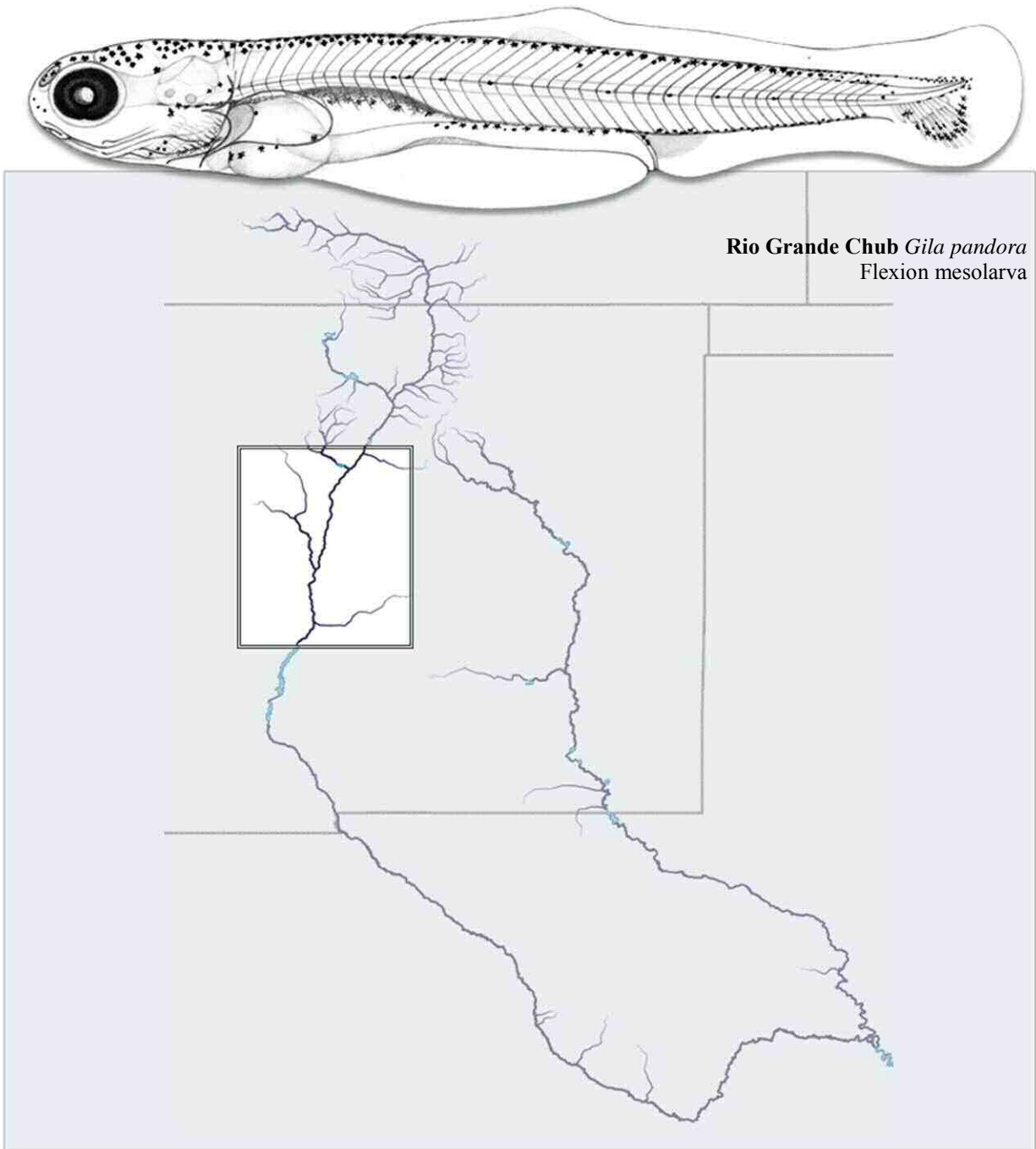


CYPRINIFORM FISH LARVAE AND EARLY JUVENILES OF THE MIDDLE RIO GRANDE, NEW MEXICO

Morphological Descriptions, Comparisons, and Computer-Interactive Key



By
Darrel E. Snyder, Sean C. Seal, Jennifer A. Charles, W. Howard Brandenburg, and C. Lynn Bjork

**CYPRINIFORM FISH LARVAE AND EARLY JUVENILES OF
THE MIDDLE RIO GRANDE, NEW MEXICO**

Morphological Descriptions, Comparisons, and Computer-interactive Keys

Revised Final Report
July 30, 2019
(with corrections and edits as of November 2019)

Revision of December 30, 2013, Final Report
(Middle Rio Grande Larval Fish Identification Guide)

U.S. Bureau of Reclamation, Salt Lake City
Cooperative Agreement R08AC40811 (formerly 08-FC-40-2811)
CESU 9-FG-81-0143, Colorado State University Project 5-34159
Initiation date: September 17, 2008
Completion date: July 31, 2012, extended to September 30, 2013

Submitted to

Mark McKinstry
U.S. Bureau of Reclamation
125 South State Street, Room 6107
Salt Lake City, Utah 84138-1147

by

Darrel E. Snyder^{1,3}, Sean C. Seal¹, Jennifer A. Charles¹,
W. Howard Brandenburg², and C. Lynn Bjork¹

¹ Larval Fish Laboratory
Department of Fish, Wildlife, and Conservation Biology
Colorado State University
1474 Campus Delivery
Fort Collins, Colorado 80523-1474

² American Southwest Ichthyological Researchers, L.L.C.
800 Encino Place, NE
Albuquerque, New Mexico 87102-2606

³ Telephone: (970) 491-5295, Fax: (970) 491-5091
E-mail: Darrel.Snyder@ColoState.edu

Larval Fish Laboratory
Contribution 215

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

Research
Early Life Stages/Adults
Native Fish Biology/Ecology
Aquatic Toxicology/Behavior

Education
Extension/Consultation
Study Design/Analysis
Shortcourses/Guest Lectures

Service
Identification/Verification
Sample Processing/Depository
Descriptions/Keys/Illustrations

ACKNOWLEDGMENTS

Developmental studies and preparation of this guide for identification of cypriniform fish larvae of the Middle Rio Grande (MRG), New Mexico, were funded through 2013 by the U.S. Department of the Interior Bureau of Reclamation (BR, Upper Colorado Regional Office, Salt Lake City, Utah) via Cooperative Agreement R08AC40811 (originally 08-FC-40-2811; CESU 9-FG-81-0143) to facilitate fish research and monitoring efforts of the Middle Rio Grande Endangered Species Act Collaborative Program. For four shared species accounts, this project also helped fund completion of a similar guide to cyprinid larvae of the Upper Colorado River Basin (UCRB) which was prepared for the Upper Colorado River Endangered Fish Recovery Program (Recovery Program Project 149) and published as Colorado Parks and Wildlife Technical Publication 47 (Snyder et al. 2016). Completion of this guide as a revision of the project's 2013 final report (Snyder 2013) has been primarily a voluntary effort of the senior author with support of the Colorado State University Larval Fish Laboratory (LFL) and substantial contributions by co-authors.

Most specimens newly examined for this guide (and shared portions of the UCRB guide) were maintained as part of the LFL Collection or borrowed from MSB, but these holdings had to be supplemented with newly reared developmental series for four species. Manuel Ulibarri, Catherine Sykes, and William Knight of Dexter National Fish Hatchery and Technology Center (NM; now the Southwestern Native Aquatic Resources and Recovery Center) reared, preserved, and contributed series of Rio Grande Silvery Minnow *Hybognathus amarus*, Bullhead Minnow *Pimephales vigilax*, and Flathead Chub *Platygobio gracilis*. Terina Perez of the Albuquerque Biological Park Rio Grande Silvery Minnow Rearing and Refugia Facility also contributed a series of juvenile Rio Grande Silvery Minnow. A series of Flathead Chub was also reared in-house by Kevin Bestgen (LFL) and others with parental stock provided by Harry Crocket of the Colorado Division of Wildlife (now Colorado Parks and Wildlife, CPW). David Schnoor and Thomas Mix of the CPW Mumma Native Aquatic Species Restoration Facility (Alamosa, CO) provided a preserved series of larval Rio Grande Chub *Gila pandora* as well as live larvae and early juveniles which were further reared in-house by LFL staff to complete the developmental series. They also reared and contributed recently hatched Rio Grande Sucker *Catostomus plebeius*.

This guide incorporates modified versions of the four species accounts also prepared for the aforementioned UCRB cyprinid guide (Common Carp *Cyprinus carpio*, Red Shiner *Cyprinella lutrensis*, Fathead Minnow *Pimephales promelas*, and Longnose Dace *Rhinichthys cataractae*), and two species accounts from prior LFL guides (White Sucker *Catostomus commersonii* from Snyder and Muth 2004 and Rio Grande Sucker from Snyder 1998). Most of those prior version species accounts had been built progressively upon accounts in still earlier LFL guides (Snyder 1981, Snyder and Muth 1990, and/or Snyder et al. 2005). Please see those reports and publications for acknowledgement of the many persons that contributed to and organizations that supported those descriptions.

All larval and juvenile descriptive data and illustrations for the River Carpsucker *Carpiodes carpio* and Smallmouth Buffalo *Ictiobus bubalus* species accounts were extracted or calculated from prior publications. Bruce Yeager, William Wrenn, Bobby Grinstead, Larry Kay, Robert Wallus, and Lee Fuiman granted permission to use selected data and (or) illustrations from their descriptions or accounts of those species (Wrenn and Grinstead 1971, Yeager 1980, Yeager and Baker 1982, Fuiman 1982a, and Kay et al. 1994). Likewise, Lee Fuiman, Gerard

Buynak, and Harold Mohr previously had provided and granted permission to reprint selected illustrations from their published descriptions of larval Longnose Dace (Fuiman and Loos 1977, Buynak and Mohr 1979a) and White Sucker (Buynak and Mohr 1978, Fuiman 1979).

Kevin Bestgen, John Alves (CPW), and Anita Martinez (CPW) contributed, via personal communications, information included in brief descriptions of the adults and reproduction for the Rio Grande Sucker species account; likewise, Kevin Bestgen and Theodore Smith (CPW) for the Rio Grande Chub account and Kevin Bestgen and Matthew Haworth (LFL) for the Flathead Chub account. Species account distribution maps are based on collection and report data respectively provided by Alexandra Snyder (Division of Fishes, Museum of Southwestern Biology, University of New Mexico—MSB) and Steven Platania (American Southwest Ichthyological Researchers, LLC, Albuquerque, NM—ASIR). Robert Dudley (ASIR) summarized ASIR and MSB data used to complete a list of fishes collected in the MRG since 1993 (Table 1).

Robert Wallus granted permission to adapt and modify for Appendix IV portions of a pictorial guide to families of fish larvae included in Wallus et al. (1990). Michael Dallwitz provided periodic guidance in the use of *Intkey* and other DELTA programs (Dallwitz et al. 1993 onwards and 1995 onwards) for preparation of the computer-interactive keys.

We thank the above acknowledged persons and organizations and the many other associates and contacts who contributed time, effort, materials, and information to this project and associated earlier investigations; also, Matthew Haworth (LFL) and Steven Platania for their reviews of the species accounts. We especially thank BR project coordinator Mark McKinstry and other responsible parties and cooperators in the Collaborative Program for their support and patience, and Kevin Bestgen, LFL Director, for his support, project administration, and report, species account, and manuscript reviews.

DISCLAIMER

Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the authors, Colorado State University Larval Fish Laboratory, or the U.S. Bureau of Reclamation.

SUGGESTED CITATION

Snyder, D. E., S. C. Seal, J. A. Charles, W. H. Brandenburg, and C. L. Bjork. 2019. Cypriniform fish larvae and early juveniles of the Middle Rio Grande, New Mexico — morphological descriptions, comparisons, and computer-interactive keys. Revised final report of Colorado State University Larval Fish Laboratory to U.S. Bureau of Reclamation, Salt Lake City, Utah. (Revision of December 30, 2013, final report). Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (date accessed; to be posted in November 2019).

TABLE OF CONTENTS

| | |
|--|-----|
| ACKNOWLEDGMENTS, DISCLAIMER, and SUGGESTED CITATION | iii |
| TABLE OF CONTENTS and LISTS OF TABLES, FIGURES, and KEY WORDS | v |
| EXECUTIVE SUMMARY | xi |
| INTRODUCTION | 1 |
| Importance of Early Life History Investigations and Identification | 1 |
| The Middle Rio Grande and Its Fishes | 2 |
| This Guide, Objectives, and Prior Descriptions | 9 |
| A Combined Developmental Interval Terminology | 11 |
| Characteristics Useful in Identification of Cypriniform Fish Larvae | 13 |
| Myomeres | 16 |
| Fins and finfolds | 17 |
| Other countable structures | 19 |
| Morphology | 20 |
| Pigmentation | 22 |
| Osteology | 23 |
| METHODS | 25 |
| Specimens Examined | 25 |
| Specimen Data, Observations, and Illustrations | 25 |
| Computer-Interactive Key | 29 |
| RESULTS AND DISCUSSION | 31 |
| Species Accounts | 31 |
| <i>Cyprinella lutrensis</i> | 33 |
| <i>Cyprinus carpio</i> | 39 |
| <i>Gila pandora</i> | 45 |
| <i>Hybognathus amarus</i> | 51 |
| <i>Pimephales promelas</i> | 57 |
| <i>Pimephales vigilax</i> | 63 |
| <i>Platygobio gracilis</i> | 69 |
| <i>Rhinichthys cataractae</i> | 75 |
| <i>Catostomus commersonii</i> | 81 |
| <i>Catostomus plebeius</i> | 87 |
| <i>Carpiodes carpio</i> | 93 |
| <i>Ictiobus bubalus</i> | 99 |
| Comparative Summary Tables | 105 |
| Size relative to developmental state | 106 |
| Selected meristics | 112 |
| Selected morphometrics | 118 |
| Selected eye, mouth, and fin position characters | 127 |
| Size relative to acquisition of eye, body, and peritoneal pigmentation | 131 |
| Selected melanophore pigmentation patterns | 137 |
| Computer-Interactive Key | 159 |
| Installation | 159 |
| Use | 160 |
| CONCLUSIONS AND RECOMMENDATIONS | 164 |

| | |
|---|---|
| LITERATURE CITED | 165 |
| APPENDIX I—Glossary | 184 |
| APPENDIX II— Prior Descriptions of Larvae for Cypriniform Fishes. . .MRG | 197 |
| APPENDIX III—Specimens Analyzed for this Guide and Sources of Reared . . . Series | 199 |
| APPENDIX IV—Pictorial Guide to Families of Fish Larvae in the Middle Rio Grande | 201 |
| USB MEMORY STICK OR CARD—Computer-Interactive Keys | 205 |
| | (inside back cover of printed version of publication) |

LIST OF TABLES

| | | |
|----|--|----|
| 1 | Fishes of the Middle Rio Grande, New Mexico | 5 |
| 2 | Selected juvenile and adult meristics for <i>Cyprinella lutrensis</i> | 33 |
| 3 | Size at onset of selected developmental events for <i>Cyprinella lutrensis</i> | 33 |
| 4 | Size at developmental interval and gut phase transitions for <i>Cyprinella lutrensis</i> | 34 |
| 5 | Summary of morphometrics and myomere counts . . . for <i>Cyprinella lutrensis</i> | 34 |
| 6 | Selected juvenile and adult meristics for <i>Cyprinus carpio</i> | 39 |
| 7 | Size at onset of selected developmental events for <i>Cyprinus carpio</i> | 39 |
| 8 | Size at developmental interval and gut phase transitions for <i>Cyprinus carpio</i> | 40 |
| 9 | Summary of morphometrics and myomere counts . . . for <i>Cyprinus carpio</i> | 40 |
| 10 | Selected juvenile and adult meristics for <i>Gila pandora</i> | 45 |
| 11 | Size at onset of selected developmental events for <i>Gila pandora</i> | 45 |
| 12 | Size at developmental interval and gut phase transitions for <i>Gila pandora</i> | 46 |
| 13 | Summary of morphometrics and myomere counts . . . for <i>Gila pandora</i> | 46 |
| 14 | Selected juvenile and adult meristics for <i>Hybognathus amarus</i> | 51 |
| 15 | Size at onset of selected developmental events for <i>Hybognathus amarus</i> | 51 |
| 16 | Size at developmental interval and gut phase transitions for <i>Hybognathus amarus</i> | 52 |
| 17 | Summary of morphometrics and myomere counts . . . for <i>Hybognathus amarus</i> | 52 |
| 18 | Selected juvenile and adult meristics for <i>Pimephales promelas</i> | 57 |
| 19 | Size at onset of selected developmental events for <i>Pimephales promelas</i> | 57 |
| 20 | Size at developmental interval and gut phase transitions for <i>Pimephales promelas</i> | 58 |
| 21 | Summary of morphometrics and myomere counts . . . for <i>Pimephales promelas</i> | 58 |
| 22 | Selected juvenile and adult meristics for <i>Pimephales vigilax</i> | 63 |
| 23 | Size at onset of selected developmental events for <i>Pimephales vigilax</i> | 63 |
| 24 | Size at developmental interval and gut phase transitions for <i>Pimephales vigilax</i> | 64 |
| 25 | Summary of morphometrics and myomere counts . . . for <i>Pimephales vigilax</i> | 64 |
| 26 | Selected juvenile and adult meristics for <i>Platygobio gracilis</i> | 69 |
| 27 | Size at onset of selected developmental events for <i>Platygobio gracilis</i> | 69 |
| 28 | Size at developmental interval and gut phase transitions for <i>Platygobio gracilis</i> | 70 |
| 29 | Summary of morphometrics and myomere counts . . . for <i>Platygobio gracilis</i> | 70 |
| 30 | Selected juvenile and adult meristics for <i>Rhinichthys cataractae</i> | 75 |
| 31 | Size at onset of selected developmental events for <i>Rhinichthys cataractae</i> | 75 |
| 32 | Size at developmental interval and gut phase transitions for <i>Rhinichthys cataractae</i> | 76 |
| 33 | Summary of morphometrics and myomere counts . . . for <i>Rhinichthys cataractae</i> | 76 |
| 34 | Selected juvenile and adult meristics for <i>Catostomus commersonii</i> | 81 |
| 35 | Size at onset of selected developmental events for <i>Catostomus commersonii</i> | 81 |

| | | |
|----|--|-----|
| 36 | Size at developmental interval and gut phase transitions for <i>Catostomus commersonii</i> | 82 |
| 37 | Summary of morphometrics and myomere counts . . . for <i>Catostomus commersonii</i> | 82 |
| 38 | Selected juvenile and adult meristics for <i>Catostomus plebeius</i> | 87 |
| 39 | Size at onset of selected developmental events for <i>Catostomus plebeius</i> | 87 |
| 40 | Size at developmental interval and gut phase transitions for <i>Catostomus plebeius</i> | 88 |
| 41 | Summary of morphometrics and myomere counts . . . for <i>Catostomus plebeius</i> | 88 |
| 42 | Selected juvenile and adult meristics for <i>Carpionodes carpio</i> | 93 |
| 43 | Size at onset of selected developmental events for <i>Carpionodes carpio</i> | 93 |
| 44 | Size at developmental interval and gut phase transitions for <i>Carpionodes carpio</i> | 94 |
| 45 | Summary of morphometrics and myomere counts . . . for <i>Carpionodes carpio</i> | 94 |
| 46 | Selected juvenile and adult meristics for <i>Ictiobus bubalus</i> | 99 |
| 47 | Size at onset of selected developmental events for <i>Ictiobus bubalus</i> | 99 |
| 48 | Size at developmental interval and gut phase transitions for <i>Ictiobus bubalus</i> | 100 |
| 49 | Summary of morphometrics and myomere counts . . . for <i>Ictiobus bubalus</i> | 100 |
| 50 | Comparison of size. . .at onset of . . . developmental events . . . larger cyprinids | 106 |
| 51 | Comparison of size. . .at onset of . . . developmental events . . . smaller cyprinids | 108 |
| 52 | Comparison of size. . .at onset of . . . developmental events . . . catostomids | 110 |
| 53 | Comparison of selected meristics for larvae . . . juveniles of larger cyprinids | 112 |
| 54 | Comparison of selected meristics for larvae . . . juveniles of smaller cyprinids | 114 |
| 55 | Comparison of selected meristics for larvae . . . juveniles of catostomids | 116 |
| 56 | Comparison of . . . morphometrics for larvae . . . juveniles of larger cyprinids | 118 |
| 57 | Comparison of . . . morphometrics for larvae . . . juveniles of smaller cyprinids | 121 |
| 58 | Comparison of . . . morphometrics for larvae . . . juveniles of catostomids | 124 |
| 59 | Comparison of selected eye, mouth . . . characters for larvae . . . of larger cyprinids | 127 |
| 60 | Comparison of selected eye, mouth . . . characters for larvae . . . of smaller cyprinids | 129 |
| 61 | Comparison of selected eye, mouth . . . characters for larvae . . . of catostomids | 130 |
| 62 | Comparison of size relative to . . . pigmentation . . . peritoneum . . . of larger cyprinids | 131 |
| 63 | Comparison of size relative to . . . pigmentation . . . peritoneum . . . smaller cyprinids | 133 |
| 64 | Comparison of size relative to . . . pigmentation . . . peritoneum . . . of catostomids | 135 |
| 65 | Comparison of . . . pigmentation patterns for larvae . . . of larger cyprinids | 137 |
| 66 | Comparison of . . . pigmentation patterns for larvae . . . of smaller cyprinids | 148 |
| 67 | Comparison of . . . pigmentation patterns for larvae . . . of catostomids | 152 |

LIST OF FIGURES

| | | |
|----|---|----|
| 1 | The Middle Rio Grande | 4 |
| 2 | Selected anatomical features of cypriniform fish eggs and embryos | 14 |
| 3 | Selected anatomical features of cypriniform fish larvae | 15 |
| 4 | Measures and counts for larval and early juvenile fishes | 26 |
| 5 | Phases of gut coil development in cypriniform fish larvae and early juveniles | 28 |
| 6 | <i>Cyprinella lutrensis</i> adult | 33 |
| 7 | Recent distribution of <i>Cyprinella lutrensis</i> in the Middle Rio Grande | 33 |
| 8 | <i>Cyprinella lutrensis</i> protolarva, recently hatched | 35 |
| 9 | <i>Cyprinella lutrensis</i> protolarva | 35 |
| 10 | <i>Cyprinella lutrensis</i> flexion mesolarva, recently transformed | 36 |

| | | |
|----|--|----|
| 11 | <i>Cyprinella lutrensis</i> postflexion mesolarva | 36 |
| 12 | <i>Cyprinella lutrensis</i> metalarva, recently transformed..... | 37 |
| 13 | <i>Cyprinella lutrensis</i> metalarva..... | 37 |
| 14 | <i>Cyprinella lutrensis</i> juvenile, recently transformed | 38 |
| 15 | <i>Cyprinella lutrensis</i> juvenile..... | 38 |
| 16 | <i>Cyprinus carpio</i> adult | 39 |
| 17 | Recent distribution of <i>Cyprinus carpio</i> in the Middle Rio Grande | 39 |
| 18 | <i>Cyprinus carpio</i> protolarva, recently hatched | 41 |
| 19 | <i>Cyprinus carpio</i> protolarva | 41 |
| 20 | <i>Cyprinus carpio</i> flexion mesolarva, recently transformed | 42 |
| 21 | <i>Cyprinus carpio</i> postflexion mesolarva | 42 |
| 22 | <i>Cyprinus carpio</i> metalarva, recently transformed | 43 |
| 23 | <i>Cyprinus carpio</i> metalarva | 43 |
| 24 | <i>Cyprinus carpio</i> juvenile, recently transformed | 44 |
| 25 | <i>Cyprinus carpio</i> juvenile | 44 |
| 26 | <i>Gila pandora</i> adult | 45 |
| 27 | Recent distribution of <i>Gila pandora</i> in the Middle Rio Grande | 45 |
| 28 | <i>Gila pandora</i> protolarva, recently hatched | 47 |
| 29 | <i>Gila pandora</i> protolarva | 47 |
| 30 | <i>Gila pandora</i> flexion mesolarva, recently transformed | 48 |
| 31 | <i>Gila pandora</i> postflexion mesolarva | 48 |
| 32 | <i>Gila pandora</i> metalarva, recently transformed | 49 |
| 33 | <i>Gila pandora</i> metalarva | 49 |
| 34 | <i>Gila pandora</i> juvenile, recently transformed | 50 |
| 35 | <i>Gila pandora</i> juvenile | 50 |
| 36 | <i>Hybognathus amarus</i> adult | 51 |
| 37 | Recent distribution of <i>Hybognathus amarus</i> in the Middle Rio Grande | 51 |
| 38 | <i>Hybognathus amarus</i> protolarva, recently hatched | 53 |
| 39 | <i>Hybognathus amarus</i> protolarva | 53 |
| 40 | <i>Hybognathus amarus</i> flexion mesolarva, recently transformed | 54 |
| 41 | <i>Hybognathus amarus</i> postflexion mesolarva | 54 |
| 42 | <i>Hybognathus amarus</i> metalarva, recently transformed | 55 |
| 43 | <i>Hybognathus amarus</i> metalarva | 55 |
| 44 | <i>Hybognathus amarus</i> juvenile, recently transformed | 56 |
| 45 | <i>Hybognathus amarus</i> juvenile | 56 |
| 46 | <i>Pimephales promelas</i> adult | 57 |
| 47 | Recent distribution of <i>Pimephales promelas</i> in the Middle Rio Grande | 57 |
| 48 | <i>Pimephales promelas</i> protolarva, recently hatched | 59 |
| 49 | <i>Pimephales promelas</i> protolarva | 59 |
| 50 | <i>Pimephales promelas</i> flexion mesolarva, recently transformed | 60 |
| 51 | <i>Pimephales promelas</i> postflexion mesolarva | 60 |
| 52 | <i>Pimephales promelas</i> metalarva, recently transformed | 61 |
| 53 | <i>Pimephales promelas</i> metalarva | 61 |
| 54 | <i>Pimephales promelas</i> juvenile, recently transformed | 62 |
| 55 | <i>Pimephales promelas</i> juvenile | 62 |
| 56 | <i>Pimephales vigilax</i> adult | 63 |

| | | |
|-----|---|----|
| 57 | Recent distribution of <i>Pimephales vigilax</i> in the Middle Rio Grande | 63 |
| 58 | <i>Pimephales vigilax</i> protolarva, recently hatched | 65 |
| 59 | <i>Pimephales vigilax</i> protolarva | 65 |
| 60 | <i>Pimephales vigilax</i> flexion mesolarva, recently transformed | 66 |
| 61 | <i>Pimephales vigilax</i> postflexion mesolarva | 66 |
| 62 | <i>Pimephales vigilax</i> metalarva, recently transformed | 67 |
| 63 | <i>Pimephales vigilax</i> metalarva | 67 |
| 64 | <i>Pimephales vigilax</i> juvenile, recently transformed | 68 |
| 65 | <i>Pimephales vigilax</i> juvenile | 68 |
| 66 | <i>Platygobio gracilis</i> adult | 69 |
| 67 | Recent distribution of <i>Platygobio gracilis</i> in the Middle Rio Grande | 69 |
| 68 | <i>Platygobio gracilis</i> protolarva, recently hatched | 71 |
| 69 | <i>Platygobio gracilis</i> protolarva | 71 |
| 70 | <i>Platygobio gracilis</i> flexion mesolarva, recently transformed | 72 |
| 71 | <i>Platygobio gracilis</i> postflexion mesolarva | 72 |
| 72 | <i>Platygobio gracilis</i> metalarva, recently transformed | 73 |
| 73 | <i>Platygobio gracilis</i> metalarva | 73 |
| 74 | <i>Platygobio gracilis</i> juvenile, recently transformed | 74 |
| 75 | <i>Platygobio gracilis</i> juvenile | 74 |
| 76 | <i>Rhinichthys cataractae</i> adult | 75 |
| 77 | Recent distribution of <i>Rhinichthys cataractae</i> in the Middle Rio Grande | 75 |
| 78 | <i>Rhinichthys cataractae</i> protolarva, recently hatched | 77 |
| 79 | <i>Rhinichthys cataractae</i> protolarva | 77 |
| 80 | <i>Rhinichthys cataractae</i> flexion mesolarva, recently transformed | 78 |
| 81 | <i>Rhinichthys cataractae</i> postflexion mesolarva | 78 |
| 82 | <i>Rhinichthys cataractae</i> metalarva, recently transformed | 79 |
| 83 | <i>Rhinichthys cataractae</i> metalarva | 79 |
| 84 | <i>Rhinichthys cataractae</i> juvenile, recently transformed | 80 |
| 85 | <i>Rhinichthys cataractae</i> juvenile | 80 |
| 86 | <i>Catostomus commersonii</i> adult | 81 |
| 87 | Recent distribution of <i>Catostomus commersonii</i> in the Middle Rio Grande | 81 |
| 88 | <i>Catostomus commersonii</i> protolarva, recently hatched | 83 |
| 89 | <i>Catostomus commersonii</i> protolarva | 83 |
| 90 | <i>Catostomus commersonii</i> flexion mesolarva, recently transformed | 84 |
| 91 | <i>Catostomus commersonii</i> postflexion mesolarva | 84 |
| 92 | <i>Catostomus commersonii</i> metalarva, recently transformed | 85 |
| 93 | <i>Catostomus commersonii</i> metalarva | 85 |
| 94 | <i>Catostomus commersonii</i> juvenile, recently transformed | 86 |
| 95 | <i>Catostomus commersonii</i> juvenile | 86 |
| 96 | <i>Catostomus plebeius</i> adult | 87 |
| 97 | Recent distribution of <i>Catostomus plebeius</i> in the Middle Rio Grande | 87 |
| 98 | <i>Catostomus plebeius</i> protolarva, recently hatched | 89 |
| 99 | <i>Catostomus plebeius</i> protolarva | 89 |
| 100 | <i>Catostomus plebeius</i> flexion mesolarva, recently transformed | 90 |
| 101 | <i>Catostomus plebeius</i> postflexion mesolarva | 90 |
| 102 | <i>Catostomus plebeius</i> metalarva, recently transformed | 91 |

| | | |
|-----|---|-----|
| 103 | <i>Catostomus plebeius</i> metalarva | 91 |
| 104 | <i>Catostomus plebeius</i> juvenile, recently transformed | 92 |
| 105 | <i>Catostomus plebeius</i> juvenile | 92 |
| 106 | <i>Carpionodes carpio</i> adult | 93 |
| 107 | Recent distribution of <i>Carpionodes carpio</i> in the Middle Rio Grande | 93 |
| 108 | <i>Carpionodes carpio</i> protolarva, recently hatched | 95 |
| 109 | <i>Carpionodes carpio</i> protolarvae | 95 |
| 110 | <i>Carpionodes carpio</i> flexion mesolarvae | 96 |
| 111 | <i>Carpionodes carpio</i> postflexion mesolarvae | 96 |
| 112 | <i>Carpionodes carpio</i> postflexion mesolarva, almost metalarva | 97 |
| 113 | <i>Carpionodes carpio</i> metalarva | 97 |
| 114 | <i>Carpionodes carpio</i> juvenile, recently transformed | 98 |
| 115 | <i>Ictiobus bubalus</i> adult | 99 |
| 116 | Recent distribution of <i>Ictiobus bubalus</i> in the Middle Rio Grande | 99 |
| 117 | <i>Ictiobus bubalus</i> protolarvae, recently hatched | 101 |
| 118 | <i>Ictiobus bubalus</i> protolarvae | 101 |
| 119 | <i>Ictiobus bubalus</i> flexion mesolarva, recently transformed | 102 |
| 120 | <i>Ictiobus bubalus</i> postflexion mesolarva | 102 |
| 121 | <i>Ictiobus bubalus</i> postflexion mesolarva, almost metalarva | 103 |
| 122 | <i>Ictiobus bubalus</i> metalarva, recently transformed | 103 |
| 123 | <i>Ictiobus bubalus</i> juvenile, recently transformed | 104 |
| 124 | <i>Ictiobus bubalus</i> juvenile, recently transformed | 104 |

LIST OF KEY WORDS

Fish
 Larvae
 Juveniles
 Cyprinidae
 Catostomidae
 Middle Rio Grande
 New Mexico
 Descriptions
 Ontogeny
 Development
 Morphology
 Morphometrics
 Meristics
 Pigmentation
 Species Accounts
 Taxonomic Key
 Computer-interactive Key

EXECUTIVE SUMMARY

Accurate identification is essential for use of larval and early (young-of-the-year) juvenile fish collections in research and monitoring programs. Such collections can be used to help determine fish spawning sites and seasons and are essential for assessing larval production, transport, distribution, nursery habitat, and survival. Morphological identification of these early life stages requires knowledge of the ever-changing appearance of not only the target species, but also all similar species in the waters sampled, as well as the diagnostic criteria for distinguishing them.

This guide is intended to facilitate identification of the larvae and early juveniles of eight cyprinid and four catostomid fishes inhabiting the Middle Rio Grande of New Mexico and thereby aid research for management and recovery of native fishes, including the endangered Rio Grande Silvery Minnow *Hybognathus amarus*. It, and a similar, recently completed companion guide to the cyprinids of the middle and lower Pecos River and Rio Grande above their confluence, are modeled after a previously published guide to the cyprinid larvae and early juveniles of the Upper Colorado River Basin. Based on studies of reared or collected developmental series for the cyprinids, new descriptive species accounts for Rio Grande Silvery Minnow, Rio Grande Chub *Gila pandora*, Flathead Chub *Platygobio gracilis*, and Bullhead Minnow *Pimephales vigilax* were prepared for this guide, and previously published accounts for Red Shiner *Cyprinella lutrensis*, Common Carp *Cyprinus carpio*, Fathead Minnow *Pimephales promelas*, and Longnose Dace *Rhinichthys cataractae* were updated with new data and illustrations for both this and the Upper Colorado River Basin guide. Previously published species accounts for White Sucker *Catostomus commersonii* and Rio Grande Sucker *Catostomus plebeius* also were adapted for this guide, the latter account incorporating new data and illustrations based on a reared series of recently hatched larvae. Finally, the descriptive data and illustrations for the River Carpsucker *Carpionodes carpio*, and Smallmouth Buffalo *Ictiobus bubalus* accounts herein were extracted or summarized from prior descriptions by others.

Each species account begins with an illustration and brief description of the adult, information regarding reproduction and the young (early life history), a table of juvenile and adult meristics, and a map of recent distribution in the Middle Rio Grande. They continue with tables summarizing larval and early juvenile descriptive data for size relative to developmental events and transitions, morphometrics, and myomere counts, and conclude with dorsal, lateral, and ventral-view illustrations of protolarvae, mesolarvae, metalarvae, and early juveniles.

To aid species identification, most descriptive data in the species accounts and additional data for selected morphological and pigmentation characters are incorporated in comparative summary tables and associated cyprinid and catostomid computer-interactive keys. Also included are an adapted pictorial guide and an accompanying computer-interactive key for identification of all Middle Rio Grande fish larvae to family.

CYPRINIFORM FISH LARVAE AND EARLY JUVENILES OF THE MIDDLE RIO GRANDE, NEW MEXICO

Morphological Descriptions, Comparisons, and Computer-interactive Keys

Darrel E. Snyder, Sean C. Seal, Jennifer A. Charles,
W. Howard Brandenburg, and C. Lynn Bjork

INTRODUCTION

Importance of Early Life History Investigations and Identification ¹

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

Furthermore, for most fishes, larval and early juvenile development includes a least a few life-history phases that are ecologically distinct from each other, as well as later juveniles and adults (Snyder 1990; such phases do not necessarily correspond with the morphologically based developmental intervals defined below). Accordingly, knowledge of fish early life history is often essential for better understanding aquatic ecosystems and communities and effective monitoring, protection, or management of fish populations and habitats. Such knowledge is particularly valuable for environmental impact assessments and endangered species recovery.

Research or monitoring based on collections of fish larvae usually requires accurate identification of captured specimens. Inland fishery managers and researchers have often excluded potentially critical larval-fish investigations specifically because they haven't done it before or the taxonomic tools needed for the job—adequate descriptions of larvae, diagnostic criteria, and keys for identification—are not available.

Descriptive information and diagnostic criteria for larval fish identification must be well founded, sufficiently detailed, and documented for current and future use by others. Taxonomic knowledge gained by one or a few specialists must be shared and transferred to avoid loss and the need for redevelopment. Although the inventory of such information is gradually increasing, much descriptive and taxonomic research on the early life stages of fish remains piecemeal and difficult to access.

Simon (1986) compiled a relatively comprehensive listing of 230 regional larval-fish guides, keys, and comparative descriptions available through the early 1980's, but only about 80 of these (35%) pertain to or include freshwater species. Kelso et al. (2012, updating Snyder 1983 and Kelso and Rutherford 1996) listed over two dozen regionally oriented larval-fish identification manuals for or including North American freshwater species. Overlooked or subsequently published guides to larvae in North American freshwaters include a series of four

¹ Modified from Snyder et al. (2016).

for the Sacramento-San Joaquin River Delta in California (Wang 2007, Wang and Reyes 2007, Wang and Reyes 2008, and Wang 2010—all updating corresponding portions of Wang 1986) and one each for Alaska (Sturm 2004—in part updating Sturm 1988), the St. Johns River in Florida (Scripter 2009, unpublished laboratory guide available upon request), the lower Hudson River in New York (Arvidson and Alber 2013), the Upper Colorado River Basin in Wyoming, Utah, Colorado, Arizona, and New Mexico (Snyder et al. 2016), and the middle and lower Pecos River and Rio Grande (550 km above confluence with the Pecos R.) in New Mexico and Texas (Brandenburg et al. 2018a). In addition to the Ohio River drainage series of guides listed by Kelso et al. (2012) (mostly by Wallus and Simon), new volumes are in preparation to cover the cyprinids of that region.

More general freshwater fish guides sometimes include brief accounts of, or references to, early life history, descriptions, and (or) illustrations. For example, in *Fishes of the Great Lakes Region*, Hubbs et al. (2004) included an appendix of larval fish illustrations selected from Auer (1982), one of the more comprehensive guides to freshwater fish larvae in North America.

Larval fish descriptions, guides, and keys are the foundation for field research thereon, but many gaps remain (Snyder 1996). In a recent assessment of early life-stage descriptions in guides and selected comparative literature published through early 2010, Snyder et al. (2012) found that about 60% of 823 freshwater or anadromous fishes in the United States or Canada remain undescribed as larvae. Furthermore, only about 26% were determined to be sufficiently well-described for identification purposes, just 11% more than estimated 35 years before (Snyder 1976a). Among the Cyprinidae (minnows, 245 species) and Catostomidae (suckers, 65 species), just 15% and 46%, respectively, were well-described as larvae.

The Middle Rio Grande and Its Fishes

The Rio Grande is a highly altered river system that originates in southwestern Colorado, east of the Continental Divide, passes south through New Mexico to Texas and Mexico, then flows along the southwestern border of Texas to the Gulf of Mexico as the international boundary between the United States and Mexico. Dams, reservoirs, irrigation diversions, and groundwater pumping have severely impacted its natural flow regime, sometimes dewatered historically perennial portions of the system, degraded aquatic and riparian habitats, and imperiled its native biota (Propst et al. 1987, Sublette et al. 1990, Rinne and Platania 1995, Cowley 2006).

As defined for the Middle Rio Grande Endangered Species Collaborative Program, the Middle Rio Grande drainage (MRG) in New Mexico extends from the Colorado border downstream to the Elephant Butte Reservoir inflow at full pool (Widmer et al. 2010). This basin corresponds to U.S. Geological Survey Water Resources Subregion HUC (Hydrologic Unit Code) 1302 (Rio Grande-Elephant Butte), less the southern-most sub-basin (HUC 13020211, Elephant Butte Reservoir) and peripheral closed sub-basins (<https://water.usgs.gov/GIS/huc.html>). However, for some purposes, the northern extent of the MRG has been limited to that below the confluence of the Rio Chama with the Rio Grande (Rinne and Platania 1995) or below Cochiti Reservoir (Cowley et al. 2007, Sallenave et al. 2010, Dudley et al. 2016). The latter upper limit to the drainage completely excludes sub-basin HUC 130201 (Upper Rio Grande) and the very northern portion of sub-basin HUC 1302021 (Rio Grande-Santa Fe) above Cochiti Dam, leaving the remainder of the subregion, HUC 130202 (also named Rio Grande-Elephant Butte), less the same subunits as noted above. This more limited definition of the MRG includes the

remaining range of the endangered Rio Grande Silvery Minnow *Hybognathus amarus* (Bestgen and Platania 1991, USDI 1994, NMDGF 2018) and has been adopted for species distribution maps in this guide (Figure 1).

The MRG, flowing through the expansive Rio Grande Rift, was historically typical of rivers in semi-arid regions (Platania and Dudley 2002). It was relatively shallow and highly braided throughout most of the year because of low precipitation, but subject to periods of high flows from the annual spring snowmelt in its headwaters and intense summer rainstorms. These high-flow events inundated wide floodplains which provided backwater habitat and helped maintain a perennial flow throughout the summer, except during extended droughts.

The Rio Grande Valley has supported irrigated agriculture for over half a millennium, beginning with early Pueblo communities, but modifications to the MRG since the 1930's for flood control and much more extensive irrigation systems have resulted in aggradation, degradation, armoring, and narrowing of the river channel in portions of the reach (Lagasse 1980, as cited by Platania and Dudley 2002). Flow in the MRG is regulated by upstream reservoirs, primarily Cochiti Reservoir which was completed in 1973, and by many irrigation diversion dams (Dudley et al. 2016). Three major main-stem diversion dams were constructed between Cochiti and Elephant Butte reservoirs, effectively dividing the MRG into four reaches, each named for the upstream dam—Cochiti, Angostura (sometimes referred to as the Albuquerque Reach), Isleta, and San Acacia (Figure 1). Flow modification, dewatering, and fragmentation of the MRG have increased sediment deposition, blocked upstream fish movement, and, together with the introduction of invasive non-native species, otherwise severely impacted the aquatic ecosystem and fish communities therein, including extirpation of a few species (Cowley 2006, Dudley and Platania 2007).

As listed in Table 1, the MRG has been inhabited by at least 51 species of fish (13 families), 43 of which (10 families) have been recorded as present during the last 25 years and are assumed to be current residents. Two more species (and one family) listed for the MRG by Rinne and Platania (1995) may still be present despite lack of more recent observations (listed as “present?” in Table 1), thereby possibly increasing the total number of extant species to 45 (11 families). Six extant species in this list were not previously reported in the MRG by Rinne and Platania (1995) or Sublette et al. (1990)—Bullhead Minnow *Pimephales vigilax*, Vermiculated Sailfin Catfish *Pterygoplichthys disjunctivus*, Brown Bullhead *Ameiurus nebulosus*, Striped Bass *Morone saxatilis*, Spotted Bass *Micropterus punctulatus*, and Bigscale Logperch *Percina macrolepida*. Two more were not indicated as extant in the MRG by Sublette et al. (1990)—Goldfish *Carassius auratus* and Golden Shiner *Notemigonus crysoleucas*.

Based on Table 1, native species account for 33% (17) of the 51 species ever reported as present in the MRG and about 25% (11) of the 43–45 species reported therein during the last 25 years. Four additional MRG species (three extant—Gizzard Shad *Dorosoma cepedianum*, Western Mosquitofish *Gambusia affinis*, and Bluegill *Lepomis macrochirus*, and one possibly extirpated—Roundnose Minnow *Dionda episcopa*) were designated as native to the Rio Grande in New Mexico by Sublette et al. (1990) and Cowley et al. (2006), but were determined by Rinne and Platania (1995) to instead have been introduced (non-native) in the MRG reach. Two native fishes are now extinct and four more have been extirpated from the MRG. The native Blue Catfish *Ictalurus furcatus* also had been listed as extirpated by Rinne and Platania 1995, but remains present based on more recent collections (Table 1).

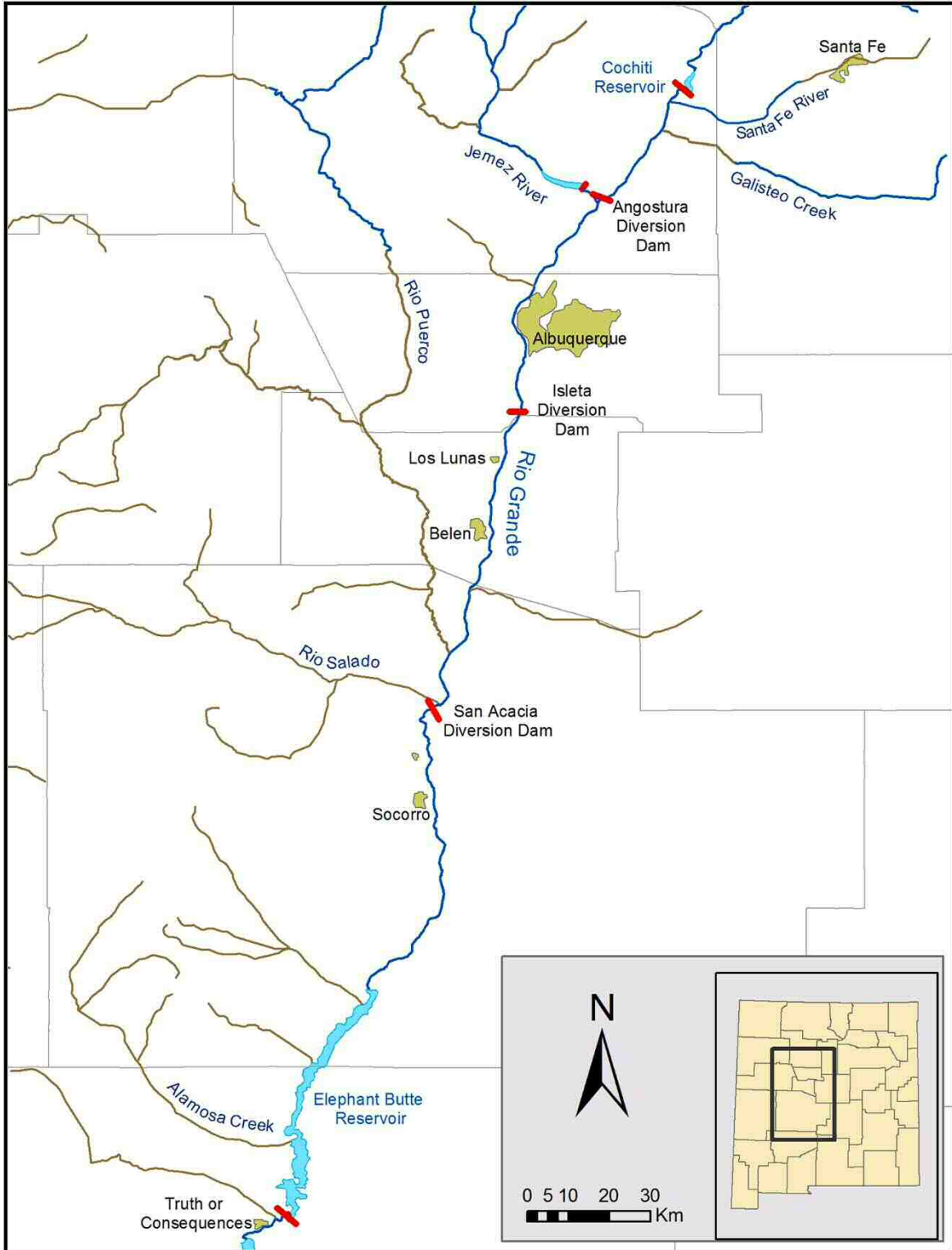


Figure 1. Middle Rio Grande drainage, New Mexico, Cochiti Reservoir dam to inflow of Elephant Butte Reservoir (normally perennial waters drawn in blue, intermittent streams in brown).

Table 1. Fishes of the Middle Rio Grande, New Mexico, based on 1993-2018 American Southwest Ichthyological Researchers LLC (ASIR, Albuquerque, NM) and Museum of Southwestern Biology (MSB, Albuquerque) data from Rio Grande Silvery Minnow population monitoring (seine) and estimation (seine and electrofishing) programs as summarized by R.K. Dudley (ASIR and MSB, personal communication, June 2019); 1993–2009 fish monitoring datasets (including some by ASIR and MSB) summarized by Widmer et al. (2010, Table 4.2); and additional and historically present taxa (preceded by “#”) as listed by Rinne and Platania (1995, Table 1). Resident status is as listed by Rinne and Platania (1995; N = native, En = endemic to the Rio Grande Basin, I = introduced). Recent population status is based on the greatest capture percentage (>5% = Abundant, 1–5% = Common, <1% = Rare; <10 captures by all gear = Incidental) among gear types (seines, fyke nets, electrofishing) summarized by Widmer et al. (2010) or otherwise as footnoted. Conservation status (E = endangered, T = threatened, SC = species of special concern or greatest conservation need) is as listed for Rio Grande Basin states (CO, NM, TX) and countries (US, MX) by Contreras-Balderas et al. (2003), CPW (2015), NMDGF (2016a, 2018), TPW (2011, 2018) and USFWS (2018). Common and scientific names follow Page et al. (2013). Asterisk (*) follows names of species covered in this guide.

| Taxa | Status: Resident | Population | Conservation |
|--|------------------|-------------------------|------------------|
| <u># Acipenseridae</u> | | | |
| # <i>Scaphirhynchus platyrhynchus</i> (Shovelnose Sturgeon) | N | Extirpated | T-TX |
| <u># Anguillidae</u> | | | |
| # <i>Anguilla rostrata</i> (American Eel) | N | Extirpated | SC-TX |
| <u>Clupeidae</u> | | | |
| <i>Dorosoma cepedianum</i> (Gizzard Shad) | I ^a | Rare ^b | |
| <i>Dorosoma petenense</i> (Threadfin Shad) | I | Rare | |
| <u>Cyprinidae</u> | | | |
| <i>Campostoma anomalum</i> (Central Stoneroller) | I | Incidental | |
| <i>Carassius auratus</i> (Goldfish) | I | Incidental ^c | |
| <i>Cyprinella lutrensis</i> (Red Shiner) * | N | Abundant | SC-MX |
| <i>Cyprinus carpio</i> (Common Carp) * | I | Abundant ^d | |
| # <i>Dionda episcopa</i> (Roundnose Minnow) | I ^a | Present? ^e | E-MX; SC-TX |
| <i>Gila pandora</i> (Rio Grande Chub) * | N, En | Incidental ^f | T-TX; SC-NM, CO |
| <i>Hybognathus amarus</i> (Rio Grande Silvery Minnow) * | N, En | Abundant ^g | E-US, NM, TX, MX |
| # <i>Macrhybopsis aestivalis</i> (Speckled Chub) | N | Extirpated | T-MX; SC-TX |
| <i>Notemigonus crysoleucas</i> (Golden Shiner) | I | Incidental ^h | |
| # <i>Notropis jemezianus</i> (Rio Grande Shiner) | N, En | Extirpated | T-MX; SC-TX |
| # <i>Notropis orca</i> (Phantom Shiner) | N, En | Extinct | |
| # <i>Notropis simus simus</i> (Rio Grande Bluntnose Shiner) ⁱ | N, En | Extinct | |
| <i>Pimephales promelas</i> (Fathead Minnow) * | N | Abundant | |
| <i>Pimephales vigilax</i> (Bullhead Minnow) * | I | Rare ^j | |
| <i>Platygobio gracilis</i> (Flathead Chub) * | N | Abundant ^d | SC-CO |
| <i>Rhinichthys cataractae</i> (Longnose Dace) * | N | Common | SC-TX |

(continued)

Table 1. Continued.

| Taxa | Status: Resident | Population | Conservation |
|---|------------------|--------------------------|-----------------|
| <u>Catostomidae</u> | | | |
| <i>Carpionodes carpio</i> (River Carpsucker) * | N | Abundant ^d | SC-MX |
| <i>Catostomus commersonii</i> (White Sucker) * | I | Abundant ^d | |
| # <i>Catostomus plebeius</i> (Rio Grande Sucker) * | N | Incidental ^k | E-CO;T-MX;SC-NM |
| <i>Ictiobus bubalus</i> (Smallmouth Buffalo) * | N | Common ^l | SC-MX |
| <u>Loricariidae</u> | | | |
| <i>Pterygoplichthys disjunctivus</i> (Vermiculated Sailfin Catfish) | I | Incidental ^m | |
| <u>Ictaluridae</u> | | | |
| <i>Ameiurus melas</i> (Black Bullhead) | I | Rare ⁿ | |
| <i>Ameiurus natalis</i> (Yellow Bullhead) | I | Rare ⁿ | |
| <i>Ameiurus nebulosus</i> (Brown Bullhead) | I | Incidental ^o | |
| <i>Ictalurus furcatus</i> (Blue Catfish) | N | Rare ^p | |
| <i>Ictalurus punctatus</i> (Channel Catfish) | I | Abundant ^d | |
| <i>Pylodictis olivaris</i> (Flathead Catfish) | I | Rare | |
| <u>Salmonidae</u> | | | |
| # <i>Oncorhynchus clarkii virginalis</i> (Rio Grande Cutthroat Trout) ^q | N, En | Incidental? ^r | SC-CO, TX |
| <i>Oncorhynchus mykiss</i> (Rainbow Trout) | I | Rare ^s | |
| <i>Salmo trutta</i> (Brown Trout) | I | Rare ^s | |
| # <i>Salvelinus fontinalis</i> (Brook Trout) | I | Incidental? ^t | |
| <u># Fundulidae</u> | | | |
| # <i>Lucania parva</i> (Rainwater Killifish) | I | Present? ^e | |
| <u>Poeciliidae</u> | | | |
| <i>Gambusia affinis</i> (Western Mosquitofish) | I ^a | Abundant | |
| <u>Moronidae</u> | | | |
| <i>Morone chrysops</i> (White Bass) | I | Rare | |
| <i>Morone saxatilis</i> (Striped Bass) | I | Incidental ^u | |
| <u>Centrarchidae</u> | | | |
| <i>Lepomis cyanellus</i> (Green Sunfish) | I | Rare | |
| <i>Lepomis gulosus</i> (Warmouth) | I | Incidental ^v | |
| <i>Lepomis macrochirus</i> (Bluegill) | I ^a | Rare | |
| <i>Lepomis megalotis</i> (Longear Sunfish) | I | Incidental | |
| <i>Micropterus dolomieu</i> (Smallmouth Bass) | I | Rare ^w | |
| <i>Micropterus punctulatus</i> (Spotted Bass) | I | Rare ^x | |
| <i>Micropterus salmoides</i> (Largemouth Bass) | I | Rare ^y | |
| <i>Pomoxis annularis</i> (White Crappie) | I | Rare | |
| <i>Pomoxis nigromaculatus</i> (Black Crappie) | I | Rare | |
| <u>Percidae</u> | | | |
| <i>Perca flavescens</i> (Yellow Perch) | I | Rare | |
| <i>Percina macrolepida</i> (Bigscale Logperch) | I | Incidental ^z | T-NM, MX |
| <i>Sander vitreus</i> (Walleye) | I | Rare | |

(continued)

Table 1. Continued.

| | | | |
|------------------------------|----|---|-------|
| Number of native species | 17 | Number of extirpated or extinct natives | 6 |
| Number of endemic species | 6 | Number of extant native species | 11 |
| Number of introduced species | 34 | Number of extant introduced species | 32-34 |
| Total number of species | 51 | Total number of extant species | 43-45 |

^a Considered native by Sublette et al. (1990).

^b Also rare based on ASIR-MSB data (Dudley, personal communication) where captured annually in the San Acacia Reach.

^c Based on ASIR-MSB data; two captures in Angostura Reach in 1999 (MSB catalog # 432554) and one in 2010. Not indicated as extant in the Middle Rio Grande (MRG) by Sublette et al. (1990) or Widmer et al. (2010), but listed by Rinne and Platania (1995).

^d Common based on ASIR-MSB data.

^e Possibly still present despite lack of recent captures (after 1992).

^f Rare based on ASIR-MSB data; 14 captures, 9 since 2009, mostly in Cochiti Reach.

^g Listed as rare by Rinne and Platania (1995), but more recently abundant based on Widmer et al. (2010) and ASIR-MSB data. Also reported as abundant in MRG irrigation systems by Sallenave et al. (2010).

^h Not indicated as extant in the MRG by Sublette et al. (1990).

ⁱ Subspecies per Chernoff et al. (1982).

^j Also rare based on ASIR-MSB data where captured in the San Acacia Reach almost annually since 2004. Not previously listed as present by Rinne and Platania (1995) or Sublette et al. (1990).

^k Listed as rare by Rinne and Platania (1995), but assumed incidental. Reported present below Cochiti Dam by Platania (1993, 4 specimens) and more recently in MRG irrigation systems by Sallenave et al. (2010).

^l Rare based on ASIR-MSB data, but captured almost annually since 2002 in the San Acacia Reach. Also listed as rare by Rinne and Platania (1995).

^m Based on ASIR-MSB data; 1 captured in Isleta Reach in 2018 (Dudley et al. 2019). Not previously reported in MRG.

ⁿ Also rare based on ASIR-MSB data where captured annually.

^o Not listed as present by Rinne and Platania (1995) or Sublette et al. (1990), nor in ASIR-MSB data.

^p Based on ASIR-MSB data where captured in the San Acacia Reach almost annually since 2008; incidental based on data summarized by Widmer et al. (2010). Also reported in MRG irrigation systems by Sallenave et al. (2010). Previously listed as extirpated by Rinne and Platania (1995).

^q Subspecies per Behnke (1988, 1992).

^r Status in main-stem river and lower reaches of tributaries; present in cooler upstream and headwater reaches of northern tributaries. Listed as rare by Rinne and Platania (1995) and documented as present in certain tributary headwaters in Sante Fe National Forest by USFWS (2014). Also, reared and stocked in tributary headwaters and reservoirs by New Mexico Department of Game and Fish (NMDGF 2016b).

(continued)

Table 1. Continued.

- ^s Status in main-stem river and lower reaches of tributaries—incidental based on ASIR-MSB data. More common to locally abundant in cooler upstream and headwater reaches of northern tributaries (NMDGF 2016c).
- ^t Status in main-stem river and lower reaches of tributaries; present in some cooler upstream and headwater reaches of northern tributaries (NMDGF 2016c).
- ^u Based on ASIR-MSB data; 6 captured in San Acacia Reach in 2008. Not previously reported in MRG.
- ^v Based on ASIR-MSB data; 2 captured in 1995; also listed by Rinne and Platania (1995).
- ^w Not present in ASIR-MSB data.
- ^x Incidental based on ASIR-MSB data. Not previously listed as present by Rinne and Platania (1995) or Sublette et al. (1990).
- ^y Reported as abundant in MRG irrigation systems by Cowley et al. (2007) and Sallenave et al. (2010).
- ^z Also incidental based on ASIR-MSB data; not listed as present by Rinne and Platania (1995) or Sublette et al. (1990).
-

The order Cypriniformes accounts for more than one-third of the fish known to have inhabited the MRG (16 cyprinids plus 4 catostomids of 51 species, 39%), as well as those assumed to be current residents (11–12 cyprinids plus 4 catostomids of 43–45 species, 33–37%). Among native species, the cypriniforms represent 76% (10 cyprinids plus 3 catostomids) of the 17 historically present in the MRG, including five of six species endemic to the Rio Grande Basin, and 82% (6 cyprinids and 3 catostomids) of the 11 that remain, including two Rio Grande endemics.

