposed publication will be useful wherever the covered species may occur in Colorado, the Southwest, and North America. Still other biologists will find it valuable as a model and proof of concept for the application of computer-interactive keys to identification of closely related or very similar fish larvae.

IV. Study Goals, Objectives, End Product:

The goal is to make more readily available the updated and new descriptive information and new taxonomic tool constituting the final report for Recovery Project 112 to facilitate easier and more accurate identification larval and early juvenile suckers collected in the UCRB or wherever the covered species might occur. Also to promote use of the computer-interactive key as a model and proof-of-concept for preparation of other keys to early life stages of fish.

The objective is to accomplish these goals complete part 1 of a comprehensive guide to cypriniform fishes of western Colorado and the UCRB by formal publication of a modification of the final report as a supplemental update to the 1990 guide, with a limited reprint of that guide, or as an integral part of a new edition of that 1990 guide.

Assuming CDOW is willing to serve as the publication outlet (to be negotiated), the end product would be either publication of 1,000 or 1,500 copies of a supplemental update to the 1990 guide as a CDOW Special Report, with a 500 or 1000-copy reprint of the 1990 guide (CDOW Technical Publication 38), or, preferably, publication of 1,500

copies of a new edition of the guide as a CDOW Technical Publication. If FY 2003 funds can be made available, publication could be concluded this summer in time for analysis of 2003 collections. If CDOW is not willing to serve as the publication outlet, other recognized serial publication outlets will need to be considered and the budget adjusted accordingly.

V. Study area: UCRB

VI. Study Methods/Approach *[provide a clear description of sampling methods, gear types, numbers and life stages of fish to be collected, statistical analyses to be used, etc.]*

I would work with CDOW publication specialist Nancy Wild, or other CDOW personnel . . .

VII. Task Description and Schedule

VIII. FY-2004 Work

1. Deliverables/Due Dates
4. Budget *[Broken out by task and funding target; see budget detail example requirements, attached]*
   - Labor
   - Travel
   - Equipment
   - Other
   - Total

FY-2005 Work (for multi-year study)

1. Deliverables/Due Dates
4. Budget *[Broken out by task and funding target; see budget detail example requirements, attached]*
   - Labor
   - Travel
   - Equipment
   - Other
   - Total

FY-2006 etc. (for multi-year study)

IX. Budget Summary *[Provide total AND break-out by funding target (e.g. station)]*[*]
FY-2004
FY-2005
FY-2006

Total:

X. Reviewers *[For new projects or ongoing-revised projects, list name, affiliation, phone, and address of people who have reviewed this proposal.]*

XI. References

[*] Do NOT include overhead costs on funds transferred from Reclamation to the Service.

Scope of Work Budget Detail Requirements

Budgets should be broken down by task, category (at least labor, travel, supplies, and equipment) and funding target. Under "labor," please identify: the type of labor (e.g., project manager, technician, secretary, etc.), the labor rate (per day, per week, or whatever calculation your office uses), and the expected amount of effort (expressed in terms of hours or weeks). If supplies exceed 5% of the project budget, please explain those costs. All equipment expenses for any single item ≥$1,000 should be itemized and justified.

Example:

FY 2004 Costs:

	Agency A	Agency B	Contractor	Total
Task 1				
Labor				
Proj. mgr ($1833/wk; 3 wks @ agency A, $1800/wk; 2 wks @ agency B)	$5,500	$3,600	$0	$9,100
Technicians (10 wks per agency; $810/wk @ agency A; $900/wk @ agency B)	$8,100	$9,000	$0	$17,100
Travel				
Per diem (20 days)	$600	$700	$0	$1,300
Vehicle (20 days)	$1,200	$1,500	$0	$2,700
*Equipment				
Boat	$0	$12,000	$0	$12,000
Trailer	$0	$6,000	$0	$6,000
Motor	$0	$2,000	$0	$2,000
Electrofishing Unit	$0	$4,000	$0	$4,000
Supplies	$700	$800	$0	$1,500
Task subtotal	$16,100	$39,600	$0	$55,700

*Justification: Additional outfitted electrofishing boat and trailer needed for concurrent sampling in two river reaches as required by population estimate protocol. Current equipment inventory of agency B includes only one outfitted electrofishing boat and trailer.

Task 2				
Labor				
Biologist (2 wks; $1500/wk @agency B; contractor $2000/wk)	$0	$3,000	$4,000	$7,000
Technician (3.5 wks @ $900/wk)	$0	$3,150	$0	$3,150
Task subtotal	$0	$6,150	$4,000	$10,150
FY 2004 TOTAL	$16,100	$45,750	$4,000	**$65,850**

FY 2005 Costs:

	Agency A	Agency B	Contractor	Total
Task 2				
Labor				
Proj. leader (2 wks @ Agency B @ $1800/wk; 3 wks contractor @$2500/wk)	$0	$3,600	$7,500	$11,100
Biologist (5 wks at each: $1500/wk @ agency B; $2000/wk contractor)	$0	$7,500	$10,000	$17,500
Task subtotal	$0	$11,100	$17,500	$28,600
Task 3				
Labor				
Biologist (4 wks @ each: $1500/wk @ agency A&B; $2000/wk contractor)	$6,000	$6,000	$8,000	$20,000
Proj. leader (2 wks @ each: $1833/wk @ agency A; $1800/wk @ agency B)	$3,700	$3,600	$5,000	$12,300
Travel				
Vehicle (5 days)	$300	$350	$300	$950
Airfare (1 trip)	$500	$700	$650	$1,850
Per diem (7 days)	$210	$245	$210	$665
Equipment	$0	$0	$0	$0
Supplies				
Tags		$1,150		$1,150
Glassware		$250		$250
Sample bottles		$100		$100
Task subtotal	$10,710	$12,395	$14,160	$37,265
FY 2005 TOTAL	$10,710	$23,495	$31,660	**$65,865**