During the past century, two of the ten cyprinids native to the MRG (one a subspecies) have become extinct (Phantom Shiner *Notropis orca* and Rio Grande Bluntnose Shiner *N. simus simus*; Bestgen and Platania 1990), two have been extirpated from the MRG (Speckled Chub *Macrhybopsis aestivalis* and Rio Grande Shiner *N. jemezianus*; Rinne and Platania 1995) and one, the Rio Grande Silvery Minnow, had been extirpated everywhere except in the MRG (Bestgen and Platania 1991). Accordingly, the latter species has been designated as federally endangered (USDI 1994) and, since the turn of the century, subject to recovery efforts via the Middle Rio Grande Endangered Species Collaborative Program (and since 2008, a reintroduction effort in the Big Bend region of the Rio Grande, Texas and Mexico—Edwards 2017). All five of these cyprinids belong (or belonged) to the reproductive guild of pelagic-spawning fishes (non-guarding, open-substrate pelagophils), broadcasting semibouyant eggs in open flowing water, and all but the Speckled Chub are (or were) endemic to the Rio Grande Basin (Platania and Altenbach 1998). The only pelagic-spawning cyprinid remaining in the MRG is the Rio Grande Silvery Minnow (Bestgen and Platania 1991). The reproductive guilds (Balon 1975a, 1981; Simon 1998) for other extant cypriniforms in the MRG include non-guarding, open-substrate lithopelagophils, lithophils, phytolithophils, and phytophils; non-guarding, brood-hiding lithophils and speleophils; and guarding, nest-spawning speleophils.

Except for the Rio Grande Silvery Minnow, the Rio Grande Chub *Gila pandora* (also endemic to the Rio Grande Basin), and the somewhat more broadly distributed Rio Grande Sucker *Catostomus plebeius*, most cypriniform species recently reported in the MRG are widely distributed in the midwestern U.S., many also elsewhere in the southwestern U.S. and (or) in

Mexico, some throughout much of the U.S., a few even into Canada, and two world-wide (the non-native Common Carp *Cyprinus carpio* and Goldfish). Within the MRG, the Rio Grande Chub and Rio Grande Sucker (also inhabitants of the upper Rio Grande in New Mexico and Colorado) have been recently found only in the upper extent of the basin (Cochiti Reach and upper end of the Angostura Reach), the Bullhead Minnow and Smallmouth Buffalo only in the lower portion of the basin (San Acacia Reach), the Rio Grande Silvery Minnow in all but the upper end (Cochiti Reach), and the remaining common or abundant cypriniforms in all four main-stem reaches of the basin.

The Rio Grande Silvery Minnow is the only U.S. federally protected fish in the MRG (USFWS 2018), and as such it is designated as a state endangered species by New Mexico (NMDGF 2018) and Texas (TPW 2018); it also has been listed as endangered by Mexico (Contreras-Balderas et al. 2003). New Mexico also protects the Rio Grande Sucker and Rio Grande Chub as species of greatest conservation need (NMDGF 2016a). Outside New Mexico, the Rio Grande Sucker is designated as endangered by Colorado (CPW 2015) and threatened by Mexico (Contreras-Balderas et al. 2003), and the Rio Grande Chub as threatened by Texas (TWP 2018) and a species of special concern by Colorado (CPW 2015). Several other MRG fishes also have been designated as endangered, threatened, or species of greatest conservation need or special concern by Rio Grande Basin states and (or) Mexico (Table 1).

This Guide, Objectives, and Prior Descriptions

Collections of the early life stages of fish are an essential component for research on and monitoring of Rio Grande Silvery Minnow in the Middle Rio Grande, and may be for the study and management of other fishes therein. Identification of specimens in those collections requires knowledge of the morphological appearance of not only the target species but also all similar species in the waters sampled and the diagnostic criteria for segregating them. Fortunately, the larvae and early juveniles of most species in the MRG have been moderately to well described. However, for many species, including cyprinids and catostomids, morphological criteria for identification change dramatically as the fish grow and develop, making diagnosis especially difficult. This is well exemplified by the 60-page key in Snyder and Muth (1990) which covers the larvae and early juveniles of just six of the seven species of catostomids in the Upper Colorado River Basin (UCRB).

The purposes of this guide, with its detailed and well-illustrated species accounts, comparative summary tables, and associated computer-interactive keys, are to: (1) describe the larvae and early juveniles of, or adapt existing descriptions for, 12 cypriniform fishes inhabiting the MRG; (2) better facilitate their identification; and (3) thereby aid research for management and recovery of native fishes, including the endangered Rio Grande Silvery Minnow. The descriptive information herein should be useful also for identification of any of the respective species wherever they may occur outside the MRG.

This guide, like a similar guide for the Pecos River by Brandenburg et al. (2018a), is modeled after a previously published guide to the cyprinid larvae and early juveniles of the UCRB (Snyder et al. 2016). It covers all cypriniform fishes recently present in the MRG except four introduced (non-native) cyprinids listed in Table 1 as either “Present?” or “Incidental.” Of the 12 species covered, nine are native (6 of the 8 cyprinids and 3 of the 4 catostomids).

Based on studies of reared or collected developmental series for the cyprinids, the guide includes new descriptive species accounts (and other tabulated data) for Rio Grande Silvery

Minnow, Rio Grande Chub, Flathead Chub *Platygobio gracilis*, and Bullhead Minnow, and builds upon prior work for Red Shiner *Cyprinella lutrensis*, Common Carp, Fathead Minnow *Pimephales promelas*, and Longnose Dace *Rhinichthys cataractae* (Snyder et al. 1977, Snyder 1981, and Snyder et al. 2005). The latter four species accounts were completed or updated concurrently with new data and illustrations for both this and the UCRB guide (Snyder et al. 2016), from which the accounts were adapted. Recently hatched larvae were also studied and illustrated to update a species account for Rio Grande Sucker from a report on catostomid larvae of the Rio Grande in Colorado (Snyder 1998). The White Sucker *Catostomus commersonii* account herein also had been progressively built upon prior work (Snyder 1981, Snyder and Muth 1990, and Snyder 1998) and completed for a guide to catostomid larvae of the UCRB (Snyder and Muth 2004), from which it was adapted. Finally, in the absence of our own developmental studies, the descriptive data and illustrations for the River Carpsucker *Carpionodes carpio*, and Smallmouth Buffalo *Ictiobus bubalus* accounts herein were extracted or summarized entirely from prior illustrations, descriptions, and accounts by others (May and Gasaway 1967, Wrenn and Grinstead 1971, Hoyt et al. 1979, Yeager 1980, Yeager and Baker 1982, Fuiman 1982a, Scheidegger 1990, and Kay et al. 1994), mostly based on fish reared from Alabama or Arkansas stock.

The larvae and early juveniles of many of the cypriniform fishes in the MRG have been frequently described, compared, and (or) included in other guides (Appendix II). However, despite very good and detailed prior descriptions for some species, differences in the specific characters examined and methods for assessing and summarizing them made it difficult to directly compare much of the data among those descriptions and incorporate it in our own species accounts, comparative summaries, and keys. Consequently, for completeness and comparability, it was necessary to conduct our own detailed analyses of mostly regionally collected and (or) reared developmental series, and include only that data (except juvenile and adult meristics or as otherwise noted) in species accounts for this guide or prior work from which some accounts were updated or adapted (Snyder 1998, Snyder and Muth 2004, and Snyder et al. 2016). The only exceptions for this guide, as noted above, are the data (and illustrations) for River Carpsucker and Smallmouth Buffalo. When comparable, our data generally match well with that in prior descriptions, but there are some notable discrepancies, probably due to differences in the specific populations examined (in some cases subspecies). For example, the early larvae of Longnose Dace described from eastern U.S. populations are notably larger than described for Colorado populations.

Also, despite many fine illustrations in prior descriptions and guides, it was necessary for comparative purposes to prepare original three-view drawings for most larval and juvenile illustrations herein. Previously published illustrations of the specific developmental stages needed were often not available, consisted of only lateral views, or lacked sufficient detail.

All extant fishes in the MRG are covered herein at the family level in an appended pictorial guide modified from Wallus et al. (1990) and in an associated computer-interactive key, except the very recently reported Vermiculated Sailfin Catfish. Based on the description of a congeneric by Jumawan et al. (2014), the undescribed larvae of the Vermiculated Sailfin Catfish (family Loricariidae) would be similar to larvae of Ictaluridae. The larvae of all other non-cypriniform species are covered in guides or descriptions by Auer (1982), Martinez (1983, 1984), Simon and Wallus (2004, 2006), Wallus and Simon (2006, 2008), Wallus et al. (1990), or Wang (2010), and by additional references cited therein.

A Combined Developmental Interval Terminology ²

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

The larval phase terminologies most commonly used in recent years, particularly for descriptive purposes, are those defined by Hardy et al. (1978—yolk-sac larva, larva, prejuvenile; modified from Mansueti and Hardy 1967), Ahlstrom et al. (1976—preflexion, flexion, postflexion; expanded upon by Kendall et al. 1984), and Snyder (1976b and 1981—protolarva, mesolarva, metalarva). Definitions for all three terminologies were presented in a chapter on "Fish Eggs and Larvae" by Snyder (1983) in the first edition of *Fisheries Techniques* (Neilson and Johnson 1983), as well as in expanded updates of that chapter by Kelso and Rutherford (1996) and Kelso et al. (2012). The individual terms are also defined in the glossary for this guide (Appendix I). During a workshop on standardization of such terminologies, held as part of the Seventh Annual Larval Fish Conference (Colorado State University, January 16–19, 1983), it became obvious that these are not competing terminologies, as they often are treated, but rather complementary options with subdivisions or phases defined for different purposes (Snyder and Holt 1984). As such, it is possible to utilize all three terminologies simultaneously to: (1) facilitate comparative descriptions and preparation of keys based on fish in similar states of development with respect to morphogenesis of finfold and fins; (2) segregate, for fishes with homocercal tails, morphometric data based on standard length measured to the end of the notochord prior to and during notochord flexion from those measured to the posterior margin of the hypural plates following notochord flexion; and (3) approximate transition from at least partially endogenous nutrition (utilization of yolk material) to fully exogenous nutrition (dependence on ingested food) based on presence or absence of yolk material.

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

The definition for the end of the larval period is necessarily a compromise deleting all requirements (some taxon-specific, others difficult to determine precisely) except acquisition of the full complement of fin spines and rays in all fins and loss of all finfold (last remnants usually

² Reprinted with minor modifications from Snyder et al. (2016).

Combined Developmental Interval Terminology

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

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

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

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

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

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

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

Juvenile: Period of fish development from the larval period to the adult period which begins with the attainment of sexual maturity.

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

part of the preanal finfold). Provisions for taxon-specific prejuvenile (or transitional) phases are also deleted. In some cases, finfold persists through the endpoint for such special intervals, which are then effectively included in the larval period.

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

The combined terminology is designed to be relatively simple but comprehensive, precise in its transition criteria, applicable to nearly all teleost fishes, and flexible. It can be utilized in part (essentially as one of its component terminologies) or its entirety depending on purposes of the user. For example, if it is necessary to acknowledge only that the fish is a larva and whether it bears yolk, the terms "yolk-sac larva" and "larva without yolk" are all that is needed. Biologists who formerly utilized one of its component terminologies should have no difficulty in adapting to the combined terminology because the essential features and terms of the original terminologies have been retained.

Characteristics Useful in Identification of Cypriniform Fish Larvae ³

Fishes of the families Cyprinidae (minnows and carps) and Catostomidae (suckers), order Cypriniformes, are closely related and morphologically similar. As noted earlier, together the two families account for over one-third (35%) of the 43 species reported in the MRG during the past 25 years (Table 1). Generalizations in the following discussion with respect to the order Cypriniformes refer specifically to North American species in these two families. Figures 2 and 3 identify the more obvious morphological features and structures of cypriniform eggs and larvae; most are also defined in an appended glossary (Appendix I).

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

Berry and Richards (1973) noted that "although species of a genus may vary from one geographical area to another, generally the larval forms of closely related species look alike. At the same time, larvae of distantly related forms may be closely similar in gross appearance." As a group, cypriniform larvae in North America are distinctive and generally easy to distinguish

³ Modified from Snyder et al. (2016).

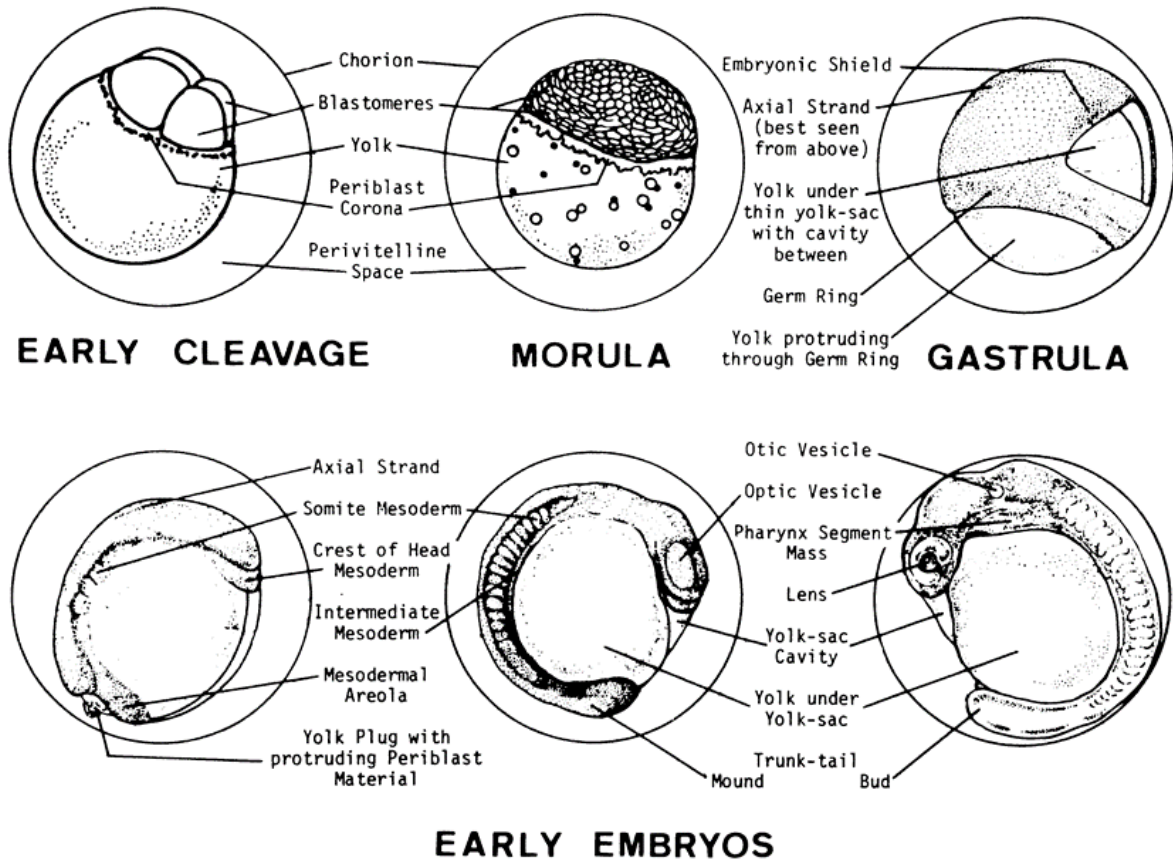


Figure 2. Selected anatomical features of cypriniform fish eggs and embryos (from Snyder 1981, based on drawings from Long and Ballard 1976).

from larvae of other families. Beginning researchers should become familiar with the general larval characteristics of each family likely to be encountered. The guides and keys listed by Kelso et al. (2012) and discussed earlier in this introduction are most useful in this respect. Auer (1982) is particularly recommended because the guide covers all families (except Loricariidae) and most non-native species in the MRG. Also recommended are discussions of taxonomic characters by Berry and Richards (1973) and Kendall et al. (1984) and the pictorial guides to families in Holland-Bartels et al. (1990) and Wallus et al. (1990; also subsequent volumes in the Ohio River drainage series by Kay et al. 1994, Simon and Wallus 2004 and 2006, and Wallus and Simon 2006 and 2008). An adaptation of the latter pictorial guide to families is appended to this guide (Appendix IV).

Most cypriniform larvae in North America are readily distinguished as either cyprinids or catostomids. However, if members of the cyprinid subfamily Cyprininae (carps) and the catostomid subfamily Ictiobinae (carpsuckers and buffalofishes) are present, as in the MRG, identification at the family level can be more difficult.

Within their respective families, and especially at the subfamily level, cypriniform larvae are very homogeneous in gross structure and appearance. Accordingly, they may be especially difficult to discriminate at the genus or species levels. Specific identification of these larvae

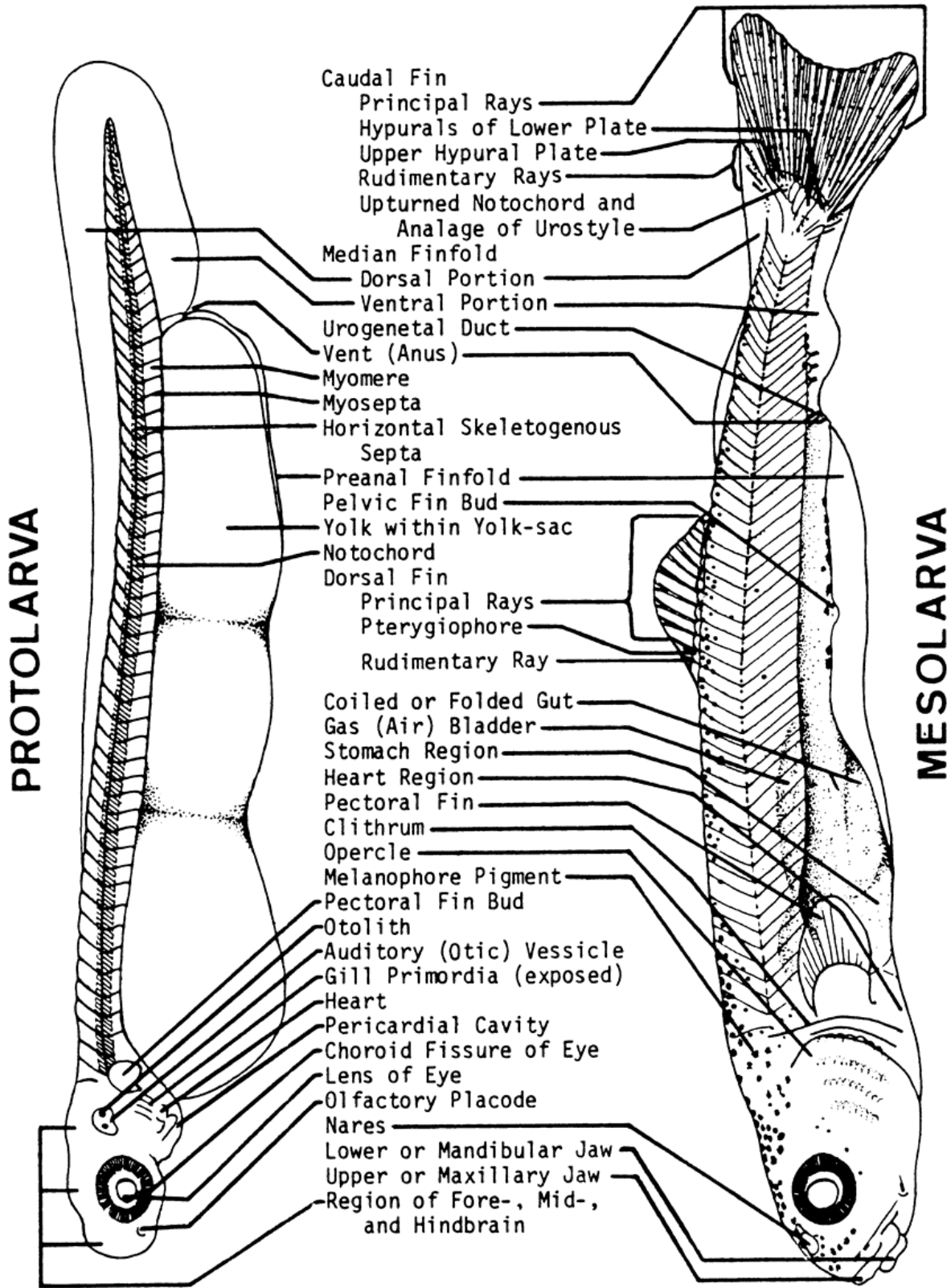


Figure 3. Selected anatomical features of cypriniform fish larvae (from Snyder 1981).

relies on differences in meristics, size at onset of certain developmental events, form of the gut, morphometrics, melanistic (brown or black) pigment patterns, presence of certain morphological structures, and (or) sometimes internal osteological characters. There is often a notable amount of intra- as well as inter-regional variability in many of these characters. Accordingly, it is usually necessary to confirm a specimen's identity based on multiple diagnostic characters.

Myomeres

Because myomeres are obvious morphological features and relatively consistent in number and position, they are one of the most useful characters available for identification of larvae above (and sometimes at) the species level, especially for protolarvae and mesolarvae. They begin as part of the embryonic somites and are usually formed in their full complement prior to hatching. Throughout the protolarval and much of the mesolarval phase, myomeres are chevron-shaped, but by the metalarval phase they evolve to their typical three-angled adult form. Fish (1932) and many subsequent authors observed that there is a nearly direct, one-to-one correlation between total myomeres and total vertebrae (including Weberian ossicles in cypriniforms). Fuiman (1982b) further documented this correspondence in teleosts with total myomere counts one greater than total vertebrae, but rather than defining all myomeres to be bounded anteriorly and posteriorly by myosepta (as treated herein), he considered the first myomere to precede the first myoseptum and the last, a urostylar segment corresponding to the final vertebra or ural centrum, to follow the most posterior myoseptum. As noted by Fuiman, except for these first and last segments, the posterior half of one vertebra and the anterior half of the next develop within each myomere (with neural and hemal arches of the vertebrae forming in the myosepta between them), thereby accounting for one more myomere than vertebrae in his counts, and one less if segments before the first and after the last at least partial myosepta are not counted as myomeres. Snyder (1979) and Conner et al. (1980) summarized myomere and vertebral counts for many cypriniform fishes.

The most anterior and most posterior myosepta and therefore myomeres are frequently difficult to distinguish and probably account for at least some myomere count discrepancies in the literature. The most posterior myomere is defined herein, and by most authors, as lying anterior to the most posterior complete myoseptum. Siefert (1969) describes a "false (partial) myoseptum" posterior to the last complete myoseptum which adds to the difficulty of discerning the last myomere. The most anterior myomeres in cypriniform fishes are apparent only or mostly in the epaxial or dorsal half of the body, the first often being deltoid in shape and immediately behind the occiput. This first myomere, bounded anteriorly by what might be considered only a partial or epaxial myoseptum, might effectively correspond to the first myomere as defined by Fuiman (1982b), and if so, would result in the same number of total myomeres as vertebrae (as most often recorded herein) rather than the expected one less. Early in the larval period, myomeres are most readily observed using transmitted light. Polarizing filters, depending on thickness and certain other qualities of the preserved tissues, can dramatically increase contrast between the muscle tissue of myomeres and the myosepta that separate them. Myomeres of some metalarvae and most juveniles are difficult to observe, even with polarizing filters; reflected light at a low angle from one side and higher magnification sometimes facilitates observation.

Typical counts used in taxonomic work include total, preanal, and postanal myomeres. Partial counts also may be used to reference the location of structures other than the vent or anus.

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

In the United States and Canada, the range of total myomere (and vertebral) counts recorded for cyprinids, 28 to 52, is slightly larger and nearly includes that for catostomids, 32 to 53. Ranges for preanal and postanal myomere counts also overlap with 19 to 35 and 9 to 22, respectively, for cyprinids and 25 to 42 and 4 (possibly 3) to 14, respectively, for catostomids. The ranges and degree of overlap are somewhat smaller in the MRG with 19–31 preanal, 9–15 postanal, and 31–44 total myomeres for cyprinids versus 27–40, 4–12, and 34–49, respectively, for catostomids. Despite the magnitude of overlap in these ranges, proportions of postanal to preanal and preanal to total myomeres will distinguish most cyprinids from catostomids (Snyder 1979). The postanal to preanal myomere proportion is at least 0.40 (often greater than 0.50) for most cyprinids and less (often less than 0.33) for catostomids. Also, the proportion of preanal to total myomeres is .71 or less (often less than 0.67) for most cyprinids and greater (often greater than 0.75) for catostomids. These myomere proportion criteria work well for all catostomid and most cyprinid larvae in the MRG, the exceptions being Common Carp and especially Rio Grande Silvery Minnow with combinations of high preanal and low postanal or high total myomere counts within their respective ranges; also excepted are a few other cyprinids when they have extremely high preanal and extremely low postanal myomere counts. Among MRG catostomids, most larvae can be readily identified to subfamily based on preanal or total myomere counts—31–40 and 41–49 respectively for Catostominae versus 27–32 and 34–41 for Ictiobinae.

Fins and finfolds

Fin-ray meristics and fin positions are among the most useful characters for later mesolarvae and metalarvae. These data can be determined from older juveniles and adults or gleaned from published descriptions of adults. Also, the origin (anterior-most insertion) of finfolds, the sequence and timing of fin development (e.g., size at initial and final ray formation), fin lengths, and basal lengths of the dorsal and anal fins may be useful in the diagnosis of some larvae.

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

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

The caudal fin is the first fin to differentiate from the median finfold in cypriniform and most other fishes with homocercal tails. The base of the finfold initially thickens along the ventral side of the posterior end of the notochord, then differentiates into the hypural elements of the caudal skeleton. Immediately thereafter, the first caudal-fin rays appear (beginning of flexion mesolarval phase) and the posterior portion of the notochord begins to bend or flex upward (striations or folds in the caudal portion of the finfold can be mistaken easily as developing fin rays). As the fin develops and the notochord continues to flex upward, the hypurals and developing caudal-fin rays, all ventral to the notochord, move to a posterior or terminal position. The first principal rays are medial and subsequent principal rays form progressively above and below. Principal caudal-fin rays articulate with hypural bones of the caudal structure and ultimately include all branched rays plus two adjacent unbranched rays, one above and one below the branched rays. Branching and segmentation of rays can be observed as or shortly after the full complement of principal rays becomes evident and notochord flexion is completed (beginning of postflexion mesolarval phase).

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

Dorsal and ventral rudimentary rays of the caudal fin (shorter unbranched rays anterior to the outermost principal rays which also remain unbranched in later stages) begin forming sequentially in an anterior direction immediately after all or nearly all principal caudal-fin rays are formed. Rudimentary caudal-fin rays are among the last groups of fin rays to form their full adult complement (others being the pectoral- and pelvic-fin rays); if last and all finfold has been absorbed, their full acquisition defines the end of the larva period. Accordingly, counts of rudimentary caudal-fin rays are usually ignored in larval fish identification, but they may be of diagnostic value for juveniles and adults.

The dorsal and anal fins, which typically form either simultaneously (many cyprinids) or dorsal first (most catostomids), usually begin development prior to attainment of the full complement of principal caudal-fin rays. Tissue first thickens at the base of the median finfold in vicinity of the future fin, after which pterygiophores, the skeletal supports of fin rays,

gradually become evident. The latter structures, each ultimately supporting a single principal ray, permit limited diagnostic use of dorsal and anal fin position and meristics about midway through the mesolarval phase before all the rays are formed. Anterior principal fin rays develop first and subsequent rays are added in a posterior direction. The first or most anterior principal ray in each fin remains unbranched whereas all other principal fin rays branch distally after ray segmentation becomes evident. In cypriniform fishes, the last or most posterior principal ray in each fin also branches at the base and consists of two elements that appear to be separate rays but are counted as one. Those branches actually form on the last pterygiophore as separate, but closely spaced, elements and later merge or fuse at their proximal, articulating ends. The anterior element forms first, but for purposes of defining transition to the metalarva phase, the full complement of rays in these fins is not considered complete until both elements of the last ray are evident. The first rudimentary ray (shorter unbranched rays anterior to the principal rays) in each fin frequently forms before the most posterior principal rays. If more than one, rudimentary fin rays are subsequently added in an anterior direction.

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

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

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

Other countable structures

Other structures that may be treated meristically (and in some cases morphologically) include branchiostegals, gill rakers, pharyngeal teeth, and scales. Branchiostegals form early in

larval development, but counts are usually constant within major taxon groups. Within the order Cypriniformes, all members of superfamily Cyprinoidea, which includes Cyprinidae and Catostomidae, have three branchiostegals (McAllister 1968). Due to later development, small size or internal location, the other characters are seldom used to diagnose fish larvae. Gill rakers form gradually in postflexion mesolarvae or metalarvae with numbers increasing throughout much of the early portion of the juvenile period. The adult complement of gill rakers on the first gill arch is not achieved in many Catostominae until they reach about 70 mm standard length (Smith 1966). Although he didn't mention a minimum size, Muth (1990) found gill raker counts essentially complete and diagnostically useful for distinguishing young-of-the-year juvenile Bonytail *Gila elegans* from Humpback Chub *G. cypha* and Roundtail Chub *G. robusta*. Pharyngeal teeth form relatively early but may not be sufficiently well developed to be readily removed and observed until late in the larval period or early in the juvenile period. Detailed study of gill rakers and pharyngeal teeth might reveal some useful diagnostic qualities, including size, shape, and number. However, most specimens are more easily identified using external characters. Scales typically become apparent late in the larval period or early in the juvenile period. First scales on cypriniforms typically appear midlaterally on the posterior half of the body and from there spread anteriorly, dorsally, and ventrally toward adult coverage. Scales of large-scaled species are sometimes sufficiently obvious by late in the metalarval phase to distinguish certain species or genera.

Morphology

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

Morphometric data emphasize the relative position and relative size of various body components and dimensions and may be critical to species identification. Such measurements may be allometric, changing in proportion as the fish grow; thus morphometric data should be related to size, at least for protolarvae and mesolarvae. Referencing Bookstein et al. (1985), Fuiman and Corazza (1979), Humphries et al. (1981), and Strauss and Bookstein (1982), among others, Muth (1990) briefly reviewed and discussed the problem of allometry and alternatives for presenting and analyzing morphometric and shape-related data. Some morphometric data, particularly body depths and widths, may be directly affected by the condition of individual specimens and volume and form of food items in their digestive tracts. The source of specimens and the preservative in which they are stored also may affect morphometric data. Some measures in wild fish may differ from those of laboratory-reared specimens (e.g., fin lengths). Shrinkage and deformation are notably greater for fish preserved in alcohol than in formalin solutions (see Kelso et al. 2012 for the latest recommendations regarding fixation and preservation of fish larvae).

Morphometric data in this guide are reported as percentages of standard length (% SL). Use of standard length (SL) avoids the allometric influence of caudal fin growth included in percentages based on total length (TL). As explained later (Methods), if TL is included as % SL,

other individual specimen and mean data recorded as % SL (but generally not summarized ranges) can be easily converted to % TL, and vice versa, for comparison with other works. Prior to hypural plate formation and completion of notochord flexion (protolarvae and flexion mesolarvae), SL is the length from snout to posterior end of the notochord (notochord length). Thereafter, SL is measured from the anterior margin of the snout to the most posterior margin of the hypural plates (usually the superior plate or hypurals). Use of notochord length for flexion mesolarvae gives the appearance of greater allometric growth differences than may really exist, at least in comparison with subsequent measures based on the posterior margin of the forming hypural plates. This undesirable effect is a result of upward bending or flexing of the notochord and the switch from use of end of the notochord to posterior margin of the hypurals as the basis for SL measurement. This transition must be taken into account when reviewing morphometric data herein.

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

Snout-to-vent length is measured to the posterior margin of the vent or anus. It is a primary diagnostic character for many species, especially at the family and sometimes subfamily level. In the MRG, most cyprinid larvae are readily differentiated from catostomid larvae by snout-to-vent lengths less than 73% SL. Exceptions are many larvae of Common Carp, many later larvae of Rio Grande Silvery Minnow, and rarely later larvae of Rio Grande Chub and Flathead Chub. The term "preanal length" is often applied to this measure but might be misinterpreted, or alternatively defined, as length to the anterior margin of the anus or origin of the anal fin. For many fishes, including cypriniforms, the latter measurement would be approximately the same as snout-to-vent length because the anal fin begins at or just behind the posterior margin of the vent.

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

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

Other morphological characters such as position, size, and form of the mouth and gut, and related changes, can be among the more useful characters for identification at the species level. Size of the mouth, as well as its position, its angle of inclination, and the form of specific mouth structures are diagnostic for some cypriniforms, especially in metalarvae. Timing of mouth migration from terminal to inferior position can be especially useful for catostomid metalarvae. Gut-loop length, timing of loop formation, and eventual degree and form of gut loops, folds, or coils can be diagnostic for the larvae of many fishes. Such gut characters are useful in identifying postflexion mesolarvae, metalarvae, and early juveniles of catostomids and certain cyprinids that have long, coiled or well-folded guts as later juveniles and adults, and especially in distinguishing these from most other cyprinids which develop shorter guts that are folded back or looped just once in a flattened S-shape.

Pigmentation

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

In cypriniform and most other fishes, chromatophores other than melanophores have not been sufficiently studied for identification purposes. Such chromatophores are typically neither as numerous nor as obvious as melanophores and their pigments are difficult to preserve. In contrast, melanin, the amino acid breakdown product responsible for the dark, typically black, appearance of melanophores (Lagler et al. 1962), remains relatively stable in preserved specimens. However, melanin is subject to fading and bleaching if specimens are stored or studied extensively in bright light for long periods of time, stored in alkaline preservatives, or subjected to changing concentrations of preservative fluids. To minimize the latter effects, as well as shrinkage and deformation, dilute formalin solutions (3–5%, unbuffered or buffered to near neutral) are strongly recommended over alcohol solutions as storage media for specimens fixed in formalin (5% to, preferably, 10%). Most of the following discussion refers to

chromatophores in general, but in this manual and others for freshwater species in North America, pigmentation typically refers to that of melanophores.

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

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

Pigmentation often changes considerably as larvae and early juveniles grow. Most of the change is due to increased numbers and distribution of chromatophores. Observable pigmentation might also be lost from certain areas through loss of pigment in chromatophores, loss of chromatophores themselves, or, in the case of subsurface or internal chromatophores, by growth and increased opacity of overlying tissues. Peritoneal melanophore pigmentation is an obvious character for later stages of some larvae, but in late metalarvae and especially juveniles, dark peritoneal pigmentation can be obscured by overlying muscle or membranes with silvery iridophores (this silvery pigment often dissipates over time in formalin preservative, but is usually retained in alcohol). If internal melanophore pigmentation is obscured by overlying tissues, it can be observed by selective dissection or careful clearing of specimens.

Osteology

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

Dunn (1983, 1984) reviewed use of skeletal structures and the utility of developmental osteology in taxonomic studies. Among the first bones to ossify are those associated with feeding, respiration, and orientation (e.g., jaws, bones of the branchial region, cleithrum, and otoliths). The axial skeleton follows with formation of vertebrae and associated bones. Once the axial skeleton is sufficiently established, median- and pelvic-fin supports form, and fins develop. Presence, number, position, and shape of certain bones can have diagnostic value, even among some closely related species. Although use of osteological characters for identification of fish

larvae has received little attention, it has great potential value, particularly for confirmation of questionable identities and distinguishing species for which external characters are diagnostically inadequate. For example, Snyder and Muth (1990 and 2004) found selected osteological characters useful in the identification of late larval and early juvenile catostomids in the UCRB. However, aside from externally visible structures, and in some cases vertebra and fin ray counts based on cleared and stained specimens, skeletal characters were not studied or included in descriptions for this guide (see the species account for White Sucker by Snyder and Muth 2004 for selected skeletal illustrations and data not included in the adaptation of that account herein).

METHODS

Specimens Examined

Over 740 specimens were specifically analyzed, including drawing specimens, for the descriptions herein; many more specimens were at least cursorily examined. All specimens examined are maintained by MSB or as part of the LFL Collection. Appendix III lists the total number of specimens analyzed for each species and the associated MSB or LFL Collection catalog numbers for those specimens individually comprising or removed from previously cataloged lots. Individual specimen data (e.g., counts and measures), including re-examined data from that compiled for earlier descriptions, are available in computer spreadsheet files maintained by LFL.

Most specimens selected for illustration and analysis were fixed in 10% formalin, then stored in 3 or 5% buffered formalin to avoid confounding data with the greater shrinkage and deformation effects typical of alcohol-preserved specimens. However, despite those concerns, a few wild juvenile specimens preserved in 70% ethanol were analyzed for descriptions of Rio Grande Silvery Minnow (fixed in 10% formalin then transferred to 70% ethanol in steps to minimize shrinkage), Bullhead Minnow, and Rio Grande Sucker.

Larval and juvenile descriptions for most species are based on a somewhat balanced mix of cultured and positively identified wild (field-collected) specimens. However, except for some wild juveniles, the new descriptions for Rio Grande Chub, Bullhead Minnow, and Flathead Chub (the latter also excepting a few wild late metalarvae) are based only on reared specimens. Conversely, except for some reared early larvae, the updated and newly illustrated descriptions for Common Carp and Red Shiner are based only on wild specimens. For these and other descriptions, the holdings of MSB and the LFL Collection had to be supplemented with newly reared developmental series, particularly for recently hatched stages of most species and more complete series of newly described MRG species. The sources of both older and more recently reared developmental series maintained by MSB or LFL are listed by species in Appendix III.

Specimen Data, Observations, and Illustrations

Specimens were analyzed, when applicable, for differences in up to 32 morphometric, 18 meristic, 29 pigmentation, and 11 other morphological characters. Individual specimen data compiled for prior descriptions were re-examined, questionable data verified or corrected if possible, and combined with new data for summaries herein. Meristic data (except myomere counts) were supplemented with observations from larger juvenile and adult specimens, some of which were cleared and stained for skeletal characters.

Figure 4 illustrates the various measurements, fin-ray counts, and myomere counts that were made on at least two specimens, if available, in each 1-mm-TL interval throughout the larval period of each species. Thereafter, to a length of about 50 mm TL, two or more specimens were similarly processed for each 5-mm interval, if available. Specimens were studied under low-power stereo-zoom microscopes with measuring eyepiece reticles and various combinations of reflected, transmitted, and polarized light. Older morphometric analyses (i.e., those prepared for Snyder 1981 and Snyder and Muth 1990) were conducted by adjusting microscope magnification before each series of measurements to calibrate the scale in the eyepiece against a

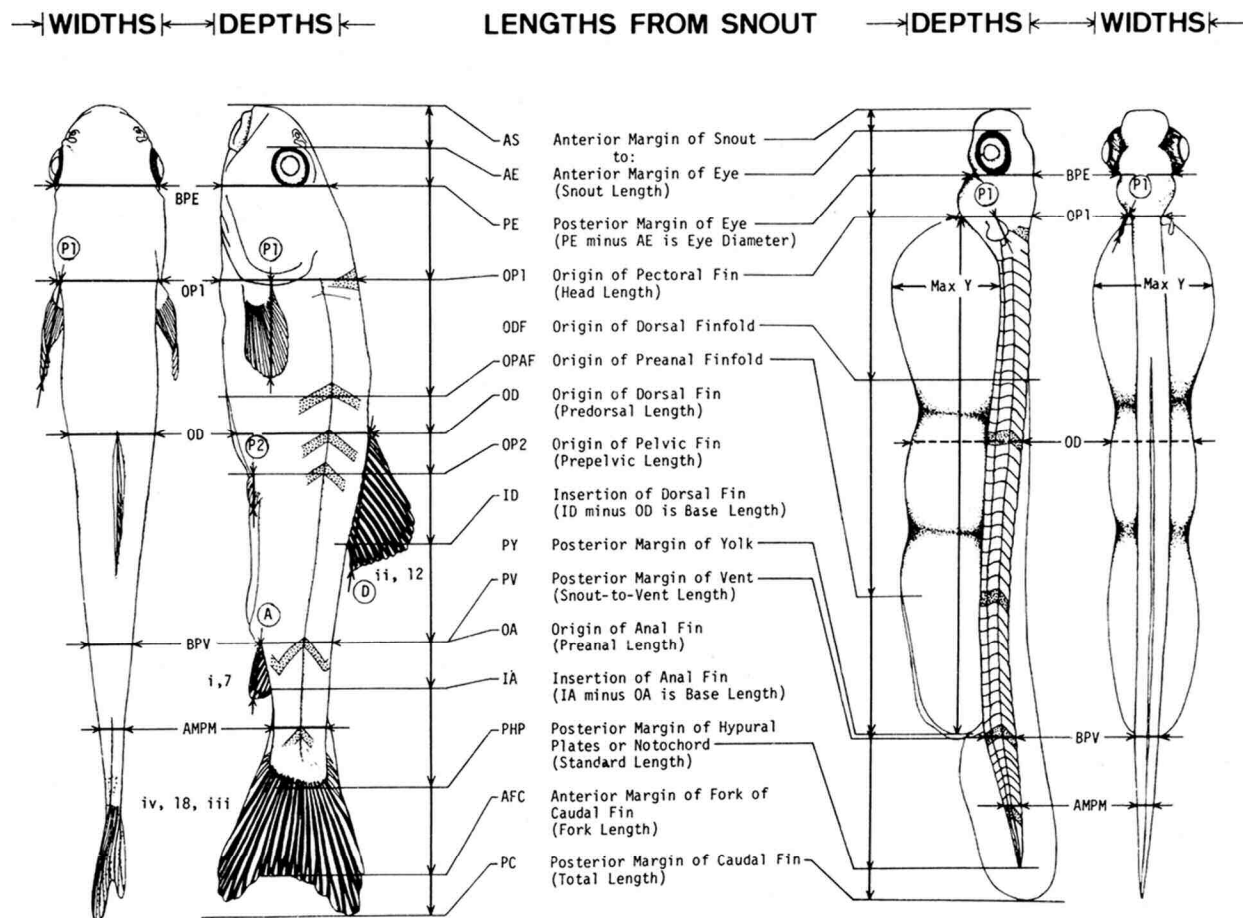


Figure 4. Measures and counts for larval and early juvenile fishes. Yolk sac and pterygiophores are included in width and depth measures but fins and finfolds are not. "B" in BPE and BPV means immediately behind. AMPM is anterior margin of most posterior myomere. Location of width and depth measures at OD prior to D formation is approximated to that of later larvae. PHP is measured to end of notochord until adult complement of principal caudal-fin rays are observed (beginning of postflexion mesolarval phase). Fin lengths (D, A, P1, and P2, encircled) are measured along plane of fin from origin to most distal margin. When reported together, rudimentary median-fin rays (outlined above) are given in lower case Roman numerals, while principal median-fin rays (darkened above) are given in Arabic numerals; rudimentary rays are not distinguished in paired fins. Most anterior, most posterior, and last myomeres in counts to specific points of reference are shaded above. (From Snyder 1981.)

stage micrometer for direct measurement. Measurements were made to the nearest 0.1 mm and occasionally to half that unit. Remeasurement of selected specimens by a second observer indicated that most measurements are repeatable to within 0.1 mm. For more recent morphometric analyses, most measurements were made using digital images of the specimens captured through the microscope and a computer image-analysis and measurement program. Most measurements are summarized herein by developmental phase as % SL (if desired, the

means can be readily converted to % TL by dividing the % SL value for the length of interest by the % SL value for TL (AS to PC) and multiplying by 100).

Other assessed characters included developmental phase, gut form (loops or folds), eye shape, mouth position, relative fin positions, presence of special structures (e.g., mouth barbels), and specifically defined pigment distribution or patterns. Gut form was categorized as one of five sequential phases (Figure 5), but for most cyprinids, the final form of the gut is a relatively short and simple S-shape (gut folded back on itself in a single loop) and only the first three phases are applicable. For cyprinids, pigmentation was categorized in 49 specifically defined characters (up to 29 applicable per developmental phase), each with two to eight alternative states, and for catostomids, 40 characters (up to 22 per developmental phase), each with two to six states (see summary Tables 62–64 for 5 of these pigment characters and the keys at the end of Tables 65 and 67 for the remaining characters).

Size at apparent onset of selected developmental events and transition to developmental and gut phases was assessed by examination of associated data for analyzed and cursorily examined specimens. Selected events were hatching, attainment of eye pigment, formation of pectoral- and pelvic-fin buds, loss of yolk and preanal finfold, formation of first and last principal fin rays in each of the median and paired fins, formation of first and last rudimentary rays of the caudal fin, and initial and complete formation of lateral scales on the body.

Fifty eight (58) new three-view (dorsal, lateral, and ventral), continuous-tone graphite and black-ink drawings of larvae or early juveniles were prepared for this guide (and shared accounts in Snyder et al. 2016): eight each for Rio Grande Silvery Minnow, Rio Grande Chub, Flathead Chub, Bullhead Minnow, and Red Shiner; seven for Common Carp; five each for Fathead Minnow and Longnose Dace, and one for Rio Grande Sucker. These drawings, together with 11 similarly prepared drawings from prior LFL guides and 11 (10 3-view and 1 lateral only) illustrations adapted from other publications (80 total), document typical body form and pigmentation at the beginning and middle of the protolarval, mesolarval, metalarval, and early (young-of-the-year) juvenile phases of development for all species covered herein except River Carpsucker and Smallmouth Buffalo. Accounts for the latter species are illustrated only with 21 drawings reprinted from prior descriptions by others (2 lateral- and ventral-view drawings and the rest lateral-view only).

For all original drawings, black ink was used only for surface or near-surface pigmentation to distinguish it from deeper pigmentation, anatomical structures, and shading rendered in graphite and sometimes gray ink. Enlarged photographs or digital prints of primary drawing specimens were traced to assure accurate body proportions. Various structures were checked and detail added while drawing specimens were examined under a microscope. If necessary, drawings were idealized (e.g., closed or frayed fins opened and smoothed and curved bodies straightened), and melanophore distribution and other structures were modified to represent a more typical pattern or condition based on secondary or tertiary drawing specimens.

All morphometric, meristic, and size at onset of selected developmental event data are summarized in species accounts with associated illustrations, maps of recent (2005–2015) MRG distribution, and brief descriptions of the adult, reproduction, and young (early life history). The more diagnostically useful of these data are also compared among species in sets of summary tables, along with all pigmentation and special character data not in the species accounts. All data, except those in terms of TL, are used also by, and accessible in, the computer-interactive keys.

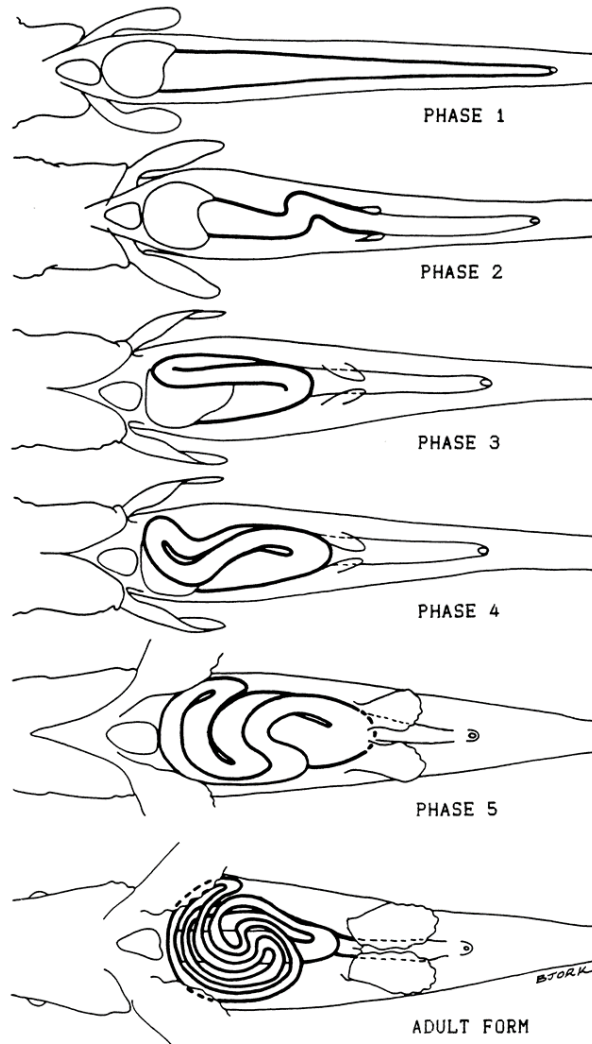


Figure 5. Phases of gut coil development in cypriniform fish larvae and early juveniles based on typical pattern in catostomid fishes and adult form in *Catostomus commersonii* (latter modified from Stewart 1926). Phase 1—essentially straight gut. Phase 2—initial loop formation (usually on left side), begins with 90° bend. Phase 3—full loop, begins with straight loop extending to near anterior end of visceral cavity (to or under liver). Phase 4—partial fold and crossover, begins with folding of first limb of loop over ventral midline; in some fish (e.g., *Pimephales promelas*), tip of main loop itself crosses midline toward opposite side (usually left to right) at anterior end of visceral cavity (behind heart). Phase 5—full fold and crossover to adult form, begins with both limbs of loop extending fully across ventral midline to opposite (usually right) side, usually resulting in four segments of gut crossing nearly perpendicular to body axis; however, in some fish (e.g., *P. promelas*), phase begins with tip of main loop completely crossing ventral midline at anterior end of visceral cavity with only two gut segments initially perpendicular to body axis (tip of loop then grows posteriorly along opposite side and secondary folds later crossover somewhat as illustrated). Later in Phase 5 and in adult form, outer portions of gut folds or coils often extend well up both sides of visceral cavity.

Computer-Interactive Keys

For complex sets of organisms, computer-interactive keys are easier to prepare, update, and expand than traditional printed keys, and much more flexible for the user. Most computer-interactive keys are data sets designed to be used with specific commercial, public-domain, or proprietary host programs (Dallwitz et al. 2000 onwards). The features and flexibility of several alternative computer-interactive key programs were compared (in part via Dallwitz 2000 onwards) during preparation of early versions of the key included in Snyder and Muth (2004). Based on this comparison, our prior experience with the DELTA (DEscriptive Language for TAXonomy) suite of programs for taxon description and keys (Dallwitz 1974, 1980, 1993; Dallwitz and Paine 1986), including *Intkey* (Dallwitz et al. 1993 onwards, 1995 onwards), and successful production of keys for Snyder and Muth (2004) and Snyder et al. (2005), we decided to continue developing our key database files for use with the *Intkey* program. The latest versions of *Intkey*, *DELTA Editor* (Dallwitz et al. 1999 onwards), and associated programs and files can be freely downloaded from the Internet (<https://www.delta-intkey.com/>).

DELTA Editor was used to update or add character data for the species covered herein (and in Snyder et al. 2016) in cyprinid and catostomid databases previously compiled for computer-interactive keys associated with Snyder and Muth (2004) and Snyder et al. (2005). Characters were encoded using the DELTA format, a powerful, flexible, and widely accepted method for recording descriptive taxonomic data for computer processing. Because developmental state changes dramatically as fish grow, and to better facilitate use of character dependencies in the key (e.g., if yolk is absent, characters such as length of yolk are removed from consideration), it was necessary to treat each developmental phase and size interval for a species as a separate taxon (e.g., *Hybognathus amarus* metalarva, 12 mm SL). Output from *DELTA Editor* to the derived files required by *Intkey* was then limited to just MRG species for each data set. Rich-text files providing an introduction to the key, beginning user instructions, and related background information were prepared or modified for access and display when using *Intkey*. Character lists and natural-language taxon descriptions were also generated as rich-text files for reference when using the key.

A similar set of data and derived and associated files was preliminarily prepared for family-level identification of the larvae of most freshwater and anadromous fishes in the United States and Canada. Subsets of families were predefined to limit the key to just families present in selected drainage basins, including one for the MRG. All characters in the key (data set) are based on external or externally visible morphology and melanophore pigmentation. Most characters are specific to larvae either with or without yolk and were derived mostly from characters used in family keys or pictorial guides by Drewry (1979) and Auer (1982) for the Great Lakes, Holland-Bartels, et al. (1990) for the upper Mississippi River, and Wallus et al. (1990) for the Ohio River. Mostly to illustrate representative larvae for use with the key, but also as an alternative to it, a pictorial guide to the families of MRG fish larvae (like ones for the Gila River Basin in Snyder et al. 2005 and UCRB in Snyder et al. 2016) was modified from pertinent portions of the pictorial guide to families of Ohio River drainage larvae by Wallus et al. (1990) and included herein as Appendix IV.

Although *Intkey* can make extensive use of taxon and character-state-selection images, such were neither critical for operation of the program nor logistically and budgetarily feasible for the keys associated with this guide. Also, such images can require a considerable amount of storage memory and at times a mostly text key may be preferable, especially for the experienced user or

when using a slower computer with limited memory. Instead, the cyprinid and catostomid keys reference illustrations in the guide species accounts for the various taxons and selected characters (mostly for pigmentation). However, as examples of how character-state-selection images function, such illustrations were prepared and included in the keys for designating developmental intervals and phases of gut development. Based on reviews and user feedback, future refinements of the keys, possibly including more character-state images, may be implemented and made available for download over the Internet.

RESULTS AND DISCUSSION

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

Whenever possible, specimen identification should be based on multiple characters. Although over 740 specimens were analyzed in detail for the descriptions herein, there are likely to be occasional specimens with character extremes beyond the recorded ranges.

Because of the similarity among some MRG cyprinids or catostomids during certain intervals of larval development, the specific identity of some larvae might remain inconclusive or questionable after application of the appropriate key and comparison with data and illustrations herein. The identity of such specimens should be considered tentative and designated as such by appending a question mark ("?") to the most probable taxon name (e.g., *Pimephales vigilax?*, preferably with a footnote regarding alternative possibilities), or left at family (e.g., unidentified Cyprinidae), or genus (i.e., *Pimephales* sp., if other genera can be eliminated). The possibility of hybrids can also complicate specimen identification.

Although prepared for use by MRG biologists, the species accounts, comparative summary tables, and keys that follow, as well as introductory information at the beginning of this guide, may also be useful to early life history investigators working elsewhere. Allowing for potential population differences in developmental morphology, these descriptions and the keys can be used for identification of covered species wherever they may occur. Most of these species also inhabit other reaches of the Rio Grande and many range elsewhere in North American. Where two or more species covered herein occur together and other closely related sympatric species can be eliminated as possibilities, the computer-interactive keys have the flexibility of being limited to just those species of concern, effectively becoming a key for that region, site, or circumstance. Similarly, the key to families of freshwater-spawning fishes in the United States and Canada prepared in part for this guide can be limited to just those families of concern.

Species Accounts

The following accounts serve as concise, detailed, and well-illustrated descriptions of the larvae and early juveniles of the subject species. Together with the comparative summary tables, they are the source of the data set for the associated computer-interactive key, provide the taxon illustrations referenced in the keys, and are intended to facilitate specimen identification with or without the keys.

Each 6-page account begins with an illustration of the adult fish; map of its recent distribution in the MRG; brief summaries of adult descriptions, reproduction (including reproductive guilds as defined by Balon 1975a and 1981, and Simon 1998), and the young (early life history); and a table of adult meristics. Much of this information was extracted from literature cited at the bottom of the first page. Each account continues with description of the

larvae and early juveniles. Page one concludes with a table of size at apparent onset of selected developmental events. Page two consists of a table of size at developmental-interval and gut-phase transitions and a table of morphometrics and myomere counts summarized by developmental phase. The next four pages illustrate eight stages of development from just hatched protolarvae through early juveniles up to about 40 mm SL (except 13 stages for Smallmouth Buffalo).

Species Account – *Cyprinella lutrensis*, Red Shiner

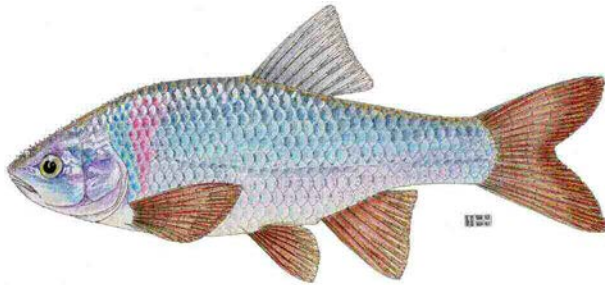


Figure 6. *Cyprinella lutrensis* adult (breeding male; © W. H. Brandenburg).

Adult description: Small, 4–9, rarely 10 cm TL. Deep-bodied and laterally compressed. Mouth small, oblique, and terminal to superior. Head relatively short with blunt snout. Dorsal fin origin over or behind pelvic fin origin. Scales large and diamond-shaped; lateral line decurved. Usually olivaceous above, silvery on sides, and white below. (Also, Table 2.)

Reproduction: Non-guarding, brood-hiding, speleophil. Mature at age 1; males are territorial; fractional spawner. Spawn early spring through late summer at $\geq 16^{\circ}\text{C}$; in Middle Rio Grande from mid-May to August, occasionally early September. Usually spawn in low-velocity areas (e.g., backwaters, pools) over or in crevices of rocks, woody debris, or aquatic vegetation. Breeding males often metallic blue dorsally and laterally, white below, and red over head and in paired, anal, and caudal fins; have small tubercles concentrated on the head, snout, and ventral surface. Water-hardened eggs are demersal, adhesive, and 1.0–1.4 (mean 1.2–1.3) mm diameter.

Young: Hatch in 2.5 d at 29°C to 5 d at 21°C . Larvae occupy near-shore, low-velocity channel margins, backwaters, eddies, and pools. Consume early instars of chironomids and other small invertebrates, algae and detritus; larger individuals may prey on fish larvae.

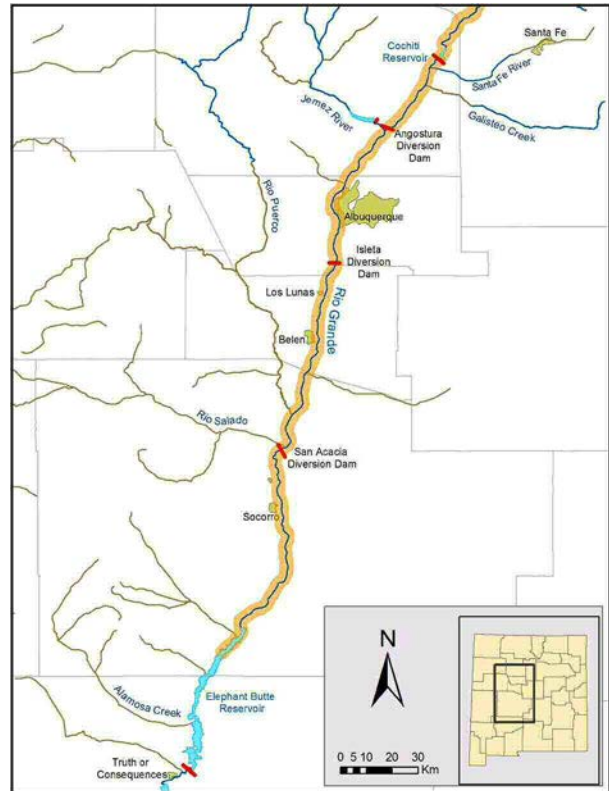


Figure 7. Distribution of *Cyprinella lutrensis* in the Middle Rio Grande, New Mexico, 2005–2015.

Table 2. Selected juvenile and adult meristics for *Cyprinella lutrensis*. (P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

| Character | Original | Literature | Character | Original | Literature |
|---------------------|---------------------------|---------------------------|----------------------|---------------------------|---------------------------------|
| Dorsal-fin rays - P | (7) <u>8</u> (9) | (6–)8(9) | Dorsal-fin rays - R | 1– <u>2</u> –3(4) | – |
| Anal-fin rays - P | 8– <u>9</u> –10 | (7)8– <u>9</u> –10(–13) | Anal-fin rays - R | (1) <u>2</u> –3 | – |
| Caudal-fin rays - P | (18)19 | (18)19 | Caudal-fin rays - RD | (5–)9– <u>10</u> –11(–13) | – |
| Pectoral-fin rays | (8–) <u>12</u> –14–15(16) | (9–)13– <u>14</u> –15(16) | Caudal-fin rays - RV | (6–)8– <u>9</u> –10(11) | – |
| Pelvic-fin rays | (6) <u>7</u> –8–9 | 8–9(10) | Lateral scales | (34–)36–38 | 30– <u>32</u> –37–40 |
| Vertebrae | 35–36 | 32– <u>35</u> –36 | Pharyngeal teeth | – | <u>0</u> –1,4(5)/4, <u>0</u> –1 |

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

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

References: Becker 1983; Beckman 1952; Clay 1975; Coburn 1986; Eddy & Underhill 1974; Etnier and Starnes 1993; Gale 1986; Lentsch et al. 1996; Minckley 1973; Muth and Snyder 1995; Page and Burr 1991; Perry and Menzel 1979; Pflieger 1997; Ruppert et al. 1993; Saksena 1962; Simon 1998; Snyder 1981; Snyder et al. 2005; Sublette et al. 1990; Tyus et al. 1982; Wang and Reyes 2007; Woodling 1985. **Account:** Modified from Snyder et al. 2016. **Other larval descriptions:** Feeney and Swift 2008; Fuiman et al. 1983; Holland-Bartels et al. 1990; Loos and Fuiman 1978; Perry 1979; Perry and Menzel 1979; Saksena 1962; Snyder 1981; Snyder et al. 2005; Taber 1969; Wang 1986; Wang and Reyes 2007.

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

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

Table 5. Summary of morphometrics and myomere counts by developmental phase for *Cyprinella lutrensis*. (See Figure 4 for abbreviations and methods of measurement and counting. Standard deviation [SD] of 0 represents a value < 0.5. Includes data extracted from selected Taber 1969 and Perry and Menzel 1979 illustrations reprinted in prior accounts by Snyder 1981 and Snyder et al. 2005.)

| | Protolarvae (N = 10) | | | Flexion mesolarvae (N = 9) | | | Postflexion mesolarvae (N = 11) | | | Metalarvae (N = 20) | | | Juveniles (N = 55) | | |
|--------------------|----------------------|-----------------|---------------------|----------------------------|----------------|---------------------|---------------------------------|----------------|--------------------|---------------------|----------------|----------------------|--------------------|----------------|----------------------|
| | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range |
| SL, mm | 4 | 1 | 3 – 5 | 6 | 0 | 5 – 6 | 7 | 0 | 6 – 8 | 9 | 1 | 7 – 12 | 21 | 9 | 10 – 41 |
| TL, mm | 5 | 1 | 3 – 5 | 6 | 0 | 6 – 7 | 8 | 0 | 7 – 9 | 11 | 1 | 9 – 15 | 26 | 11 | 13 – 50 |
| <u>Lengths %SL</u> | | | | | | | | | | | | | | | |
| AS to AE | 3 | 1 | 2 – 4 | 3 | 1 | 2 – 5 | 4 | 1 ^h | 3 – 5 ^a | 5 | 1 | 4 – 7 | 6 | 1 | 4 – 8 |
| PE | 10 | 1 | 8 – 12 | 10 | 1 | 9 – 13 | 12 | 1 | 11 – 13 | 13 | 1 | 12 – 15 | 13 | 1 | 11 – 15 |
| OP1 | 20 | 1 | 17 – 22 | 21 | 1 | 19 – 23 | 23 | 1 | 21 – 24 | 25 | 2 ^j | 22 – 28 | 25 | 2 | 22 – 28 |
| OP2 | | | | | | | 48 | 1 ⁱ | 48 | 49 | 1 | 47 – 51 | 48 | 1 ^p | 46 – 51 ^a |
| PY | 62 | 4 ^b | 57 – 66 | | | | | | | | | | | | |
| OPAF | 43 | 11 ^c | 30 – 61 | 37 | 2 | 34 – 41 | 37 | 3 | 29 – 40 | 47 | 8 | 37 – 58 | | | |
| ODF | 41 | 5 | 33 – 49 | 45 | 4 | 38 – 49 | 48 | 2 ^c | 45 – 51 | 50 | 1 ^e | 49 – 51 | | | |
| OD | | | | | | | 50 | 1 ^c | 49 – 52 | 52 | 1 | 49 – 53 ^a | 50 | 1 ^p | 47 – 52 |
| ID | | | | | | | 63 | 0 ^b | 63 – 64 | 65 | 1 | 63 – 67 | 63 | 2 | 60 – 67 |
| PV | 64 | 3 ^c | 61 – 70 | 64 | 2 | 61 – 67 | 66 | 1 | 65 – 67 | 65 | 2 | 61 – 68 | 62 | 1 | 60 – 64 |
| OA | | | | | | | 66 | 1 ^f | 65 – 66 | 64 | 1 ^c | 62 – 66 | 63 | 1 ^c | 61 – 64 |
| IA | | | | | | | | | | 76 | 1 | 74 – 78 | 76 | 1 | 73 – 78 |
| AFC | | | | | | | 109 | 3 | 102 – 112 | 112 | 2 ^j | 109 – 118 | 114 | 2 | 111 – 118 |
| PC | 105 | 1 | 104 – 108 | 107 | 2 | 104 – 111 | 112 | 2 | 108 – 116 | 120 | 3 | 115 – 126 | 125 | 2 | 120 – 129 |
| Y | 23 | 25 ^c | 0 – 57 ^a | | | | | | | | | | | | |
| P1 | 11 | 4 | 6 – 17 | 13 | 2 | 10 – 15 | 14 | 2 ^h | 11 – 16 | 14 | 2 ^k | 11 – 18 | 19 | 2 | 15 – 23 |
| P2 | | | | | | | 0 | 1 | 0 – 3 | 8 | 3 | 3 – 13 | 14 | 1 ^p | 11 – 17 |
| D | | | | | | | 14 | 1 ^b | 13 – 15 | 19 | 2 | 16 – 22 | 22 | 1 | 20 – 24 |
| A | | | | | | | | | | 16 | 2 | 13 – 21 | 20 | 1 | 17 – 23 |
| <u>Depths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 14 | 4 ^c | 11 – 23 | 13 | 1 | 11 – 13 | 13 | 1 | 12 – 14 | 15 | 1 | 12 – 18 | 16 | 1 | 14 – 18 |
| OP1 | 16 | 6 ^c | 10 – 28 | 13 | 1 | 11 – 14 | 15 | 1 | 14 – 16 | 17 | 2 | 14 – 21 | 20 | 2 | 17 – 24 |
| OD | 12 | 2 ^d | 10 – 14 | 12 | 2 ^f | 10 – 15 | 13 | 1 ^c | 12 – 15 | 16 | 1 | 14 – 19 | 20 | 2 | 17 – 25 |
| BPV | 8 | 0 ^c | 7 – 8 | 9 | 2 | 8 – 13 | 10 | 1 | 9 – 12 | 13 | 1 | 11 – 15 | 17 | 2 | 13 – 20 |
| AMPM | 4 | 0 ^c | 3 – 5 | 4 | 1 | 3 – 5 | 6 | 1 | 5 – 8 | 8 | 1 | 7 – 10 | 10 | 1 | 8 – 12 |
| Max. yolk | 6 | 9 ^c | 0 – 22 | | | | | | | | | | | | |
| <u>Widths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 12 | 1 ^c | 11 – 14 | 13 | 1 ^c | 12 – 14 | 13 | 1 ^h | 12 – 15 | 15 | 1 ^k | 12 – 16 | 14 | 1 | 12 – 16 |
| OP1 | 13 | 5 ^c | 9 – 22 | 10 | 1 ^c | 9 – 13 | 10 | 0 ^h | 10 – 11 | 12 | 1 ^k | 11 – 14 | 14 | 1 | 11 – 16 |
| OD | 6 | 2 ^d | 5 – 9 | 6 | 2 ^g | 5 – 8 | 7 | 1 ^c | 6 – 8 | 9 | 1 ^k | 8 – 11 | 12 | 2 | 9 – 17 |
| BPV | 5 | 1 ^c | 4 – 6 | 5 | 1 ^c | 4 – 8 | 6 | 1 ^h | 5 – 7 | 8 | 1 ^k | 6 – 9 | 10 | 1 | 8 – 14 |
| AMPM | 3 | 1 ^c | 2 – 4 | 3 | 1 ^c | 2 – 4 | 3 | 1 ^h | 2 – 4 | 4 | 1 ^k | 2 – 5 | 4 | 1 | 3 – 7 |
| Max. yolk | 9 | 9 ^c | 0 – 23 ^a | | | | | | | | | | | | |
| <u>Myomeres</u> | | | | | | | | | | | | | | | |
| to PY | 20 | 1 ^b | 19 – 22 | | | | | | | | | | | | |
| OPAF | 12 | 4 ^c | 9 – 17 | 9 | 1 ^c | 7 – 11 ^a | 8 | 2 | 5 – 11 | 12 | 4 ^m | 7 – 19 | | | |
| OP2 | | | | | | | 12 | 1 ⁱ | 12 | 14 | 1 ⁿ | 12 – 15 ^a | 14 | 1 ^q | 12 – 15 ^a |
| ODF | 10 | 2 ^c | 6 – 11 | 12 | 1 | 10 – 14 | 13 | 1 ^h | 11 – 15 | 15 | 2 ^s | 13 – 16 | | | |
| OD | | | | | | | 15 | 1 ^c | 14 – 16 | 15 | 1 ⁿ | 13 – 17 ^a | 15 | 1 ^q | 13 – 16 ^a |
| PV | 21 | 1 ^c | 20 – 22 | 22 | 1 | 20 – 24 | 23 | 1 | 21 – 24 | 22 | 1 ^o | 19 – 24 | 21 | 1 ^f | 19 – 22 ^a |
| Total | 35 | 2 ^c | 31 – 36 | 35 | 1 | 34 – 36 | 35 | 1 | 34 – 37 | 35 | 1 ^o | 34 – 37 | 35 | 1 ^f | 34 – 36 |
| After PV | 14 | 1 ^c | 11 – 15 | 13 | 1 | 12 – 15 | 13 | 1 | 12 – 15 | 14 | 1 ^o | 12 – 15 ^a | 14 | 1 ^f | 12 – 15 ^a |

^aRange 1 or 2 units less than reported by Snyder (1981) and/or Snyder et al. (2005) because highly questionable values were excluded from this summary. ^bN = 5. ^cN = 9. ^dN = 6. ^eN = 8. ^fN = 4. ^gN = 3. ^hN = 10. ⁱN = 1. ^jN = 19. ^kN = 18. ^lN = 16. ^mN = 13. ⁿN = 15. ^oN = 17. ^pN = 54. ^qN = 39. ^rN = 40.

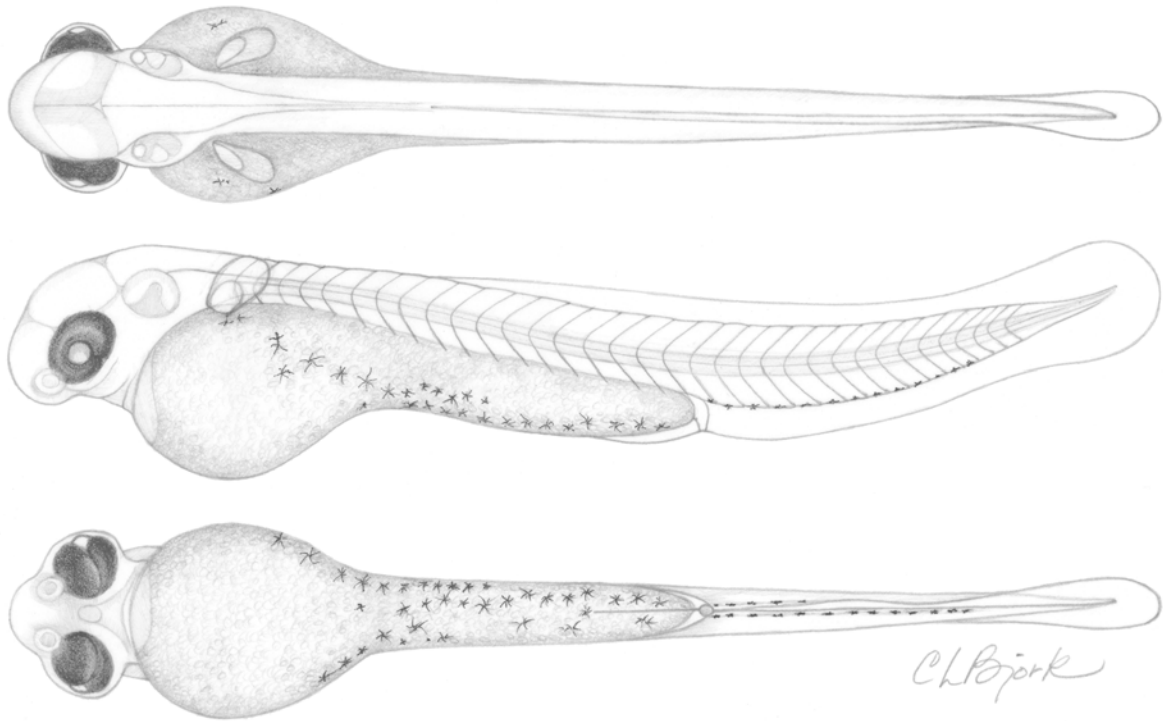


Figure 8. *Cyprinella lutrensis* protolarva, recently hatched, 4.1 mm SL, 4.3 mm TL. (Cultured in 2006 by Michelle McGree at Colorado State University with stock from Cache la Poudre River east of Fort Collins, Colorado. Some hatch without body pigmentation or with much less pigmentation over yolk.)

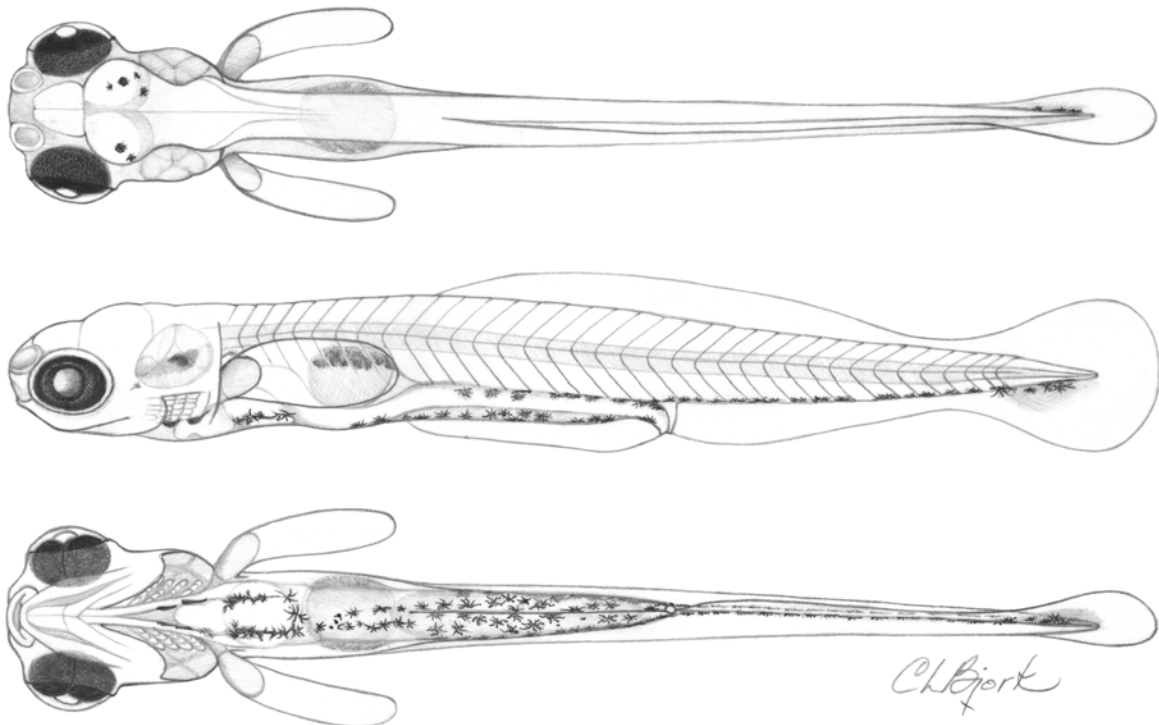


Figure 9. *Cyprinella lutrensis* protolarva, 4.6 mm SL, 4.9 mm TL. (Cultured in 2006 by Michelle McGree at Colorado State University with stock from Cache la Poudre River east of Fort Collins, Colorado. Pigmentation under gut often much less to nearly absent in wild specimens, as in Figure 10.)

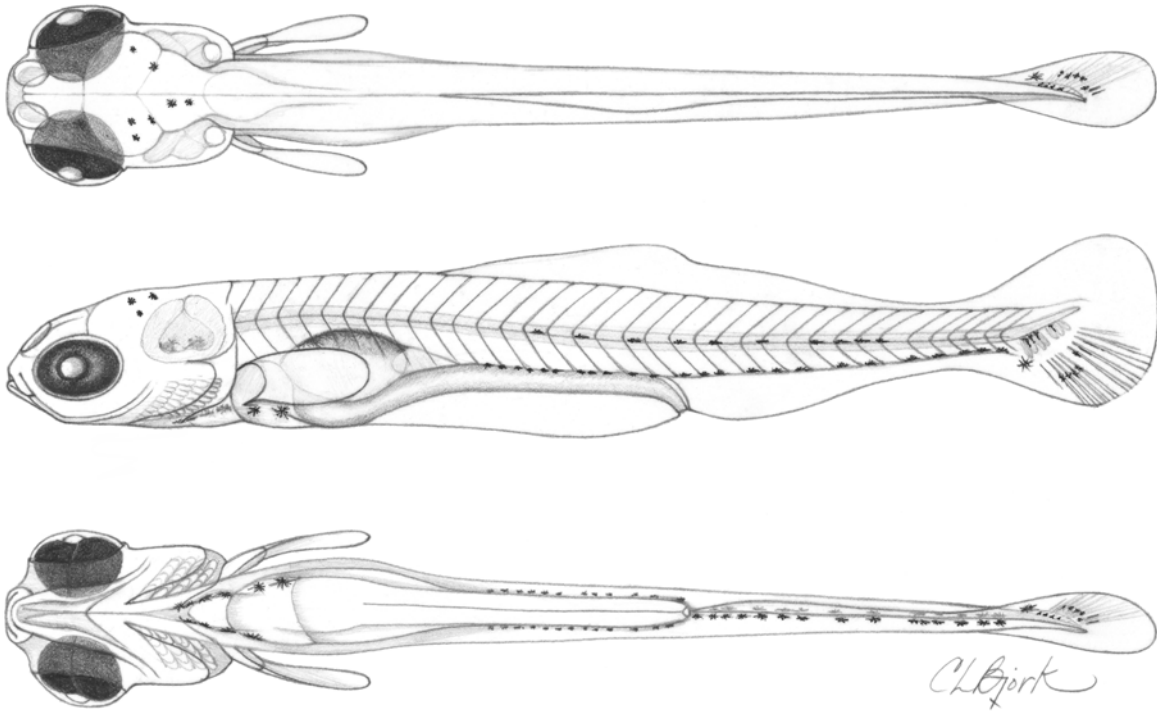


Figure 10. *Cyprinella lutrensis* flexion mesolarva, 5.5 mm SL, 5.9 mm TL. (Collected in 1987 from Yampa River in Echo Park, Dinosaur National Monument, Colorado; from LFL #48862.)

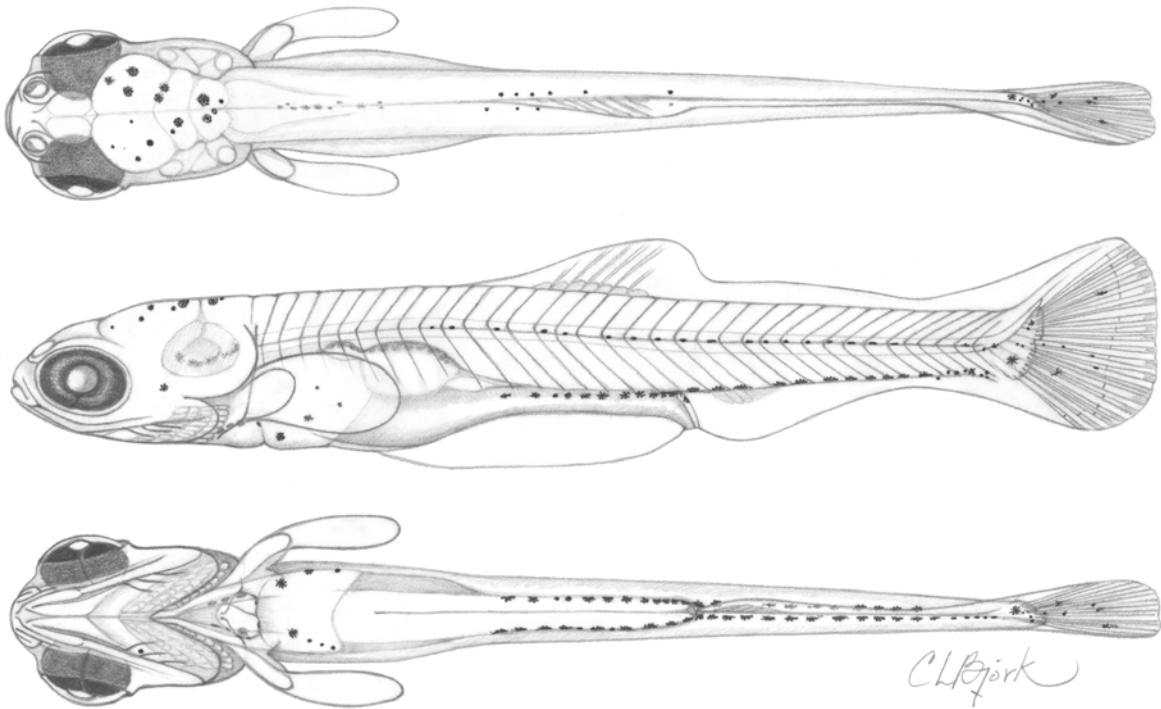


Figure 11. *Cyprinella lutrensis* postflexion mesolarva, 7.0 mm SL, 7.7 mm TL. (Collected in 2005 from Green River in Whirlpool Canyon, Dinosaur National Monument, Colorado; from LFL #97898.)

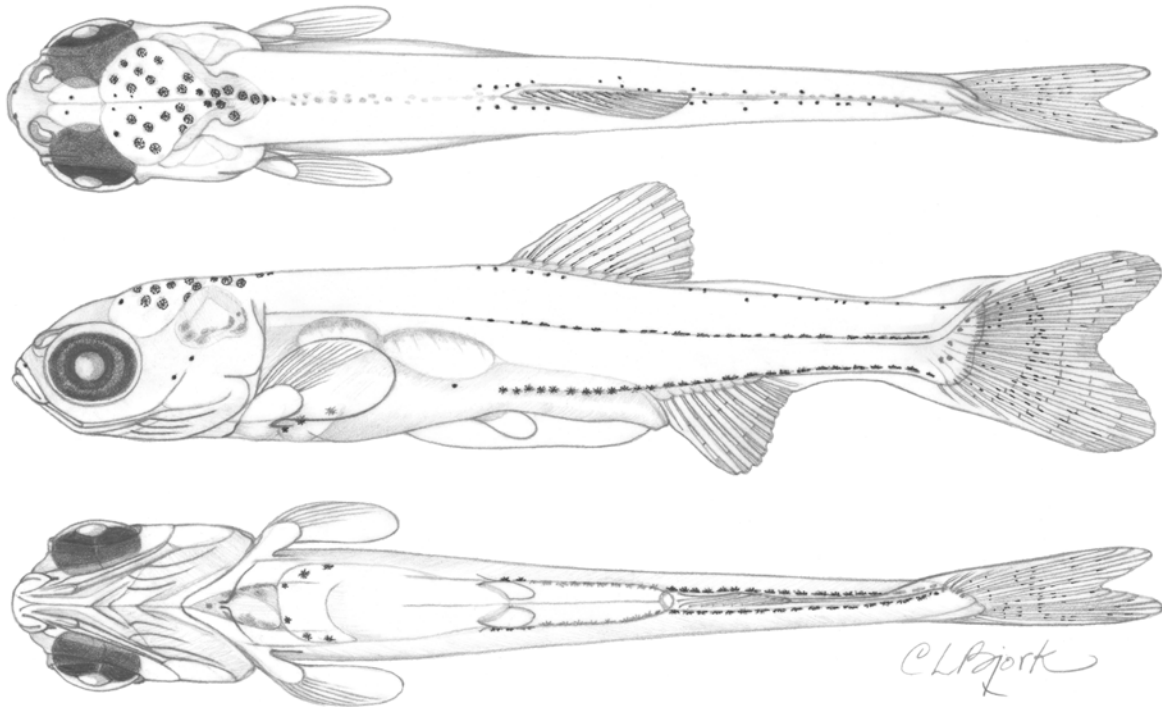


Figure 12. *Cyprinella lutrensis* metalarva, recently transformed, 8.3 mm SL, 9.9 mm TL. (Collected in 2005 from Green River in Whirlpool Canyon, Dinosaur National Monument, Colorado; from LFL #97898.)

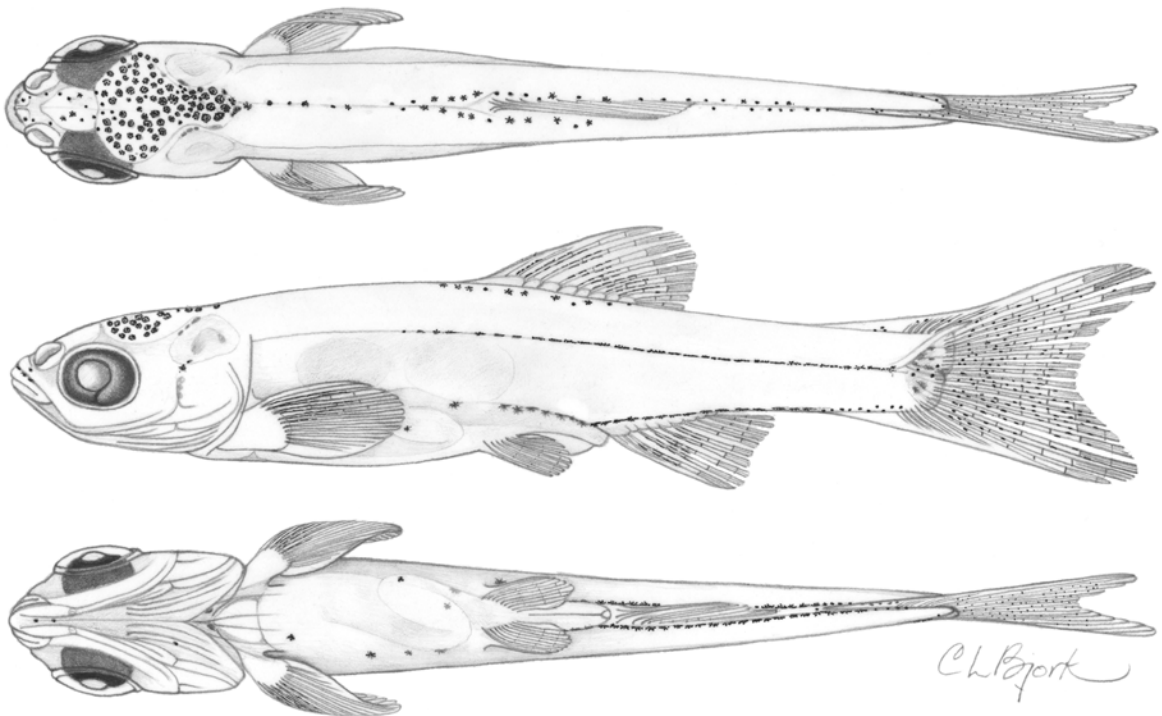


Figure 13. *Cyprinella lutrensis* metalarva, 9.7 mm SL, 11.9 mm TL. (Collected in 1979 from Gunnison River near Grand Junction, Colorado; from LFL #72828.)

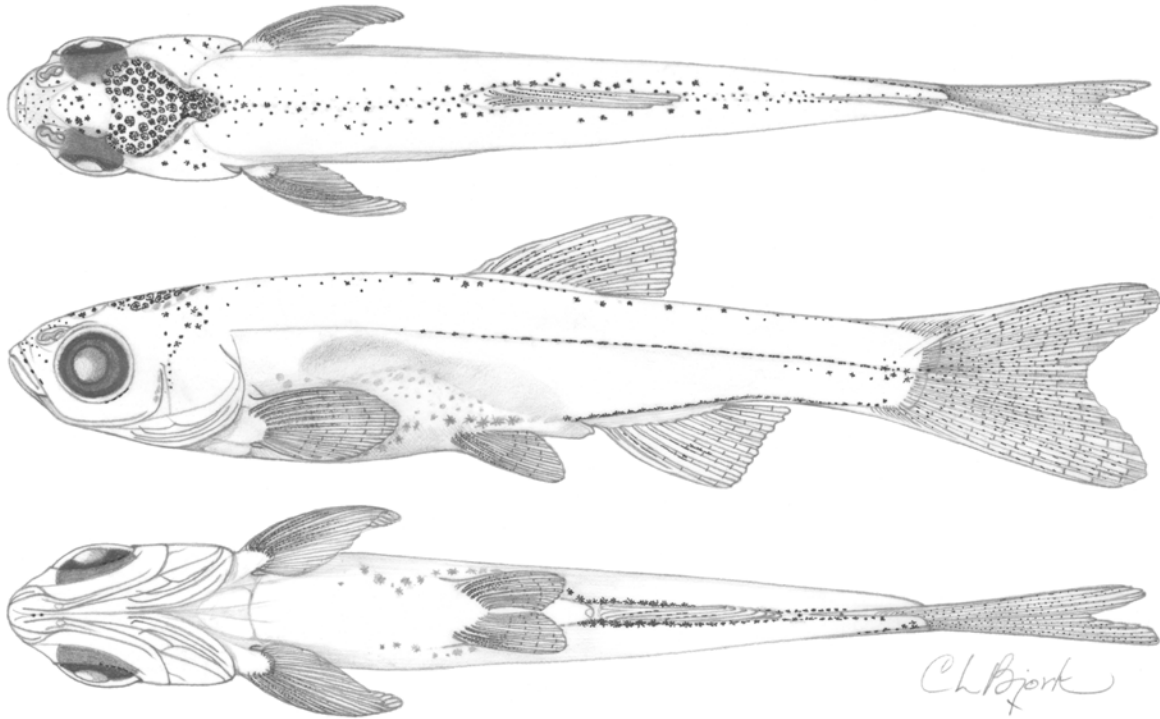


Figure 14. *Cyprinella lutrensis* juvenile, recently transformed, 11.5 mm SL, 14.5 mm TL. (Collected in 1977 from Colorado or Gunnison River near Grand Junction, Colorado; from LFL #72788.)

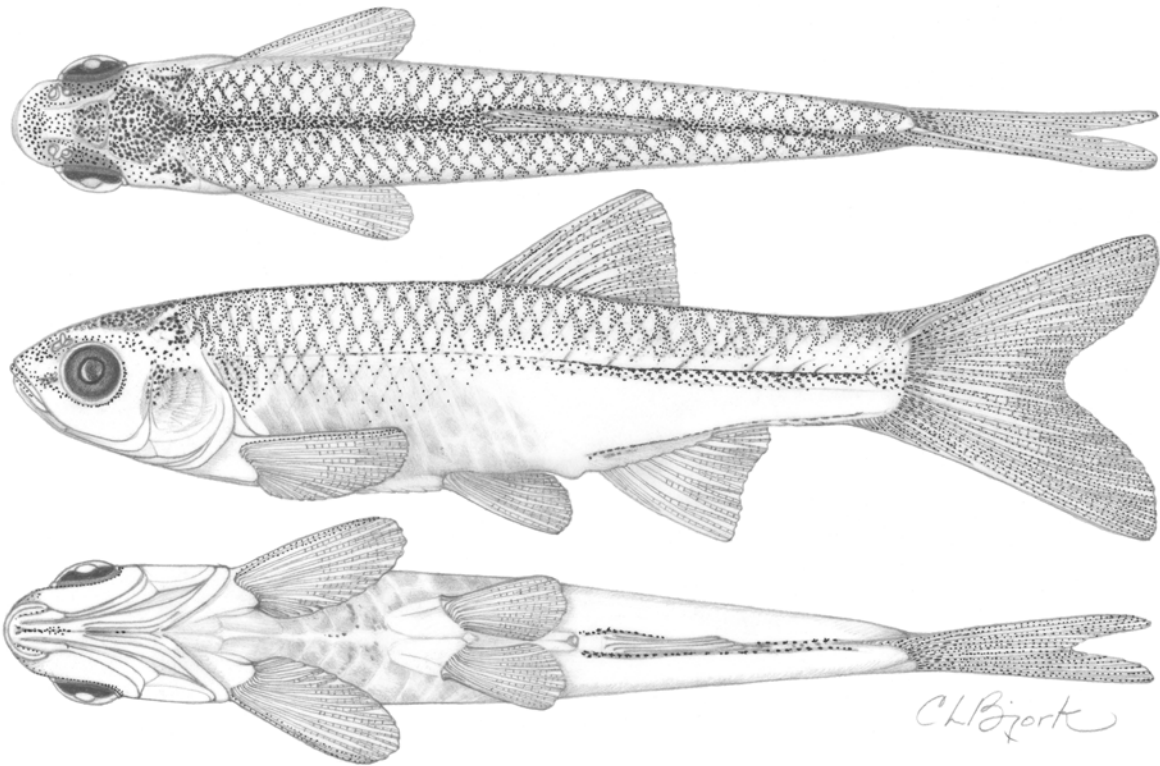


Figure 15. *Cyprinella lutrensis* juvenile, 30.7 mm SL, 38.0 mm TL. (Collected in 2005 from Green River in Whirlpool Canyon, Dinosaur National Monument, Colorado; from LFL #97881.)

Species Account – *Cyprinus carpio*, Common Carp

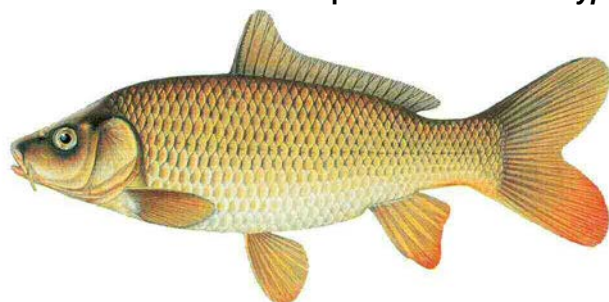


Figure 16. *Cyprinus carpio* adult (© Joseph R. Tomelleri).

Adult description: Large, 30–120 cm TL. Deep-bodied, laterally compressed, dorsally arched and often ventrally flat. Head relatively large, triangular with long snout. Mouth at least somewhat oblique, terminal to subterminal, moderate in size, ending well before highly positioned eyes, with two pair of maxillary barbels (larger at corners of mouth, smaller well forward above mouth). Gut long and folded; peritoneum gray or speckled. Dorsal fin very long; first principal ray of dorsal and anal fins spine-like and serrated on posterior margin. Scales large (variants with none or enlarged, sparsely scattered scales). Usually dark to olivaceous above, golden-yellow laterally and light ventrally; orange-tinged lower fins in breeding males. (Also, Table 6.)

Reproduction: Non-guarding, open-substrate phytolithophil. Spawn early March to August at $\geq 15^{\circ}\text{C}$; mid-April to July in Middle Rio Grande. Spawn in low-velocity areas (e.g., backwaters, pools, flooded tributary mouths, or flood plains), scattering demersal, adhesive eggs, often in clusters, usually over flooded terrestrial or submerged aquatic vegetation. Water-hardened eggs 1.3–2.1 mm diameter.

Young: Hatch in 1.5 d at 32°C to 5 d at 15°C . Initially adhere to or lie in vegetation, remain in shallow near-shore or other low-velocity habitats until ~ 12 mm TL, then move to deeper waters. Feed on plankton, small invertebrates, algae, and detritus.

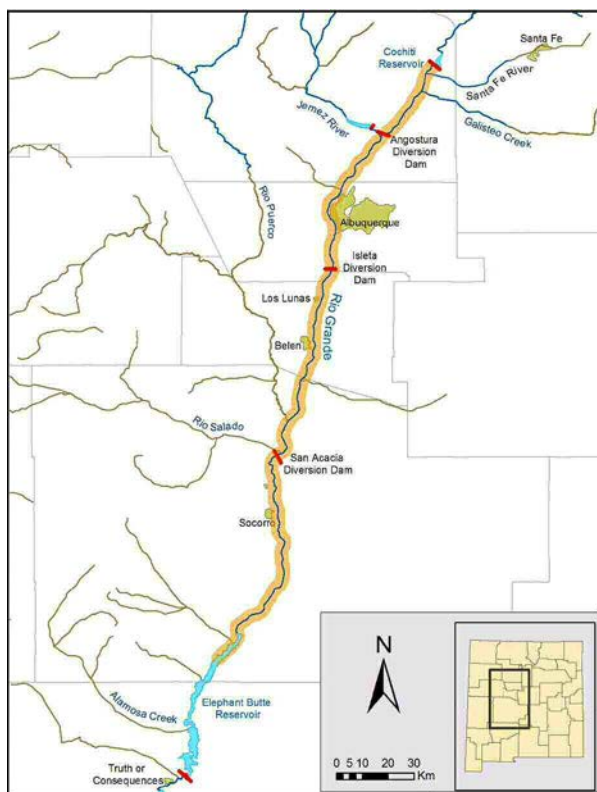


Figure 17. Distribution of *Cyprinus carpio* in the Middle Rio Grande, New Mexico, 2005–2015.

Table 6. Selected juvenile and adult meristics for *Cyprinus carpio*. (P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

| Character | Original | Literature | Character | Original | Literature |
|---------------------|-------------------|------------------|----------------------|----------------|-------------------|
| Dorsal-fin rays - P | (17)18–19–20–21* | (15–)18–22(–24)* | Dorsal-fin rays - R | (1)2–3 | 1–4 |
| Anal-fin rays - P | 5–6–7* | (4)5–6–7(8)* | Anal-fin rays - R | (1)2 | 1–3 |
| Caudal-fin rays - P | (18)19 | (18)19(20) | Caudal-fin rays - RD | (5)6–7–8–9(10) | 3–7 |
| Pectoral-fin rays | (12–)14–16–17(18) | 14–15–16–18 | Caudal-fin rays - RV | (5)6–7–8(9) | 5–7 |
| Pelvic-fin rays | (6)7–8–9 | (5–)8–9 | Lateral scales | 34–40 | 32–35–38–41 |
| Vertebrae | 37–38 | (32–)35–36(–39) | Pharyngeal teeth | – | 1,1(2),3/3,1(2),1 |

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

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

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

References: Balon 1975a; Becker 1983; Beckman 1952; Carlander 1969; Gerlach 1983; Heufelder and Fuiman 1982; Jones et al. 1978; Korwin-Kossakowski 2008; La Rivers 1962; Lentsch et al. 1996; Minckley 1973; Moyle 1976; Page and Burr 1991; Scott and Crossman 1973; Simon 1998; Snyder 1981; Snyder et al. 2005; Sublette et al. 1990; Sweet and McCrimmon 1966; Tyus et al. 1982; Woodling 1985.

Account: Modified from Snyder et al. 2016. **Other larval descriptions:** See end of account.

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

| Transition to | mm SL | mm TL | Transition to | mm SL | mm TL |
|-----------------------|-----------|-----------|-----------------------|-----------|-----------|
| Flexion mesolarva | 7–8 | 8 | 2 - 90° bend | 11–12 | (12)13–15 |
| Postflexion mesolarva | (8)9(10) | (9)10(11) | 3 - Full loop | 12–15 | 15–19 |
| Metalarva | 12–13 | 15–16 | 4 - Partial crossover | 19–27 | 23–32 |
| Juvenile | (17)18–19 | (21)22–23 | 5 - Full | 27–31(32) | 32–39 |

Table 9. Summary of morphometrics and myomere counts by developmental phase for *Cyprinus carpio*. (See Figure 4 for abbreviations and methods of measurement and counting. Standard deviation [SD] of 0 represents a value < 0.5. Includes data extracted from selected Fish 1932, Bragensky 1960, Nakamura 1969, Taber 1969, and Wang and Kernehan 1979 illustrations reprinted in prior accounts by Snyder 1981 and Snyder et al. 2005.)

| | Protolarvae (N = 14) | | | Flexion mesolarvae (N = 8) | | | Postflexion mesolarvae (N = 18) | | | Metalarvae (N = 19) | | | Juveniles (N = 21) | | |
|--------------------|----------------------|-----------------|---------|----------------------------|----------------|---------|---------------------------------|----------------|---------|---------------------|----------------|---------|--------------------|----------------|---------|
| | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range |
| SL, mm | 6 | 1 | 5–8 | 8 | 1 | 7–10 | 11 | 1 | 8–13 | 15 | 2 | 12–18 | 29 | 7 | 19–42 |
| TL, mm | 6 | 1 | 5–8 | 9 | 1 | 8–11 | 13 | 2 | 10–16 | 19 | 2 | 15–22 | 35 | 9 | 23–50 |
| <u>Lengths %SL</u> | | | | | | | | | | | | | | | |
| AS to AE | 4 | 1 | 3–6 | 5 | 1 | 4–7 | 6 | 1 | 5–7 | 7 | 1 | 6–9 | 9 | 1 ^f | 7–11 |
| PE | 11 | 1 | 9–13 | 13 | 1 | 11–15 | 15 | 1 ^g | 13–17 | 16 | 1 | 13–18 | 17 | 1 ^f | 14–19 |
| OP1 | 20 | 2 | 16–23 | 24 | 1 | 22–26 | 29 | 2 | 26–33 | 32 | 2 | 29–35 | 31 | 2 ^f | 29–34 |
| OP2 | | | | | | | 52 | 2 ^h | 49–55 | 52 | 1 | 50–55 | 53 | 2 | 48–56 |
| PY | 68 | 3 ^a | 63–71 | | | | | | | | | | | | |
| OPAF | 42 | 7 | 34–59 | 37 | 4 | 31–45 | 43 | 6 ⁱ | 35–57 | 56 | 7 ^p | 44–64 | | | |
| ODF | 42 | 3 | 37–47 | 46 | 2 | 44–49 | 48 | 2 ^f | 46–51 | 47 | ^m | 47 | | | |
| OD | | | | | | | 49 | 1 ^j | 48–52 | 49 | 1 | 47–52 | 49 | 2 | 46–51 |
| ID | | | | | | | | | | 81 | 1 ^p | 79–83 | 82 | 1 | 80–86 |
| PV | 72 | 1 | 70–75 | 74 | 2 | 70–75 | 76 | 1 | 74–78 | 75 | 1 | 72–77 | 75 | 1 | 72–77 |
| OA | | | | | | | 76 | 1 ^k | 74–77 | 74 | 1 ^q | 74–75 | 74 | 2 ^a | 72–77 |
| IA | | | | | | | 82 | 0 ^l | 82–82 | 83 | 1 | 80–84 | 83 | 2 | 80–86 |
| AFC | | | | | | | 111 | 2 | 108–113 | 112 | 2 ^s | 109–115 | 112 | 2 | 109–116 |
| PC | 106 | 1 | 104–110 | 108 | 1 | 106–110 | 118 | 4 | 109–125 | 122 | 3 | 118–127 | 123 | 2 | 117–127 |
| Y | 42 | 19 ^b | 0–59 | | | | | | | | | | | | |
| P1 | 11 | 3 | 4–14 | 14 | 1 | 12–15 | 13 | 2 | 10–18 | 14 | 2 ^p | 12–17 | 16 | 2 ^f | 12–19 |
| P2 | | | | | | | 4 | 3 | 0–9 | 10 | 1 | 8–13 | 14 | 2 | 11–17 |
| D | | | | | | | | | | 34 | 1 | 31–36 | 38 | 2 | 35–41 |
| A | | | | | | | 13 | ^m | 13 | 14 | 1 ^p | 10–16 | 17 | 2 | 14–19 |
| <u>Depths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 15 | 1 | 13–18 | 16 | 1 ^f | 15–18 | 20 | 2 | 12–23 | 22 | 1 | 20–24 | 23 | 1 | 21–25 |
| OP1 | 17 | 4 ^b | 13–29 | 18 | 1 | 16–20 | 23 | 2 | 19–27 | 27 | 1 | 24–30 | 31 | 2 | 28–35 |
| OD | 13 | 1 | 11–16 | 12 | 2 | 11–16 | 20 | 4 | 13–25 | 27 | 2 | 23–30 | 33 | 2 | 30–37 |
| BPV | 7 | 1 | 6–8 | 7 | 1 | 6–8 | 11 | 3 | 7–15 | 15 | 1 | 13–17 | 20 | 2 | 17–23 |
| AMPM | 4 | 1 | 2–5 | 5 | 1 | 4–7 | 8 | 1 | 7–10 | 10 | 1 | 8–12 | 12 | 1 | 11–13 |
| Max. yolk | 11 | 8 ^c | 0–23 | | | | | | | | | | | | |
| <u>Widths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 14 | 1 ^d | 12–16 | 15 | 1 | 13–16 | 18 | 1 | 15–20 | 20 | 1 ^s | 19–20 | 19 | 1 ^s | 18–21 |
| OP1 | 11 | 6 ^c | 6–28 | 11 | 1 | 10–13 | 15 | 2 | 11–17 | 18 | 2 ^s | 16–21 | 21 | 2 ^s | 18–24 |
| OD | 7 | 1 ^d | 5–10 | 7 | 1 | 5–8 | 11 | 2 ^g | 7–15 | 15 | 2 ^s | 11–17 | 19 | 2 ^s | 16–22 |
| BPV | 5 | 1 ^d | 3–5 | 5 | 1 | 4–7 | 8 | 1 | 6–11 | 9 | 1 ^s | 8–12 | 12 | 3 ^p | 8–17 |
| AMPM | 2 | 1 ^e | 1–4 | 3 | 1 | 2–5 | 4 | 1 | 2–6 | 5 | 1 ^s | 3–6 | 6 | 2 ^s | 3–9 |
| Max. yolk | 11 | 8 ^f | 0–25 | | | | | | | | | | | | |
| <u>Myomeres</u> | | | | | | | | | | | | | | | |
| to PY | 23 | 1 ^e | 22–26 | | | | | | | | | | | | |
| OPAF | 10 | 2 | 7–15 | 7 | 1 ^f | 5–9 | 9 | 2 ^d | 7–12 | 15 | 3 ⁿ | 10–20 | | | |
| OP2 | | | | | | | 14 | 1 ⁿ | 13–15 | 13 | 1 ^b | 11–14 | 12 | 1 ^f | 11–14 |
| ODF | 10 | 1 | 9–12 | 11 | 1 | 10–13 | 12 | 1 ^o | 10–12 | | | | | | |
| OD | | | | | | | 12 | 1 ^q | 11–13 | 11 | 1 ^b | 10–13 | 10 | 1 ^f | 9–11 |
| PV | 26 | 1 | 23–27 | 27 | 1 | 25–28 | 27 | 1 ^b | 26–28 | 26 | 1 ^b | 25–28 | 25 | 1 ^f | 24–27 |
| Total | 37 | 1 | 35–38 | 38 | 1 | 36–39 | 37 | 1 ^b | 36–38 | 37 | 1 ^b | 36–39 | 37 | 0 ^f | 36–37 |
| After PV | 11 | 1 | 10–12 | 11 | 1 | 10–11 | 11 | 1 ^b | 10–12 | 11 | 1 ^b | 10–12 | 12 | 1 ^f | 10–13 |

^aN = 9. ^bN = 13. ^cN = 10. ^dN = 12. ^eN = 11. ^fN = 7. ^gN = 17. ^hN = 14. ⁱN = 16. ^jN = 15. ^kN = 4. ^lN = 2. ^mN = 1. ⁿN = 8. ^oN = 6. ^pN = 18. ^qN = 10. ^rN = 20. ^sN = 19.

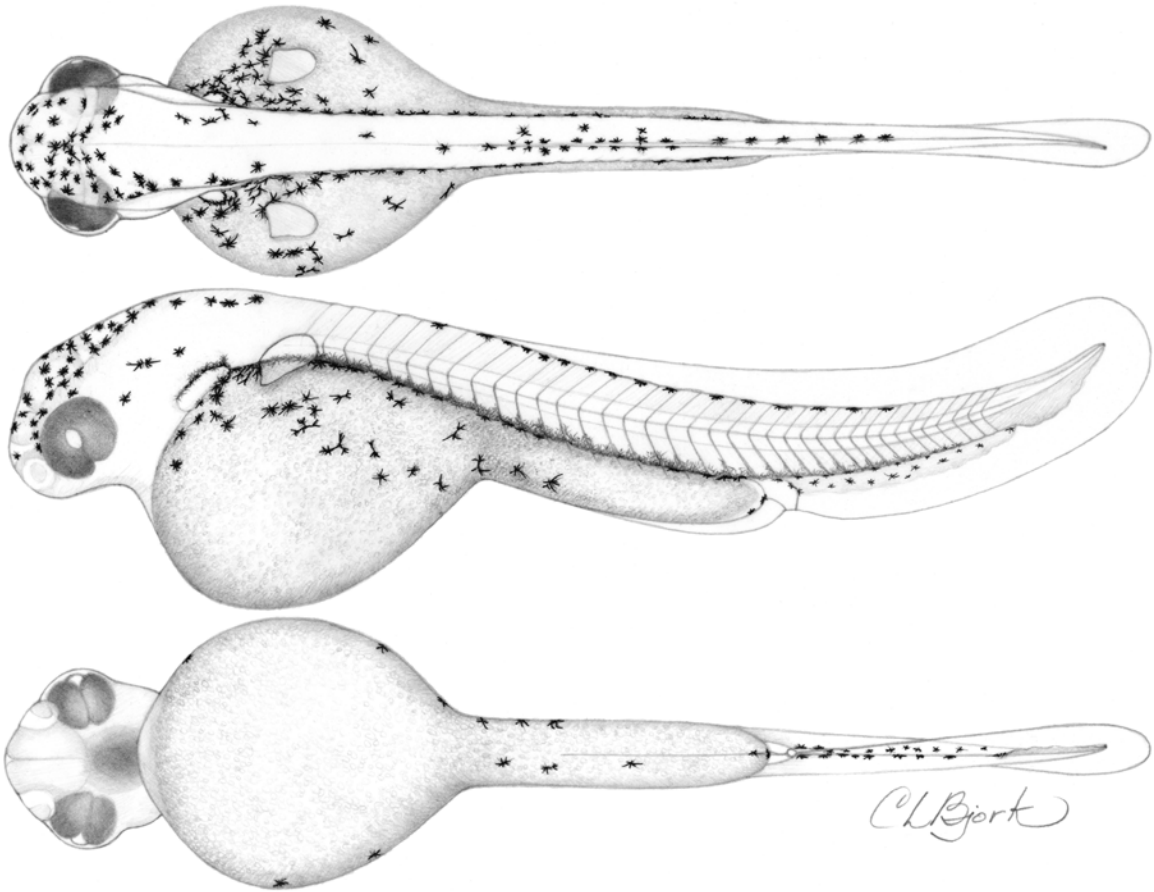


Figure 18. *Cyprinus carpio* protolarva, recently hatched, 4.8 mm SL, 5.0 mm TL. (Cultured in 2007 by Larval Fish Laboratory at Colorado State University from eggs collected at Riverbend Ponds, Fort Collins, Colorado.)

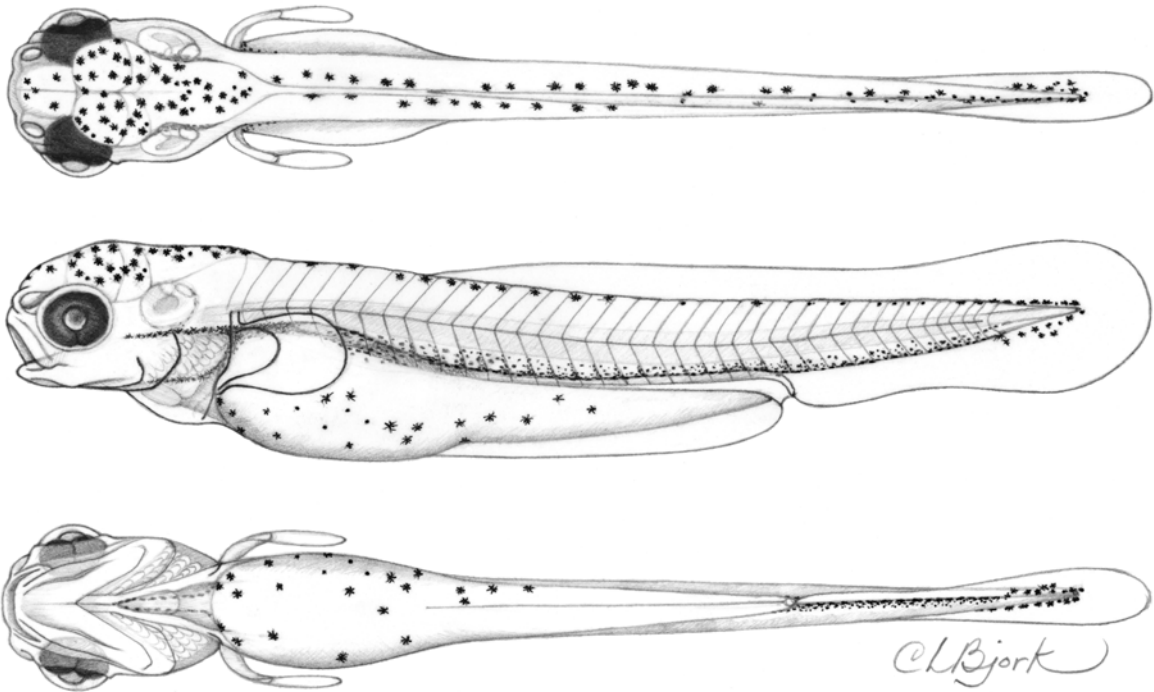


Figure 19. *Cyprinus carpio* protolarva, 5.7 mm SL, 6.1 mm TL. (Collected in 1976 or 1977 from Yampa River between Dinosaur National Monument and Hayden, Colorado; from LFL #73048.)

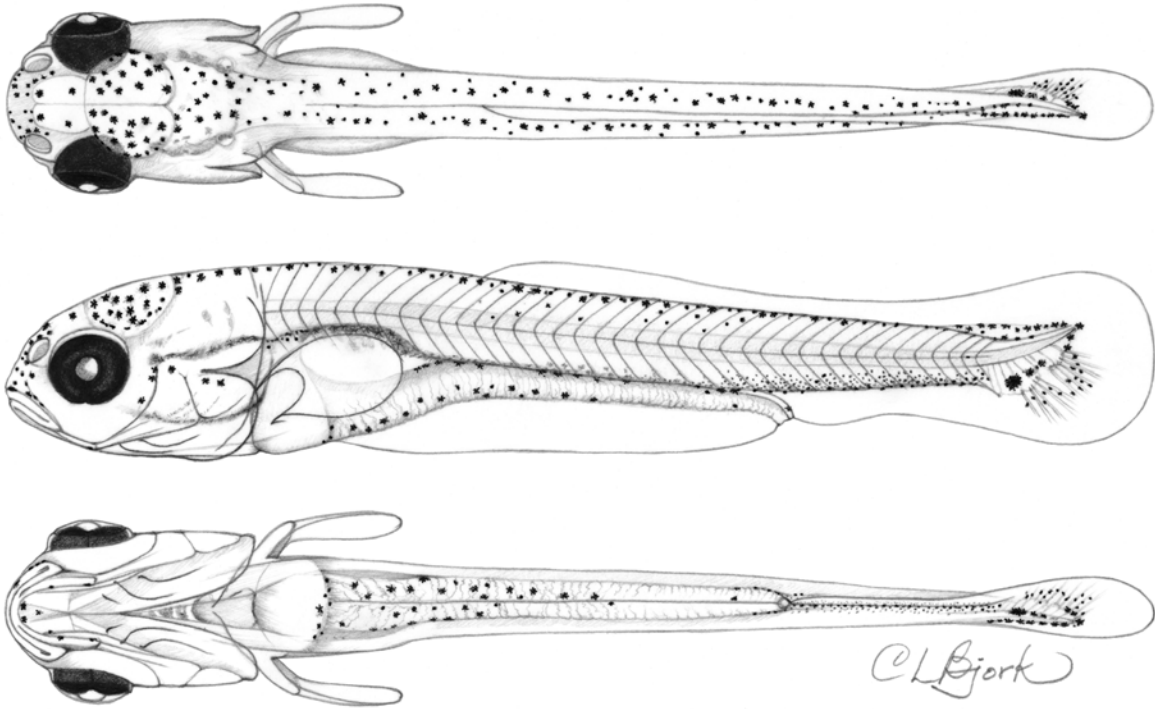


Figure 20. *Cyprinus carpio* flexion mesolarva, recently transformed, 8.2 mm SL, 8.8 mm TL. (Collected in 1996 from Gunnison River near Grand Junction, Colorado; from LFL #31315.)

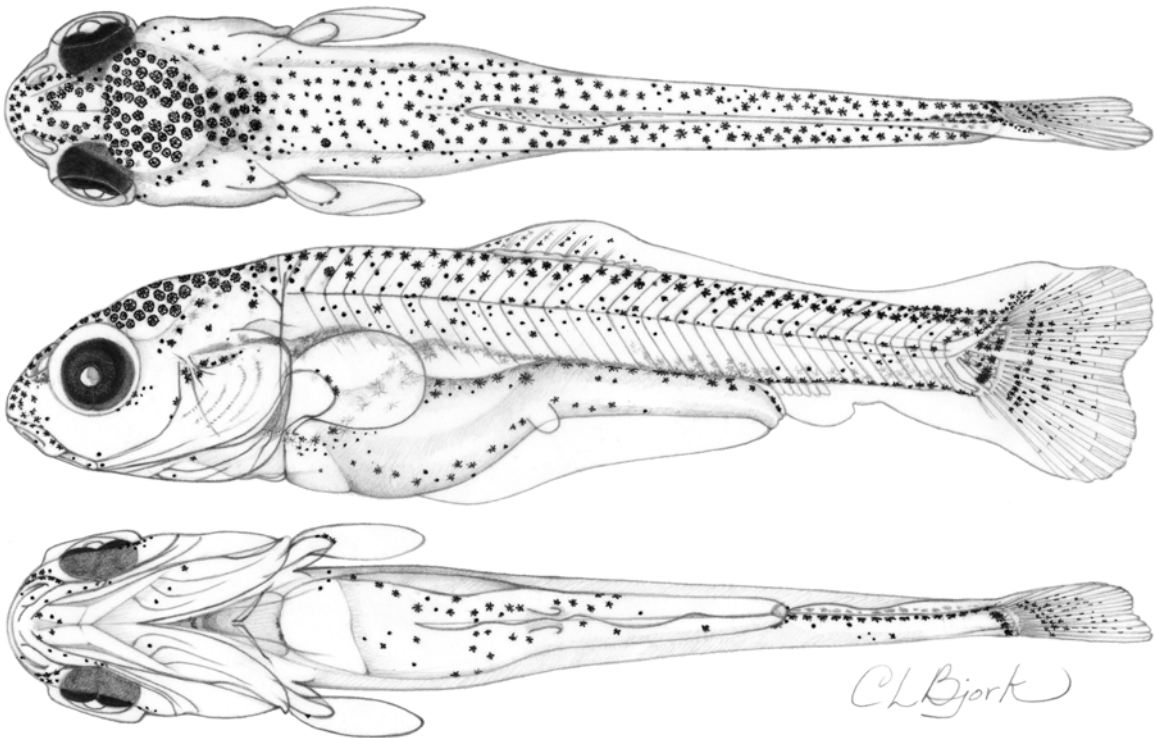


Figure 21. *Cyprinus carpio* postflexion mesolarva, 10.5 mm SL, 12.1 mm TL. (Collected in 2002 from Gunnison River near Escalante, Colorado; from LFL #82354.)

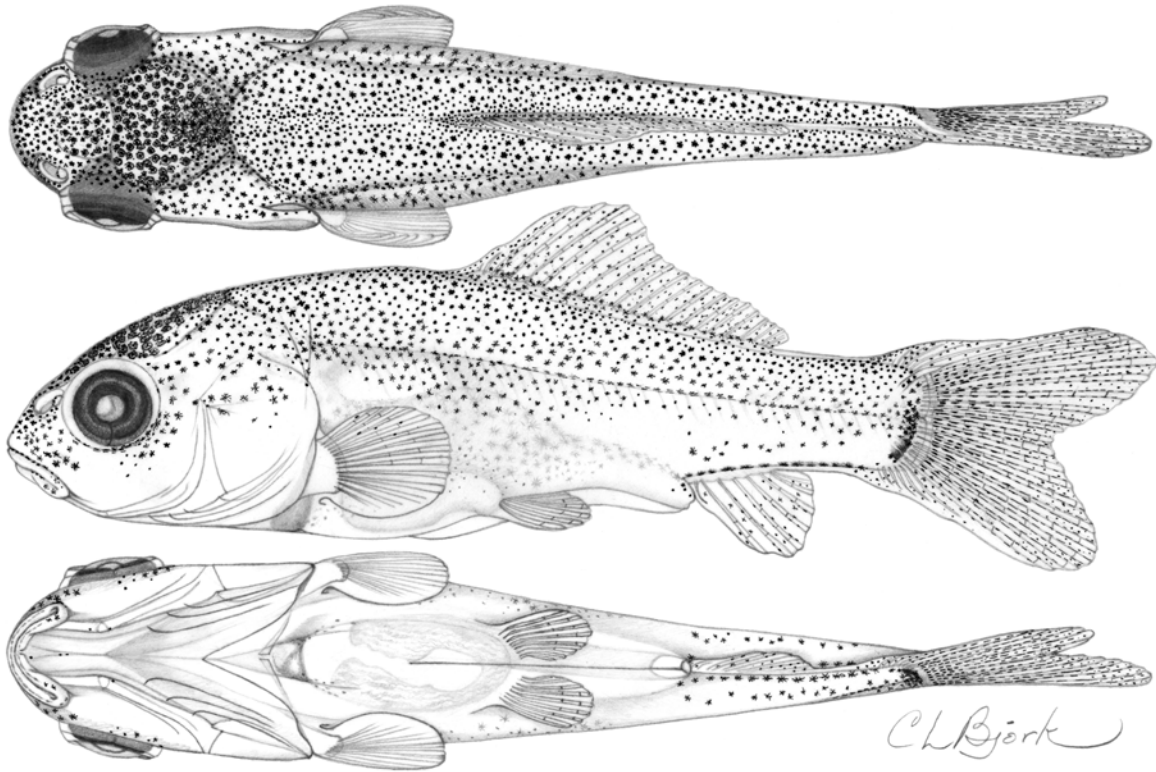


Figure 22. *Cyprinus carpio* metalarva, recently transformed, 13.1 mm SL, 16.4 mm TL. (Collected in 1989 from Gunnison River near Grand Junction, Colorado; from LFL #8515.)

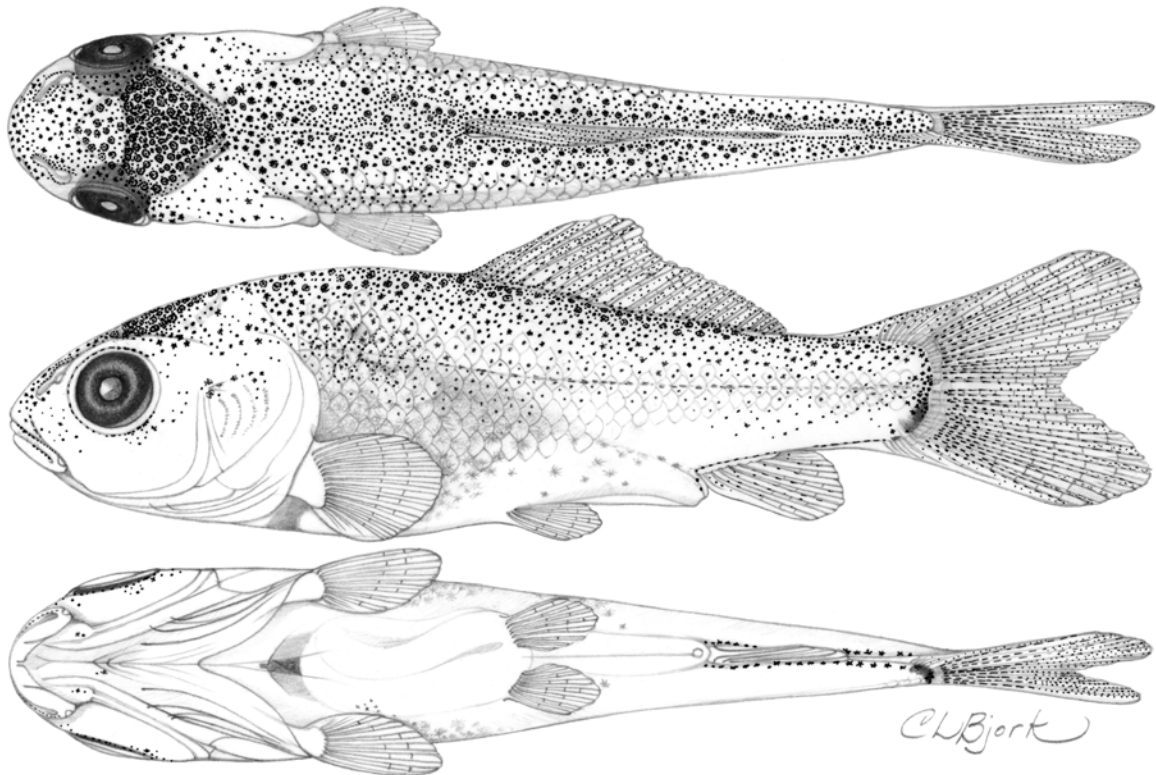


Figure 23. *Cyprinus carpio* metalarva, 17.3 mm SL, 21.2 mm TL. (Collected in 2003 from Green River, Dinosaur National Monument, Colorado; from LFL #87799.)



Figure 24. *Cyprinus carpio* juvenile, recently transformed, 22.4 mm SL, 27.5 mm TL. (Collected in 2004 from Green River, Dinosaur National Monument, Colorado; from LFL #88897.)

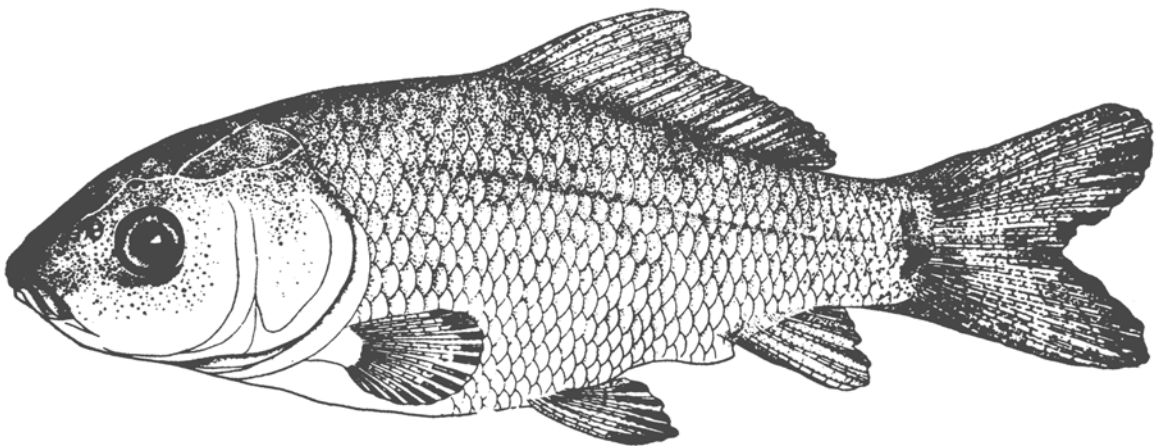


Figure 25. *Cyprinus carpio* juvenile, 24.2 mm SL, 30.0 mm TL. (From Bragensky 1960, Figure 9.)

Other larval descriptions: Arvidson and Alber 2013; Balon 1958; Bragensky 1960; Conner et al. 1980; Ehrenbaum 1909; Faber 2006 onwards; Fish 1932; Fuiman et al. 1983; Gerlach 1983; Heufelder and Fuiman 1982; Hikita 1956; Hoda and Tsukahara 1971; Hogue et al. 1976; Holland-Bartels et al. 1990; Itazawa 1963; Jones et al. 1978; Jude et al. 1979; Korwin-Kossakowski 2008; Lippson and Moran 1974; Loos et al. 1979; Mansueti and Hardy 1967; May and Gasaway 1967; McCrimmon and Swee 1967; McGowan 1988; Nakamura 1969; Nakatani et al. 2001; Nordqvist 1914; Okada 1960; Penaz et al. 1983; Pinder 2001; Scheidegger 1990; Smallwood and Derrickson 1933; Smallwood and Smallwood 1931; Snyder 1981; Snyder et al. 2005; Snyder et al. 2016; Taber 1969; Verma 1970; Wang 1986; Wang and Kernehan 1979; Wang and Reyes 2007; others cited by these.

Species Account – *Gila pandora*, Rio Grande Chub

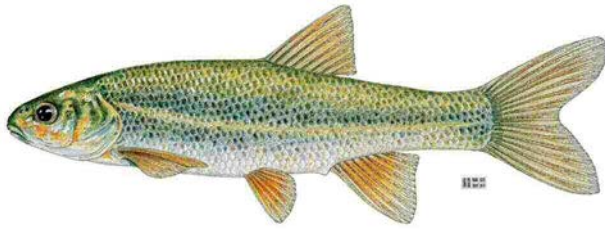


Figure 26. *Gila pandora* adult (© W. H. Brandenburg).

Adult description: Usually < 20 cm TL; up to 30 cm. Body and caudal peduncle moderately deep. Slightly subterminal to terminal mouth. Dorsal fin posterior to pelvic fin origin. Lateral line decurved. Dorsal and lateral surfaces dusky to dark, often with darker lateral bands above and anteriorly below a light band; upper dark band sometimes ending in a small caudal spot. Ventral surface light, silvery, sometimes with yellow to orange at bases of anal, pelvic and pectoral fins. Peritoneum tan with dark speckles. (Also, Table 10.)

Reproduction: Non-guarding, open-substrate lithophil. Spawn in stream riffles (probably also pools) or lakes (presumably shallows or shoreline) during spring to mid-summer, sometimes again in fall. Captives in CO ponds spawn from April to early July at 13–18°C. Females mature at > 9 cm. Breeding colors: orange on lower body, red-orange on side of head and proximally on anal and paired fins; usually more intense in males. Fecundity about 1,400–6,300. Water-hardened eggs are demersal, adhesive, and 2.3–2.6 mm diameter (size orig. data).

Young: Hatch in 8 d at 12–13°C, 4–5 d at 18–19°C. Tank-reared larvae lie on the bottom for up to a week and absorb yolk before swim up. Young are silvery or dark in color and have been found in beds of aquatic macrophytes and under overhanging banks.

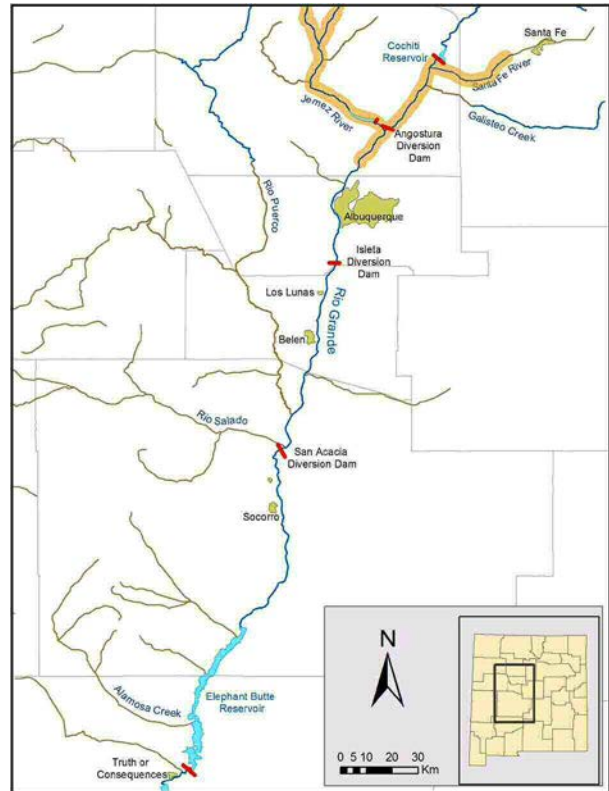


Figure 27. Distribution of *Gila pandora* in the Middle Rio Grande, New Mexico, 2005–2015.

Table 10. Selected juvenile and adult meristics for *Gila pandora*. (P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

| Character | Original | Literature | Character | Original | Literature |
|---------------------|-------------|--------------------|----------------------|-------------|-----------------|
| Dorsal-fin rays - P | 8(9–10) | (7)8(9) | Dorsal-fin rays - R | (1)2(3) | – |
| Anal-fin rays - P | (7)8(9) | (7)8(9) | Anal-fin rays - R | 2–3 | – |
| Caudal-fin rays - P | (18)19 | (18)19 | Caudal-fin rays - RD | (8)9–10(11) | – |
| Pectoral-fin rays | (13)14–16 | (12–)14–17–18(–20) | Caudal-fin rays - RV | (7–)9–10 | – |
| Pelvic-fin rays | 8– <u>9</u> | 8–9(10)* | Lateral scales | 53–61 | (51–)56–65(–68) |
| Vertebrae | – | (40)41–43(44) | Pharyngeal teeth | – | (1)2,5/4,2(1) |

* Typically 9 in Rio Grande and 8 in Pecos River populations.

Table 11. Size at onset of selected developmental events for *Gila pandora*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses.)

| Event or structure | Onset or formation | | Fin rays or scales | First formed | | Last formed | |
|--------------------|--------------------|-----------|--------------------|--------------|--------|-------------|-----------|
| | mm SL | mm TL | | mm SL | mm TL | mm SL | mm TL |
| Hatched | 7 | 7 | Dorsal - P | 9(10) | 10 | 11–12 | 13–14 |
| Eyes pigmented | * | * | Anal - P | 9–10 | (10)11 | 11–12 | 13–14 |
| Yolk assimilated | 8–9 | (8)9(10) | Caudal - P | 8(9) | (8)9 | 9–10 | 10–11 |
| Finfold absorbed | 18–19 | (22)23–24 | Caudal - R | 11 | 12–13 | (17)18(19) | (21)22–23 |
| Pectoral-fin buds | * | * | Pectoral | 11 | 13 | (15)16(17) | 19–20(21) |
| Pelvic-fin buds | 10–11 | 11–12 | Pelvic | 12 | 14 | (15)16 | 19–20 |
| * before hatching | | | Scales | 21–23 | 26–29 | 22–27 | 27–33 |

References: Beckman 1952; Bestgen, K., (Colo. St. Univ. Larval Fish Lab.) pers. comm. 2017; Bestgen et al. 2003; Koster 1957; Miller and Hubbs 1962; Moore 1968; Page and Burr 1991; Rees et al. 2005; Rinne 1995; Smith, T., (Colo. Parks and Wildlife Native Aquatic Species Restoration Facility) pers. comm. 2017; Sublette et al. 1990; Suttkus and Cashner 1981; Woodling 1985; Zuckerman and Langlois 1990.

Other larval descriptions: none.

Table 12. Size at developmental interval (left) and gut phase (right) transitions for *Gila pandora*. (See Figure 5 for phases of gut folding. Rare values in parentheses.)

| Transition to | mm SL | mm TL | Transition to | mm SL | mm TL |
|-----------------------|-------|-----------|-----------------------|------------------|-------|
| Flexion mesolarva | 8(9) | (8)9 | 2 - 90° bend | 12(13) | 14–15 |
| Postflexion mesolarva | 9–10 | 10–11 | 3 - Full loop | 16–18 | 20–22 |
| Metalarva | 11–12 | 13–14 | 4 - Partial crossover | (not applicable) | |
| Juvenile | 18–19 | (22)23–24 | 5 - Full | (not applicable) | |

Table 13. Summary of morphometrics and myomere counts by developmental phase for *Gila pandora*. (See Figure 4 for abbreviations and methods of measurement and counting. Standard deviation [SD] of 0 represents a value < 0.5.)

| | Protolarvae (N = 8) | | Flexion mesolarvae (N = 6) | | Postflexion mesolarvae (N = 9) | | Metalarvae (N = 14) | | Juveniles (N = 18) | |
|--------------------|---------------------|----------------|----------------------------|-----------------------|--------------------------------|-----------------------|---------------------|-----------------------|--------------------|-----------------------|
| | \bar{x} | \pm SD Range | \bar{x} | \pm SD Range | \bar{x} | \pm SD Range | \bar{x} | \pm SD Range | \bar{x} | \pm SD Range |
| SL, mm | 8 | 1 7– 8 | 9 | 1 8– 10 | 10 | 1 9– 12 | 15 | 2 11– 19 | 26 | 6 18– 39 |
| TL, mm | 8 | 1 7– 9 | 10 | 1 8– 11 | 12 | 2 10– 14 | 18 | 3 13– 24 | 32 | 8 23– 48 |
| <u>Lengths %SL</u> | | | | | | | | | | |
| AS to AE | 3 | 0 3– 4 | 3 | 1 3– 4 | 5 | 1 4– 6 | 6 | 1 5– 7 | 6 | 1 5– 8 |
| PE | 11 | 1 10– 11 | 10 | 1 9– 12 | 12 | 1 11– 14 | 13 | 1 12– 16 | 13 | 1 12– 16 |
| OP1 | 19 | 1 17– 19 | 20 | 1 19– 22 | 23 | 2 21– 26 | 27 | 1 25– 29 | 27 | 1 25– 30 |
| OP2 | | | | | 49 | 2 ^b 46– 50 | 51 | 2 48– 53 | 52 | 1 49– 53 |
| PY | 67 | 4 61– 72 | 49 | 1 ^a 47– 50 | 32 | 2 30– 34 | 44 | 10 33– 60 | | |
| OPAF | 36 | 5 30– 45 | 29 | 1 27– 31 | 44 | 2 42– 47 | 50 | 1 ^d 48– 52 | | |
| ODF | 40 | 2 38– 44 | 40 | 3 35– 43 | 52 | 1 51– 54 | 54 | 1 53– 55 | 53 | 1 51– 55 |
| OD | | | | | 62 | 1 ^c 60– 64 | 64 | 1 63– 65 | 65 | 1 63– 67 |
| ID | | | | | 69 | 1 68– 71 | 68 | 2 66– 71 | 66 | 1 64– 69 |
| PV | 69 | 2 67– 73 | 66 | 1 65– 67 | 69 | 1 67– 70 | 67 | 1 65– 69 | 67 | 1 65– 68 |
| OA | | | | | 76 | 1 ^a 75– 77 | 77 | 1 75– 79 | 77 | 1 76– 80 |
| IA | | | | | 110 | 1 107– 112 | 113 | 1 110– 115 | 115 | 1 113– 116 |
| AFC | | | | | 112 | 3 109– 118 | 121 | 3 116– 124 | 124 | 1 122– 127 |
| PC | 105 | 1 104– 106 | 106 | 2 105– 110 | | | | | | |
| Y | 49 | 7 38– 57 | 6 | 6 0– 13 | | | | | | |
| P1 | 8 | 2 4– 9 | 12 | 1 11– 13 | 14 | 1 12– 14 | 16 | 1 13– 17 | 18 | 1 16– 20 |
| P2 | | | | | 4 | 1 ^b 3– 5 | 9 | 3 5– 13 | 14 | 1 13– 17 |
| D | | | | | 14 | 1 ^a 13– 15 | 18 | 2 15– 22 | 22 | 2 19– 26 |
| A | | | | | 11 | 1 ^a 10– 11 | 15 | 2 12– 18 | 18 | 1 17– 20 |
| <u>Depths %SL</u> | | | | | | | | | | |
| at BPE | 13 | 1 12– 14 | 13 | 1 12– 13 | 15 | 1 14– 17 | 17 | 1 16– 19 | 17 | 1 16– 19 |
| OP1 | 16 | 3 13– 19 | 14 | 1 12– 14 | 17 | 2 15– 20 | 20 | 1 18– 21 | 21 | 1 20– 23 |
| OD | 14 | 1 12– 16 | 11 | 1 10– 13 | 13 | 1 12– 15 | 17 | 2 12– 20 | 22 | 1 20– 23 |
| BPV | 9 | 0 8– 10 | 8 | 0 8– 9 | 9 | 1 8– 11 | 12 | 2 9– 15 | 15 | 1 14– 17 |
| AMPM | 4 | 1 4– 5 | 4 | 1 4– 5 | 6 | 1 5– 8 | 9 | 1 7– 10 | 10 | 1 9– 11 |
| Max. yolk | 9 | 3 5– 12 | 1 | 1 0– 3 | | | | | | |
| <u>Widths %SL</u> | | | | | | | | | | |
| at BPE | 13 | 1 12– 14 | 13 | 1 13– 15 | 15 | 1 13– 16 | 16 | 1 15– 17 | 16 | 1 15– 18 |
| OP1 | 11 | 2 9– 15 | 10 | 1 10– 11 | 13 | 1 11– 15 | 16 | 1 14– 19 | 17 | 1 16– 19 |
| OD | 7 | 0 7– 8 | 6 | 0 6– 6 | 8 | 1 6– 10 | 11 | 2 7– 14 | 15 | 1 13– 16 |
| BPV | 5 | 0 5– 6 | 5 | 0 5– 5 | 6 | 1 5– 7 | 8 | 1 6– 10 | 11 | 1 9– 13 |
| AMPM | 3 | 0 3– 3 | 3 | 0 2– 3 | 3 | 1 2– 4 | 4 | 0 3– 5 | 5 | 1 4– 6 |
| Max. yolk | 12 | 4 7– 18 | 2 | 2 0– 4 | | | | | | |
| <u>Myomeres</u> | | | | | | | | | | |
| to PY | 28 | 2 25– 31 | 19 | 1 ^a 18– 20 | | | | | | |
| OPAF | 12 | 4 7– 19 | 7 | 1 7– 8 | 8 | 1 6– 8 | 13 | 5 8– 22 | | |
| OP2 | | | | | 16 | 1 ^b 16– 17 | 17 | 1 16– 18 | 17 | 1 ^c 17– 18 |
| ODF | 13 | 1 12– 14 | 14 | 1 13– 16 | 14 | 1 12– 15 | 17 | 1 ^d 16– 18 | | |
| OD | | | | | 19 | 1 18– 20 | 19 | 0 18– 20 | 19 | 1 ^c 18– 20 |
| PV | 30 | 1 29– 31 | 30 | 1 29– 31 | 29 | 1 28– 30 | 29 | 1 27– 30 | 28 | 1 ^c 27– 29 |
| Total | 43 | 1 42– 44 | 43 | 1 42– 43 | 42 | 1 41– 43 | 43 | 1 42– 43 | 42 | 1 ^c 42– 43 |
| After PV | 13 | 1 12– 14 | 13 | 1 11– 14 | 13 | 1 12– 14 | 14 | 1 12– 15 | 14 | 1 ^c 14– 15 |

^aN = 3. ^bN = 4. ^cN = 6. ^dN = 10. ^eN = 5.

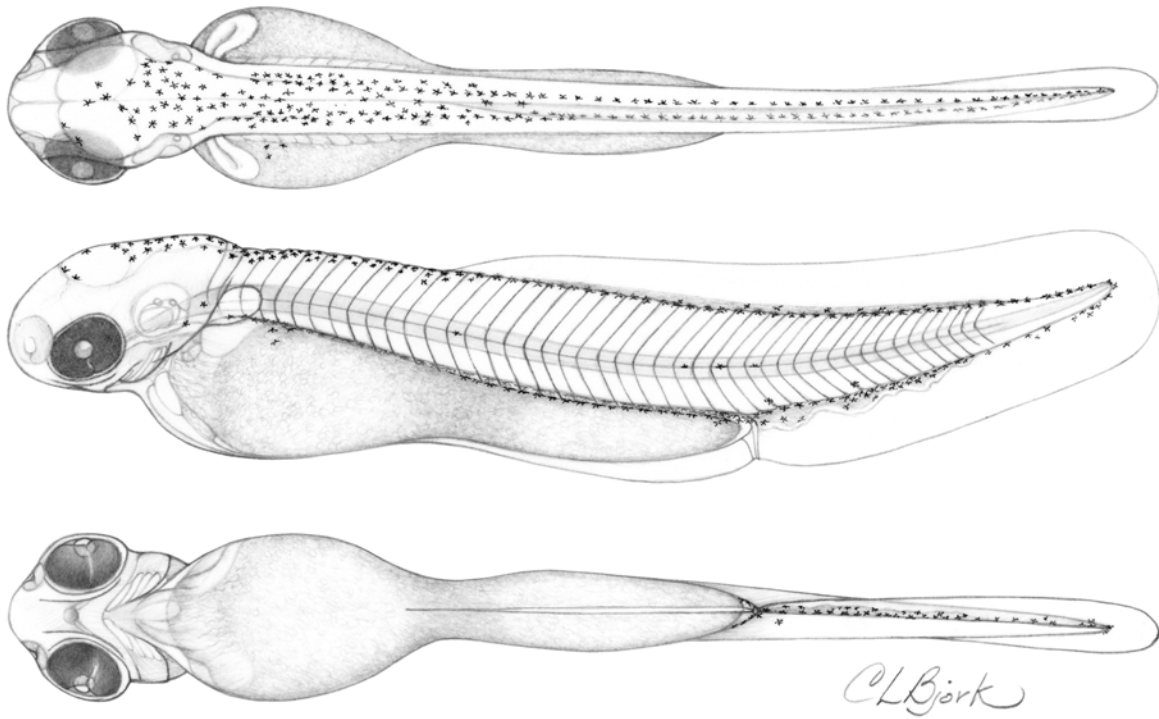


Figure 28. *Gila pandora* protolarva, recently hatched, 7.0 mm SL, 7.4 mm TL. (Cultured in 2007 by Colorado Division of Wildlife Native Aquatic Species Restoration Facility with stock from Hot Creek, Conejos County, Colorado; from LFL #105726.)

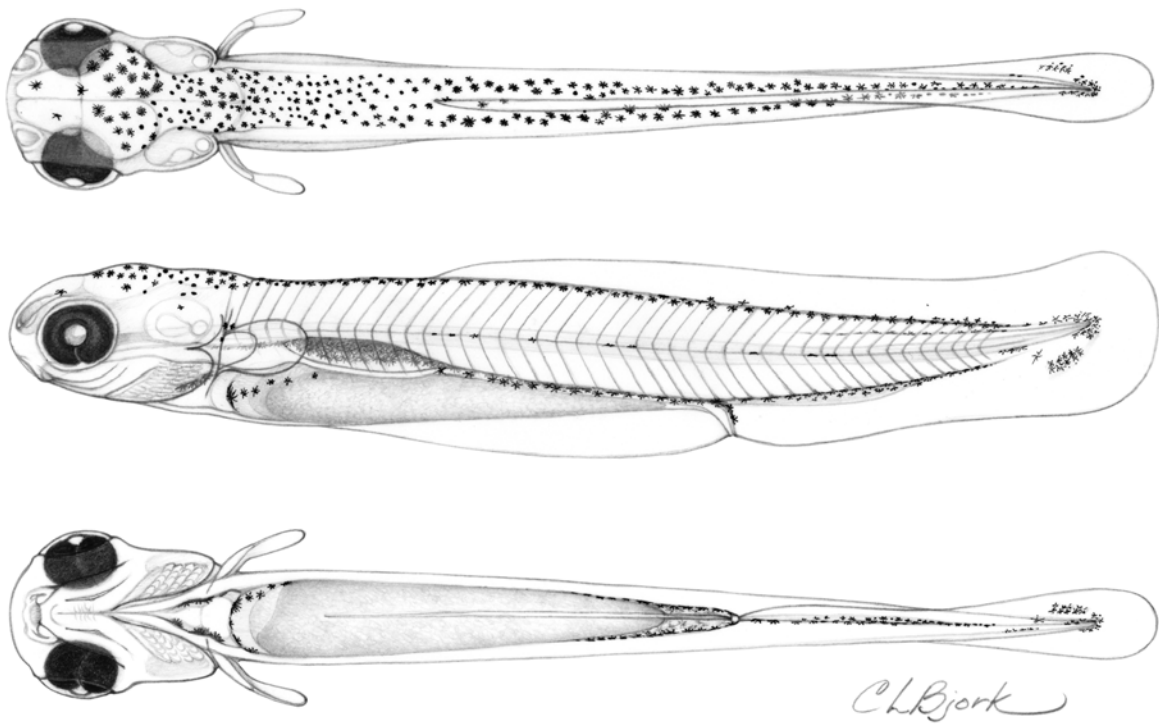


Figure 29. *Gila pandora* protolarva, 8.0 mm SL, 8.5 mm TL. (Cultured in 2007 by Colorado Division of Wildlife Native Aquatic Species Restoration Facility with stock from Hot Creek, Conejos County, Colorado; from LFL #105732.)

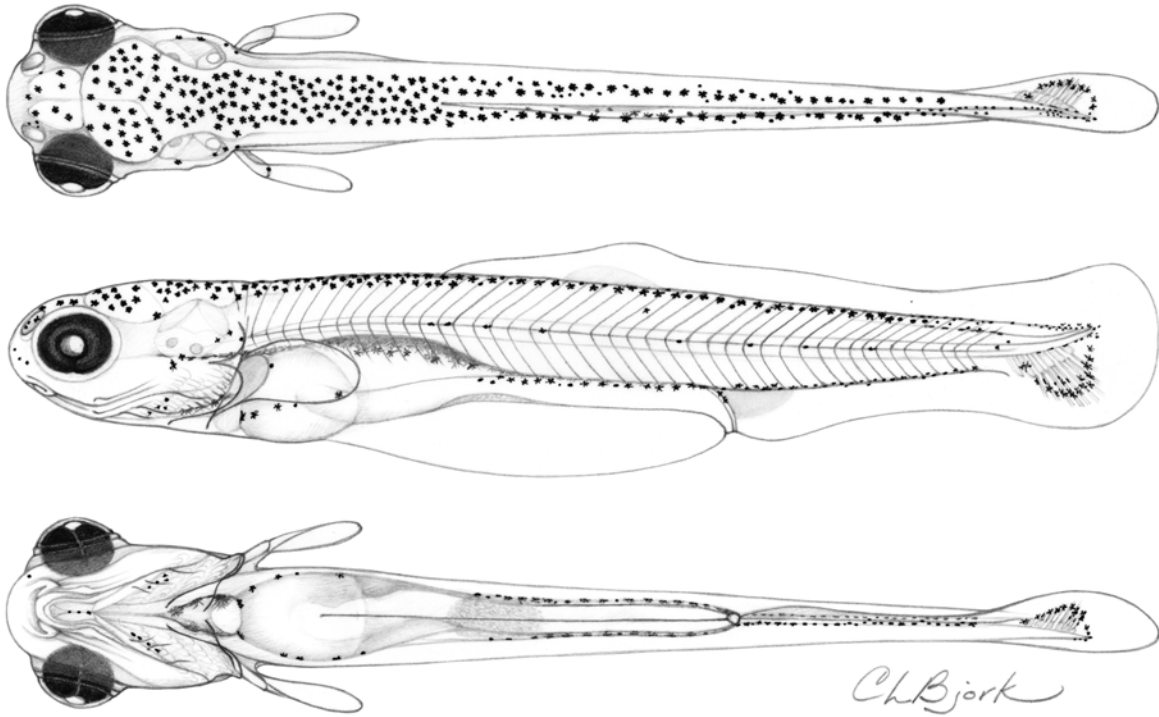


Figure 30. *Gila pandora* flexion mesolarva, recently transformed, 9.1 mm SL, 9.6 mm TL. (Cultured in 2007 by Colorado Division of Wildlife Native Aquatic Species Restoration Facility with stock from Hot Creek, Conejos County, Colorado; from LFL #105736.)

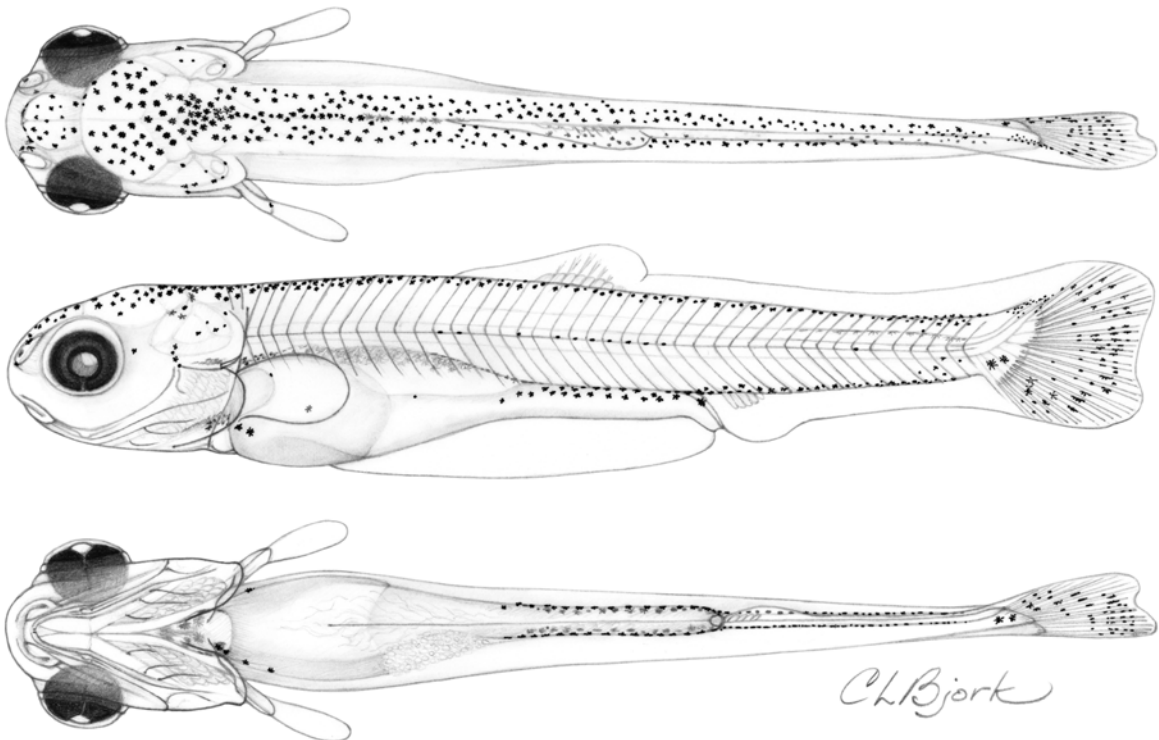


Figure 31. *Gila pandora* postflexion mesolarva, 10.1 mm SL, 11.2 mm TL. (Cultured in 2007 by Colorado Division of Wildlife Native Aquatic Species Restoration Facility with stock from Hot Creek, Conejos County, Colorado; from LFL #105742.)



Figure 32. *Gila pandora* metalarva, recently transformed, 12.9 mm SL, 15.4 mm TL. (Cultured in 2007 by Colorado Division of Wildlife Native Aquatic Species Restoration Facility with stock from Hot Creek, Conejos County, Colorado; from LFL #105748.)

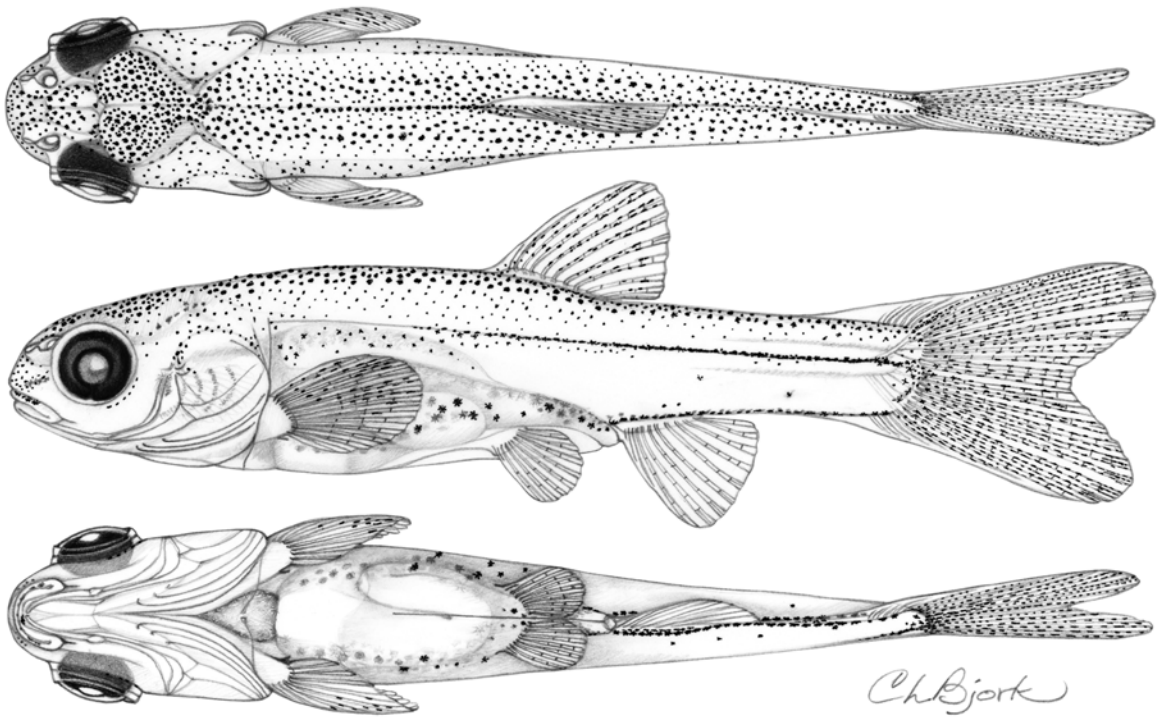


Figure 33. *Gila pandora* metalarva, 15.6 mm SL, 19.3 mm TL. (Cultured in 2007 by Colorado Division of Wildlife Native Aquatic Species Restoration Facility with stock from Hot Creek, Conejos County, Colorado; from LFL #105755.)

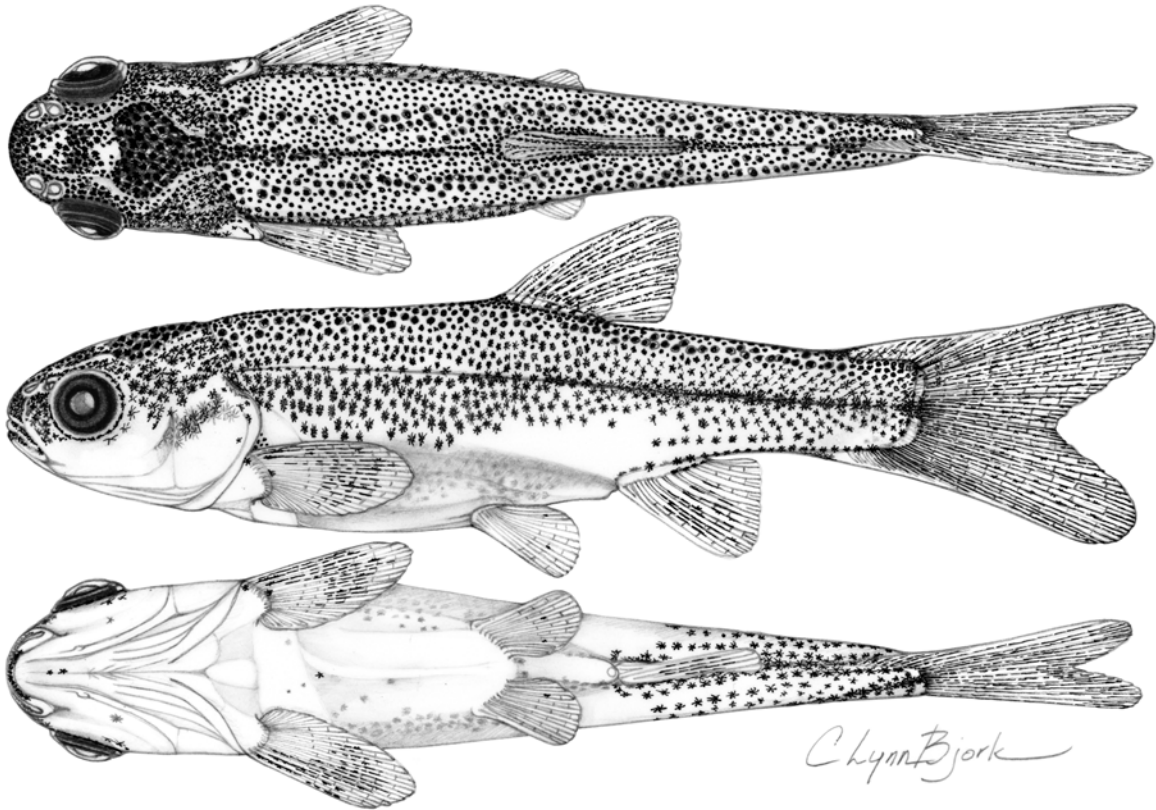


Figure 34. *Gila pandora* juvenile, recently transformed, 18.9 mm SL, 23.6 mm TL. (Cultured in 2010 initially by Colorado Division of Wildlife Native Aquatic Species Restoration Facility, then by Colorado State University Larval Fish Laboratory with stock from a Rio Grande tributary—Hot Creek, Rio San Antonio, or Roaring Fork Pond, Conejos or Mineral Co., CO.)

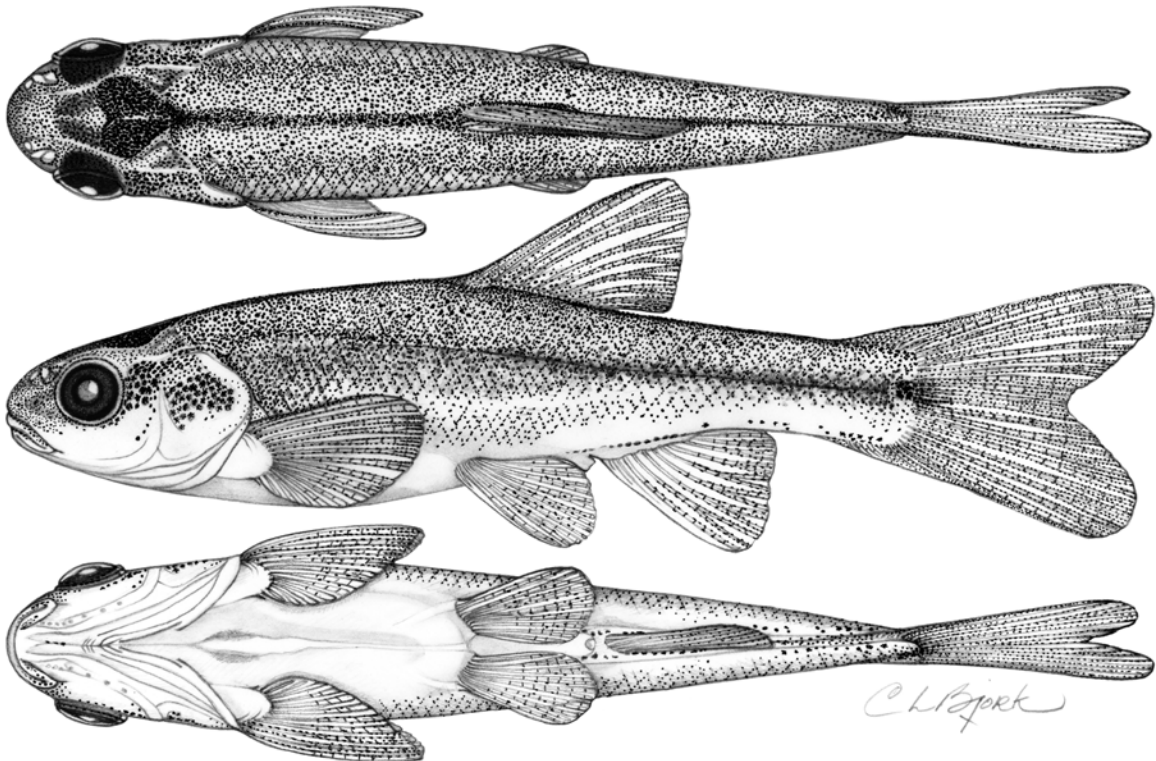


Figure 35. *Gila pandora* juvenile, 29.3 mm SL, 37.0 mm TL. (Collected in 2002 by Colorado State University Larval Fish Laboratory from Hot Creek, Hot Creek State Wildlife Area, Conejos County, Colorado; from LFL #89833.)

Species Account – *Hybognathus amarus*, Rio Grande Silvery Minnow

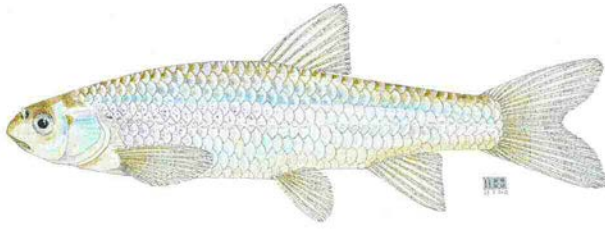


Figure 36. *Hybognathus amarus* adult (© W. H. Brandenburg).

Adult description: Small, usually 4–9 cm, rarely 10 cm TL. Body heavy, round to ovate. Rounded snout with small, slightly oblique, subterminal mouth and moderately small eyes. Fins moderate in length; dorsal origin anterior to pelvic fins. Scales with approximately 8 radii, sometimes lightly outlined with pigment. Silver to olive dorsally and laterally with a middorsal band. Lateral band behind head, absent to dusky anteriorly, darker posteriorly. Long, coiled gut with dark peritoneum. (Also, Table 14.)

Reproduction: Non-guarding, open-substrate pelagophil. Broadcast spawn in open water column during high-flow events when temperatures reach ~20–24°C, usually in May or June. Eggs are non-adhesive and ~1.5–1.6 mm diameter at fertilization, but quickly swell to (2.5)2.6–3.2–3.5–3.9(–4.2) mm, becoming semibuoyant and drifting downstream.

Young: Hatch in (1)2–3(4) d at 3.0–3.6–4.0–4.4 mm SL at 20–25°C (extremes 1–6 d at 2.9–4.8 mm at 15–30°C). Recently hatched larvae swim up repeatedly towards the surface and drift downstream for 3–5 d, after which their air bladders fill, allowing more horizontal movement, yolk is absorbed, and active feeding begins. Young seek low-velocity shoreline or backwater habitats which are shallower, warmer, and more productive than the main channel. In the laboratory at 20–30°C, larvae grew slowly, ~0.14–0.16 mm/d, some becoming juveniles in about 48 d. In the wild, growth is more rapid with juveniles reaching ~40 mm TL by late fall.

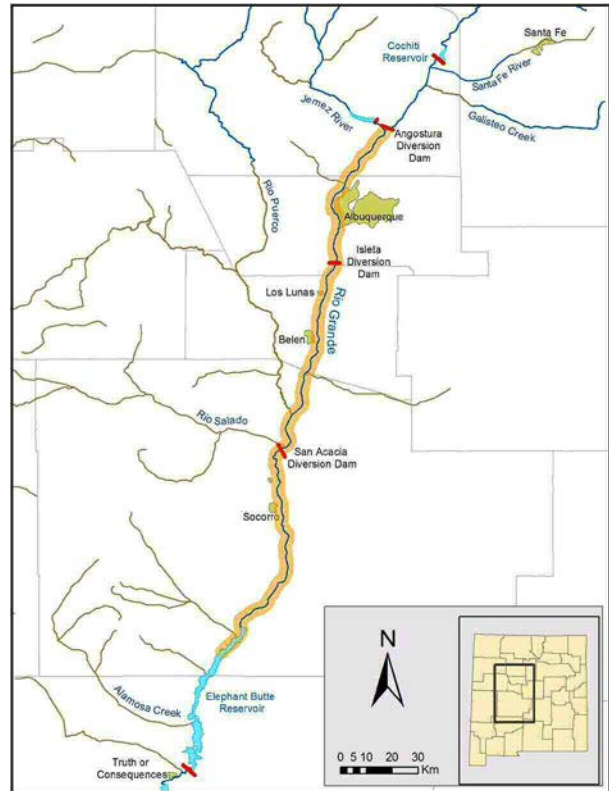


Figure 37. Distribution of *Hybognathus amarus* in the Middle Rio Grande, New Mexico, 2005–2015.

Table 14. Selected juvenile and adult meristics for *Hybognathus amarus*. (P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

| Character | Original | Literature | Character | Original | Literature |
|---------------------|---------------|-----------------|----------------------|-----------------------|-----------------------------|
| Dorsal-fin rays - P | (7)8 | (7)8(9) | Dorsal-fin rays - R | 2 | – |
| Anal-fin rays - P | 7– <u>8</u> | 7– <u>8</u> (9) | Anal-fin rays - R | 2 | – |
| Caudal-fin rays - P | (18)19 | (15–)19(20) | Caudal-fin rays - RD | (8)9–10 | – |
| Pectoral-fin rays | 13–14(15) | 14–16(–18) | Caudal-fin rays - RV | 8(9) | – |
| Pelvic-fin rays | 7– <u>8</u> | 8(9) | Lateral scales | 34– <u>36</u> –37(38) | (31–)34– <u>37</u> –40(–44) |
| Vertebrae | 36–37 (N = 3) | 35–37 | Pharyngeal teeth | 0,4/4,0 (N = 5) | 0,(5)4/4(5),0 |

Table 15. Size at onset of selected developmental events for *Hybognathus amarus*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses.)

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

References: Bestgen and Propst 1996; Dudley and Platania 1999, 2007; Platania 1995, 1998, 2000; Platania and Altenbach 1998; Rinne and Platania 1995; Sublette et al. 1990; USFWS 1999, 2010.

Other larval descriptions: Platania 1995, 2000.

Table 16. Size at developmental interval (left) and gut phase (right) transitions for *Hybognathus amarus*. (See Figure 5 for phases of gut folding. Rare values in parentheses.)

| Transition to | mm SL | mm TL | Transition to | mm SL | mm TL |
|-----------------------|---------|--------|-----------------------|----------|-----------|
| Flexion mesolarva | 5–6 | 6–7 | 2 - 90° bend | (7–)9 | (8–)10 |
| Postflexion mesolarva | (6)7(8) | 7–8(9) | 3 - Full loop | 9 | 10(11) |
| Metalarva | 9(10) | (10)11 | 4 - Partial crossover | 9–10(11) | (10)11–12 |
| Juvenile | 13–14 | 16–17 | 5 - Full | (11)12 | 14 |

Table 17. Summary of morphometrics and myomere counts by developmental phase for *Hybognathus amarus*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. Standard deviation [SD] of 0 represents a value < 0.5.)

| | Protolarvae (N = 10) | | | Flexion mesolarvae (N = 17) | | | Postflexion mesolarvae (N = 19) | | | Metalarvae (N = 20) | | | Juveniles (N = 19) | | |
|--------------------|----------------------|-----------------|---------|-----------------------------|----------|---------|---------------------------------|----------------|---------|---------------------|----------------|---------|--------------------|----------------|---------|
| | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range |
| SL, mm | 5 | 1 | 5–6 | 6 | 1 | 5–8 | 8 | 1 | 6–10 | 11 | 2 | 9–14 | 25 | 9 | 13–45 |
| TL, mm | 6 | 1 | 5–7 | 7 | 1 | 6–9 | 9 | 1 | 7–11 | 13 | 2 | 10–17 | 32 | 12 | 16–57 |
| <u>Lengths %SL</u> | | | | | | | | | | | | | | | |
| AS to AE | 3 | 0 | 2–3 | 3 | 0 | 3–4 | 4 | 0 | 3–5 | 5 | 1 | 4–6 | 5 | 1 | 4–6 |
| PE | 10 | 1 | 9–11 | 11 | 1 | 10–12 | 11 | 1 | 10–12 | 12 | 1 | 11–13 | 12 | 1 | 10–13 |
| OP1 | 18 | 1 | 17–20 | 21 | 1 | 20–23 | 22 | 1 | 20–23 | 25 | 1 | 22–28 | 26 | 1 | 23–28 |
| OP2 | | | | | | | 51 | 1 ^c | 51–52 | 55 | 2 | 53–58 | 56 | 2 | 54–59 |
| PY | 64 | 6 ^a | 56–69 | | | | | | | | | | | | |
| OPAF | 33 | 6 | 27–50 | 32 | 2 | 30–37 | 32 | 3 | 25–37 | 43 | 10 | 30–61 | | | |
| ODF | 42 | 2 | 38–45 | 45 | 2 | 42–49 | 48 | 3 ^d | 42–52 | 50 | 2 ^b | 48–54 | | | |
| OD | | | | | | | 53 | 1 ^c | 51–54 | 54 | 1 | 52–56 | 53 | 1 | 52–56 |
| ID | | | | | | | 62 | 1 ^c | 60–63 | 63 | 1 | 61–65 | 65 | 1 | 63–66 |
| PV | 71 | 1 | 69–72 | 72 | 1 | 70–75 | 74 | 1 | 72–75 | 74 | 1 | 71–76 | 72 | 1 | 70–74 |
| OA | | | | | | | 73 | 1 ^a | 71–74 | 73 | 1 | 70–75 | 73 | 1 | 71–74 |
| IA | | | | | | | 79 | 1 ^a | 78–81 | 81 | 1 | 78–83 | 81 | 2 | 79–83 |
| AFC | | | | | | | 110 | 1 | 109–112 | 113 | 2 | 110–116 | 116 | 2 | 112–120 |
| PC | 106 | 1 | 105–107 | 107 | 2 | 105–111 | 113 | 3 | 109–119 | 120 | 2 | 116–124 | 127 | 3 | 122–131 |
| Y | 22 | 27 ^b | 0–58 | | | | | | | | | | | | |
| P1 | 11 | 2 | 6–12 | 12 | 1 | 10–13 | 13 | 1 | 11–14 | 14 | 1 | 12–17 | 18 | 2 | 14–22 |
| P2 | | | | | | | 1 | 1 | 0–3 | 7 | 3 ^b | 2–11 | 14 | 2 | 11–17 |
| D | | | | | | | 12 | 1 ^f | 11–13 | 16 | 2 | 13–19 | 22 | 2 | 19–24 |
| A | | | | | | | 8 | 1 ^a | 7–9 | 11 | 1 | 8–14 | 16 | 1 | 14–17 |
| <u>Depths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 14 | 1 | 13–15 | 14 | 1 | 13–15 | 15 | 1 | 13–17 | 17 | 1 | 15–18 | 16 | 2 | 14–19 |
| OP1 | 14 | 1 | 13–15 | 15 | 1 | 13–16 | 16 | 1 | 15–19 | 19 | 2 | 14–23 | 21 | 1 | 18–23 |
| OD | 11 | 1 | 10–12 | 11 | 1 | 10–13 | 13 | 1 | 12–17 | 19 | 3 | 14–23 | 22 | 2 | 18–25 |
| BPV | 7 | 1 | 6–8 | 7 | 1 | 6–8 | 9 | 1 | 7–11 | 12 | 1 | 10–14 | 16 | 1 | 13–18 |
| AMPM | 3 | 1 | 2–4 | 4 | 1 | 3–5 | 6 | 1 | 4–7 | 7 | 1 | 6–9 | 10 | 1 | 8–12 |
| Max. yolk | 3 | 4 ^b | 0–10 | | | | | | | | | | | | |
| <u>Widths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 13 | 1 | 12–14 | 13 | 1 | 12–14 | 15 | 1 | 13–17 | 16 | 1 | 13–17 | 15 | 2 | 13–18 |
| OP1 | 10 | 1 | 9–13 | 10 | 1 | 8–12 | 13 | 1 | 11–16 | 15 | 2 | 11–18 | 17 | 1 | 15–19 |
| OD | 6 | 1 | 4–8 | 7 | 1 | 5–8 | 9 | 1 | 6–11 | 12 | 2 | 8–16 | 15 | 2 | 12–18 |
| BPV | 5 | 1 | 4–6 | 5 | 0 | 4–6 | 6 | 1 | 4–8 | 8 | 1 | 7–10 | 10 | 1 | 8–13 |
| AMPM | 2 | 1 | 1–3 | 3 | 1 | 2–4 | 4 | 1 | 3–5 | 4 | 1 | 3–6 | 4 | 1 | 3–5 |
| Max. yolk | 5 | 6 ^b | 0–13 | | | | | | | | | | | | |
| <u>Myomeres</u> | | | | | | | | | | | | | | | |
| to PY | 24 | 3 ^a | 20–27 | | | | | | | | | | | | |
| OPAF | 10 | 3 | 6–16 | 8 | 1 | 6–11 | 6 | 1 | 5–8 | 11 | 5 | 6–20 | | | |
| OP2 | | | | | | | 17 | 0 ^c | 16–17 | 17 | 1 | 16–19 | 17 | 1 ⁱ | 16–18 |
| ODF | 14 | 1 | 12–16 | 14 | 1 | 12–16 | 15 | 1 ^d | 13–16 | 15 | 1 ⁱ | 13–16 | | | |
| OD | | | | | | | 17 | 1 ^e | 16–18 | 16 | 1 | 15–18 | 16 | 1 ⁱ | 15–16 |
| PV | 27 | 1 | 26–28 | 27 | 1 | 26–29 | 27 | 1 | 26–29 | 26 | 1 | 25–27 | 26 | 1 ⁱ | 25–27 |
| Total | 38 | 1 | 36–39 | 38 | 1 | 37–39 | 37 | 1 | 35–39 | 36 | 1 | 35–37 | 36 | 1 ⁱ | 35–37 |
| After PV | 11 | 1 | 10–12 | 11 | 1 | 10–12 | 10 | 1 | 9–11 | 10 | 1 | 9–11 | 10 | 1 ^j | 9–11 |

^aN = 4. ^bN = 9. ^cN = 5. ^dN = 17. ^eN = 12. ^fN = 11. ^gN = 13. ^hN = 16. ⁱN = 8. ^jN = 10.

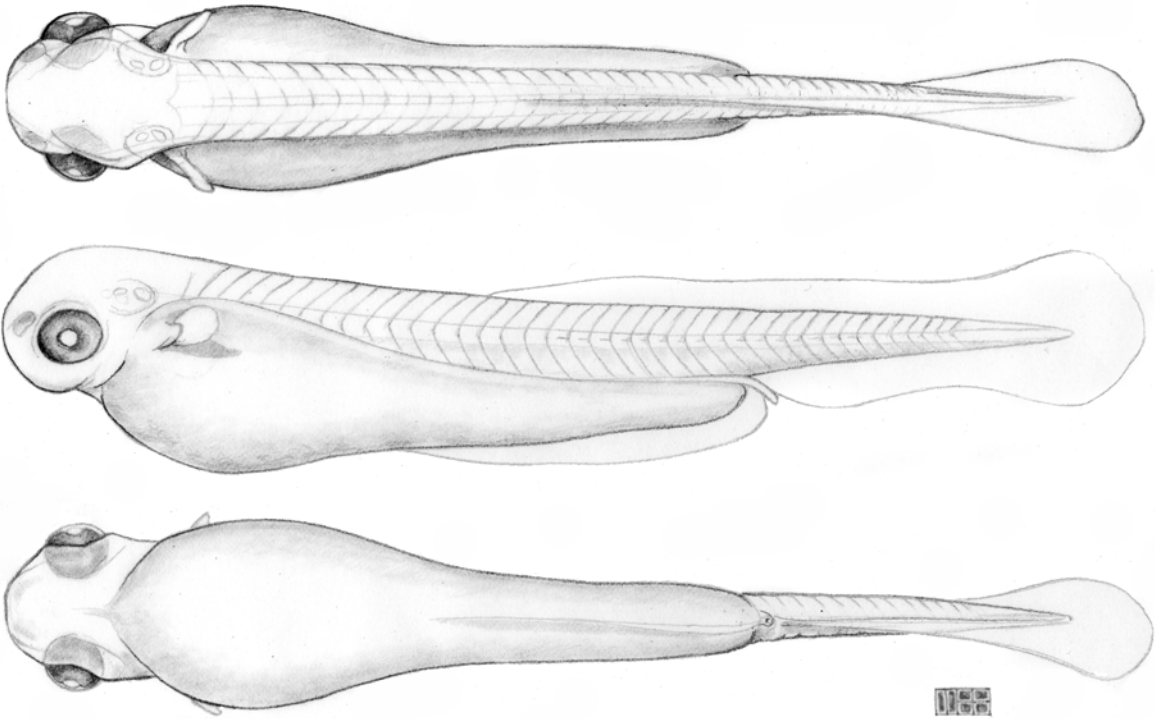


Figure 38. *Hybognathus amarus* protolarva, recently hatched, 4.7 mm SL, 5.0 mm TL. (Cultured in 1994 at the Museum of Southwestern Biology, University of New Mexico, with stock from the Rio Grande east of Socorro, New Mexico; from MSB #49967.)

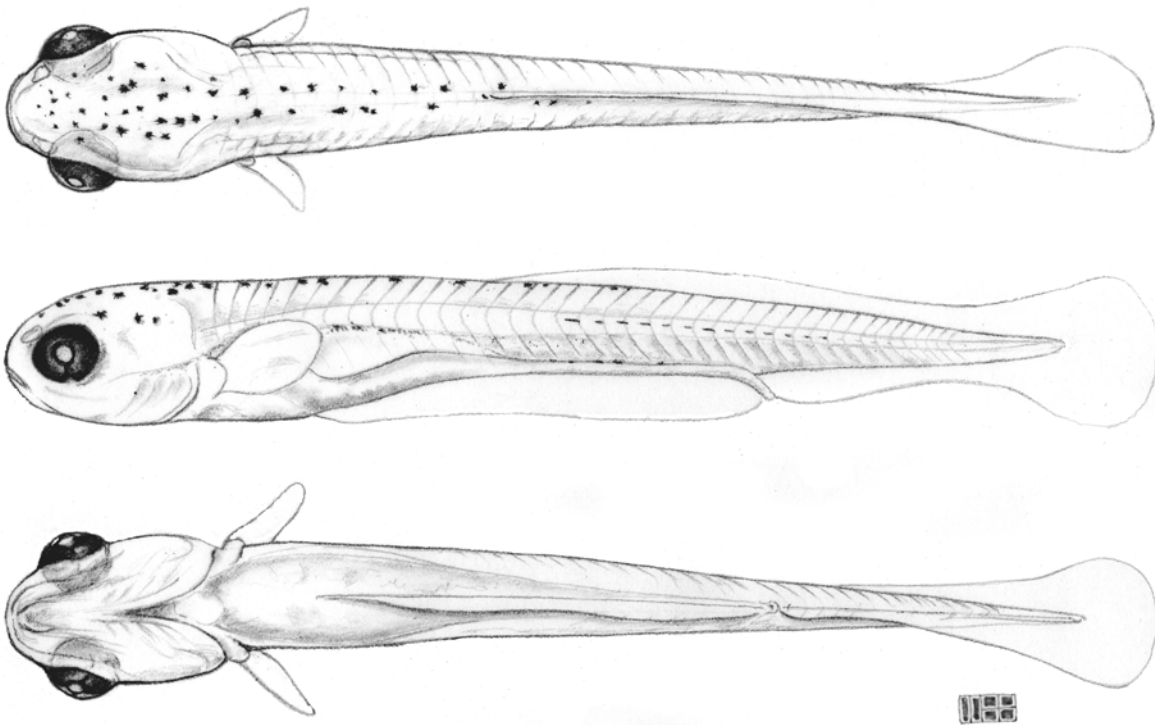


Figure 39. *Hybognathus amarus* protolarva, 5.4 mm SL, 5.7 mm TL. (Cultured in 1994 at Museum of Southwestern Biology, University of New Mexico, with stock from Rio Grande east of Socorro, New Mexico; from MSB #49967.)

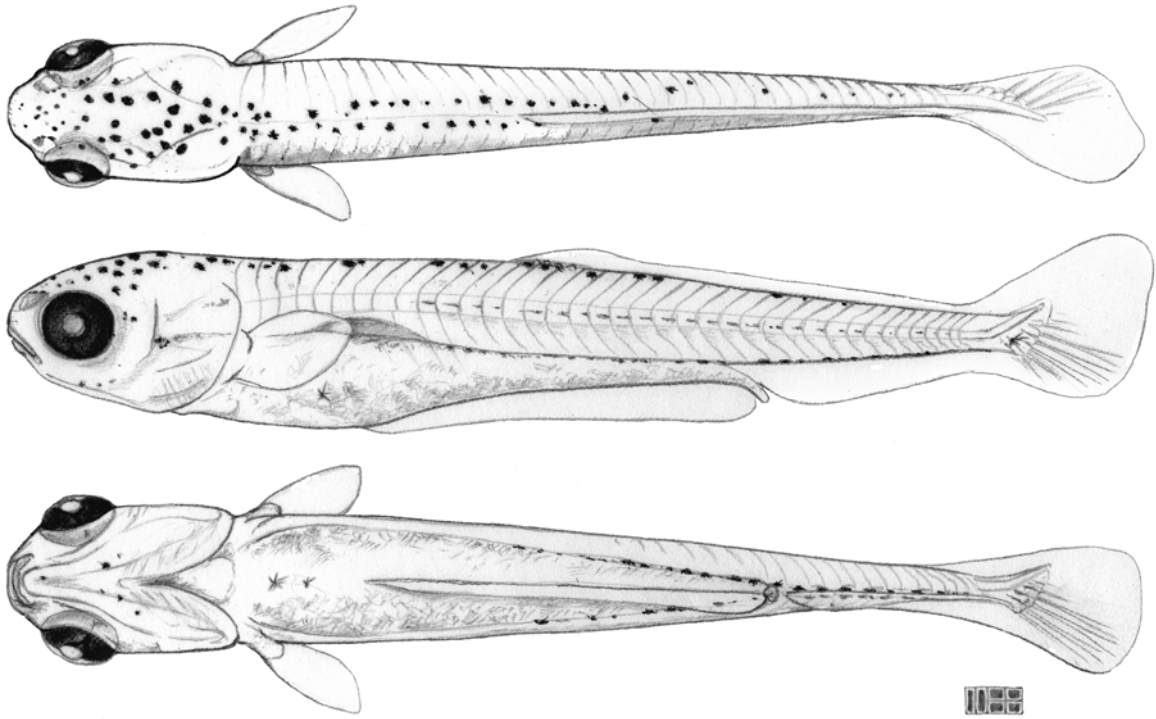


Figure 40. *Hybognathus amarus* flexion mesolarva, recently transformed, 6.0 mm SL, 6.5 mm TL. (Cultured in 1994 at Museum of Southwestern Biology, University of New Mexico, with stock from Rio Grande east of Socorro, New Mexico; from MSB #49967.)

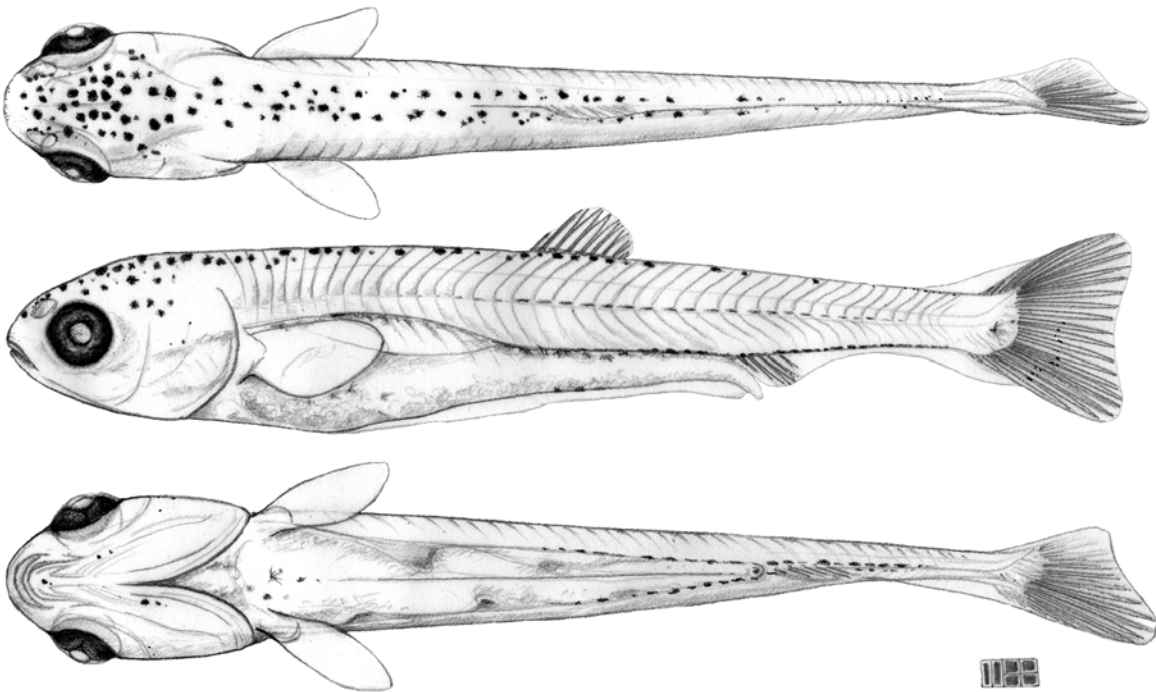


Figure 41. *Hybognathus amarus* postflexion mesolarva, 7.2 mm SL, 7.9 mm TL. (Cultured in 1994 at Museum of Southwestern Biology, University of New Mexico, with stock from Rio Grande east of Socorro, New Mexico; from MSB #49967.)

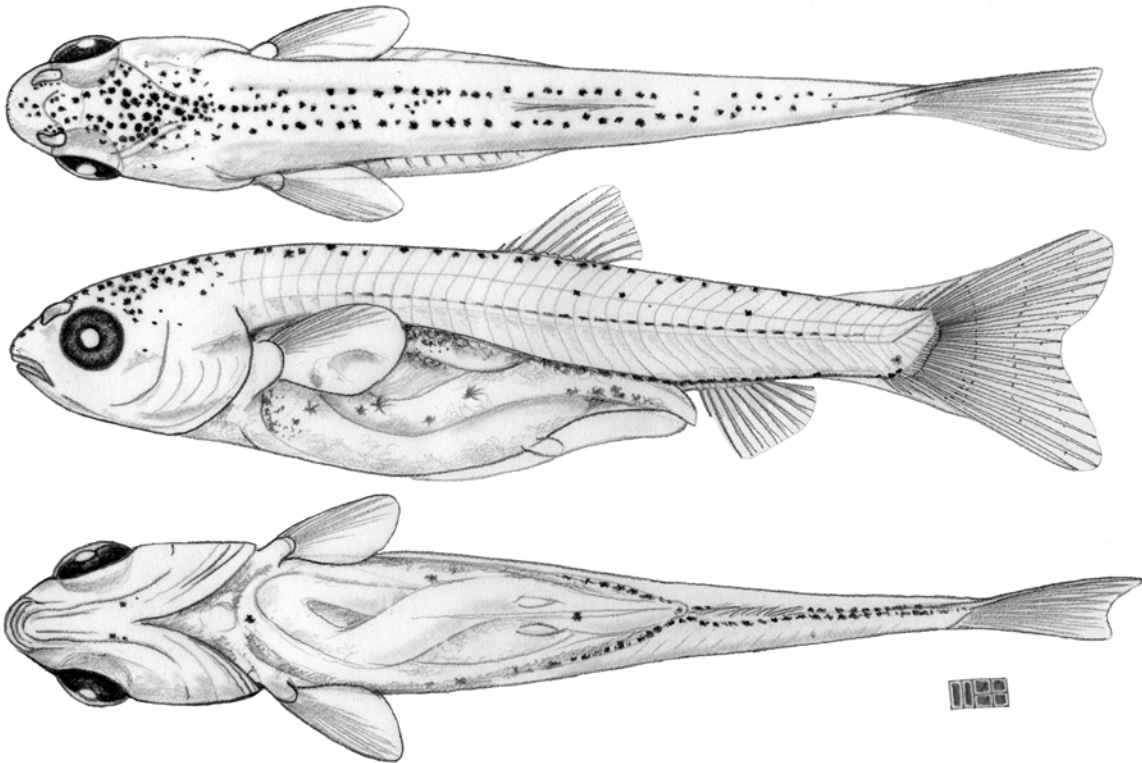


Figure 42. *Hybognathus amarus* metalarva, recently transformed, 10.1 mm SL, 12.0 mm TL. (Cultured in 1994 at Museum of Southwestern Biology, University of New Mexico, with stock from Rio Grande east of Socorro, NM; from MSB #49967.)

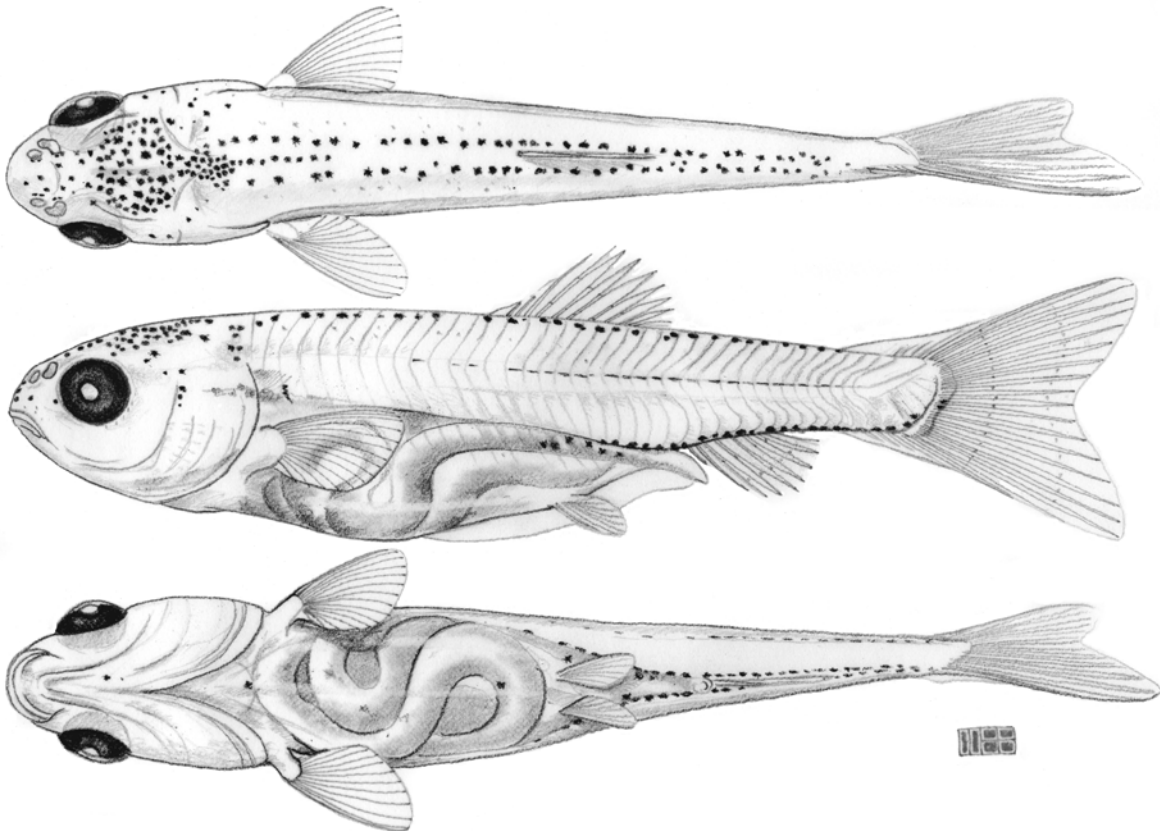


Figure 43. *Hybognathus amarus* metalarva, 12.1 mm SL, 14.8 mm TL. (Cultured in 1994 at Museum of Southwestern Biology, University of New Mexico, with stock from Rio Grande east of Socorro, New Mexico; from MSB #49967.)

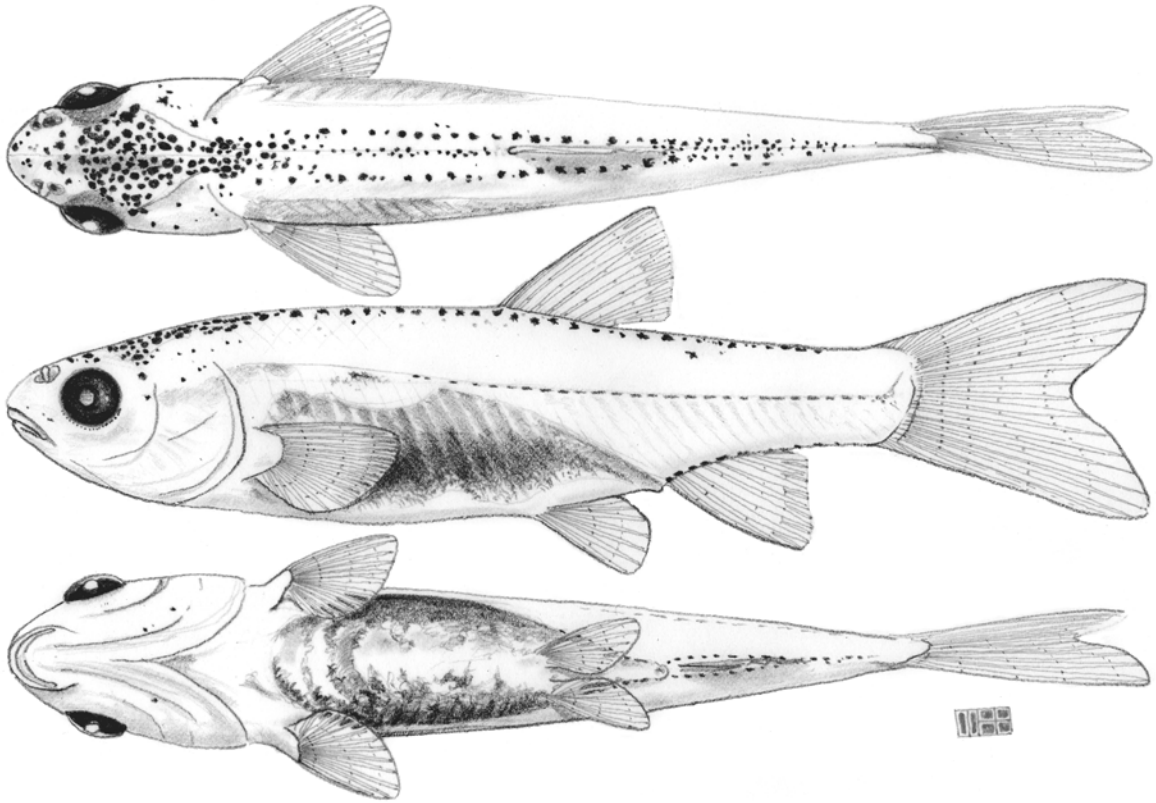


Figure 44. *Hybognathus amarus* juvenile, recently transformed, 17.6 mm SL, 21.8 mm TL. (Cultured in 1994 at Museum of Southwestern Biology, University of New Mexico, with stock from Rio Grande east of Socorro, NM; from MSB # 49967.)

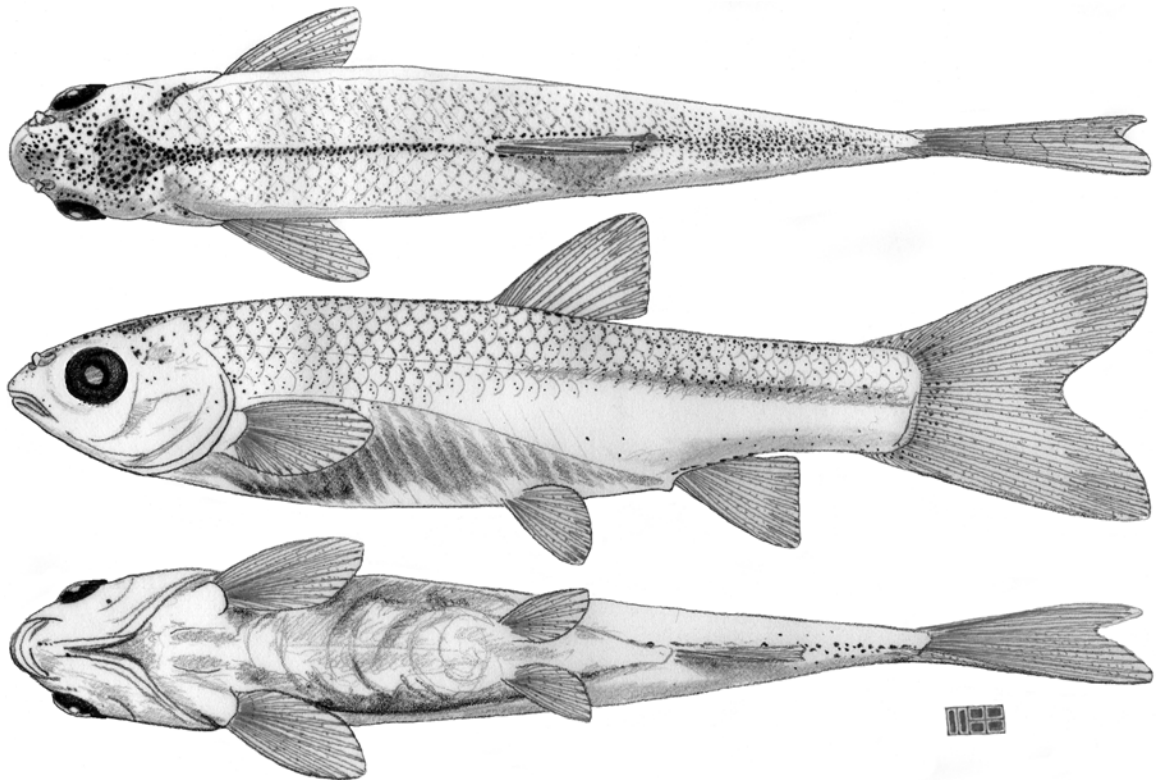


Figure 45. *Hybognathus amarus* juvenile, 28.0 mm SL, 35.6 mm TL. (Cultured in 1994 at Museum of Southwestern Biology, University of New Mexico, with stock from Rio Grande east of Socorro, New Mexico; from MSB #49967.)

Species Account – *Pimephales promelas*, Fathead Minnow

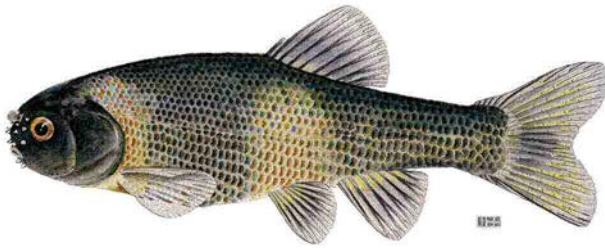


Figure 46. *Pimephales promelas* adult (breeding male, © W. H. Brandenburg).

Adult description: Small, 4–8, rarely 9 cm TL. Heavy-bodied, round to oval in cross section. Head short; fat and rounded in males. Mouth small, terminal to slightly subterminal, somewhat oblique. Gut long and coiled; peritoneum dark. Dorsal fin rounded, last rudimentary ray often thickened, origin usually over pelvic origin. Scales outlined, moderately large posteriorly, but smaller and crowded dorsally before dorsal fin. Generally olivaceous above, silvery-grey laterally and white below, usually with a dusky lateral band and anterior spot in dorsal fin. (Also, Table 18.)

Reproduction: Guarding, nest-spawning speleophil. Usually mature at age 1 and spawn mid-spring through summer at 16–29 °C, typically in shallow, low-velocity areas (e.g., backwaters, pools, shorelines). Females are fractional spawners and deposit clutches of adhesive eggs on exposed undersides of solid surfaces (e.g., rocks, vegetation) cleared by territorial males, who mate with several females, then guard and care for the eggs. Breeding males are very dark, often with broad, light, vertical bands behind head and between dorsal and pelvic fins; have dorsal pad behind head and stout tubercles on very rounded snout. Eggs are 1.1–1.6, usually 1.3–1.5, mm diameter.

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

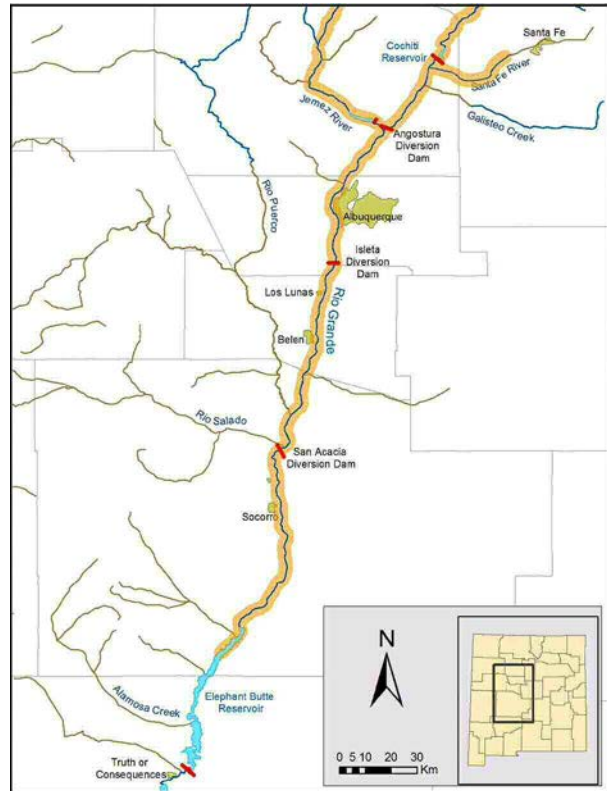


Figure 47. Distribution of *Pimephales promelas* in the Middle Rio Grande, New Mexico, 2005–2015.

Table 18. Selected juvenile and adult meristics for *Pimephales promelas*. (P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

| Character | Original | Literature | Character | Original | Literature |
|---------------------|----------------|---------------------------|----------------------|-------------------|------------------------------------|
| Dorsal-fin rays - P | (7)8(9) | (7)8(9) | Dorsal-fin rays - R | 2(3) | 1 |
| Anal-fin rays - P | 7 | 7 | Anal-fin rays - R | 2(3) | – |
| Caudal-fin rays - P | 19(20) | 19 | Caudal-fin rays - RD | <u>11</u> –12 | – |
| Pectoral-fin rays | 14–15(16) | 14– <u>15</u> –16–18 | Caudal-fin rays - RV | (9)10–11 | – |
| Pelvic-fin rays | 7– <u>8</u> –9 | <u>8</u> –9 | Lateral scales | 43– <u>48</u> –51 | 40– <u>44</u> – <u>48</u> –54(–60) |
| Vertebrae | – | <u>35</u> – <u>37</u> –38 | Pharyngeal teeth | – | 0,4/4,0 |

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

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

References: Andrews & Flickinger 1974; Balon 1975a; Baxter & Simon 1970; Becker 1983; Beckman 1952; Carlander 1969; Gale & Buynak 1982; Heufelder & Fuiman 1982; Hubbs & Lagler 1958; Lentsch et al. 1996; Markus 1934; Minckley 1973; Moore 1968; Moyle 1976; Muth & Snyder 1995; Page & Burr 1991; Pflieger 1997; Scott & Crossman 1973; Simon 1998; Snyder et al. 1977, 2005; Sublette et al. 1990; Tyus et al. 1982; Woodling 1985; Wynne-Edwards 1932. **Account:** Modified from Snyder et al. 2016. **Other larval descriptions:** Andrews 1970; Buynak & Mohr 1979b; Feeny & Swift 2008; Fish 1932; Fuiman et al. 1983; Heufelder & Fuiman 1982; (continued at bottom of next page).

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

| Transition to | mm SL | mm TL | Transition to | mm SL | mm TL |
|-----------------------|----------|-----------|-----------------------|--------|--------|
| Flexion mesolarva | 6–7 | (6)7 | 2 - 90° bend | 9–10 | (10)11 |
| Postflexion mesolarva | 7–8 | 8–9 | 3 - Full loop | 11–14 | 14–16 |
| Metalarva | 8–10(11) | 9–12 | 4 - Partial crossover | (15)16 | (18)19 |
| Juvenile | 14–15 | (16)17–18 | 5 - Full | 16 | 19–20 |

Table 21. Summary of morphometrics and myomere counts by developmental phase for *Pimephales promelas*. (See Figure 4 for abbreviations and methods of measurement and counting. Standard deviation [SD] of 0 represents a value < 0.5. Includes data extracted from selected Snyder et al. 1977 and Perry and Menzel 1979 illustrations reprinted herein or in prior accounts by Snyder 1981 and Snyder et al. 2005.)

| | Protolarvae (N = 9) | | | Flexion mesolarvae (N = 5) | | | Postflexion mesolarvae (N = 5) | | | Metalarvae (N = 9) | | | Juveniles (N = 14) | | |
|--------------------|---------------------|----------------|---------|----------------------------|----------------|---------|--------------------------------|----------------|---------|--------------------|----------------|---------|--------------------|----------------|---------|
| | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range |
| SL, mm | 5 | 1 | 4–6 | 7 | 1 | 6–8 | 9 | 1 | 7–10 | 11 | 2 | 8–14 | 23 | 7 | 15–34 |
| TL, mm | 5 | 1 | 4–6 | 7 | 1 | 7–9 | 10 | 2 | 8–12 | 13 | 3 | 9–16 | 29 | 9 ^f | 18–42 |
| <u>Lengths %SL</u> | | | | | | | | | | | | | | | |
| AS to AE | 3 | 1 | 1–4 | 3 | 1 | 2–4 | 4 | 1 | 3–5 | 5 | 0 | 4–5 | 5 | 1 | 4–7 |
| PE | 10 | 1 | 8–12 | 11 | 1 | 10–12 | 12 | 1 | 10–13 | 13 | 1 | 11–15 | 13 | 1 | 11–15 |
| OP1 | 19 | 1 | 18–21 | 20 | 0 ^c | 20–21 | 23 | 1 | 21–24 | 26 | 1 | 25–28 | 25 | 1 | 23–27 |
| OP2 | | | | | | | 49 | 1 ^d | 48–49 | 51 | 1 | 49–53 | 52 | 2 | 49–55 |
| PY | 63 | 2 ^a | 61–66 | | | | | | | | | | | | |
| OPAF | 39 | 10 | 31–57 | 32 | 2 ^c | 30–34 | 36 | 1 | 35–39 | 43 | 8 ^b | 38–56 | | | |
| ODF | 41 | 2 | 38–45 | 43 | 1 ^c | 41–44 | 48 | 3 | 43–49 | 51 | 3 ^d | 49–55 | | | |
| OD | | | | | | | 51 | 2 | 49–54 | 52 | 2 | 51–56 | 51 | 2 | 49–54 |
| ID | | | | | | | 62 | 1 | 61–64 | 65 | 2 | 63–69 | 64 | 1 | 63–66 |
| PV | 65 | 3 | 60–68 | 65 | 1 | 64–66 | 70 | 2 | 68–72 | 69 | 1 | 67–71 | 67 | 1 | 65–69 |
| OA | | | | | | | 68 | 1 ^c | 67–70 | 68 | 1 | 66–70 | 66 | 1 | 65–69 |
| IA | | | | | | | 77 | 1 ^d | 76–77 | 76 | 1 | 74–78 | 75 | 1 | 73–78 |
| AFC | | | | | | | 110 | 1 | 108–111 | 111 | 2 | 108–113 | 114 | 2 ^f | 110–117 |
| PC | 105 | 1 | 104–107 | 106 | 1 | 104–108 | 112 | 3 | 108–114 | 118 | 3 | 114–122 | 122 | 2 ^f | 118–126 |
| Y | 28 | 27 | 0–54 | | | | | | | | | | | | |
| P1 | 10 | 4 | 4–15 | 12 | 1 ^c | 11–12 | 12 | 2 | 11–14 | 13 | 1 | 11–15 | 16 | 2 ^f | 13–20 |
| P2 | | | | | | | 3 | 3 | 0–6 | 7 | 2 | 4–12 | 13 | 2 | 9–17 |
| D | | | | | | | 16 | 1 ^d | 16–18 | 19 | 2 | 14–21 | 21 | 2 | 18–24 |
| A | | | | | | | 10 | 0 ^d | 10–11 | 13 | 1 | 11–15 | 15 | 1 | 13–18 |
| <u>Depths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 14 | 1 | 11–16 | 13 | 1 ^c | 11–14 | 14 | 1 | 13–15 | 16 | 1 | 14–18 | 17 | 1 | 16–19 |
| OP1 | 17 | 5 | 12–25 | 13 | 1 ^c | 12–15 | 17 | 2 | 15–19 | 20 | 2 | 17–22 | 22 | 1 | 19–24 |
| OD | 11 | 1 | 10–12 | 11 | 1 ^c | 9–13 | 15 | 3 | 11–17 | 17 | 3 | 13–22 | 21 | 2 | 18–25 |
| BPV | 7 | 1 | 6–8 | 8 | 1 ^c | 7–8 | 9 | 1 | 8–11 | 12 | 2 | 9–14 | 14 | 2 | 12–17 |
| AMPM | 4 | 1 | 3–4 | 4 | 0 ^c | 4–5 | 7 | 1 | 6–8 | 9 | 1 | 7–10 | 10 | 1 | 9–12 |
| Max. yolk | 8 | 8 | 0–20 | | | | | | | | | | | | |
| <u>Widths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 12 | 1 ^b | 11–14 | 12 | 0 ^c | 12–13 | 14 | 1 | 13–15 | 16 | 1 ^b | 15–19 | 15 | 1 ^f | 14–16 |
| OP1 | 11 | 3 ^b | 9–16 | 9 | 1 ^c | 8–10 | 12 | 1 | 10–13 | 15 | 2 ^b | 11–18 | 16 | 1 ^f | 14–19 |
| OD | 6 | 0 ^b | 5–7 | 6 | 1 ^c | 5–8 | 8 | 2 | 6–10 | 11 | 2 ^b | 9–13 | 14 | 2 ^f | 11–18 |
| BPV | 5 | 0 ^b | 4–5 | 5 | 1 ^c | 4–6 | 6 | 1 | 5–7 | 8 | 1 ^b | 6–9 | 10 | 2 ^f | 7–12 |
| AMPM | 2 | 0 ^b | 2–3 | 3 | 0 ^c | 2–3 | 4 | 0 | 3–4 | 5 | 1 ^b | 4–6 | 5 | 1 ^f | 4–6 |
| Max. yolk | 8 | 8 ^b | 0–18 | | | | | | | | | | | | |
| <u>Myomeres</u> | | | | | | | | | | | | | | | |
| to PY | 22 | 1 ^a | 20–23 | | | | | | | | | | | | |
| OPAF | 11 | 4 | 6–18 | 8 | 2 ^c | 6–10 | 9 | 2 | 6–10 | 12 | 4 ^b | 8–19 | | | |
| OP2 | | | | | | | 15 | 0 ^d | 15–15 | 15 | 1 | 14–17 | 16 | 1 ^g | 15–17 |
| ODF | 12 | 1 | 10–15 | 14 | 1 ^c | 13–14 | 14 | 1 | 12–15 | 14 | 1 ^c | 13–14 | | | |
| OD | | | | | | | 16 | 1 | 15–16 | 15 | 1 | 15–16 | 16 | 1 ^g | 15–16 |
| PV | 23 | 1 | 21–25 | 24 | 1 ^c | 23–25 | 25 | 2 | 23–27 | 25 | 1 | 24–25 | 24 | 1 ^g | 23–25 |
| Total | 36 | 1 | 36–37 | 37 | 1 ^c | 35–37 | 36 | 1 | 35–38 | 36 | 1 | 34–37 | 37 | 1 ^g | 36–38 |
| After PV | 13 | 1 | 11–15 | 13 | 1 ^c | 11–14 | 11 | 1 | 10–13 | 11 | 1 | 10–13 | 13 | 1 ^b | 11–14 |

^aN = 5. ^bN = 8. ^cN = 4. ^dN = 3. ^eN = 2. ^fN = 13. ^gN = 7.

Other larval descriptions (continued from bottom of previous page): Hogue et al. 1976; Holland-Bartels et al. 1990; Perry 1979; Perry & Menzel 1979; Remple & Markle 2005; Snyder 1981; Snyder et al. 1977, 2005; Wang 1986; Wang & Reyes 2007.

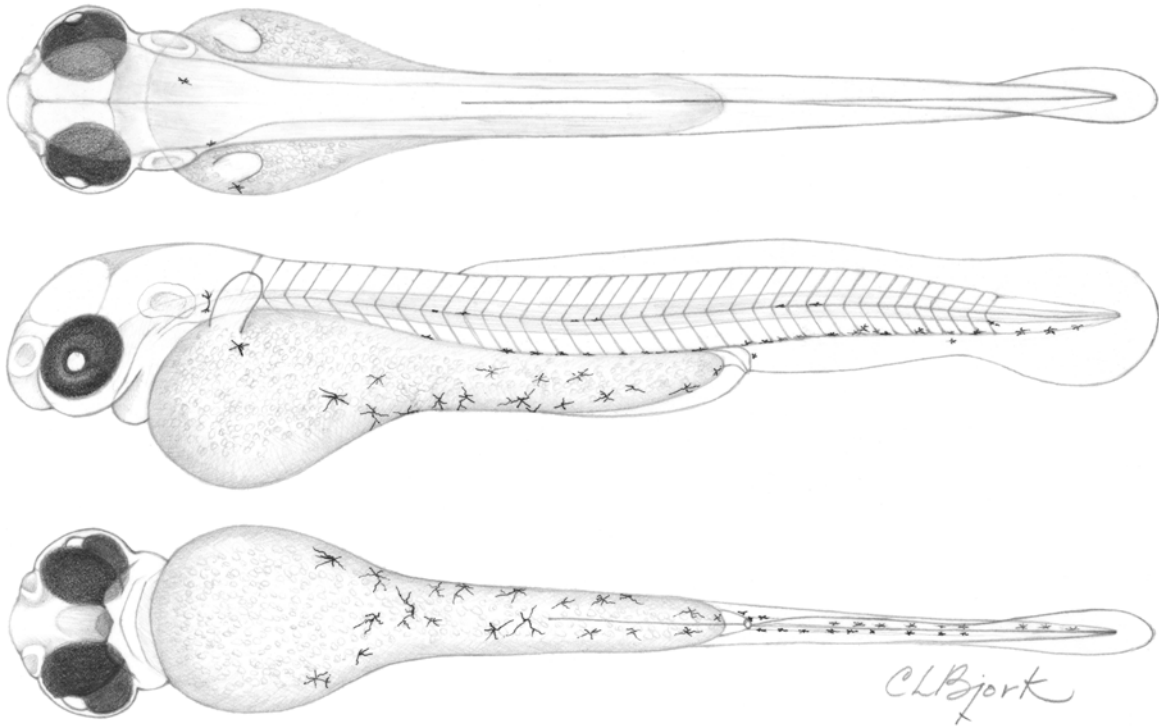


Figure 48. *Pimephales promelas* protolarva, recently hatched, 4.0 mm SL, 4.1 mm TL. (Cultured in 2006 by Larval Fish Laboratory at Colorado State University with embryos from Aquatic BioSystems, Inc., Fort Collins, Colorado.)

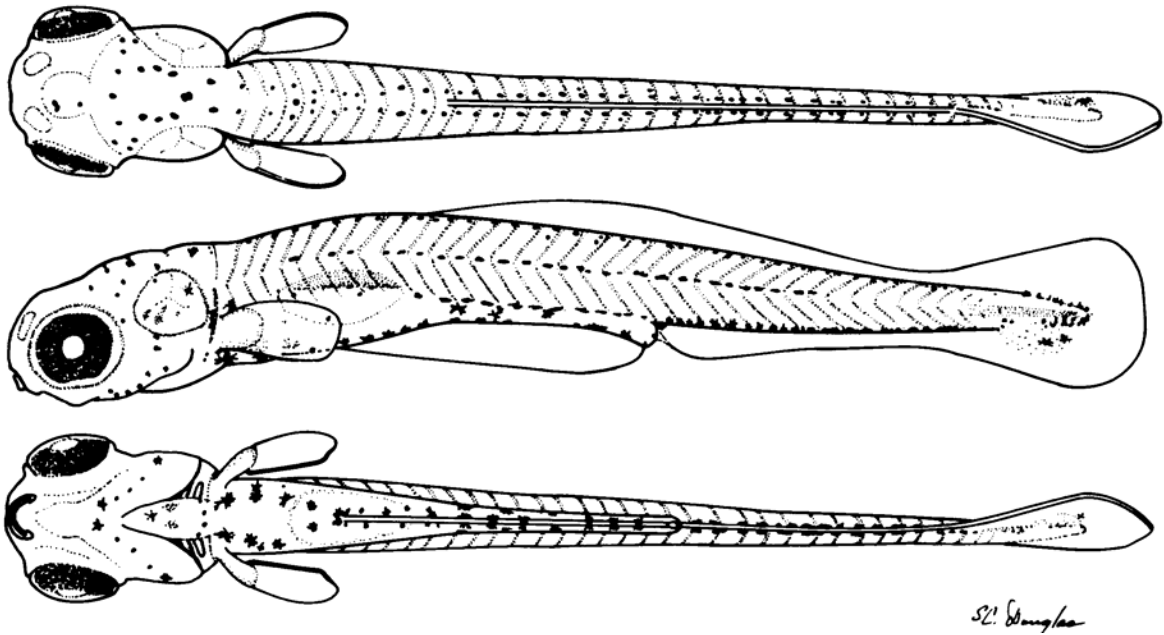


Figure 49. *Pimephales promelas* protolarva, 5.3 mm SL, 5.6 mm TL. (Cultured in 1974 by William Stone at NUS Corporation, Ecological Sciences Division, Pittsburgh, Pennsylvania, with stock from commercial bait ponds in Ohio. Modified from Snyder et al. 1977, Figure 5.)

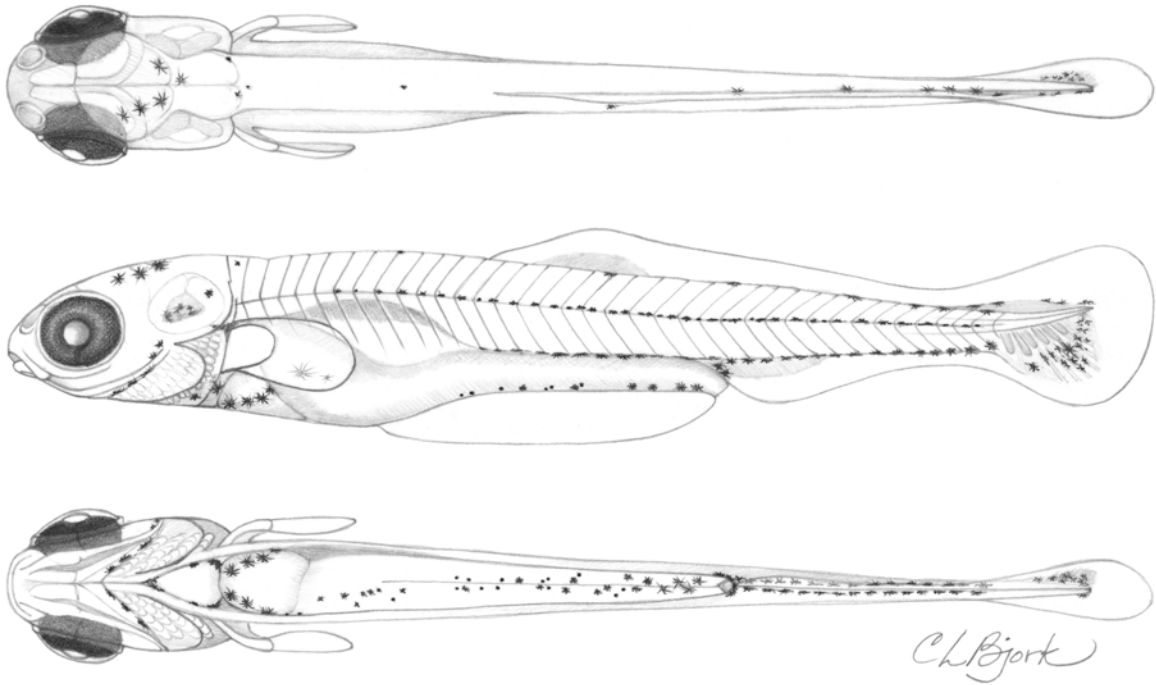


Figure 50. *Pimephales promelas* flexion mesolarva, recently transformed, 6.4 mm SL, 6.7 mm TL. (Cultured in 2006 by Larval Fish Laboratory at Colorado State University with embryos from Aquatic BioSystems, Inc., Fort Collins, Colorado.)

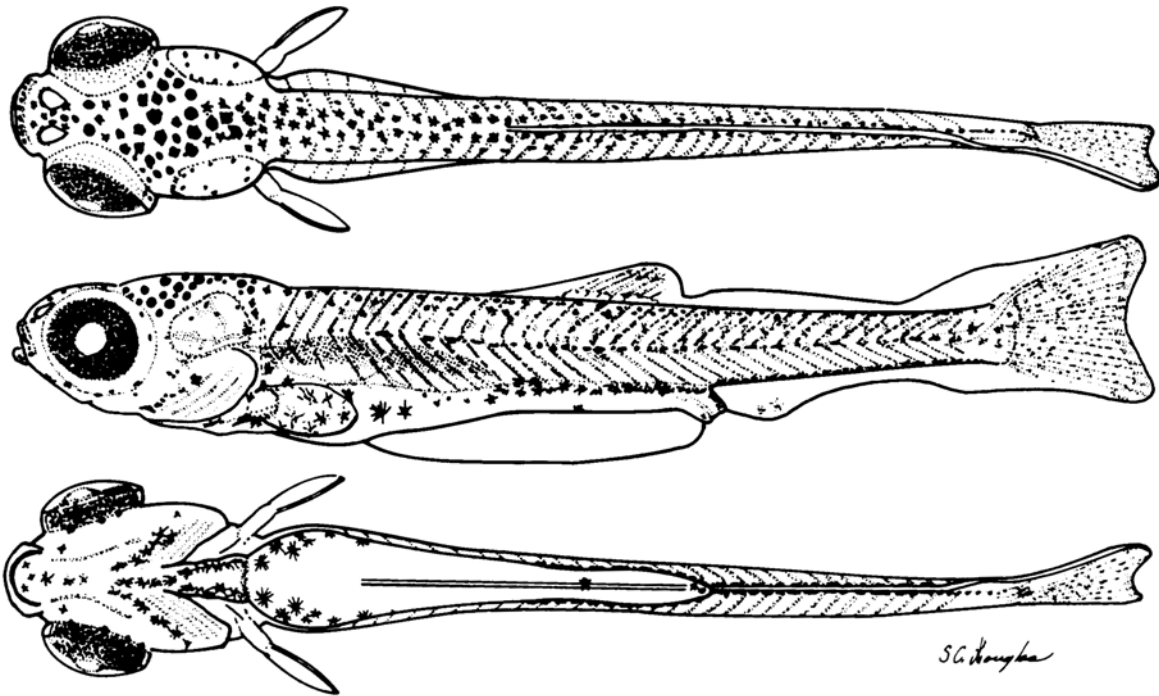


Figure 51. *Pimephales promelas* postflexion mesolarva, 7.0 mm SL, 7.9 mm TL. (Cultured in 1974 by Paul Blatt and Darrel Snyder at NUS Corporation Ecological Sciences Division, Pittsburgh, Pennsylvania, with stock from commercial bait ponds in Ohio. Modified from Snyder et al. 1977, Figure 9.)

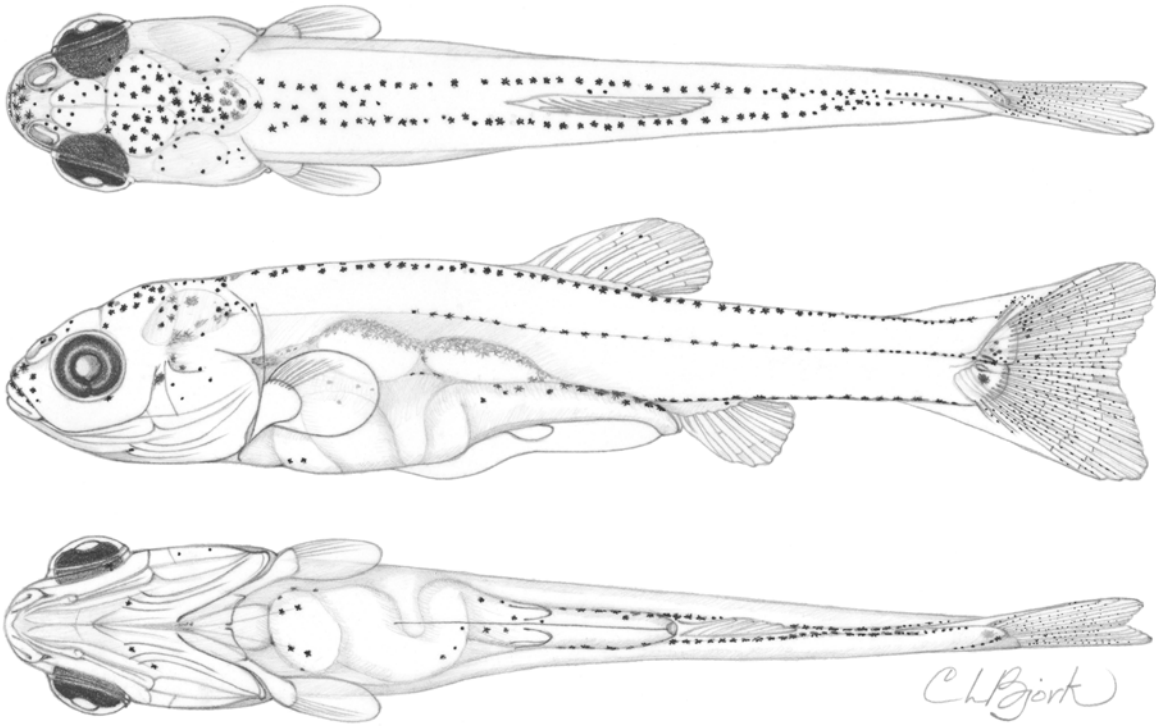


Figure 52. *Pimephales promelas* metalarva, recently transformed, 9.9 mm SL, 11.3 mm TL. (Collected in 2002 from Gunnison River, northwest of Escalante, Delta County, Colorado; from LFL #82227.)

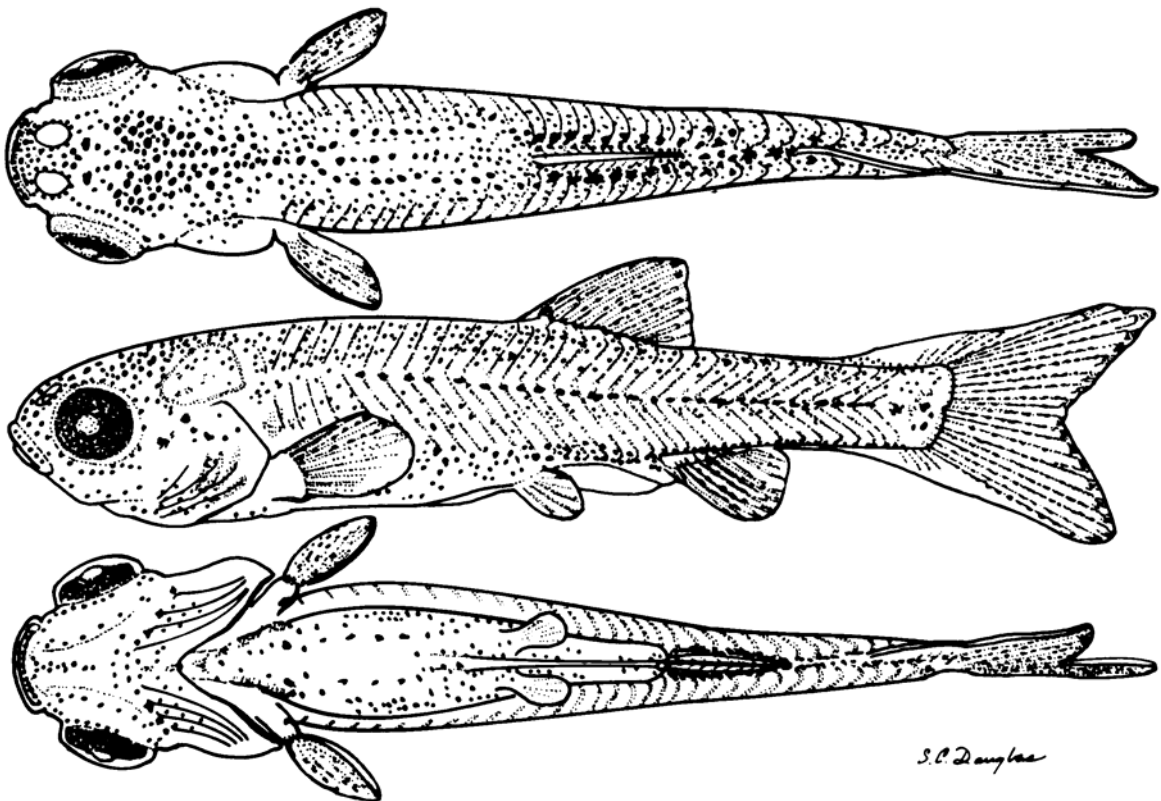


Figure 53. *Pimephales promelas* metalarva, 11.7 mm SL, 14.3 mm TL. (Collected in 1971 by Ichthyological Associates, Inc., Pottstown, Pennsylvania, locally from East Branch Perkiomen Creek. Modified from Snyder et al. 1977, Figure 13.)

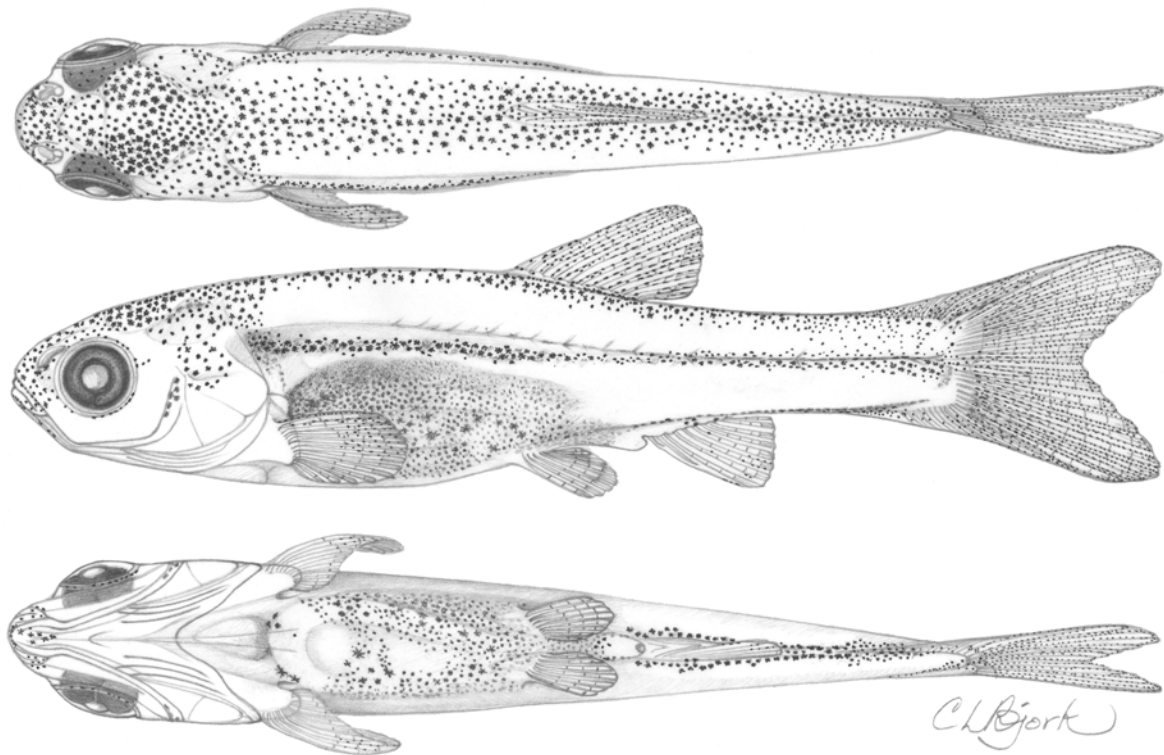


Figure 54. *Pimephales promelas* juvenile, recently transformed, 15.9 mm SL, 18.8 mm TL. (Collected in 1976 or 1977 from Yampa River between Dinosaur National Monument, Moffat County, and Hayden, Routt County, Colorado; from LFL #72877.)

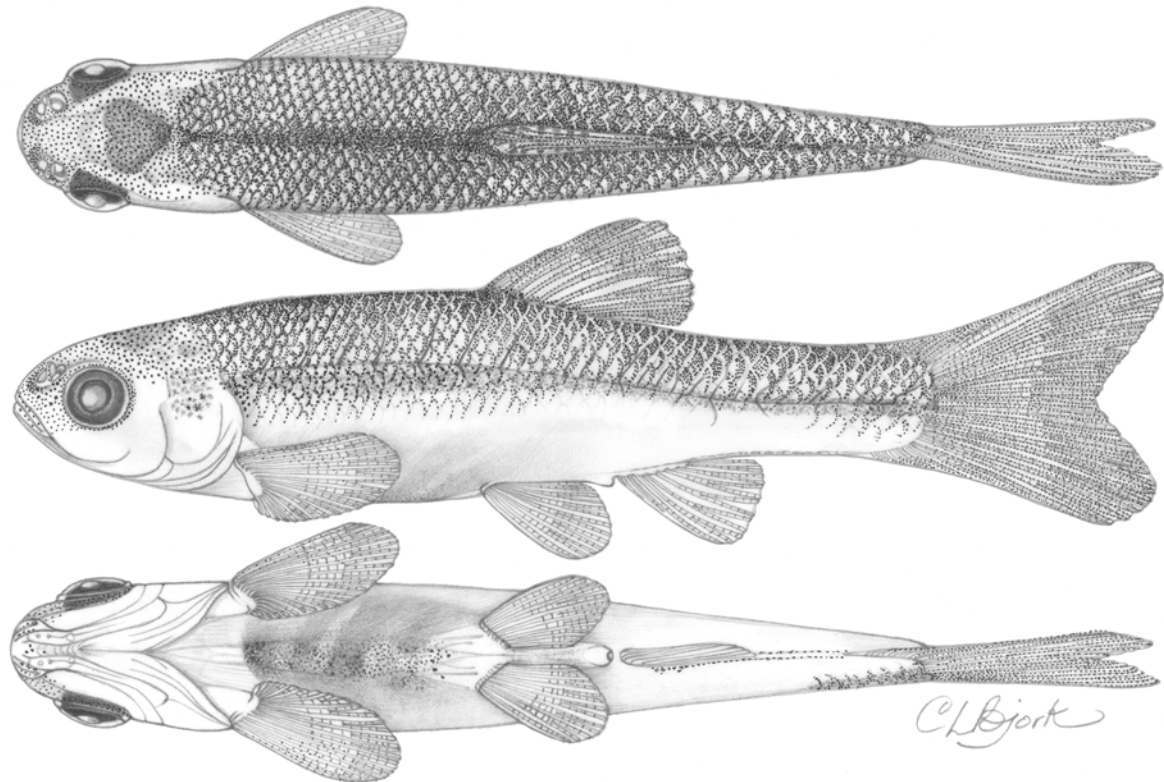


Figure 55. *Pimephales promelas* juvenile, 33.2 mm SL, 41.6 mm TL. (Collected in 1976 or 1977 from White River, Rio Blanco County, Colorado; from LFL #72860.)

Species Account – *Pimephales vigilax*, Bullhead Minnow

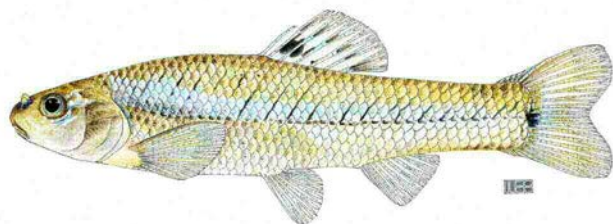


Figure 56. *Pimephales vigilax* adult (© W. H. Brandenburg).

Adult description: Usually 4–7.5 cm, up to 9 cm TL. Body stout. Rounded snout with small, typically subterminal to low terminal mouth, ending at or anterior to eye. S-shaped gut. Fins short, generally rounded; dorsal fin with a dark anterior spot, an often thickened last (or only) rudimentary ray, and an origin over or slightly before or after pelvic origin; dark caudal spot. Upper body scales smaller and crowded before dorsal fin, usually outlined or partially filled with pigment. Dorsal surface olive; lateral surface silvery, sometimes with black pigment above and below lateral-line pores and (or) a dusky to dark partial to full lateral band. Peritoneum silvery with dark speckles. (Also Table 22.)

Reproduction: Guarding, nest-spawning speleophil. Spawn in typically shallow, still to slowly flowing waters during late April to mid-September, usually late spring to early summer at 21–26 °C; mid-May to June in Middle Rio Grande. Breeding males have large nuptial tubercles on the snout, a fleshy dorsal pad behind a very dark head, dark outer pectoral-fin rays, and a generally dark body with a light ventro-lateral region and an orange vertical band below the dorsal fin. They excavate or clean and guard a cavity under a hard structure, mate with one or more females, and tend adhesive 1.0–1.4–1.6 mm diameter eggs laid in a single-layer cluster on the underside roof of the nest.

Young: Hatch in 4.5–6 d at 26–28 °C. Earliest larvae observed adhering to available substrates. Young feed mostly on bottom ooze.

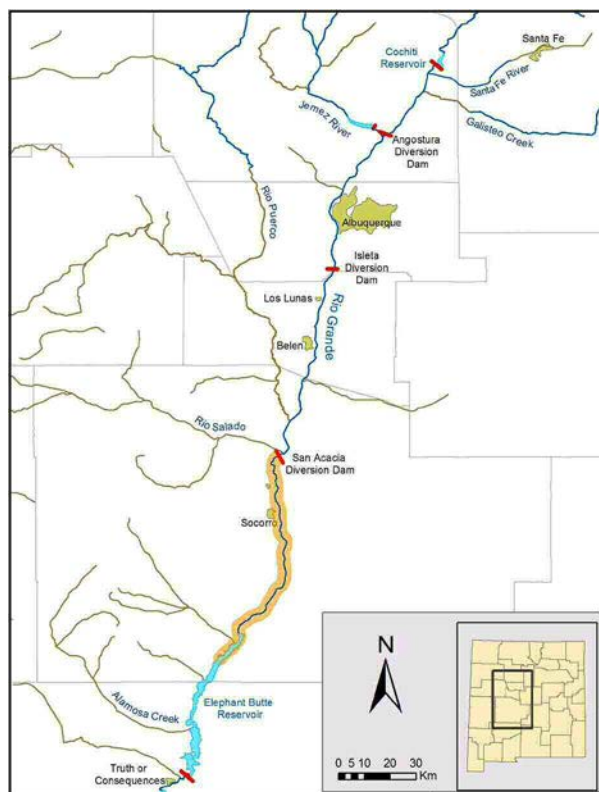


Figure 57. Distribution of *Pimephales vigilax* in the Middle Rio Grande, New Mexico, 2005–2015.

Table 22. Selected juvenile and adult meristics for *Pimephales vigilax*. (P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

| Character | Original | Literature | Character | Original | Literature |
|---------------------|--------------|------------|----------------------|-----------------------|----------------------|
| Dorsal-fin rays - P | 8(9) | (7)8(9) | Dorsal-fin rays - R | (1)2(3) | – |
| Anal-fin rays - P | (6)7 | 7(8) | Anal-fin rays - R | 1–2 | – |
| Caudal-fin rays - P | 19(20) | 19 | Caudal-fin rays - RD | (8–)10–11–12(13) | – |
| Pectoral-fin rays | (12)13–14–15 | 14–16 | Caudal-fin rays - RV | 9–10–11(12) | – |
| Pelvic-fin rays | (7)8 | 8(9) | Lateral scales | (39)40– <u>43</u> –44 | 37–39– <u>44</u> –49 |
| Vertebrae | – | 37–39 | Pharyngeal teeth | – | 0,4/4,0 |

Table 23. Size at onset of selected developmental events for *Pimephales vigilax*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses.)

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

References: Becker 1983; Clay 1975; Eddy and Underhill 1974; Hendrickson and Cohen 2015a; Heufelder and Fuiman 1982; Page and Ceas 1989; Page and Burr 1991; Parker 1964; Pflieger 1997; Pyron 2014; Simon 1998; Sublette et al. 1990; Taber 1969; Tiemann 2007; Trautman 1981.

Other larval descriptions: Fuiman et al. 1983, Heufelder and Fuiman 1982; Holland-Bartels et al. 1990; Scheidegger 1990; Taber 1969.

Table 24. Size at developmental interval (left) and gut phase (right) transitions for *Pimephales vigilax*. (See Figure 5 for phases of gut folding. Rare values in parentheses.)

| Transition to | mm SL | mm TL | Transition to | mm SL | mm TL |
|-----------------------|--------|-----------|-----------------------|------------------|-------|
| Flexion mesolarva | (5)6 | 6(7) | 2 - 90° bend | 12–13 | 14–15 |
| Postflexion mesolarva | (7)8 | 8 | 3 - Full loop | 16–17 | 20–21 |
| Metalarva | 9–10 | (10)11–12 | 4 - Partial crossover | (not applicable) | |
| Juvenile | (12)13 | 15(16) | 5 - Full | (not applicable) | |

Table 25. Summary of morphometrics and myomere counts by developmental phase for *Pimephales vigilax*. (See Figure 4 for abbreviations and methods of measurement and counting. Standard deviation [SD] of 0 represents a value < 0.5.)

| | Protolarvae (N = 9) | | | Flexion mesolarvae (N = 9) | | | Postflexion mesolarvae (N = 11) | | | Metalarvae (N = 13) | | | Juveniles (N = 31) | | |
|--------------------|---------------------|----------|---------|----------------------------|----------------|---------|---------------------------------|----------------|---------|---------------------|----------------|---------|--------------------|----------------|---------|
| | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range |
| SL, mm | 5 | 1 | 5–6 | 6 | 1 | 6–8 | 8 | 1 | 8–9 | 11 | 1 | 10–13 | 19 | 6 | 12–32 |
| TL, mm | 6 | 1 | 5–6 | 7 | 1 | 6–8 | 9 | 1 | 8–11 | 13 | 1 | 12–15 | 23 | 7 | 15–40 |
| <u>Lengths %SL</u> | | | | | | | | | | | | | | | |
| AS to AE | 3 | 1 | 3–4 | 4 | 0 | 4–4 | 4 | 0 | 4–5 | 5 | 1 | 4–6 | 6 | 1 | 5–7 |
| PE | 10 | 1 | 8–10 | 11 | 0 | 10–11 | 12 | 0 | 11–12 | 12 | 1 | 11–13 | 13 | 1 | 12–15 |
| OP1 | 19 | 1 | 18–19 | 21 | 1 | 20–23 | 24 | 0 | 23–24 | 25 | 1 | 24–26 | 25 | 1 | 23–26 |
| OP2 | | | | | | | 47 | 1 ^b | 46–48 | 49 | 1 | 48–50 | 49 | 1 | 48–51 |
| PY | 61 | 2 | 59–64 | 56 | 5 ^a | 53–60 | 45 | 2 | 42–48 | 53 | 2 | 51–59 | | | |
| OPAF | 48 | 5 | 41–56 | 40 | 2 | 37–44 | 46 | 2 | 43–49 | 48 | 1 ^d | 47–50 | | | |
| ODF | 38 | 1 | 37–40 | 41 | 2 | 38–44 | 50 | 1 | 48–51 | 50 | 1 | 48–51 | 49 | 1 | 47–52 |
| OD | | | | | | | 62 | 1 | 61–65 | 63 | 1 | 62–64 | 63 | 1 | 60–65 |
| ID | | | | | | | 68 | 1 | 67–70 | 67 | 1 | 65–69 | 66 | 1 | 63–69 |
| PV | 64 | 2 | 62–67 | 64 | 1 | 63–67 | 68 | 1 | 67–70 | 67 | 1 | 65–69 | 67 | 1 | 64–69 |
| OA | | | | | | | 68 | 1 ^c | 67–69 | 67 | 1 | 65–69 | 67 | 1 | 64–69 |
| IA | | | | | | | 75 | 1 ^c | 74–75 | 75 | 1 | 74–76 | 75 | 1 | 72–77 |
| AFC | | | | | | | 108 | 1 | 107–110 | 110 | 1 | 108–111 | 111 | 1 | 110–114 |
| PC | 104 | 1 | 104–105 | 105 | 1 | 105–107 | 111 | 2 | 108–113 | 117 | 2 | 114–121 | 121 | 2 | 118–126 |
| Y | 45 | 1 | 25–56 | 4 | 8 | 0–19 | | | | | | | | | |
| P1 | 13 | 2 | 8–16 | 13 | 1 | 12–16 | 11 | 1 | 11–12 | 12 | 1 | 11–14 | 16 | 2 | 12–21 |
| P2 | | | | | | | 3 | 2 | 0–6 | 7 | 1 | 5–9 | 11 | 2 | 8–17 |
| D | | | | | | | 16 | 1 | 15–18 | 19 | 1 | 18–20 | 21 | 1 | 19–25 |
| A | | | | | | | 9 | 1 ^a | 9–10 | 12 | 1 | 10–13 | 14 | 1 | 12–17 |
| <u>Depths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 11 | 1 | 10–12 | 11 | 0 | 11–12 | 13 | 0 | 12–13 | 14 | 1 | 13–15 | 15 | 1 | 13–17 |
| OP1 | 17 | 4 | 12–24 | 13 | 1 | 12–14 | 16 | 1 | 15–17 | 17 | 1 | 16–18 | 18 | 1 | 16–20 |
| OD | 12 | 1 | 11–13 | 12 | 1 | 11–15 | 15 | 1 | 14–16 | 17 | 1 | 16–19 | 20 | 2 | 17–24 |
| BPV | 8 | 1 | 6–9 | 8 | 1 | 7–9 | 10 | 1 | 9–11 | 12 | 1 | 11–14 | 15 | 1 | 13–17 |
| AMPM | 4 | 0 | 3–4 | 4 | 1 | 3–5 | 6 | 1 | 5–7 | 8 | 1 | 7–10 | 11 | 1 | 9–12 |
| Max. yolk | 10 | 5 | 3–17 | 0 | 1 | 0–2 | | | | | | | | | |
| <u>Widths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 11 | 0 | 11–12 | 12 | 1 | 11–13 | 13 | 0 | 13–14 | 14 | 1 | 13–15 | 14 | 1 | 13–15 |
| OP1 | 12 | 4 | 9–17 | 10 | 1 | 9–11 | 12 | 1 | 11–13 | 13 | 1 | 12–15 | 15 | 1 | 13–17 |
| OD | 6 | 1 | 5–7 | 6 | 0 | 5–7 | 8 | 1 | 7–10 | 11 | 1 | 9–13 | 13 | 2 | 10–16 |
| BPV | 4 | 0 | 4–5 | 5 | 0 | 5–6 | 7 | 1 | 6–7 | 8 | 0 | 7–9 | 10 | 1 | 8–12 |
| AMPM | 2 | 0 | 2–3 | 2 | 0 | 2–3 | 3 | 0 | 3–4 | 4 | 0 | 3–5 | 4 | 1 | 3–6 |
| Max. yolk | 11 | 5 | 3–18 | 1 | 1 | 0–3 | | | | | | | | | |
| <u>Myomeres</u> | | | | | | | | | | | | | | | |
| to PY | 23 | 1 | 22–24 | 21 | 1 ^a | 20–22 | | | | | | | | | |
| OPAF | 17 | 2 | 13–19 | 13 | 1 | 11–14 | 13 | 1 | 12–15 | 17 | 1 | 16–20 | | | |
| OP2 | | | | | | | 14 | 1 ^b | 14–16 | 15 | 0 | 15–16 | 15 | 1 ^c | 14–16 |
| ODF | 11 | 1 | 10–13 | 13 | 1 | 12–14 | 14 | 1 | 12–15 | 15 | 1 ^d | 14–15 | | | |
| OD | | | | | | | 16 | 1 | 14–16 | 15 | 1 | 15–16 | 15 | 0 ^e | 14–16 |
| PV | 24 | 1 | 23–25 | 25 | 1 | 23–26 | 25 | 1 | 24–26 | 25 | 0 | 24–25 | 24 | 0 ^e | 23–25 |
| Total | 38 | 1 | 37–38 | 38 | 1 | 37–39 | 38 | 0 | 37–38 | 37 | 1 | 37–39 | 37 | 0 ^e | 36–38 |
| After PV | 14 | 1 | 13–14 | 13 | 1 | 12–14 | 13 | 0 | 12–13 | 13 | 1 | 12–14 | 13 | 0 ^f | 12–14 |

^aN = 2. ^bN = 9. ^cN = 8. ^dN = 10. ^eN = 18. ^fN = 20.

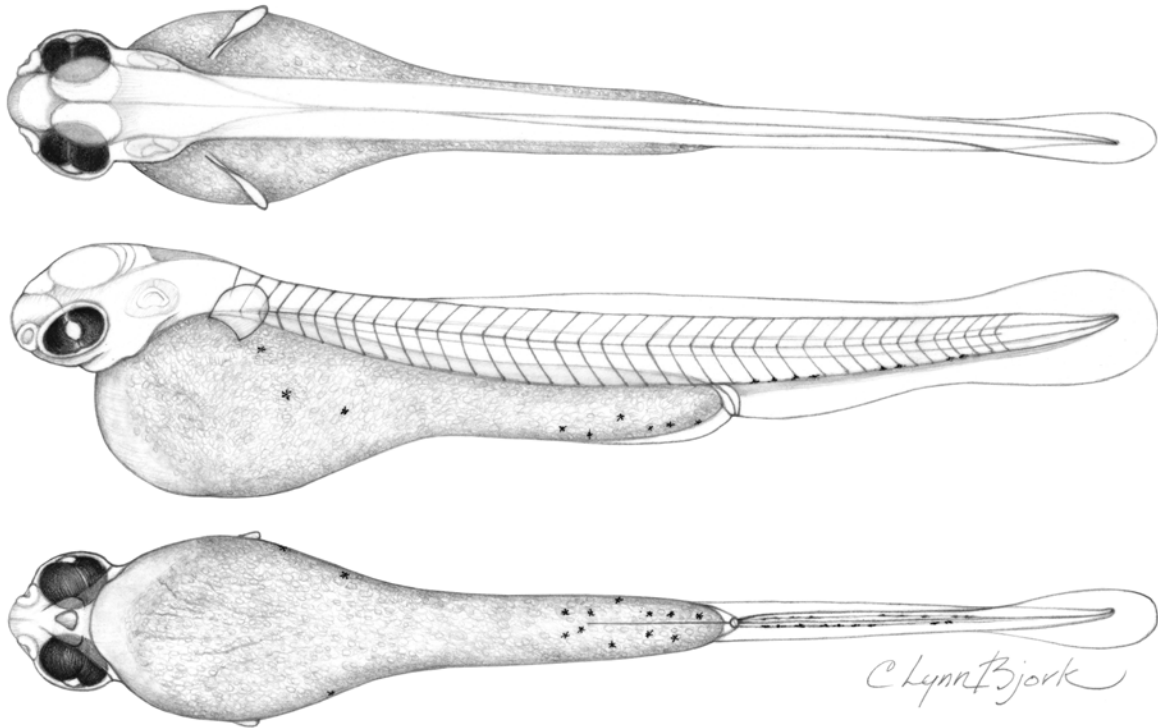


Figure 58. *Pimephales vigilax* protolarva, recently hatched, 4.6 mm SL, 4.8 mm TL. (Cultured in 2010 by Dexter National Fish Hatchery and Technology Center, New Mexico, with stock from Elephant Butte Reservoir, Rio Grande, Sierra County, New Mexico.)

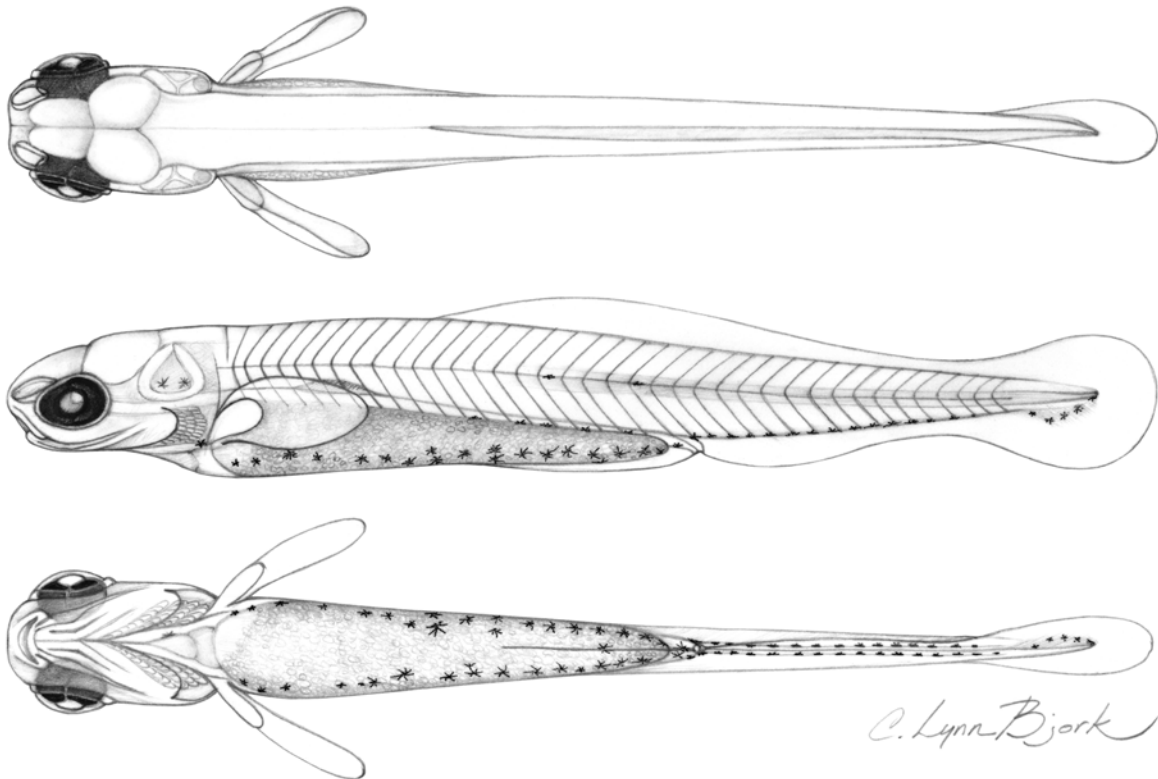


Figure 59. *Pimephales vigilax* protolarva, 5.5 mm SL, 5.8 mm TL. (Cultured in 2010 by Dexter National Fish Hatchery and Technology Center, New Mexico, with stock from Elephant Butte Reservoir, Rio Grande, Sierra County, New Mexico.)

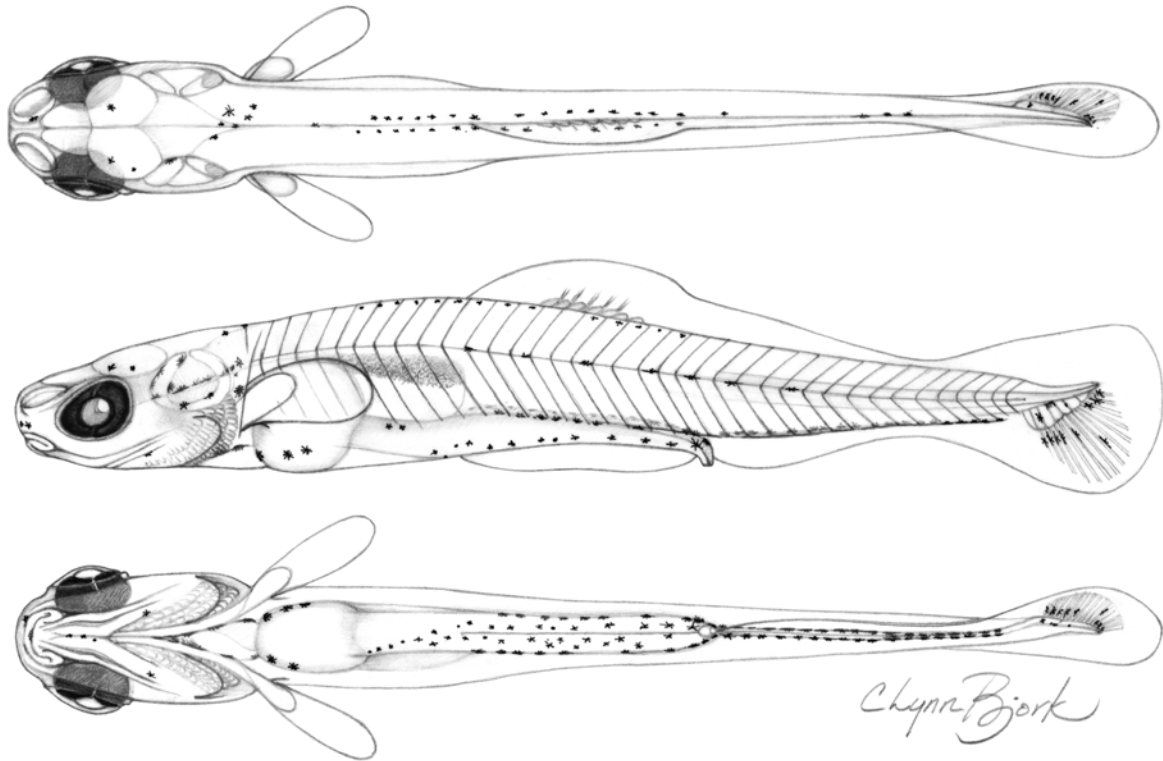


Figure 60. *Pimephales vigilax* flexion mesolarva, recently transformed, 6.8 mm SL, 7.2 mm TL. (Cultured in 2010 by Dexter National Fish Hatchery and Technology Center, New Mexico, with stock from Elephant Butte Reservoir, Rio Grande, Sierra County, New Mexico.)

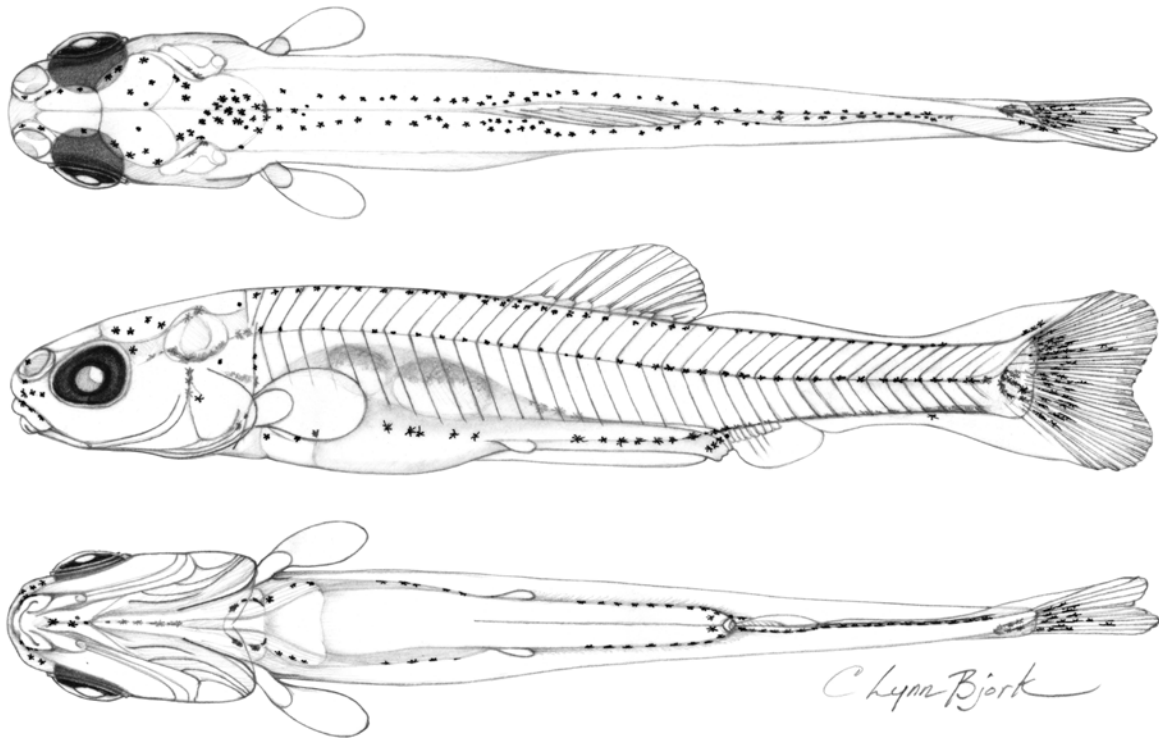


Figure 61. *Pimephales vigilax* postflexion mesolarva, 8.2 mm SL, 9.1 mm TL. (Cultured in 2010 by Dexter National Fish Hatchery and Technology Center, New Mexico, with stock from Elephant Butte Reservoir, Rio Grande, Sierra Co., New Mexico.)

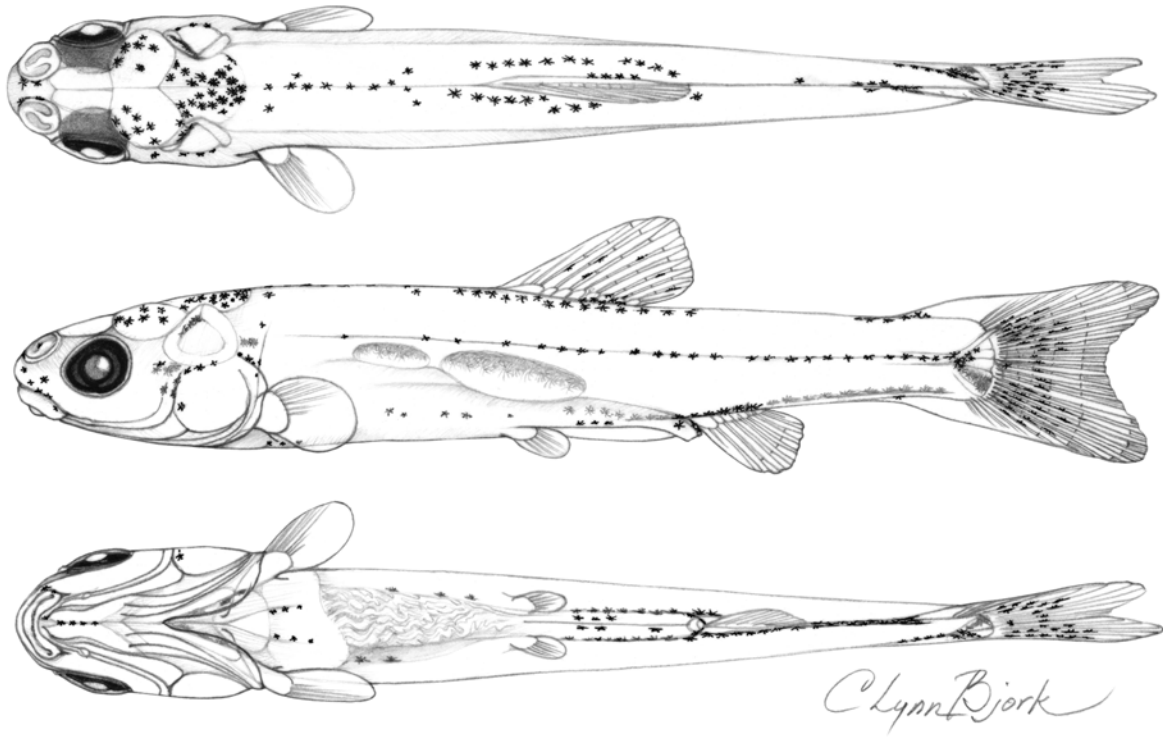


Figure 62. *Pimephales vigilax* metalarva, recently transformed, 10.2 mm SL, 11.8 mm TL. (Cultured in 2010 by Dexter National Fish Hatchery and Technology Center, New Mexico, with stock from Elephant Butte Reservoir, Rio Grande, Sierra County, New Mexico.)

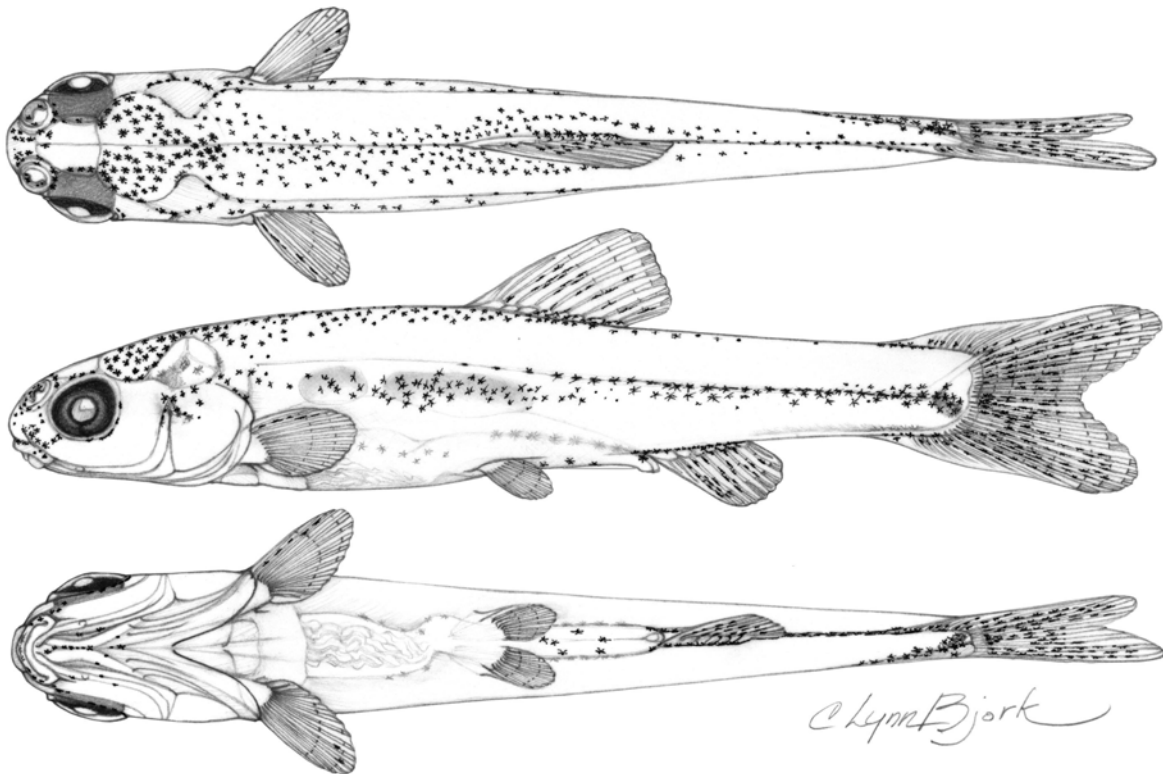


Figure 63. *Pimephales vigilax* metalarva, 12.6 mm SL, 14.9 mm TL. (Cultured in 2010 by Dexter National Fish Hatchery and Technology Center, New Mexico, with stock from Elephant Butte Reservoir, Rio Grande, Sierra County, New Mexico.)

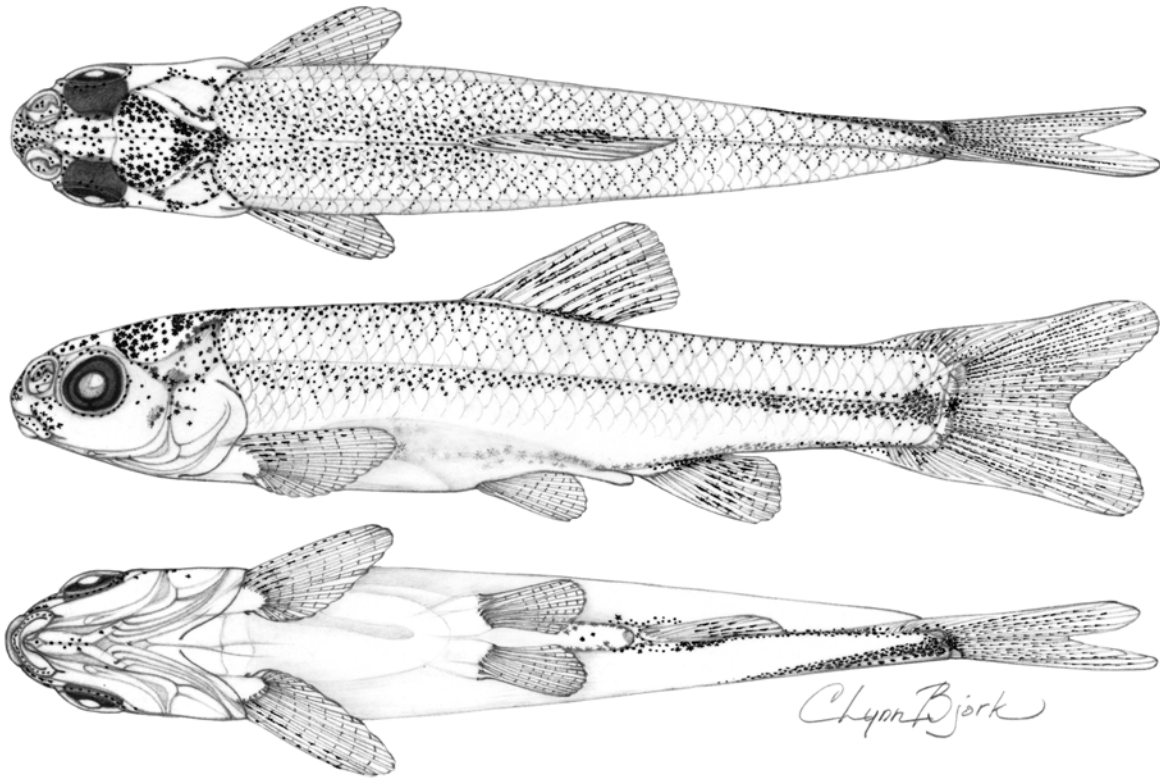


Figure 64. *Pimephales vigilax* juvenile, recently transformed, 17.3 mm SL, 21.2 mm TL. (Cultured in 2010 by Dexter National Fish Hatchery and Technology Center, New Mexico, with stock from Elephant Butte Reservoir, Rio Grande, Sierra County, New Mexico.)

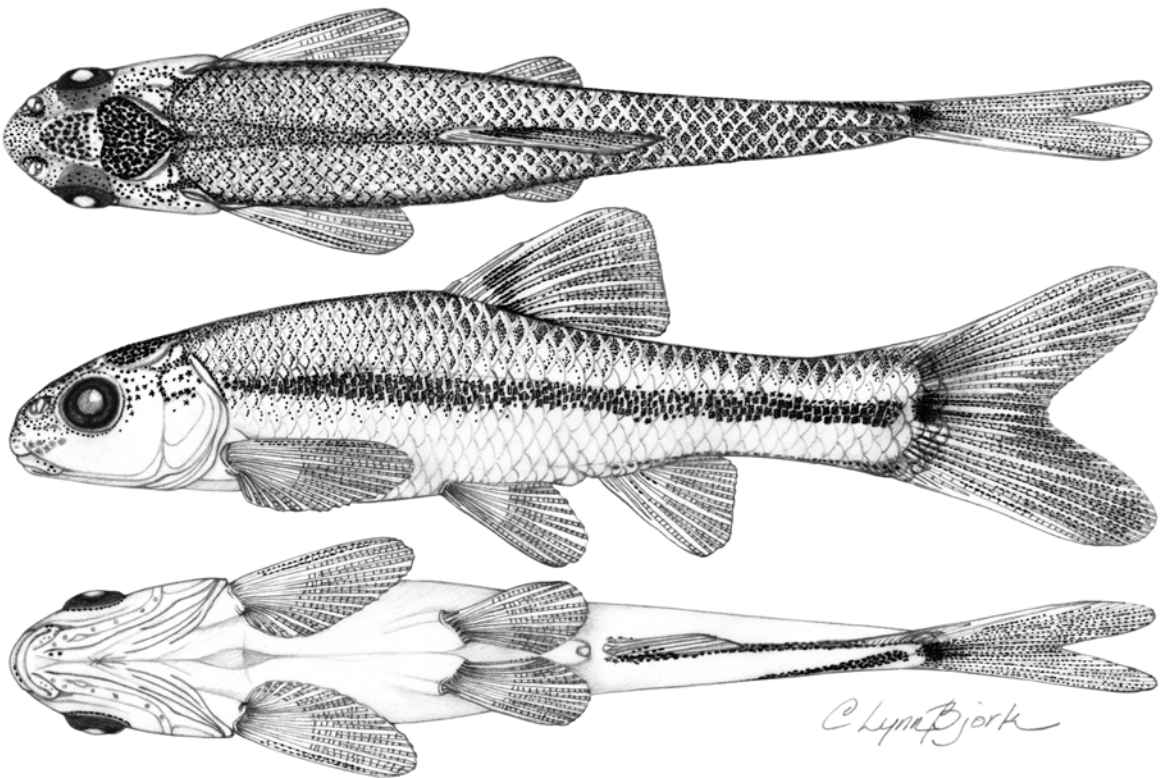


Figure 65. *Pimephales vigilax* juvenile, 30.2 mm SL, 38.0 mm TL. (Collected in 1989 from Canadian River near Logan, Quay County, New Mexico; from LFL #43011.)

Species Account – *Platygobio gracilis*, Flathead Chub

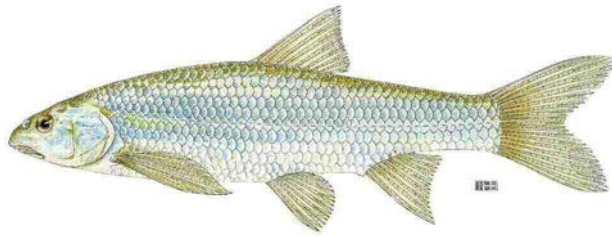


Figure 66. *Platygobio gracilis* adult (© W. H. Brandenburg).

Adult description: Usually 7–19 cm TL; 32 cm max. Body terete, long, and slender. Head broad, dorsally flat, and wedge shaped, with long pointed snout, small eyes, large flap-like narial septa, and a large, subterminal mouth with small barbel at each corner. But southwestern U.S. populations have more chubby bodies, conical heads, and rounded snouts. S-shaped gut; peritoneum silver with dark speckles. Pectoral, dorsal, and anal fins falcate; dorsal origin over or anterior to pelvic fin origin. Scales moderate in size with ~15 radii in posterior field. Back olive to tan, sides silver. (Also Table 26.)

Reproduction: Nonguarding, open-substrate litho-pelagophil. Mature by ages 1–4, mostly 2–3. Broadcast spawn in relatively shallow flowing waters (including high, declining spring, and stable low flows) from April to September at > 15 °C, but usually late May to August at 17–25 °C; late April to September in Middle Rio Grande. Males develop fine tubercles mostly over upper surfaces of head, anterior body, and pectoral fins, and usually no notable breeding colors, except sometimes a golden sheen over body with red-tinged fins. Water-hardened eggs are 1.8–2.9 mm diameter (means of 2.0–2.6 mm), non-adhesive, and semibouyant; may incubate and hatch while drifting in current or on, or in interstitial spaces of, the bottom.

Young: Hatch in 4 d at ~22 °C, 5–7 d at 20–22 °C. Larvae < 9 mm TL readily collected in drift nets. Growth and survival positively affected by flow recession or stability. Feed mostly on ostracods and cladocerans.

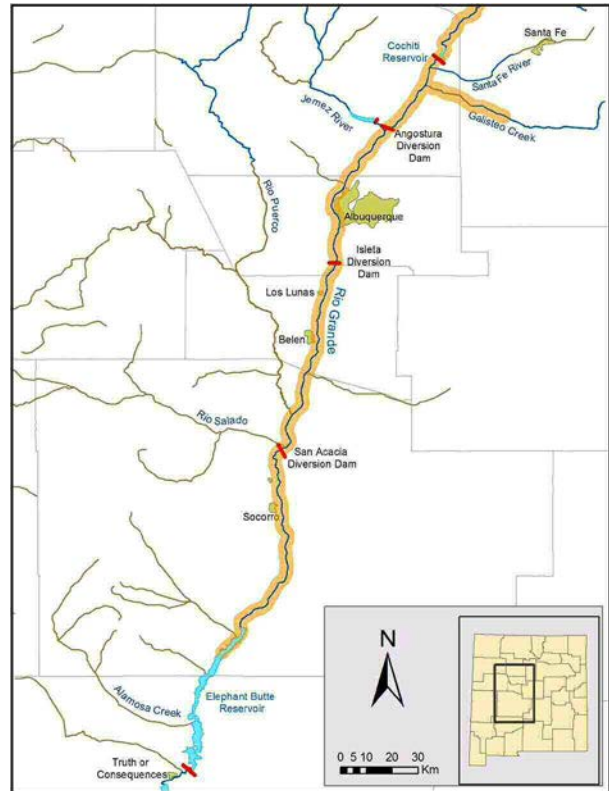


Figure 67. Distribution of *Platygobio gracilis* in the Middle Rio Grande, New Mexico, 2005–2015.

Table 26. Selected juvenile and adult meristics for *Platygobio gracilis*. (P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

| Character | Original | Literature | Character | Original | Literature |
|---------------------|-----------|----------------------------------|----------------------|------------|---------------------------|
| Dorsal-fin rays - P | 8 | (7)8(9) | Dorsal-fin rays - R | 2(3) | – |
| Anal-fin rays - P | 8 | (7)8(9) | Anal-fin rays - R | 1–2 | – |
| Caudal-fin rays - P | (18)19 | 19(20) | Caudal-fin rays - RD | (5–)7–8–10 | – |
| Pectoral-fin rays | 14–15(16) | 14–16–19(20) [<u>< 17*</u>] | Caudal-fin rays - RV | 7–8–9 | – |
| Pelvic-fin rays | (7)8 | (7)8(9) | Lateral scales | 43–48 | 42–59 [<u>< 50*</u>] |
| Vertebrae | – | 40–47 [40–42(43)*] | Pharyngeal teeth | – | 2,4/4,2 |

* Usual values for southwestern U.S. populations described as subspecies *Hybopsis gracilis gulonella* by Olund and Cross (1961).

Table 27. Size at onset of selected developmental events for *Platygobio gracilis*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses.)

| Event or structure | Onset or formation | | Fin rays or scales | First formed | | Last formed | |
|--------------------|--------------------|----------------|--------------------|--------------|----------|-------------|------------|
| | mm SL | mm TL | | mm SL | mm TL | mm SL | mm TL |
| Hatched | 5–6(7) | 5–7 | Dorsal - P | (7)8–9 | (8)9–10 | (9)10 | 11 |
| Eyes pigmented | * | * | Anal - P | (8)9–10 | (9)10–11 | (9)10 | 11 |
| Yolk assimilated | (7)8–9 | (7)8–9(10) | Caudal - P | 7(8) | (7)8 | (8)9(10) | (9)10(11) |
| Finfold absorbed | (13–)15–16(–18) | (17)19–20(–22) | Caudal - R | (8)9–10 | (9–)11 | 13–14(–18) | 16–17(–22) |
| Pectoral-fin buds | * | * | Pectoral | 9–10 | 11 | 13–16(–18) | 16–19(–22) |
| Pelvic-fin buds | (8)9(10) | 9–10(11) | Pelvic | 9–10 | 11–12 | (12)13–14 | (14–)16–17 |
| * before hatching | | | Scales | 18–19 | 22–24 | 19–20 | 24–25 |

References: Baxter and Simon 1970; Beckman 1952; Bestgen, K., (Colo. St. Univ. Larval Fish Lab.) pers. comm. 2017; Bestgen et al. 2016; Clay 1975; Gould 1985; Haworth 2015; Haworth and Bestgen 2017; Haworth, M., (Colo. St. Univ. Larval Fish Lab.) pers. comm. 2017; Hendrickson and Cohen 2015b; Moore 1968; Olund and Cross 1961; Page and Burr 1991; Pflieger 1997; Rahel and Thel 2004; Scott and Crossman 1973; Simon 1998; Sublette et al. 1990; Woodling 1985. **Other larval descriptions:** none.

Table 28. Size at developmental interval (left) and gut phase (right) transitions for *Platygobio gracilis*. (See Figure 5 for phases of gut folding. Rare values in parentheses.)

| Transition to | mm SL | mm TL | Transition to | mm SL | mm TL |
|-----------------------|-----------------|-----------------|-----------------------|------------------|-------|
| Flexion mesolarva | 7(8) | (7)8 | 2 - 90° bend | 10–11 | 12–13 |
| Postflexion mesolarva | (8)9(10) | (9)10(11) | 3 - Full loop | 17–18 | 21–22 |
| Metalarva | (9)10 | 11(12) | 4 - Partial crossover | (not applicable) | |
| Juvenile | (13–)15–16(–18) | (17–)19–20(–22) | 5 - Full | (not applicable) | |

Table 29. Summary of morphometrics and myomere counts by developmental phase for *Platygobio gracilis*. (See Figure 4 for abbreviations and methods of measurement and counting. Standard deviation [SD] of 0 represents a value < 0.5.)

| | Protolarvae (N = 13) | | | Flexion mesolarvae (N = 9) | | | Postflexion mesolarvae (N = 8) | | | Metalarvae (N = 14) | | | Juveniles (N = 20) | | |
|--------------------|----------------------|----------------|----------|----------------------------|----------------|----------|--------------------------------|----------------|----------|---------------------|----------------|----------|--------------------|----------------|----------|
| | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range |
| SL, mm | 6 | 1 | 5– 8 | 8 | 1 | 7– 10 | 9 | 1 | 8– 10 | 13 | 2 | 9– 18 | 24 | 7 | 13– 40 |
| TL, mm | 7 | 1 | 5– 8 | 9 | 1 | 7– 11 | 10 | 1 | 9– 11 | 15 | 3 | 11– 22 | 30 | 9 | 17– 49 |
| <u>Lengths %SL</u> | | | | | | | | | | | | | | | |
| AS to AE | 4 | 1 | 3– 5 | 5 | 1 | 3– 6 | 5 | 1 | 4– 7 | 6 | 1 | 5– 8 | 7 | 1 | 6– 8 |
| PE | 10 | 1 | 9– 11 | 10 | 1 | 9– 12 | 12 | 1 | 10– 14 | 13 | 1 | 11– 15 | 13 | 1 | 12– 14 |
| OP1 | 18 | 1 | 16– 21 | 21 | 1 | 20– 22 | 24 | 2 | 21– 27 | 27 | 1 | 25– 30 | 26 | 1 | 24– 28 |
| OP2 | | | | | | | 49 | 1 ^c | 47– 50 | 52 | 2 | 48– 54 | 51 | 2 | 48– 54 |
| PY | 65 | 2 ^a | 63– 68 | 55 | 6 ^b | 49– 64 | 38 | 2 | 36– 42 | 50 | 7 | 39– 63 | | | |
| OPAF | 44 | 8 | 33– 57 | 36 | 1 | 34– 38 | 49 | 1 | 48– 52 | 49 | 1 ^f | 47– 51 | | | |
| ODF | 45 | 2 | 40– 49 | 46 | 2 | 43– 49 | 51 | 1 ^d | 51– 52 | 50 | 1 | 48– 52 | 49 | 2 | 45– 52 |
| OD | | | | | | | 61 | 1 ^d | 59– 62 | 62 | 1 | 60– 65 | 61 | 1 | 58– 64 |
| ID | | | | | | | 71 | 2 | 69– 74 | 71 | 2 | 67– 74 | 68 | 2 | 64– 70 |
| PV | 68 | 1 | 67– 70 | 69 | 1 | 67– 69 | 70 | 2 ^c | 68– 72 | 70 | 2 | 68– 73 | 68 | 1 | 65– 71 |
| OA | | | | | | | 81 | ^e | 81 | 80 | 1 | 77– 82 | 79 | 1 | 76– 82 |
| IA | | | | | | | 110 | 1 | 108– 111 | 113 | 2 | 110– 116 | 115 | 1 | 113– 118 |
| AFC | | | | | | | 111 | 2 | 108– 116 | 122 | 4 | 114– 127 | 125 | 1 | 123– 128 |
| PC | 105 | 1 | 104– 107 | 107 | 1 | 106– 109 | | | | | | | | | |
| Y | 43 | 15 | 0– 55 | 9 | 9 | 0– 24 | | | | | | | | | |
| P1 | 9 | 3 | 4– 14 | 13 | 1 | 12– 14 | 14 | 1 | 13– 15 | 17 | 2 | 15– 22 | 20 | 2 | 17– 22 |
| P2 | | | | | | | 3 | 2 | 0– 6 | 10 | 2 | 5– 13 | 14 | 1 | 11– 18 |
| D | | | | | | | 12 | 1 ^d | 11– 14 | 19 | 2 | 16– 23 | 22 | 1 | 20– 25 |
| A | | | | | | | 12 | ^e | 12 | 15 | 2 | 11– 18 | 18 | 1 | 16– 20 |
| <u>Depths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 12 | 1 | 11– 14 | 13 | 0 | 12– 14 | 14 | 1 | 13– 14 | 15 | 1 | 13– 17 | 16 | 1 | 14– 17 |
| OP1 | 16 | 4 | 12– 24 | 14 | 1 | 13– 15 | 16 | 1 | 14– 17 | 19 | 1 | 17– 21 | 20 | 1 | 18– 21 |
| OD | 12 | 1 | 9– 14 | 11 | 1 | 10– 12 | 12 | 1 | 11– 13 | 17 | 2 | 15– 20 | 21 | 1 | 19– 23 |
| BPV | 7 | 1 | 6– 8 | 8 | 0 | 7– 8 | 9 | 1 | 8– 10 | 11 | 1 | 9– 14 | 14 | 1 | 13– 16 |
| AMPM | 4 | 1 | 3– 4 | 4 | 0 | 3– 4 | 5 | 1 | 5– 6 | 8 | 1 | 7– 10 | 10 | 1 | 9– 11 |
| Max. yolk | 11 | 6 | 0– 21 | 1 | 1 | 0– 4 | | | | | | | | | |
| <u>Widths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 12 | 1 | 10– 14 | 13 | 1 | 13– 15 | 15 | 1 | 14– 17 | 17 | 1 | 16– 19 | 17 | 1 | 16– 18 |
| OP1 | 12 | 4 | 7– 22 | 11 | 1 | 9– 12 | 12 | 1 | 11– 13 | 16 | 1 | 14– 19 | 18 | 1 | 16– 19 |
| OD | 7 | 1 | 5– 8 | 6 | 1 | 5– 7 | 7 | 1 | 6– 9 | 11 | 2 | 8– 14 | 15 | 1 | 13– 18 |
| BPV | 4 | 1 | 4– 5 | 4 | 0 | 4– 5 | 5 | 0 | 5– 6 | 7 | 1 | 6– 9 | 10 | 1 | 8– 12 |
| AMPM | 3 | 0 | 2– 3 | 2 | 0 | 2– 3 | 3 | 0 | 2– 4 | 4 | 0 | 3– 5 | 4 | 1 | 3– 6 |
| Max. yolk | 13 | 6 | 0– 22 | 2 | 2 | 0– 6 | | | | | | | | | |
| <u>Myomeres</u> | | | | | | | | | | | | | | | |
| to PY | 25 | 1 ^a | 24– 27 | 21 | 3 ^b | 18– 26 | | | | | | | | | |
| OPAF | 14 | 3 | 10– 20 | 10 | 1 | 9– 12 | 10 | 1 | 9– 11 | 16 | 4 | 10– 22 | | | |
| OP2 | | | | | | | 16 | 1 ^c | 15– 17 | 17 | 1 | 15– 18 | 17 | 1 ^g | 16– 18 |
| ODF | 14 | 2 | 12– 17 | 15 | 1 | 14– 18 | 16 | 1 | 14– 17 | 15 | 1 ^f | 14– 16 | | | |
| OD | | | | | | | 17 | 1 ^d | 15– 18 | 16 | 1 | 15– 17 | 16 | 1 ^g | 15– 17 |
| PV | 27 | 1 | 26– 29 | 28 | 1 | 26– 29 | 28 | 1 | 27– 29 | 28 | 1 | 26– 29 | 27 | 1 ^g | 26– 28 |
| Total | 40 | 1 | 39– 41 | 41 | 1 | 39– 43 | 41 | 2 | 39– 43 | 40 | 1 | 39– 41 | 40 | 0 ^g | 39– 40 |
| After PV | 13 | 1 | 12– 14 | 13 | 1 | 12– 14 | 13 | 1 | 11– 14 | 12 | 1 | 12– 14 | 12 | 1 ^g | 11– 13 |

^aN = 12. ^bN = 5. ^cN = 7. ^dN = 6. ^eN = 1. ^fN = 8. ^gN = 10.

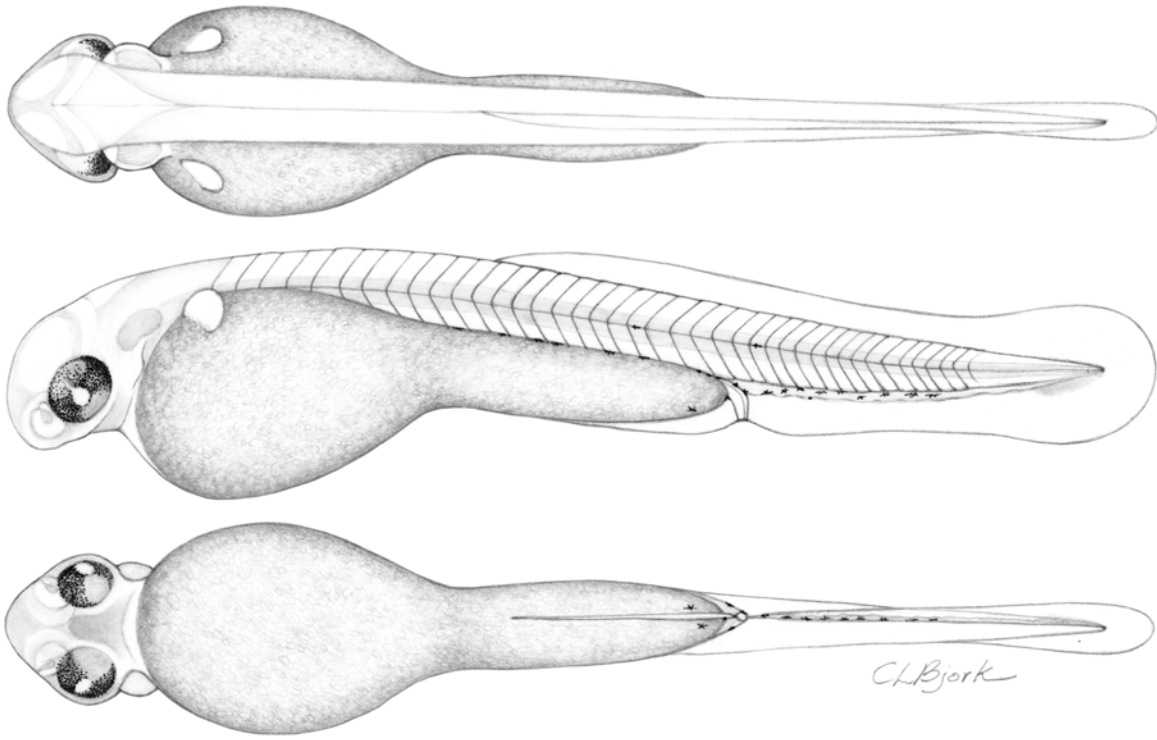


Figure 68. *Platygobio gracilis* protolarva, recently hatched, 5.8 mm SL, 6.1 mm TL. (Cultured in 2009 at Colorado State University by Larval Fish Laboratory with stock from Fountain Creek, El Paso County, Colorado.)

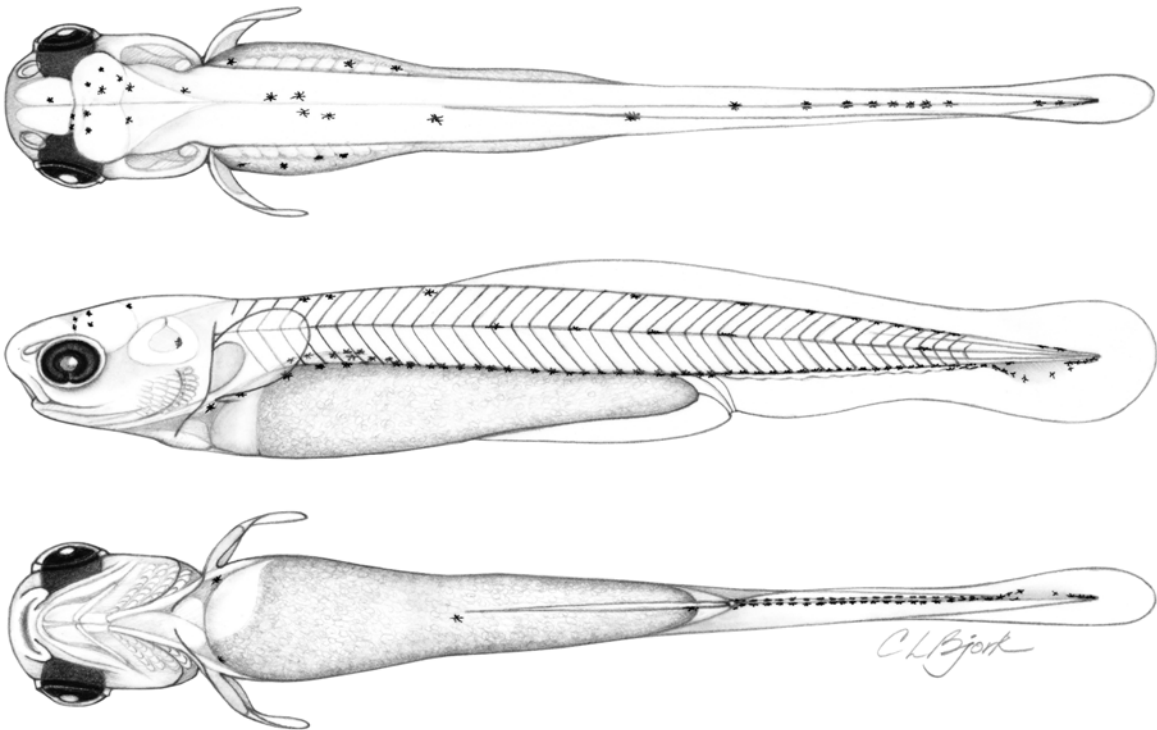


Figure 69. *Platygobio gracilis* protolarva, 7.0 mm SL, 7.4 mm TL. (Cultured in 2009 at Colorado State University by Larval Fish Laboratory with stock from Fountain Creek, El Paso County, Colorado.)

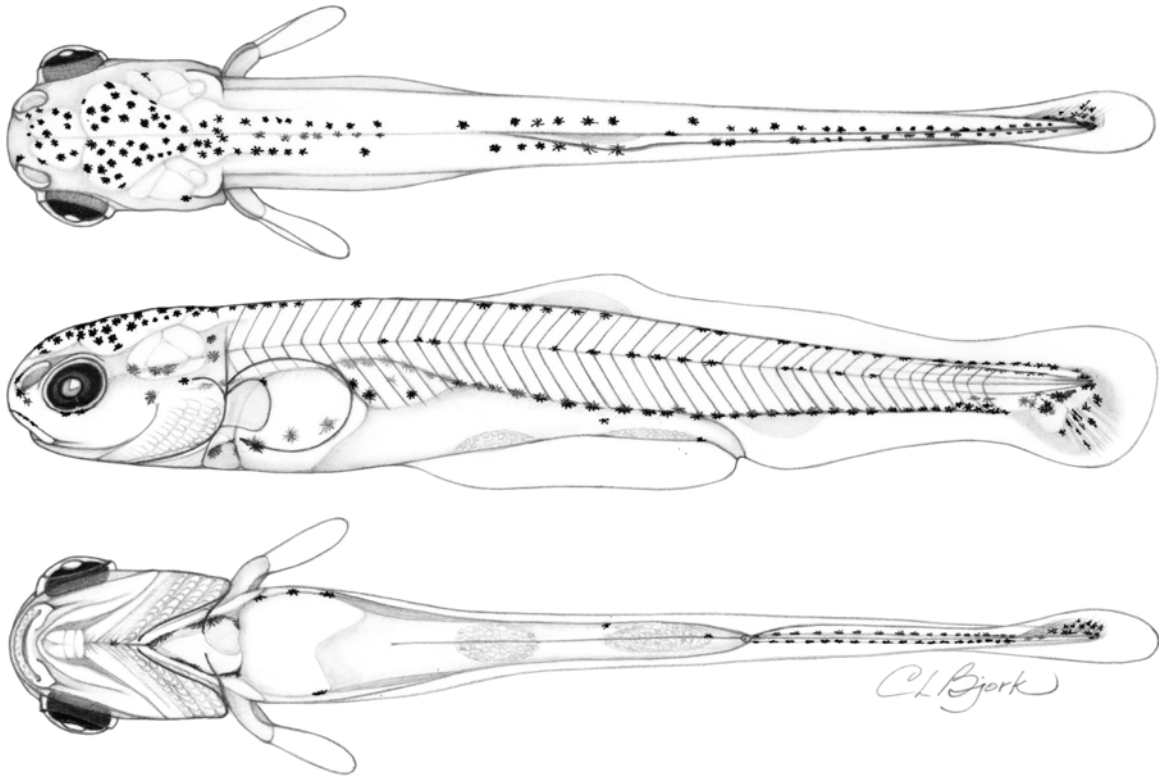


Figure 70. *Platygobio gracilis* flexion mesolarva, recently transformed, 8.5 mm SL, 9.1 mm TL. (Cultured in 2009 at Colorado State University by Larval Fish Laboratory with stock from Fountain Creek, El Paso County, Colorado.)

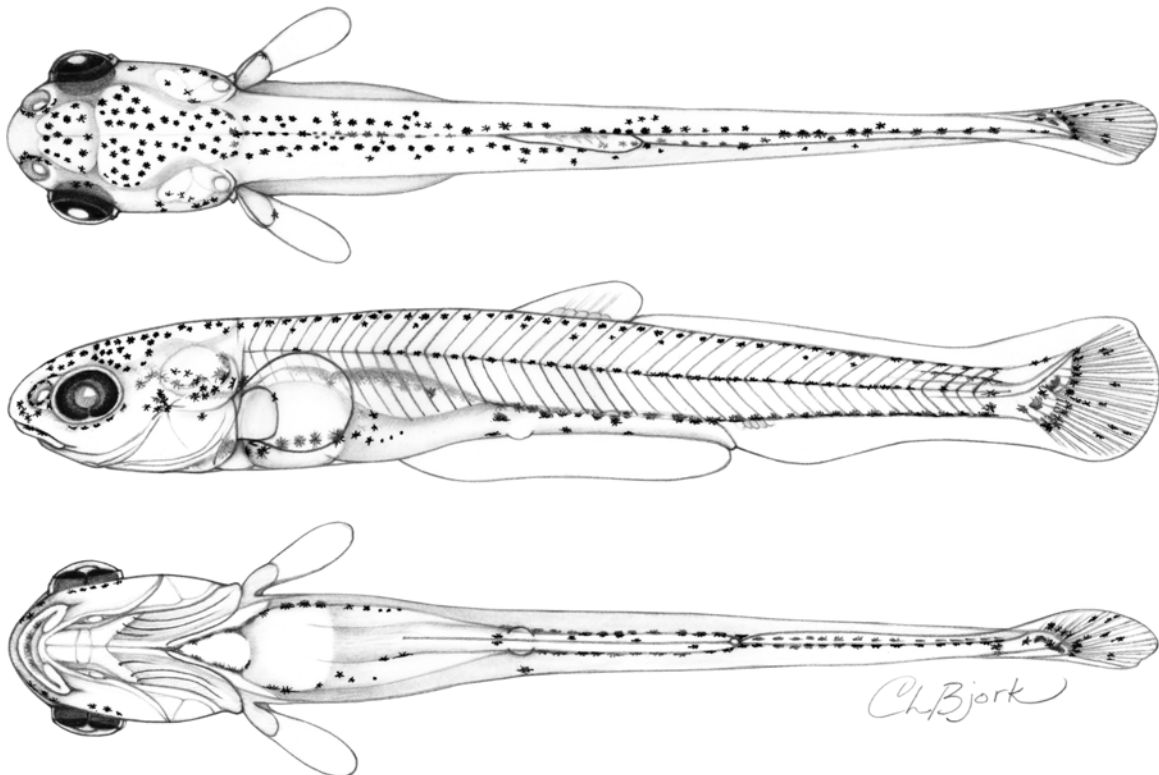


Figure 71. *Platygobio gracilis* postflexion mesolarva, 9.9 mm SL, 10.8 mm TL. (Cultured in 2009 at Colorado State University by Larval Fish Laboratory with stock from Fountain Creek, El Paso Co., Colorado.)

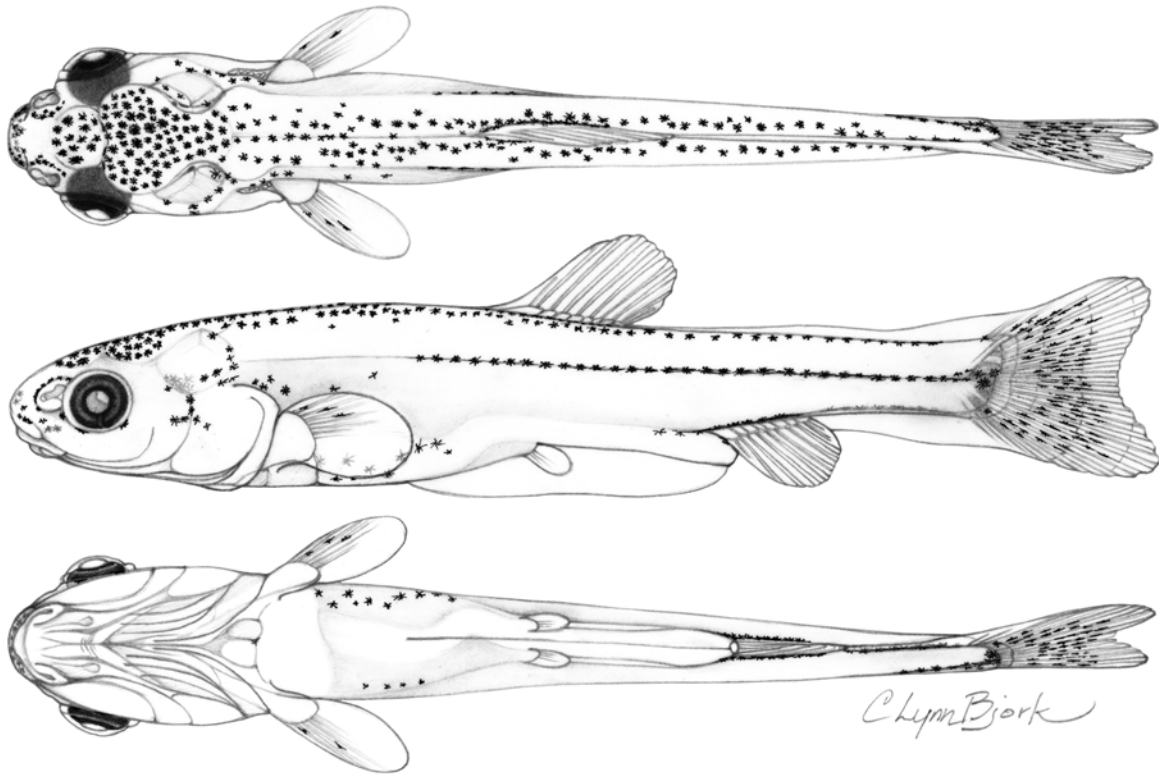


Figure 72. *Platygobio gracilis* metalarva, recently transformed, 11.3 mm SL, 12.9 mm TL. (Cultured in 2010 by Dexter National Fish Hatchery and Technology Center, New Mexico, with stock from Lower San Juan Drain outfall to Rio Grande, Sandoval County, New Mexico.)

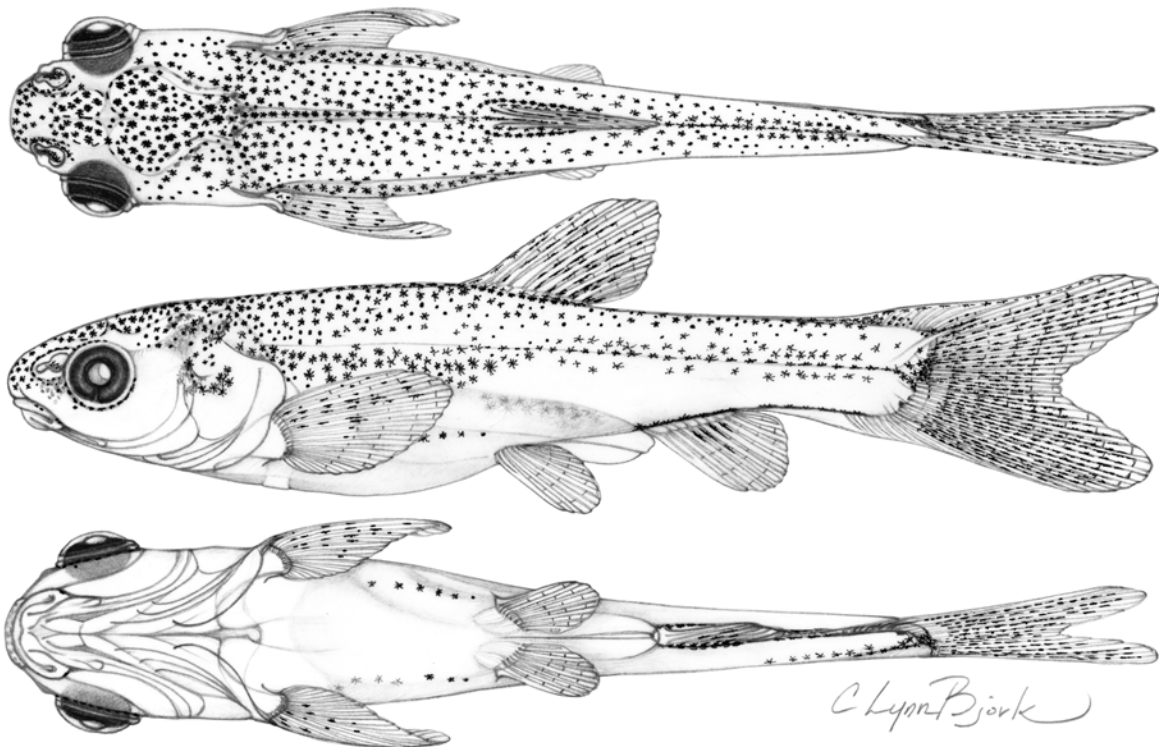


Figure 73. *Platygobio gracilis* metalarva, 13.0 mm SL, 16.2 mm TL. (Cultured in 2010 by Dexter National Fish Hatchery and Technology Center, New Mexico, with stock from Lower San Juan Drain outfall to Rio Grande, Sandoval County, New Mexico.)

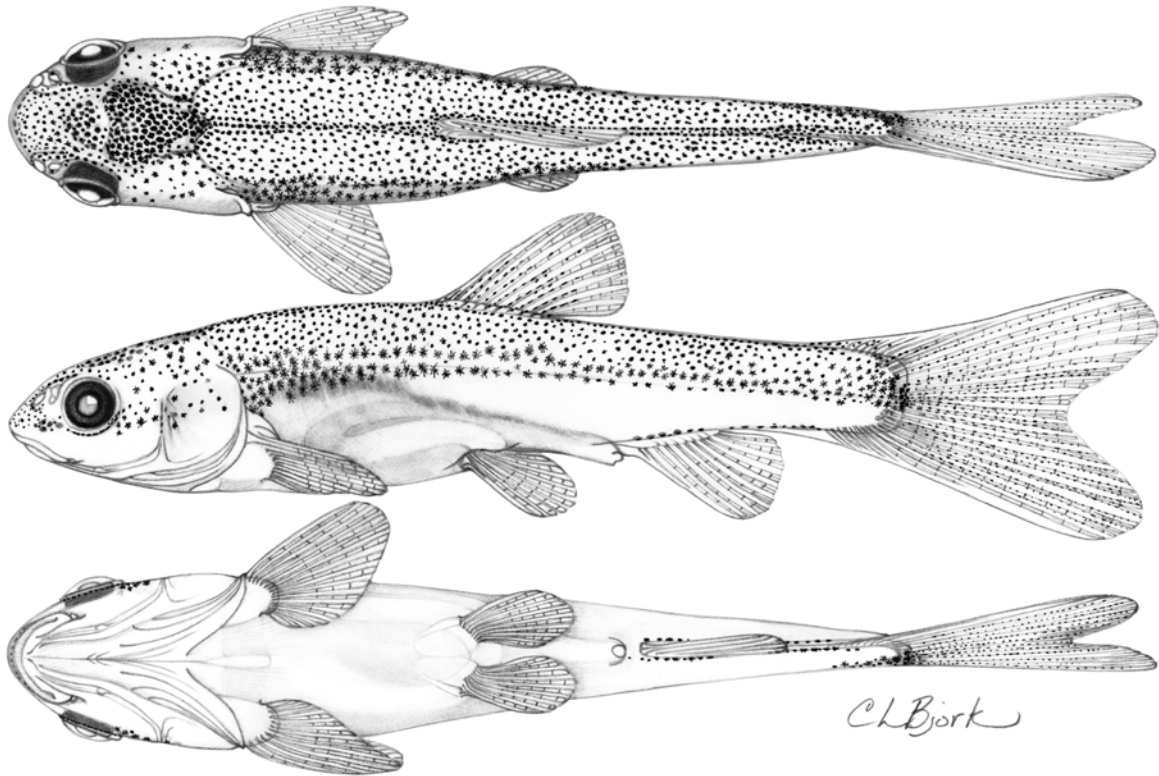


Figure 74. *Platygobio gracilis* juvenile, recently transformed, 19.0 mm SL, 24.2 mm TL. (Collected in 2006 from Purgatoire River, Las Animas County, Colorado; from LFL #99727.)

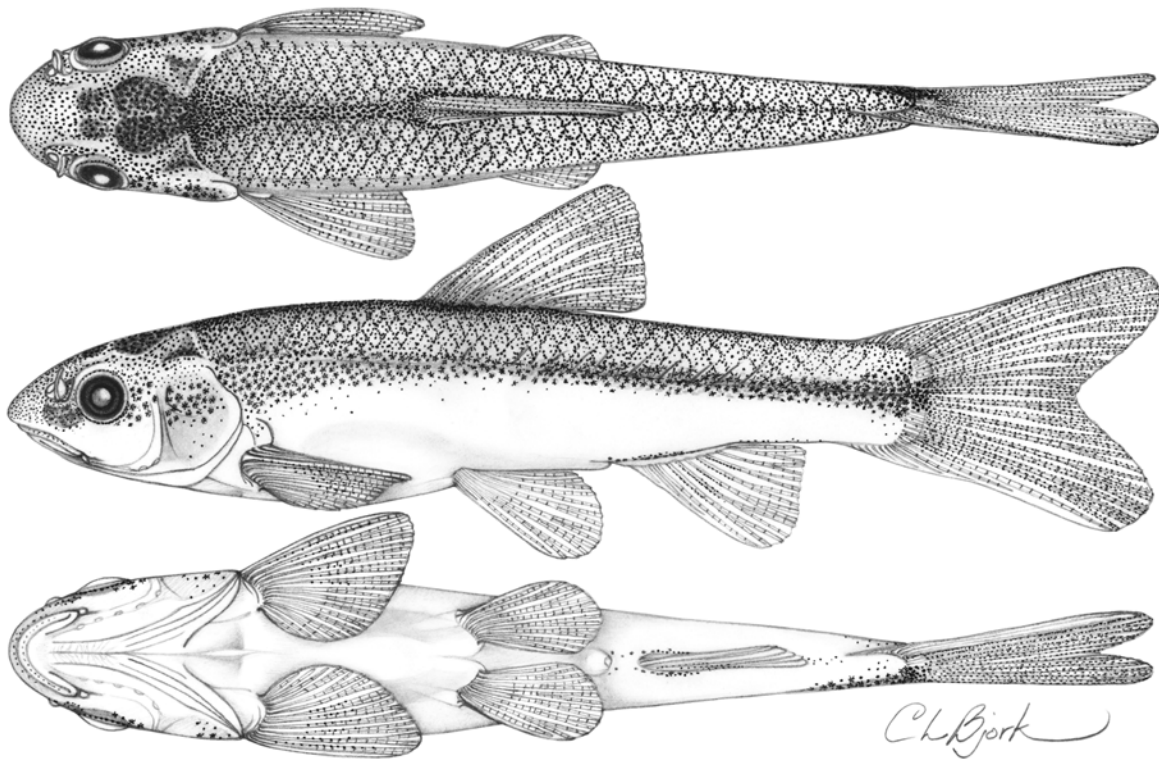


Figure 75. *Platygobio gracilis* juvenile, 32.2 mm SL, 40.1 mm TL. (Collected in 2001 from Rio Grande, Conejos County, Colorado; from LFL #80270.)

Species Account – *Rhinichthys cataractae*, Longnose Dace

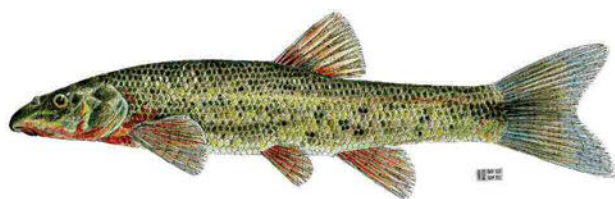


Figure 76. *Rhinichthys cataractae* adult
(© W. H. Brandenburg).

Adult description: Usually 7.5–9 cm, but up to 15 cm TL. Body moderately streamlined, elongate. Head conical or triangular; long, bulbous snout overhanging frenum and nearly horizontal, subterminal to inferior mouth. Mouth ends with small, often concealed barbels before small, highly positioned eyes. Dorsal fin base with dash of dark pigment and origin well behind that of pelvics. Gut S-shaped; peritoneum speckled. Scales small. Brown to olive dorsally and laterally, often mottled or speckled, with a dark caudal spot; silver to white below; dusky lateral band on snout and body of smaller fish. (Also, Table 30.)

Reproduction: Non-guarding, open substrate lithopelagophils or lithophils, but males may guard spawning area. Usually mature at age 2. Spawn mid-spring to early summer at 11–19°C, late May to early September in Middle Rio Grande. Spawn in swift currents over riffles or wave-swept shorelines, rarely in nests of other cyprinids. Breeding males tuberculated on top of head and orange-red at corners of mouth, sides of head, and bases of anal and paired fins (faint or absent in western subspecies). Water-hardened eggs demersal, adhesive, and 2.0–2.1 (orig. data) or 2.1–2.7 (eastern U.S.) mm diameter.

Young: Hatch in 3–10 d at 15–24°C; absorb yolk in ~7 d. Found mostly in near-shore, low-velocity habitats (e.g., backwaters, embayments) in mid-water column; remain pelagic for several weeks to 4 months before moving to benthic habitats in swifter water.

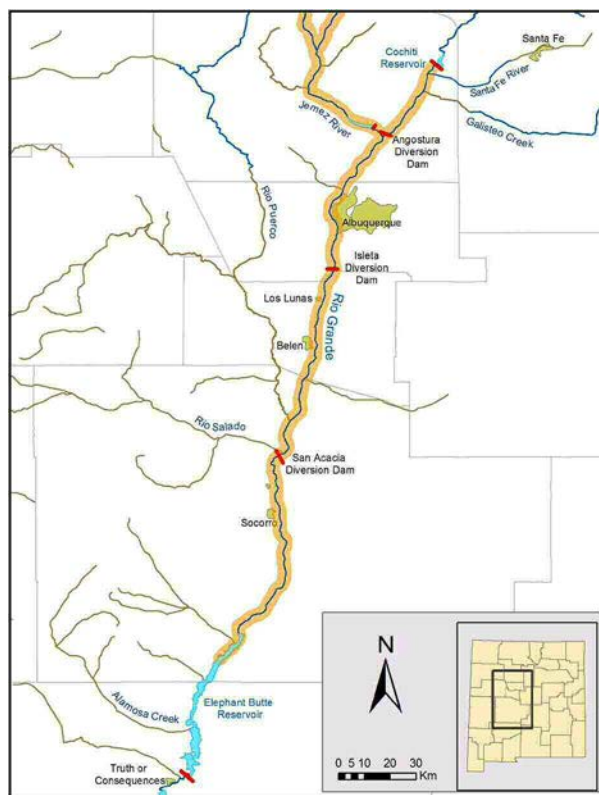


Figure 77. Distribution of *Rhinichthys cataractae* in the Middle Rio Grande, New Mexico, 2005–2015.

Table 30. Selected juvenile and adult meristics for *Rhinichthys cataractae*. (P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Pharyngeal teeth given as left outer row, inner row/right inner row, outer row. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

| Character | Original | Literature | Character | Original | Literature |
|---------------------|-------------------|----------------------|----------------------|-------------------|--------------------|
| Dorsal-fin rays - P | 8 | 7–8–9 | Dorsal-fin rays - R | <u>2</u> –3 | – |
| Anal-fin rays - P | 7 | (6)7(–9) | Anal-fin rays - R | (1) <u>2</u> –3 | – |
| Caudal-fin rays - P | (18)19(20) | 19 | Caudal-fin rays - RD | 7–8(–10) | – |
| Pectoral-fin rays | 12– <u>13</u> –14 | 12–13–14–15 | Caudal-fin rays - RV | 7–8(9) | – |
| Pelvic-fin rays | 8(9) | 7–8(9) | Lateral scales | 62– <u>64</u> –69 | (55–)58–61–72(–77) |
| Vertebrae | – | 37– <u>38</u> –40–42 | Pharyngeal teeth | – | (1)2,4/4,2(–0) |

Table 31. Size at onset of selected developmental events for *Rhinichthys cataractae*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses. Bracketed data from descriptions for eastern U.S. populations where larvae were notably larger.)

| Event or structure | Onset or formation | | Fin rays or scales | First formed | | Last formed | |
|--------------------|--------------------|---------------|--------------------|--------------|-----------|-----------------|-----------------|
| | mm SL | mm TL | | mm SL | mm TL | mm SL | mm TL |
| Hatched | (4)5[–6] | (4)5[–6] | Dorsal - P | 8 | 9 | 10 | 11–12 |
| Eyes pigmented | *4(5)[*–6] | *4(5)[*–6(7)] | Anal - P | 9 | 9–10 | 10(11) | 12(13) |
| Yolk assimilated | 7[–9] | 7–8 [9(10)] | Caudal - P | 7[–9] | 7–8[9] | 8(9) | 9 |
| Finfold absorbed | (14)15(16) | 18–19 | Caudal - R | 9–10 | 10–11(12) | 14 | 17–18 |
| Pectoral-fin buds | * | * | Pectoral | 9(10) | 10(11) | (12)13–14 | (14)15–16(17) |
| Pelvic-fin buds | 8(9)[–11] | 9[–11–12] | Pelvic | 10 | 12 | 14–15 | 18 |
| * before hatching | | | Scales | 17–19 | 21–23 | (18–)20–22(–25) | (22–)25–27(–30) |

References: Balon 1975a; Baxter and Simon 1970; Baxter and Stone 1995; Becker 1983; Beckman 1952; Coburn 1986; Eddy and Underhill 1974; Heufelder and Fuiman 1982; Lentsch et al. 1996; Moore 1968; Page and Burr 1991; Scott and Crossman 1973; Sigler and Miller 1963; Sigler and Sigler 1996; Simon 1998; Simpson and Wallace 1978; Sublette et al. 1990; Suttkus and Cashner 1981; Tyus et al. 1982; Werner 2004; Woodling 1985. **Account:** Modified from Snyder et al. 2016. **Other larval descriptions:** Bartnik 1970; Buynak and Mohr 1979a; Cooper 1978, 1980; Fish 1932 (possibly *R. atratulus*); Fuiman and Loos 1977; Fuiman et al. 1983; Heufelder and Fuiman 1982; Loos et al. 1979; Snyder 1981.

Table 32. Size at developmental interval (left) and gut phase (right) transitions for *Rhinichthys cataractae*. (See Figure 5 for phases of gut folding. Rare values in parentheses. Bracketed data from descriptions for eastern U.S. populations where larvae were notably larger.)

| Transition to | mm SL | mm TL | Transition to | mm SL | mm TL |
|-----------------------|------------|---------|-----------------------|------------------|------------|
| Flexion mesolarva | 7[-9] | 7-8[-9] | 2 - 90° bend | 11 | 13 |
| Postflexion mesolarva | 8(9) | 9 | 3 - Full loop | (21-)25(26) | (27-)30-32 |
| Metalarva | 10(11) | 12(13) | 4 - Partial crossover | (not applicable) | |
| Juvenile | (14)15(16) | 18-19 | 5 - Full | (not applicable) | |

Table 33. Summary of morphometrics and myomere counts by developmental phase for *Rhinichthys cataractae*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. Standard deviation [SD] of 0 represents a value < 0.5. Includes data extracted from Buynak and Mohr 1979a and Fuiman and Loos 1977 illustrations used herein.)

| | Protolarvae (N = 11) | | | Flexion mesolarvae (N = 7) | | | Postflexion mesolarvae (N = 12) | | | Metalarvae (N = 12) | | | Juveniles (N = 17) | | |
|--------------------|----------------------|----------------|-----------|----------------------------|----------|-----------|---------------------------------|----------------|-----------|---------------------|----------------|-----------|--------------------|----------------|-----------|
| | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range |
| SL, mm | 6 | 1 | 5 - 7 | 8 | 0 | 7 - 8 | 9 | 1 | 8 - 10 | 13 | 2 | 10 - 16 | 24 | 8 ^e | 14 - 40 |
| TL, mm | 6 | 1 | 5 - 7 | 8 | 0 | 8 - 9 | 10 | 1 | 9 - 12 | 15 | 2 | 12 - 19 | 30 | 9 ^e | 18 - 48 |
| <u>Lengths %SL</u> | | | | | | | | | | | | | | | |
| AS to AE | 3 | 0 | 3 - 4 | 4 | 1 | 3 - 5 | 4 | 1 | 3 - 5 | 5 | 1 | 4 - 8 | 8 | 1 | 6 - 10 |
| PE | 11 | 1 | 10 - 12 | 12 | 1 | 11 - 14 | 12 | 1 | 10 - 13 | 13 | 1 | 11 - 16 | 14 | 1 | 13 - 16 |
| OP1 | 19 | 1 | 18 - 21 | 21 | 1 | 20 - 23 | 23 | 1 | 20 - 25 | 25 | 1 | 23 - 28 | 26 | 1 | 23 - 27 |
| OP2 | | | | | | | 46 | 1 ^b | 45 - 48 | 50 | 1 | 48 - 51 | 50 | 2 ^h | 46 - 54 |
| PY | 62 | 6 | 51 - 68 | | | | | | | | | | | | |
| OPAF | 45 | 9 | 34 - 56 | 34 | 1 | 32 - 36 | 34 | 3 | 31 - 41 | 46 | 6 | 39 - 54 | | | |
| ODF | 44 | 2 | 39 - 48 | 44 | 2 | 40 - 46 | 45 | 3 | 42 - 53 | 49 | 1 ^d | 48 - 50 | | | |
| OD | | | | | | | 52 | 1 ^c | 50 - 55 | 52 | 1 | 50 - 53 | 53 | 1 | 51 - 55 |
| ID | | | | | | | 62 | 2 ^d | 59 - 63 | 63 | 1 ^f | 62 - 64 | 64 | 1 | 62 - 65 |
| PV | 67 | 2 | 64 - 69 | 65 | 2 | 64 - 69 | 67 | 2 | 63 - 70 | 67 | 1 | 66 - 69 | 65 | 1 | 63 - 67 |
| OA | | | | | | | 67 | 1 ^c | 65 - 69 | 66 | 1 | 65 - 68 | 65 | 1 | 62 - 67 |
| IA | | | | | | | 75 | 1 ^d | 74 - 76 | 75 | 1 | 74 - 77 | 75 | 2 | 72 - 77 |
| AFC | | | | | | | 109 | 1 | 108 - 111 | 114 | 1 ^f | 111 - 115 | 115 | 1 | 114 - 118 |
| PC | 105 | 1 | 103 - 107 | 107 | 2 | 105 - 110 | 110 | 2 | 108 - 116 | 120 | 2 | 116 - 123 | 123 | 2 ^e | 121 - 127 |
| Y | 46 | 10 | 29 - 57 | | | | | | | | | | | | |
| P1 | 7 | 3 | 4 - 11 | 14 | 0 | 13 - 14 | 14 | 1 | 11 - 16 | 16 | 1 | 14 - 17 | 19 | 1 | 17 - 23 |
| P2 | | | | | | | 4 | 1 ^b | 2 - 6 | 9 | 3 ^f | 6 - 13 | 14 | 1 | 13 - 16 |
| D | | | | | | | 14 | 1 ^c | 12 - 15 | 18 | 1 | 16 - 20 | 21 | 1 | 19 - 24 |
| A | | | | | | | 11 | 2 ^e | 9 - 12 | 15 | 2 | 12 - 19 | 19 | 2 | 15 - 21 |
| <u>Depths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 14 | 1 | 13 - 17 | 15 | 1 | 14 - 15 | 15 | 1 | 14 - 16 | 16 | 1 | 15 - 18 | 16 | 2 | 14 - 18 |
| OP1 | 19 | 4 | 15 - 26 | 15 | 1 | 15 - 17 | 17 | 1 | 16 - 18 | 19 | 1 | 18 - 22 | 20 | 1 | 17 - 23 |
| OD | 14 | 2 | 11 - 18 | 12 | 0 | 11 - 12 | 13 | 1 | 11 - 14 | 17 | 2 | 13 - 20 | 20 | 2 | 18 - 26 |
| BPV | 8 | 1 | 7 - 9 | 8 | 0 | 8 - 9 | 9 | 1 | 8 - 11 | 13 | 1 | 9 - 14 | 15 | 1 | 14 - 19 |
| AMPM | 5 | 1 | 4 - 6 | 5 | 0 | 5 - 6 | 6 | 1 | 5 - 8 | 9 | 1 | 7 - 11 | 11 | 1 | 9 - 13 |
| Max. yolk | 13 | 7 | 4 - 21 | | | | | | | | | | | | |
| <u>Widths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 13 | 1 | 11 - 15 | 14 | 1 | 13 - 16 | 15 | 1 | 14 - 16 | 16 | 0 ^f | 16 - 17 | 16 | 1 | 14 - 18 |
| OP1 | 14 | 5 | 10 - 22 | 12 | 1 | 11 - 13 | 13 | 1 | 11 - 14 | 16 | 1 ^f | 13 - 18 | 19 | 1 | 17 - 22 |
| OD | 8 | 1 | 6 - 10 | 6 | 1 | 5 - 7 | 7 | 1 | 6 - 8 | 10 | 2 ^f | 7 - 13 | 15 | 2 | 11 - 21 |
| BPV | 6 | 0 | 5 - 6 | 5 | 0 | 5 - 5 | 6 | 0 | 5 - 6 | 8 | 1 ^f | 5 - 9 | 11 | 1 | 8 - 14 |
| AMPM | 3 | 0 | 3 - 4 | 3 | 1 | 3 - 4 | 4 | 0 | 3 - 4 | 4 | 0 ^f | 4 - 5 | 5 | 1 | 5 - 7 |
| Max. yolk | 15 | 7 | 7 - 24 | | | | | | | | | | | | |
| <u>Myomeres</u> | | | | | | | | | | | | | | | |
| to PY | 22 | 3 ^a | 17 - 25 | | | | | | | | | | | | |
| OPAF | 13 | 4 ^a | 9 - 19 | 9 | 1 | 8 - 11 | 9 | 1 | 8 - 11 | 13 | 3 ^f | 9 - 18 | | | |
| OP2 | | | | | | | 16 | 1 ^b | 15 - 17 | 16 | 1 ^f | 14 - 17 | 16 | 1 ⁱ | 14 - 17 |
| ODF | 13 | 1 ^a | 12 - 15 | 14 | 1 | 13 - 16 | 15 | 1 | 14 - 16 | 16 | 1 ^d | 15 - 18 | | | |
| OD | | | | | | | 18 | 1 ^c | 17 - 19 | 17 | 1 ^f | 15 - 19 | 17 | 1 ^j | 15 - 18 |
| PV | 25 | 1 ^a | 24 - 26 | 26 | 1 | 25 - 27 | 27 | 1 | 26 - 27 | 25 | 1 ^f | 24 - 27 | 25 | 1 ^j | 23 - 26 |
| Total | 38 | 1 ^a | 36 - 40 | 39 | 1 | 38 - 40 | 39 | 1 | 38 - 40 | 39 | 1 ^f | 37 - 40 | 38 | 1 ^j | 37 - 39 |
| After PV | 13 | 1 | 12 - 15 | 13 | 1 | 12 - 14 | 13 | 1 | 11 - 14 | 13 | 1 ^f | 12 - 15 | 13 | 1 ^j | 12 - 14 |

^aN = 10. ^bN = 9. ^cN = 10. ^dN = 4. ^eN = 3. ^fN = 11. ^gN = 23. ^hN = 16. ⁱN = 7. ^jN = 8.

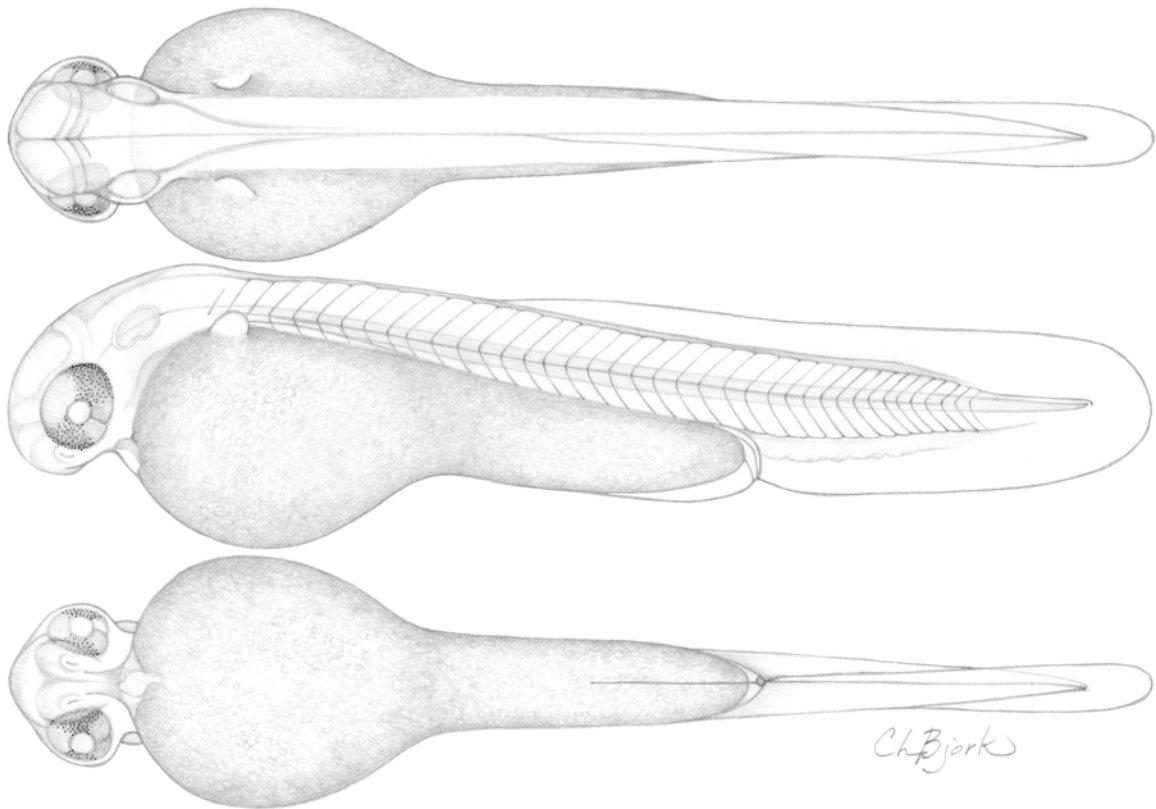


Figure 78. *Rhinichthys cataractae* protolarva, recently hatched, 4.8 mm SL, 5.1 mm TL. (Cultured in 2007 by Larval Fish Laboratory at Colorado State University with stock collected from Cache la Poudre River, Fort Collins, Colorado.)

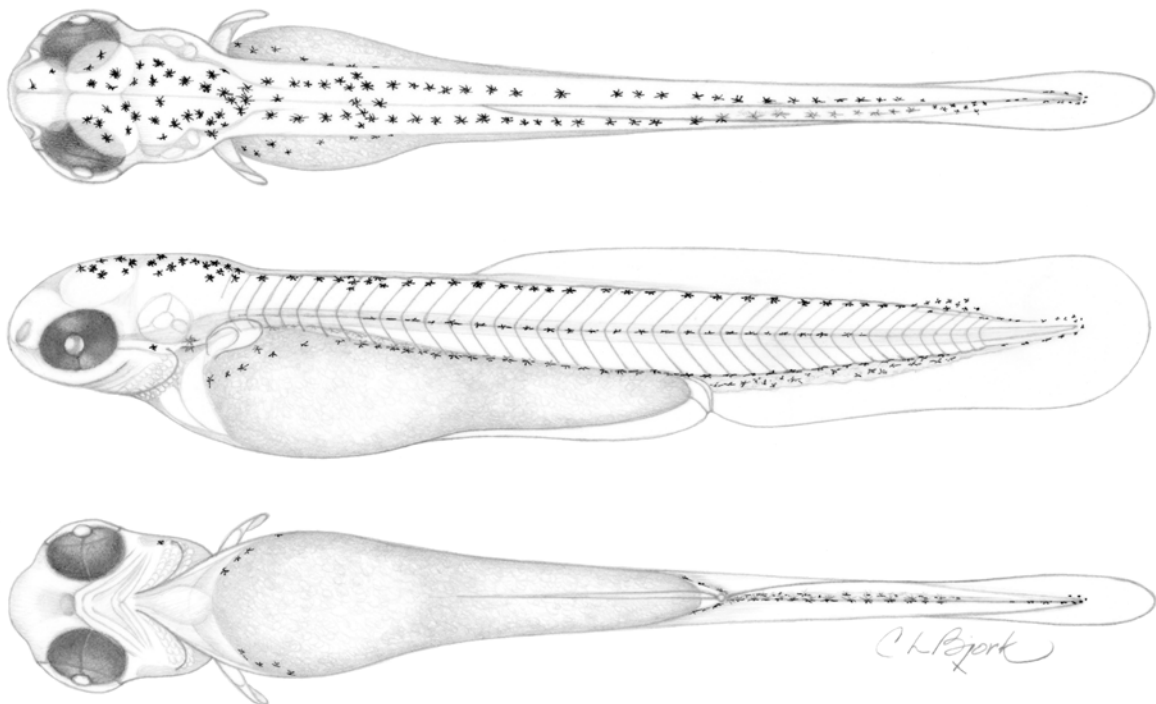


Figure 79. *Rhinichthys cataractae* protolarva, 6.0 mm SL, 6.4 mm TL. (Cultured in 2007 by Larval Fish Laboratory at Colorado State University with stock collected from Cache la Poudre River, Fort Collins, Colorado.)

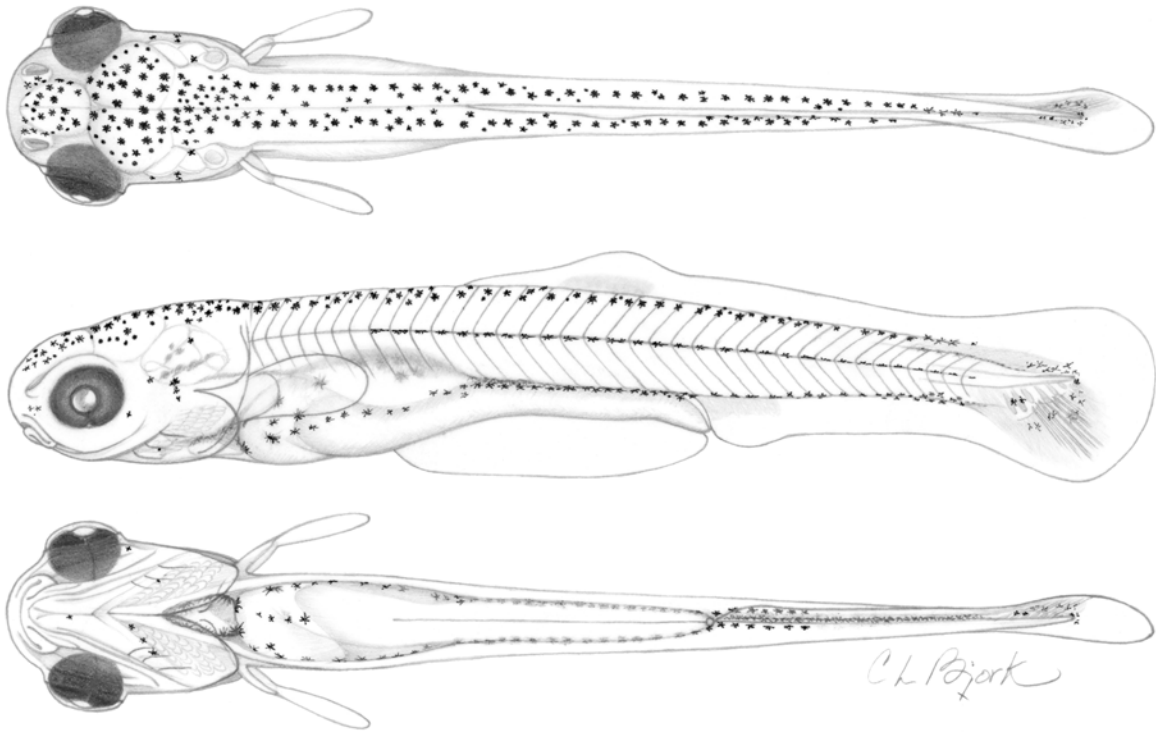


Figure 80. *Rhinichthys cataractae* flexion mesolarva, recently transformed, 7.7 mm SL, 8.3 mm TL. (Cultured in 2007 by Larval Fish Laboratory at Colorado State University with stock collected from Cache la Poudre River, Fort Collins, CO.)

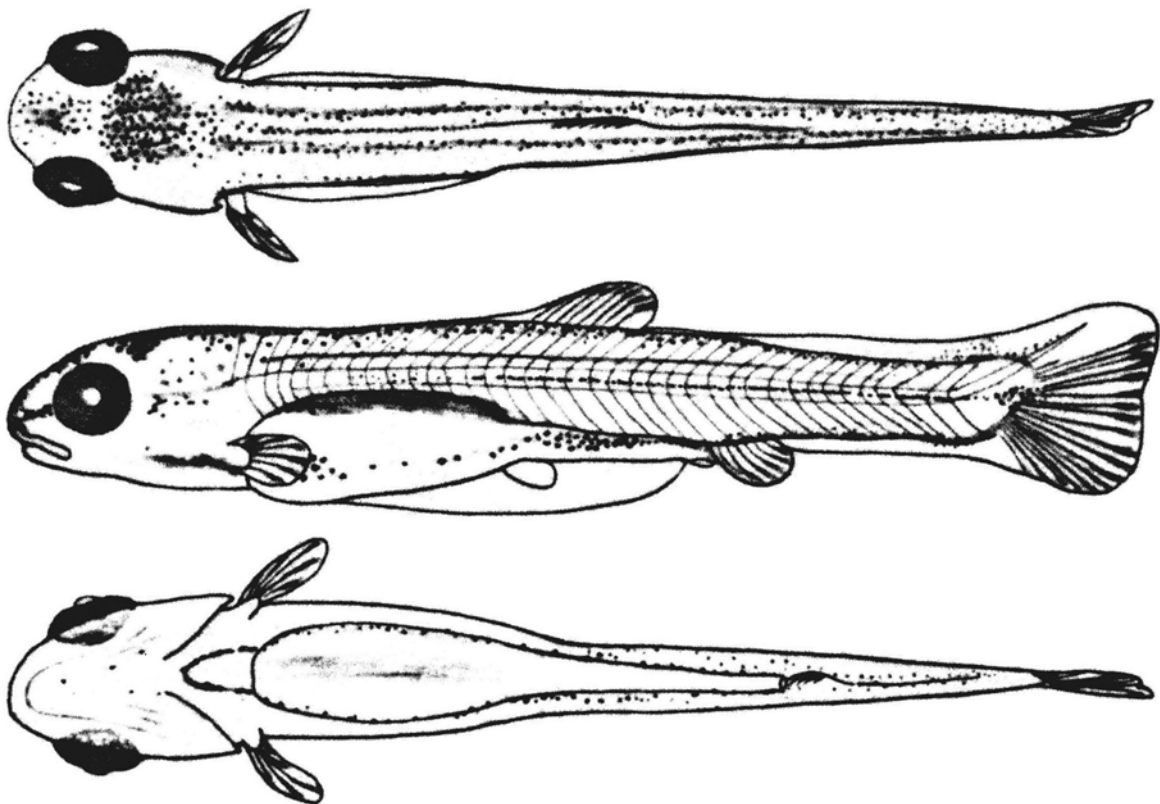


Figure 81. *Rhinichthys cataractae* postflexion mesolarva, 10.4 mm SL, 11.6 mm TL. (Cultured in 1977 by Ichthyological Associates, Inc., Berwick, Pennsylvania, with stock collected from nearby Briar Creek. Modified from Buynak and Mohr 1979a, Figure 2e, with author permission; fin ray counts not accurate.)

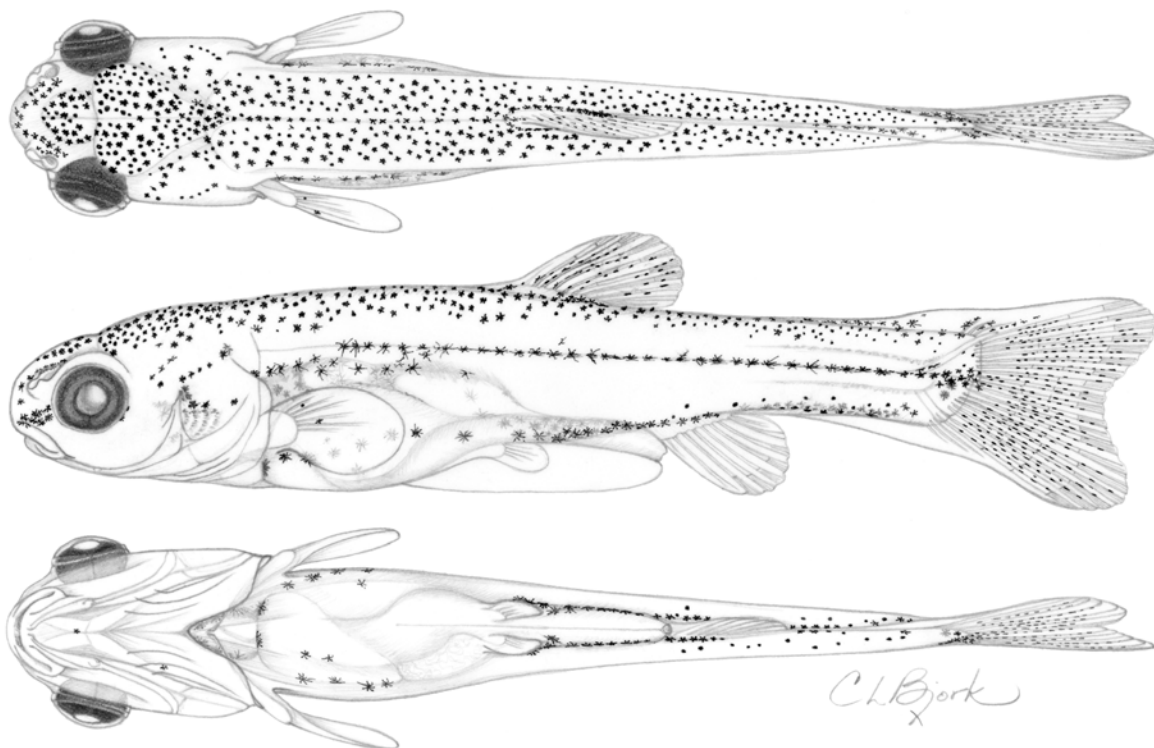


Figure 82. *Rhinichthys cataractae* metalarva, recently transformed, 11.4 mm SL, 13.5 mm TL. (Cultured in 2007 by Larval Fish Laboratory at Colorado State University with stock collected from Cache la Poudre River, Fort Collins, Colorado.)

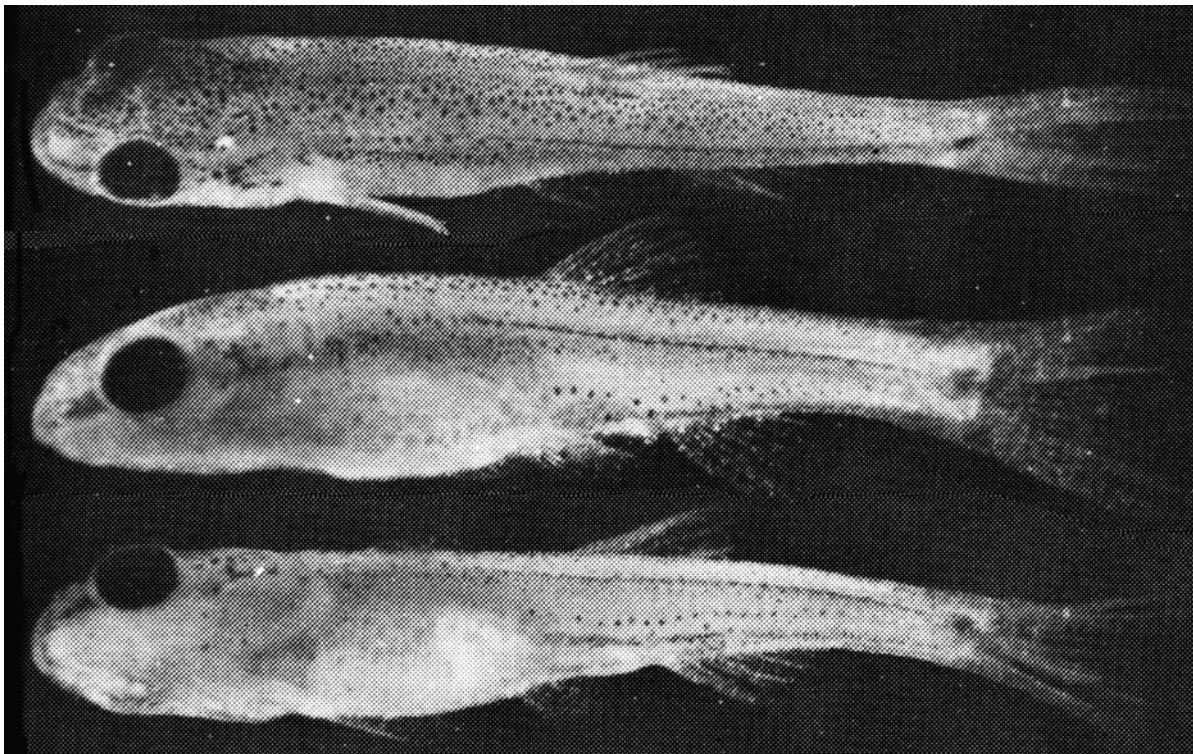


Figure 83. *Rhinichthys cataractae* metalarva, 13.1 mm SL, 15.9 mm TL. (Cultured in 1975 at the Academy of Natural Sciences of Philadelphia [ANSP] with eggs collected from Lackawaxen River, Honesdale, Pennsylvania; from ANSP #131939. Modified from Fuiman and Loos 1977, Figure 3a-c, with author permission.)

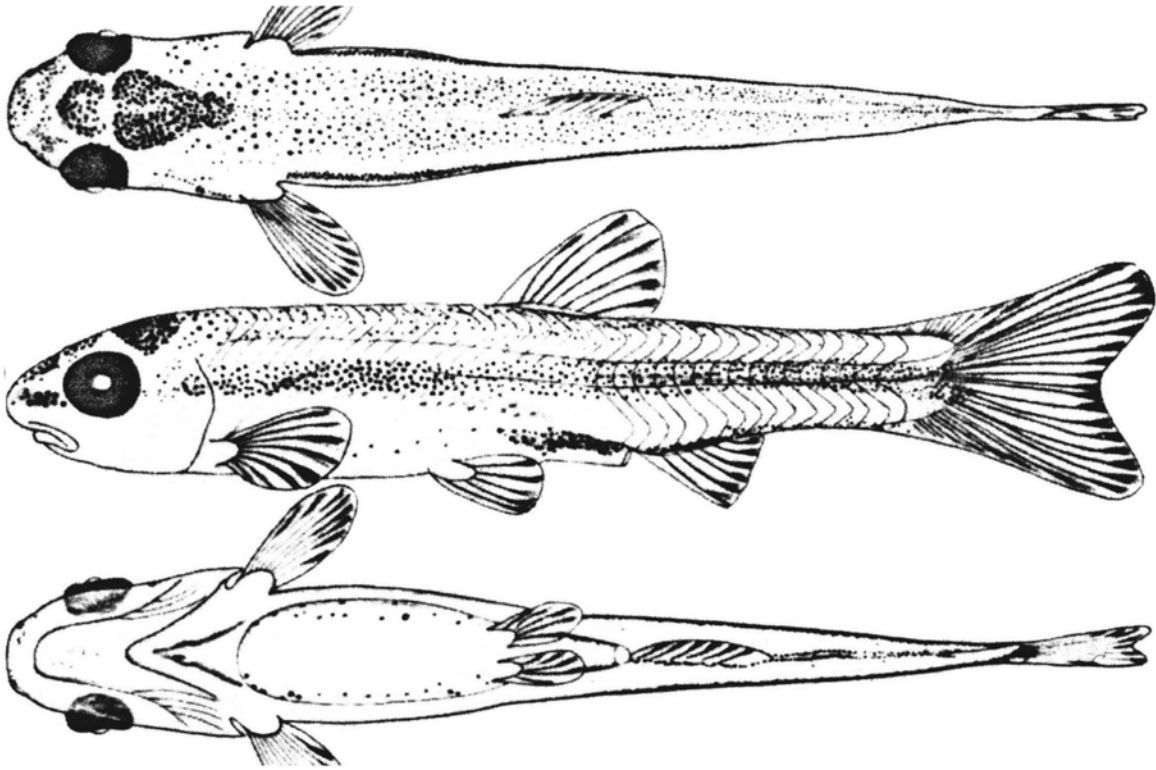


Figure 84. *Rhinichthys cataractae* juvenile, recently transformed, 14.7 mm SL, 17.8 mm TL. (Cultured in 1977 by Ichthyological Associates, Inc., Berwick, Pennsylvania, with stock collected from nearby Briar Creek. Modified from Buynak and Mohr 1979a, Figure 2h, with author permission; fin ray counts not accurate.)

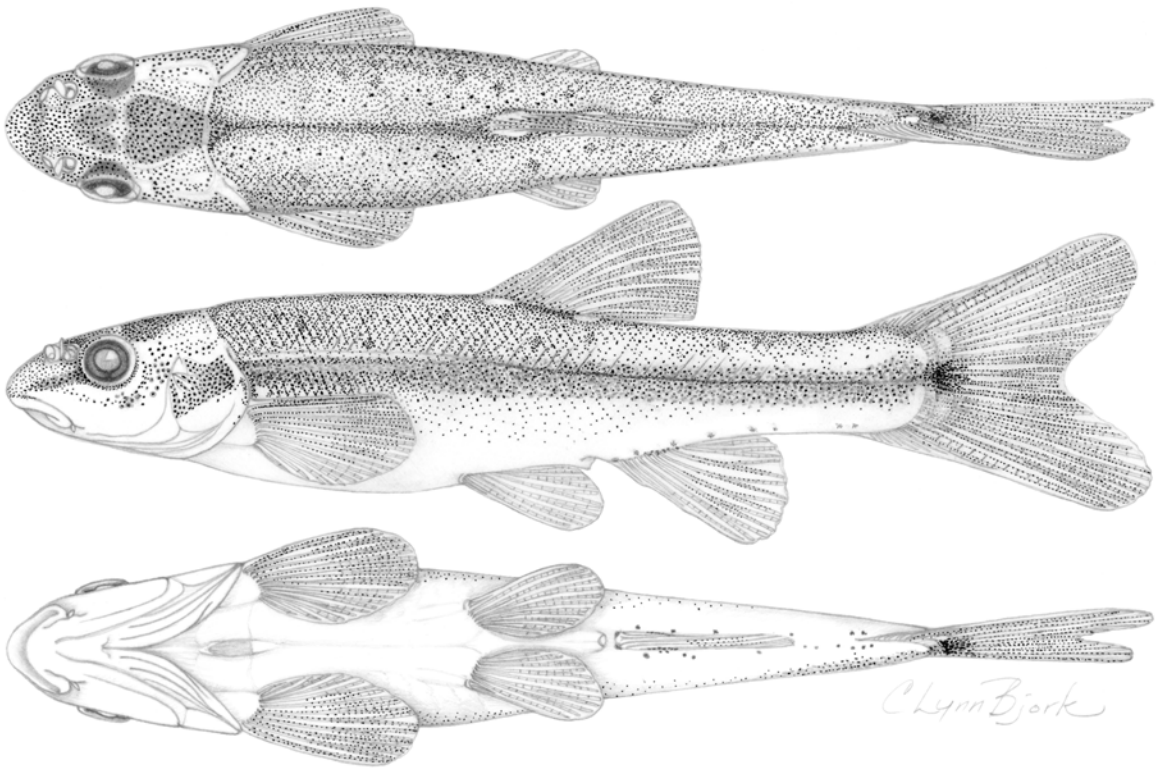


Figure 85. *Rhinichthys cataractae* juvenile, 29.6 mm SL, 36.5 mm TL. (Collected in 2001 by Colorado State University Larval Fish Laboratory from Conejos River, Conejos County, Colorado; from LFL #80239.)

Species Account – *Catostomus commersonii*, White Sucker

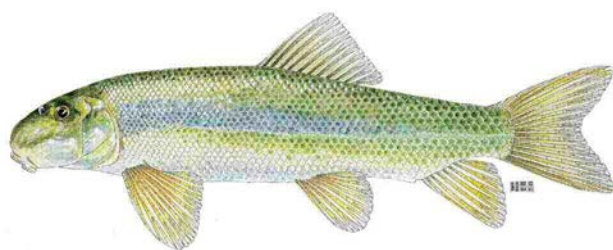


Figure 86. *Catostomus commersonii* adult (© W. H. Brandenburg).

Adult Description: Usually 30–50 cm, up to 64 cm TL. Robust. Caudal peduncle heavy, depth about 6.5–8.6% TL. Inferior, slightly overhung mouth; lips relatively small, papillose, without notches at corners; lower lip wider than long with a deep median cleft and lobes spanned by 0, or sometimes 1 or 2, rows of a few papillae. Dorsal fin nearly straight along distal margin. Scales small to moderate, size increasing posteriorly. Gill rakers relatively few, somewhat knobbed. Gut long and coiled; peritoneum pale or lightly speckled. Body dusky to olivaceous dorsally, white ventrally. (Also, Table 34.)

Reproduction: Non-guarding, open-substrate lithophil. Spawn April to August at 7–19°C, usually > 10°C; mid-April to July in Middle Rio Grande. Migrate, usually in large aggregations, to streams or lake shores to spawn in moderately flowing, shallow waters (usually < 0.3 m) over sand or gravel (often over riffles in streams). Breeding males usually darken dorsally, display rosy and/or dark lateral bands, and have well tuberculated anal and lower caudal fins. Water-hardened eggs are 2.6–3.3 mm diameter, demersal, and initially adhesive.

Young: Hatch in 5–11 d at 10–18°C. Remain in gravel 1–2 weeks, drift as late protolarvae and mesolarvae, usually at night, and subsequently occupy low velocity shoreline areas, often over sand and gravel or in aquatic vegetation. Later young-of-the-year juveniles have three large, dusky to dark blotches along each side of the body.

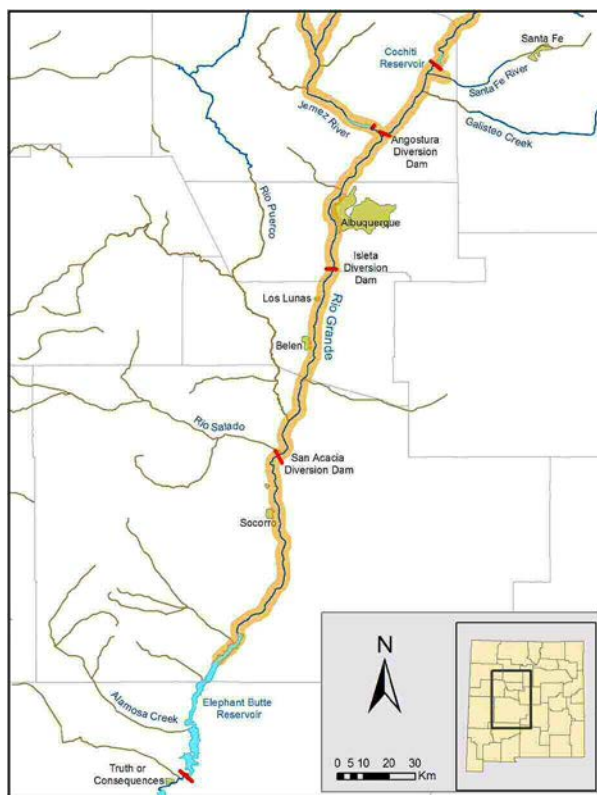


Figure 87. Distribution of *Catostomus commersonii* in the Middle Rio Grande, New Mexico, 2005–2015.

Table 34. Selected juvenile and adult meristics for *Catostomus commersonii*. (P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Gill rakers for exterior row of first arch, specimens > 70 mm SL. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

| Character | Original | Literature | Character | Original | Literature |
|----------------------|-----------------------|---------------|-----------------------|-------------------------------|------------------------------------|
| Dorsal-fin rays - P: | 10–11–12(13) | (9)10–13(–15) | Dorsal-fin rays - R: | 2–3–4(5) | – |
| Anal-fin rays - P: | (5–)7(8) | (6)7–8 | Anal-fin rays - R: | 2–3 | – |
| Caudal-fin rays - P: | 18 | 18 | Caudal-fin rays - RD: | 10–11–13 | – |
| Pectoral-fin rays: | 13– <u>15</u> –16(17) | 13–19 | Caudal-fin rays - RV: | 8–10 | – |
| Pelvic-fin rays: | 8– <u>10</u> | 9–11 | Lateral scales: | 56– <u>59</u> – <u>68</u> –72 | 53– <u>56</u> – <u>70</u> –76(–85) |
| Vertebrae: | 45– <u>46</u> –48 | 44–48 | Gill rakers: | – | 20–27 |

Table 35. Size at onset of selected developmental events for *Catostomus commersonii*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses.)

| Event or structure | Onset or formation | | Fin rays or scales | First formed | | Last formed | |
|--------------------|--------------------|----------------|--------------------|--------------|-----------|-------------|-----------|
| | mm SL | mm TL | | mm SL | mm TL | mm SL | mm TL |
| Hatched: | (7)8–10 | 8–10 | Dorsal - P: | 12–14(15) | 14–15(16) | 14–16 | 16–17 |
| Eyes pigmented: | *–(7)8 | *– 8 | Anal - P: | 14–16 | 16–17 | 15–16(17) | 18–19(20) |
| Yolk assimilated: | 10–12(–14) | (10)11–13(–15) | Caudal - P: | 10–12(13) | 10–13 | (12)13–15 | (13)14–16 |
| Finfold absorbed: | (17–)19–20 | (21–)23–24 | Caudal - R: | 13–15 | 14–16 | (17)18 | (21)22–23 |
| Pectoral-fin buds: | *–(7)8 | *– 8 | Pectoral: | 14–16 | 16–17 | 16(–20) | 19(–24) |
| Pelvic-fin buds: | 13–15 | (14)15–16 | Pelvic: | 15–16 | 18–19 | 16–18 | 19–22 |
| * before hatching | | | Scales: | 22(23) | 27 | 29–31 | 36–37 |

References: Baxter and Simon 1970; Baxter and Stone 1995; Beckman 1952; Carlander 1969; Carlson et al. 1979; Ellis 1914; Fuiman 1979, 1982a; Fuiman and Trojnar 1980; Geen et al. 1966; Hubbs et al. 1943; Jones et al. 1978; Jordan and Evermann 1896; Lee et al. 1980; Lippson and Moran 1974; Miller 1952; Minckley 1973; Prewitt 1977; Reighard 1920; Scott and Crossman 1973; Smith 1985; Stewart 1926; Sublette et al. 1990; Twomey et al. 1984; Wheeler 1997; Woodling 1985. **Account:** Modified from Snyder and Muth 2004. **Other larval descriptions:** Arvidson and Alber 2013; Buynak and Mohr 1978; Crawford 1923; Fish 1929, 1932; Fuiman 1978, 1979, 1982a; Holland-Bartels et al. 1990; Jones et al. 1978; Kay et al. 1994; Lippson and Moran 1974; Long and Ballard 1976; Loos et al. 1979; (continued at bottom of next page).

Table 36. Size at developmental interval (left) and gut phase (right) transitions for *Catostomus commersonii*. (See Figure 5 for phases of gut folding. Rare values in parentheses.)

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

Table 37. Summary of morphometrics and myomere counts by developmental phase for *Catostomus commersonii*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. Standard deviation [SD] of 0 represents a value < 0.5.)

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

^aN = 8. ^bN = 7. ^cN = 8. ^dN = 3. ^eN = 17. ^fN = 20.

Other larval descriptions (continued from bottom of previous page): Mansueti and Hardy 1967; McElman and Balon 1980; Snyder 1981, 1998; Snyder and Muth 1990; Stewart 1926; Wang and Kernehan 1979.

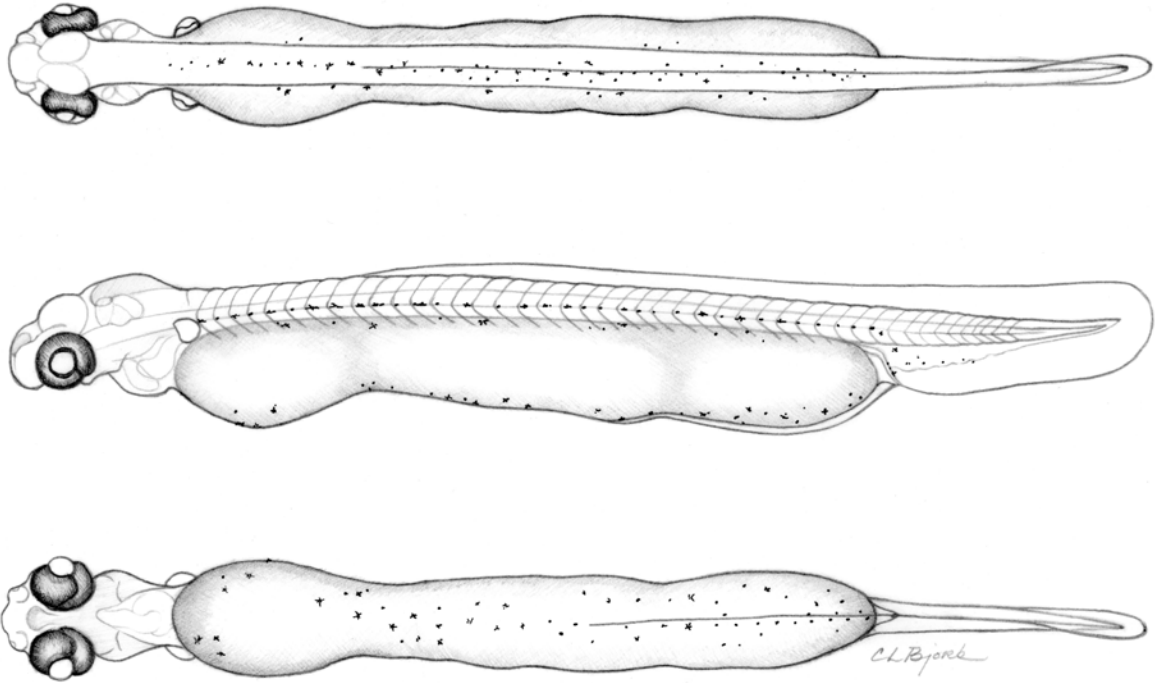


Figure 88. *Catostomus commersonii* protolarva, recently hatched, 9.3 mm SL, 9.6 mm TL. (Cultured in 1979 with stock from a private pond [Louis Swift], Fort Collins, Colorado.)

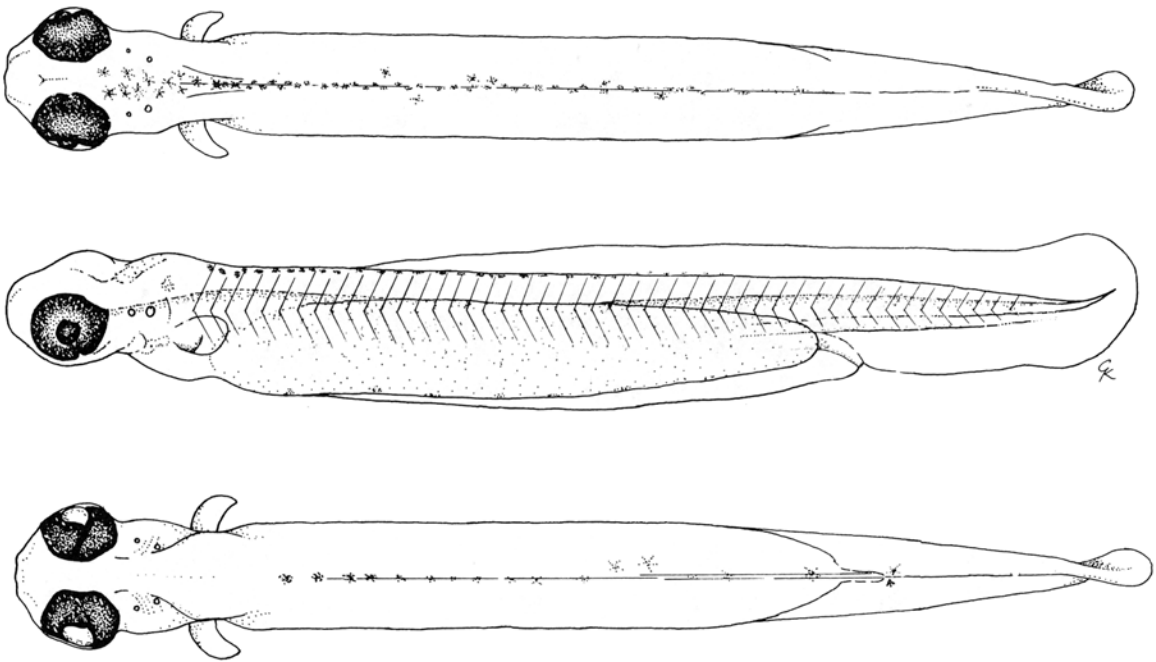


Figure 89. *Catostomus commersonii* protolarva, 10.5 mm SL, 10.7 mm TL. (Cultured in 1976 with stock from Cayuga Lake inlet, Ithaca, New York; from CU [Cornell University] #55650. From Fuiman 1979, Figure 3, with author permission.)

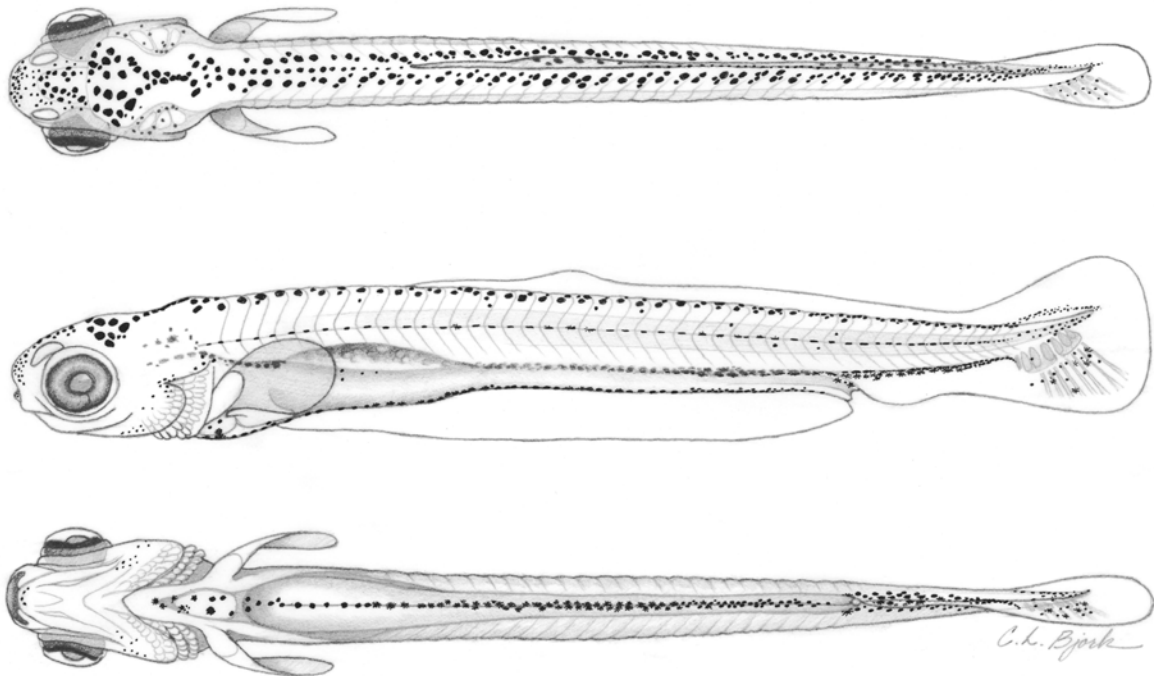


Figure 90. *Catostomus commersonii* flexion mesolarva, recently transformed, 12.8 mm SL, 13.4 mm TL. (Collected in 1977 from Yampa River, Colorado.)

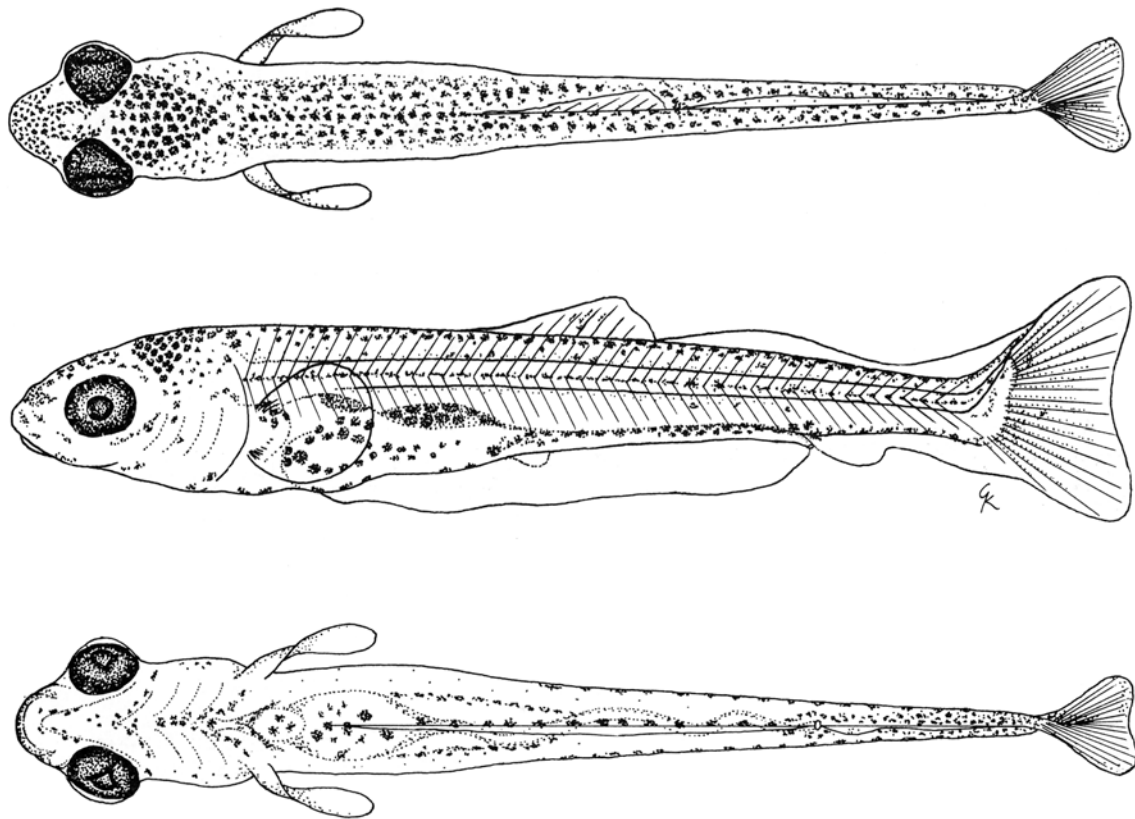


Figure 91. *Catostomus commersonii* postflexion mesolarva, 16.3 mm SL, 18.2 mm TL. (Cultured in 1976 with stock from Cayuga Lake inlet, Ithaca, New York; from CU #55651. From Fuiman 1979, Figure 5, with author permission.)

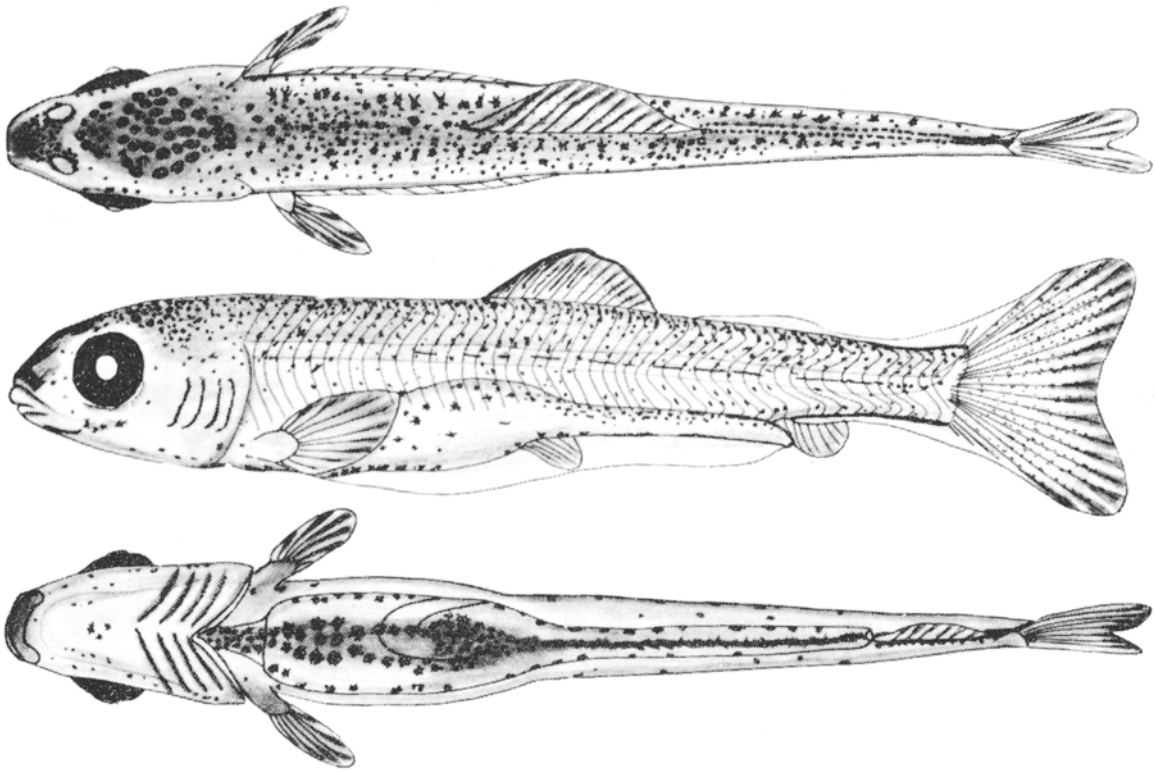


Figure 92. *Catostomus commersonii* metalarva, recently transformed, 17.8 mm SL, 20.4 mm TL. (Cultured 1975 with stock from Susquehanna River, Pennsylvania. Modified from Buynak and Mohr 1978, Figure 1J, with author permission.)

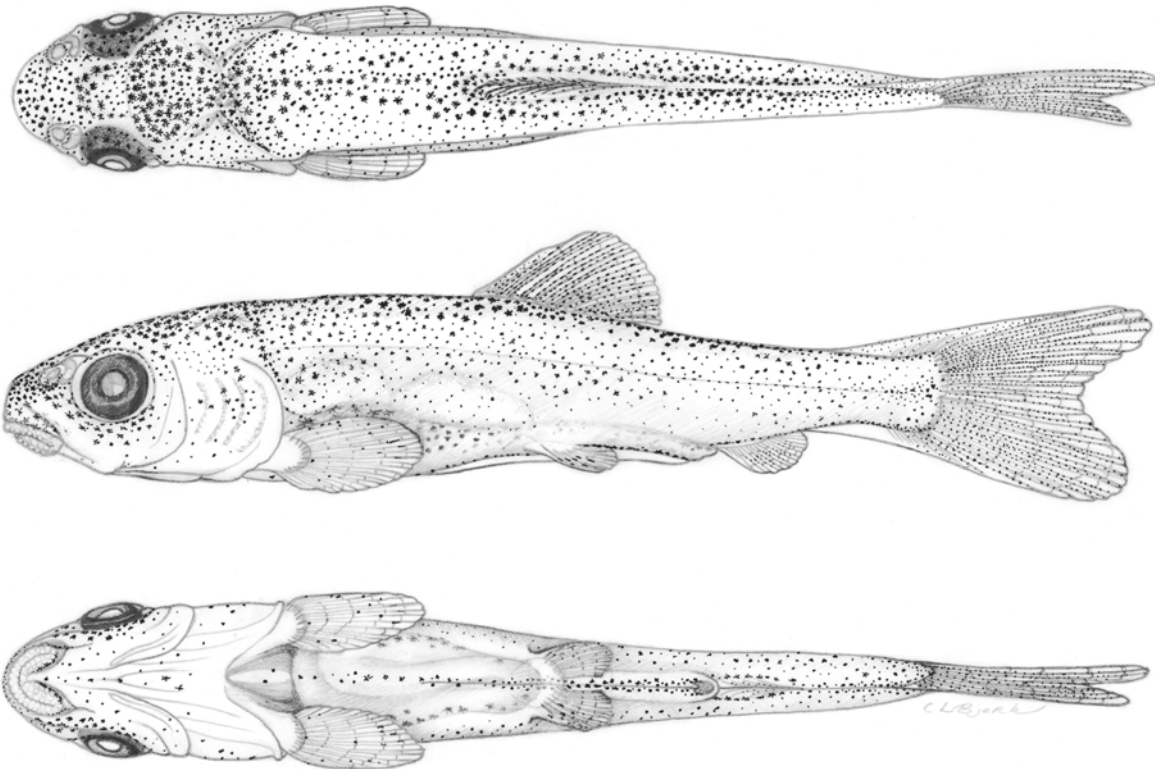


Figure 93. *Catostomus commersonii* metalarva, 19.2 mm SL, 23.1 mm TL. (Collected in 1977 from Yampa River, Colorado.)

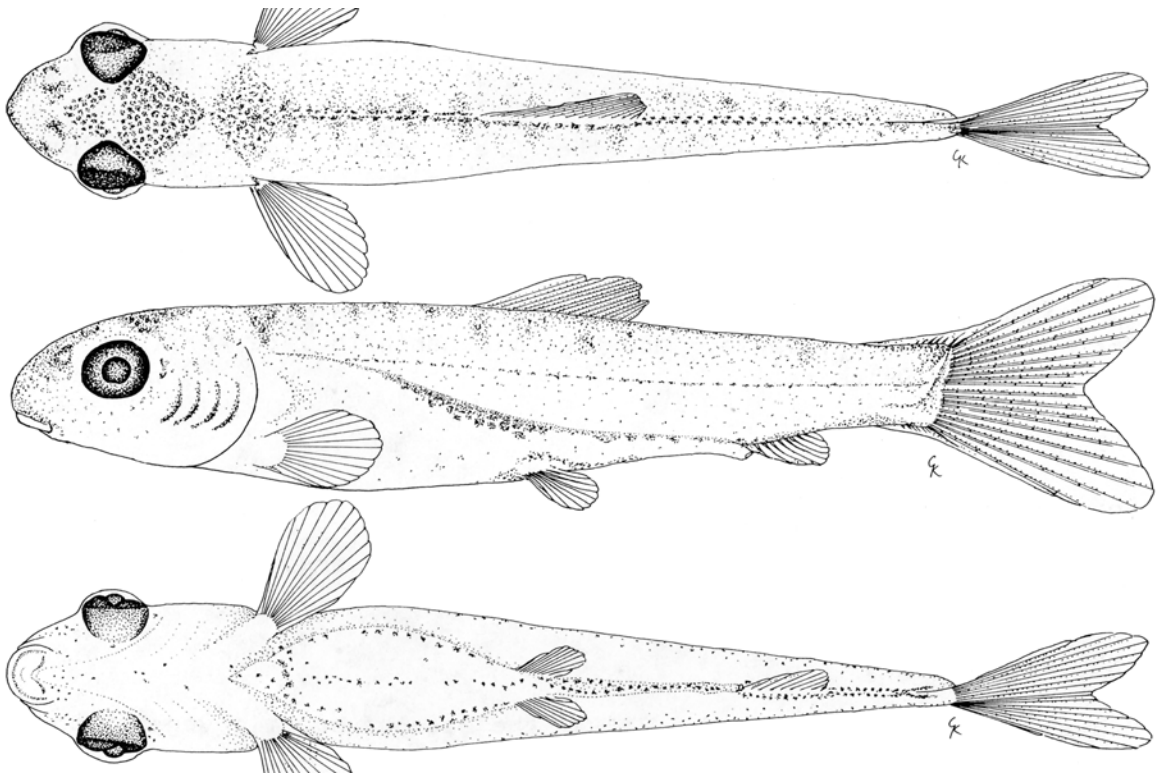


Figure 94. *Catostomus commersonii* juvenile, recently transformed, 21.3 mm SL, 25.8 mm TL. (Cultured in 1976 with stock from Cayuga Lake inlet, Ithaca, New York; from CU #55651. Modified from Fuiman 1979, Figure 6, with author permission.)



Figure 95. *Catostomus commersonii* juvenile, 30.8 mm SL, 37.9 mm TL. (Collected in 1977 from Yampa River, Colorado.)

Species Account – *Catostomus plebeius*, Rio Grande Sucker

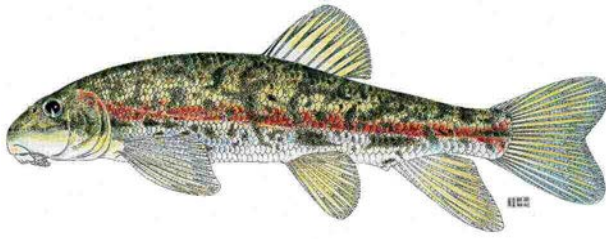


Figure 96. *Catostomus plebeius* adult (© W. H. Brandenburg).

Adult Description: Usually 10–16 cm TL, up to 30 cm. Mouth inferior, overhung by broad snout. Lips are notched at corners and uniformly covered with large papillae, including anterior surface of upper lip; lower lip lobes separated by deep median cleft, but anteriorly connected by 2 or 3 rows of papillae. Mandible with narrow, rounded, cartilaginous ridge. Isthmus relatively narrow. Fontanelle closed (nearly closed in young). Typically just 9 dorsal fin rays. Pelvic axillary process absent or variously developed. Back and sides greenish to dusky brown with dark mottling or blotches; ventral surfaces pale. Peritoneum dusky to black with densely scattered melanophores. (Also, Table 38.)

Reproduction: Non-guarding, open-substrate lithophil. Spawn over gravel in spring to early summer on waning side of peak flows, sometimes in fall. Mature at 6–9 cm TL. Breeding fish tuberculated, especially on anal fin and lower caudal peduncle, and have a typically red, or red above black, lateral band (more intense in males). Fecundity about 700–4,700. Water-hardened eggs 2.0–3.2 mm diameter (2.4–3.2 mm, orig. data), demersal, and probably adhesive.

Young: Hatch in 7–9 d at ~18°C to 14 d at 12–13°C. Swim up from gravel 6–7 d later at ~18°C, then probably drift in current. Subsequently occupy low velocity shoreline areas, often over sand and gravel or in aquatic vegetation.

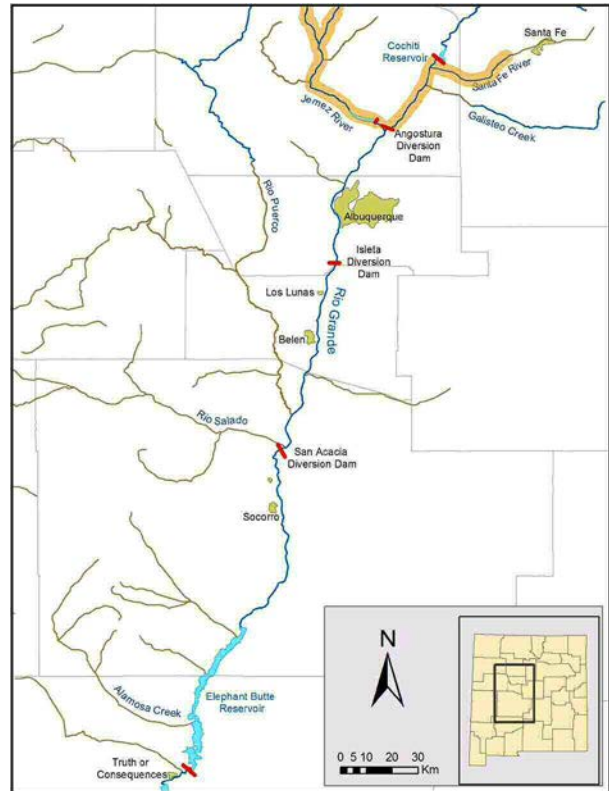


Figure 97. Distribution of *Catostomus plebeius* in the Middle Rio Grande, New Mexico, 2005–2015.

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

| Character | Original | Literature | Character | Original | Literature |
|----------------------|-------------------|-----------------------------------|-----------------------|--|---------------------------------|
| Dorsal-fin rays - P: | 8–9–10 | 8–9–10(11) | Dorsal-fin rays - R: | <u>3</u> –4 | – |
| Anal-fin rays - P: | (6)7(–9) | 7(8) | Anal-fin rays - R: | <u>2</u> – <u>3</u> | – |
| Caudal-fin rays - P: | 18(19) | – | Caudal-fin rays - RD: | 11– <u>12</u> –14 | – |
| Pectoral-fin rays: | 14– <u>15</u> –16 | 14–15 | Caudal-fin rays - RV: | 8– <u>9</u> –12 | – |
| Pelvic-fin rays: | 8– <u>9</u> | 8–9–10(11) | Lateral scales: | ~73–75 ^a , 85–91 ^b | (70–)74– <u>75</u> –95–99(–103) |
| Vertebrae: | – | 42– <u>43</u> – <u>44</u> –45(46) | Gill rakers: | – | 19– <u>20</u> – <u>23</u> –27 |

^a Hot Creek, CO, reared; N = 3, 33–38 mm TL (tentative counts).

^b Rio Bonito and Jemez River, NM, wild; N = 5, 45 & 90–135 mm TL

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

| Event or structure | Onset or formation | | Fin rays or scales | First formed | | Last formed | |
|--------------------|--------------------|---------------|--------------------|--------------|--------|-------------|-----------|
| | mm SL | mm TL | | mm SL | mm TL | mm SL | mm TL |
| Hatched: | (6)7–9 | (6)7–9 | Dorsal - P: | 12 | (13)14 | 13–15 | 15–17 |
| Eyes pigmented: | *–7 | *–7(8) | Anal - P: | 14 | (15)16 | 15–17 | 18–19 |
| Yolk assimilated: | 10–11 | 10–12 | Caudal - P: | 10 | 10–11 | 11 | 12 |
| Finfold absorbed: | 23–25 | 27–30 | Caudal - R: | 12 | (13)14 | 22–23 | 26–27(28) |
| Pectoral-fin buds: | * | * | Pectoral: | 14 | (15)16 | 19–20 | 23–24 |
| Pelvic-fin buds: | 12–14 | (13)14–15(16) | Pelvic: | 15–17 | 18–20 | 19–20 | 23–24 |
| * before hatching | | | Scales: | 23–25 | 27–30 | 27–29 | 33–35 |

References: Alves, J., (Colo. Div. Wildl.) pers. comm. 1998; Beckman 1952; Bestgen, K., (Colo. St. Univ. Larval Fish Lab.) pers. comm. 2017; Butler 1960; Ellis 1914; Hubbs et al. 1943; Jordan and Evermann 1896; Koster 1957; Langlois et al. 1994; Lee et al. 1980; McAllister 1968; Martinez, A., (Colo. Div. Wildl.) pers. comm. 1996; Miller 1952; Minckley 1973; Moore 1968; Platania 1991; Rinne 1995; Smith 1966; Smith et al. 1983; Sublette et al. 1990; Swift 1996; Woodling 1985; Zuckerman 1984; Zuckerman and Langlois 1990. **Account:** Modified from Snyder 1998, including data and illustration from specimens reared in 2006 and 2007. **Other larval descriptions:** Snyder 1988.

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

| Transition to | mm SL | mm TL | Transition to | mm SL | mm TL |
|------------------------|-------|-------|------------------------|-------|-----------|
| Flexion mesolarva: | 10 | 10–11 | 2 - 90° bend: | 14–15 | (15)16–17 |
| Postflexion mesolarva: | 11 | 12 | 3 - Full loop: | 16–18 | 18–20(21) |
| Metalarva: | 15–17 | 18–19 | 4 - Partial crossover: | 18–20 | 21–23(24) |
| Juvenile: | 23–25 | 27–30 | 5 - Full cross over: | 22–23 | 26–27(28) |

Table 41. Summary of morphometrics and myomere counts by developmental phase for *Catostomus plebeius*. (See Figure 4 for abbreviations and methods of measurement and counting. Protolarvae with unpigmented eyes excluded. Standard deviation [SD] of 0 represents a value < 0.5.)

| | Protolarvae (N = 10) | | | Flexion mesolarvae (N = 10) | | | Postflexion mesolarvae (N = 31) | | | Metalarvae (N = 19) | | | Juveniles (N = 8) | | |
|--------------------|----------------------|----------------|-----------|-----------------------------|----------------|-----------|---------------------------------|----------------|-----------|---------------------|----------|-----------|-------------------|----------|-----------|
| | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range | \bar{x} | \pm SD | Range |
| SL, mm | 9 | 1 | 8 – 10 | 11 | 1 | 10 – 11 | 14 | 1 | 11 – 17 | 18 | 2 | 15 – 25 | 31 | 5 | 23 – 37 |
| TL, mm | 10 | 1 | 8 – 11 | 11 | 1 | 10 – 12 | 15 | 2 | 12 – 19 | 22 | 3 | 18 – 30 | 37 | 7 | 27 – 46 |
| <u>Lengths %SL</u> | | | | | | | | | | | | | | | |
| AS to AE | 2 | 0 | 2 – 3 | 3 | 1 | 2 – 4 | 4 | 1 | 3 – 7 | 6 | 1 | 5 – 8 | 8 | 1 | 7 – 10 |
| PE | 10 | 0 | 9 – 11 | 10 | 1 | 8 – 11 | 12 | 1 | 10 – 15 | 14 | 1 | 12 – 15 | 15 | 1 | 13 – 17 |
| OP1 | 18 | 1 | 16 – 20 | 19 | 1 | 18 – 22 | 23 | 2 | 20 – 27 | 25 | 1 | 23 – 27 | 26 | 2 | 23 – 29 |
| OP2 | | | | | | | 53 | 1 ^d | 51 – 55 | 55 | 2 | 52 – 59 | 57 | 2 | 56 – 60 |
| PY | 75 | 4 | 72 – 82 | 71 | 1 ^c | 70 – 72 | | | | | | | | | |
| OPAF | 37 | 17 | 23 – 67 | 26 | 1 | 23 – 28 | 31 | 3 | 26 – 38 | 40 | 10 | 29 – 64 | | | |
| ODF | 43 | 4 | 38 – 49 | 41 | 1 | 39 – 44 | 44 | 2 ^c | 40 – 49 | | | | | | |
| OD | | | | | | | 50 | 1 ^c | 47 – 52 | 50 | 1 | 48 – 52 | 50 | 1 | 49 – 51 |
| ID | | | | | | | 60 | 2 ^f | 57 – 63 | 61 | 1 | 59 – 64 | 62 | 1 | 61 – 62 |
| PV | 79 | 3 | 77 – 84 | 78 | 2 | 76 – 81 | 79 | 1 | 76 – 83 | 76 | 2 | 74 – 81 | 74 | 1 | 72 – 77 |
| OA | | | | | | | 79 | 1 ^g | 77 – 81 | 77 | 2 | 75 – 80 | 75 | 2 | 72 – 77 |
| IA | | | | | | | 84 | 2 ^h | 81 – 87 | 83 | 1 | 82 – 87 | 83 | 1 | 82 – 85 |
| AFC | | | | | | | 111 | 1 | 108 – 115 | 114 | 1 | 113 – 117 | 115 | 1 | 113 – 117 |
| PC | 105 | 0 | 103 – 106 | 107 | 1 | 105 – 109 | 113 | 2 | 108 – 117 | 117 | 2 | 115 – 121 | 120 | 2 | 118 – 122 |
| Y | 52 | 7 | 43 – 64 | 14 | 23 | 0 – 49 | | | | | | | | | |
| P1 | 8 | 3 | 3 – 11 | 11 | 1 | 10 – 13 | 14 | 1 | 12 – 17 | 17 | 1 | 15 – 21 | 19 | 2 | 16 – 22 |
| P2 | | | | | | | 3 | 2 | 0 – 7 | 8 | 3 | 4 – 13 | 14 | 2 | 11 – 16 |
| D | | | | | | | 14 | 2 ^f | 10 – 18 | 18 | 1 | 15 – 19 | 20 | 2 | 18 – 23 |
| A | | | | | | | 8 | 1 ^b | 6 – 9 | 10 | 2 | 8 – 14 | 16 | 2 | 13 – 20 |
| <u>Depths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 11 | 1 | 10 – 13 | 12 | 1 | 11 – 14 | 15 | 1 | 13 – 17 | 17 | 1 | 16 – 19 | 17 | 1 | 15 – 19 |
| OP1 | 12 | 1 | 11 – 14 | 13 | 1 | 11 – 15 | 17 | 1 | 14 – 20 | 20 | 1 | 18 – 21 | 21 | 2 | 18 – 23 |
| OD | 11 | 3 | 8 – 18 | 10 | 1 | 8 – 12 | 14 | 2 | 10 – 19 | 19 | 2 | 14 – 21 | 22 | 2 | 19 – 25 |
| BPV | 7 | 1 | 6 – 8 | 7 | 1 | 6 – 8 | 8 | 1 | 6 – 9 | 10 | 1 | 8 – 13 | 13 | 1 | 11 – 14 |
| AMPM | 3 | 0 | 3 – 4 | 4 | 1 | 3 – 4 | 6 | 1 | 4 – 9 | 7 | 1 | 6 – 9 | 8 | 1 | 8 – 9 |
| Max. yolk | 7 | 4 | 1 – 13 | 1 | 2 | 0 – 5 | | | | | | | | | |
| <u>Widths %SL</u> | | | | | | | | | | | | | | | |
| at BPE | 10 | 1 | 9 – 12 | 12 | 1 | 10 – 13 | 14 | 1 | 13 – 17 | 16 | 1 | 15 – 17 | 16 | 1 | 15 – 18 |
| OP1 | 7 | 1 | 6 – 8 | 9 | 1 | 7 – 10 | 11 | 1 | 9 – 13 | 15 | 1 | 12 – 17 | 17 | 2 | 14 – 20 |
| OD | 8 | 2 | 5 – 13 | 6 | 0 | 5 – 7 | 8 | 1 | 5 – 11 | 12 | 2 | 9 – 15 | 16 | 3 | 13 – 20 |
| BPV | 4 | 1 | 2 – 4 | 4 | 0 | 4 – 5 | 5 | 1 | 4 – 6 | 7 | 1 | 6 – 9 | 8 | 2 | 7 – 11 |
| AMPM | 2 | 0 | 1 – 3 | 2 | 0 | 2 – 3 | 3 | 0 | 2 – 4 | 4 | 1 | 3 – 5 | 5 | 1 | 3 – 6 |
| Max yolk | 8 | 3 | 2 – 14 | 1 | 2 | 0 – 5 | | | | | | | | | |
| <u>Myomeres</u> | | | | | | | | | | | | | | | |
| to PY | 32 | 2 ^a | 30 – 35 | 31 | 1 ^c | 30 – 32 | | | | | | | | | |
| OPAF | 11 | 9 ^b | 4 – 26 | 6 | 1 | 5 – 7 | 7 | 1 | 6 – 10 | 11 | 6 | 6 – 26 | | | |
| OP2 | | | | | | | 20 | 1 ^d | 19 – 21 | 20 | 1 | 19 – 22 | | | |
| ODF | 15 | 2 ^a | 12 – 18 | 14 | 1 | 13 – 17 | 15 | 1 ^c | 12 – 16 | | | | | | |
| OD | | | | | | | 18 | 1 ^c | 16 – 19 | 17 | 1 | 15 – 19 | | | |
| PV | 35 | 1 ^a | 34 – 36 | 35 | 1 | 34 – 36 | 34 | 1 | 33 – 36 | 33 | 1 | 31 – 37 | | | |
| Total | 43 | 0 ^a | 42 – 43 | 43 | 1 | 42 – 45 | 43 | 1 | 41 – 45 | 43 | 1 | 42 – 45 | | | |
| After PV | 8 | 1 ^a | 6 – 9 | 8 | 1 | 7 – 9 | 8 | 1 | 7 – 10 | 10 | 1 | 8 – 11 | | | |

^aN = 6. ^bN = 8. ^cN = 3. ^dN = 22. ^eN = 25. ^fN = 24. ^gN = 13. ^hN = 7.

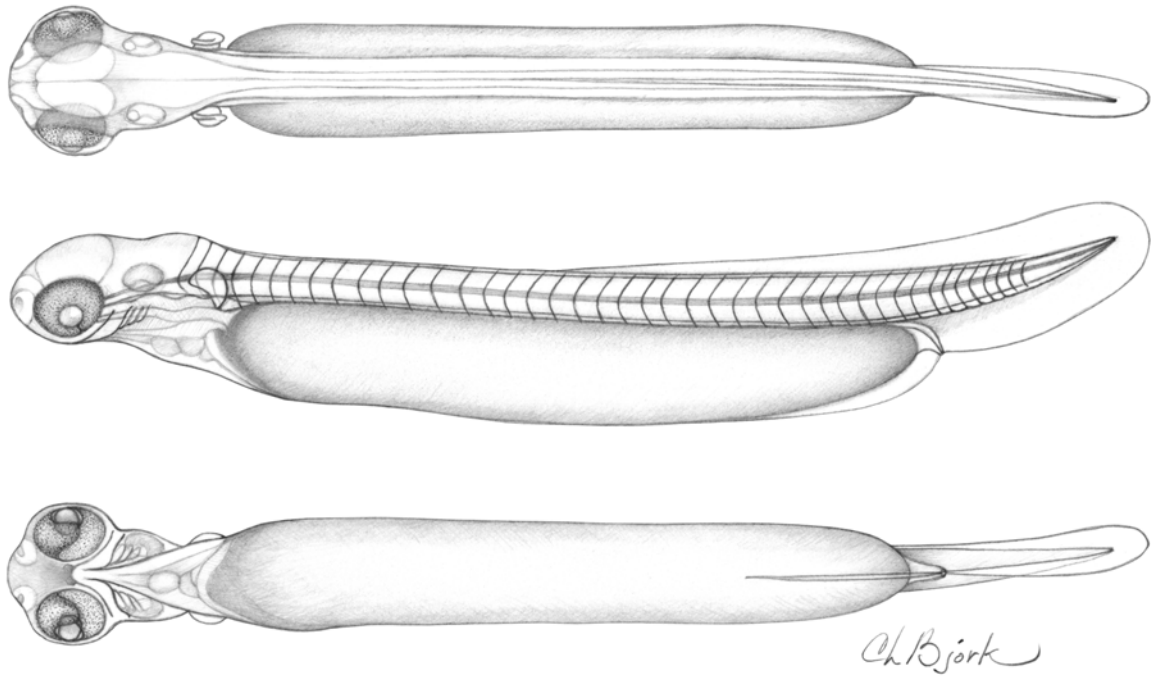


Figure 98. *Catostomus plebeius* protolarva, recently hatched, 8.5 mm SL, 8.8 mm TL. (Cultured in 2006 by Colorado Division of Wildlife Native Aquatic Species Restoration Facility with stock from Rio de las Vacas, Sandoval County, New Mexico; from LFL #102926.)

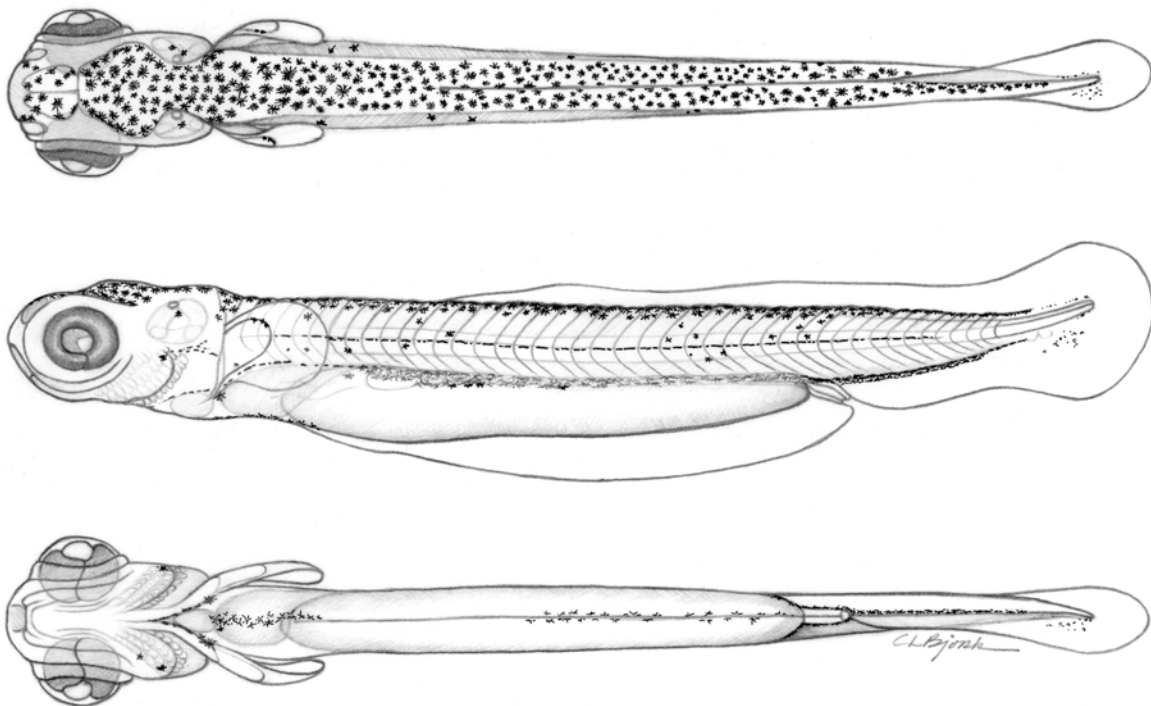


Figure 99. *Catostomus plebeius* protolarva, 9.9 mm SL, 10.4 mm TL. (Collected in 1983–84 from Sapillo Creek, Gila River Drainage, New Mexico; LFL #67322. See Snyder 1998, Figure 5, for cultured variant with much less pigmentation.)

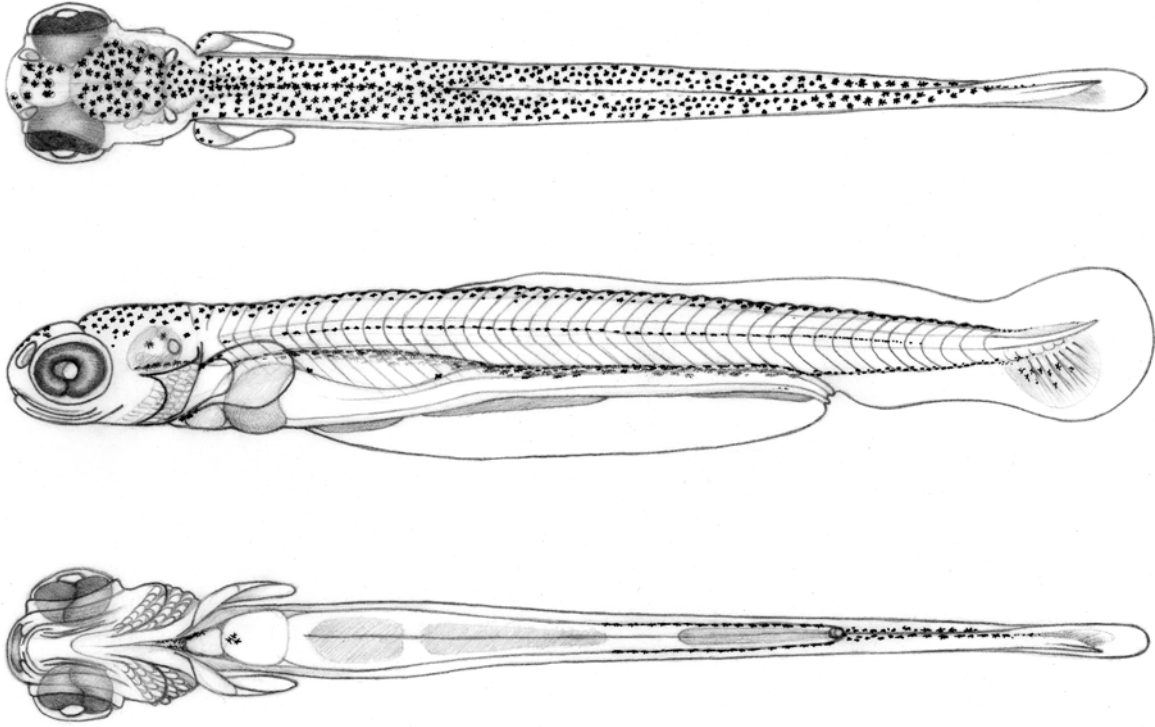


Figure 100. *Catostomus plebeius* flexion mesolarva, recently transformed (with yolk), 11.3 mm SL, 11.9 mm TL. (Collected in 1983–84 from Sapillo Creek, Gila River Drainage, New Mexico; LFL #67325.)

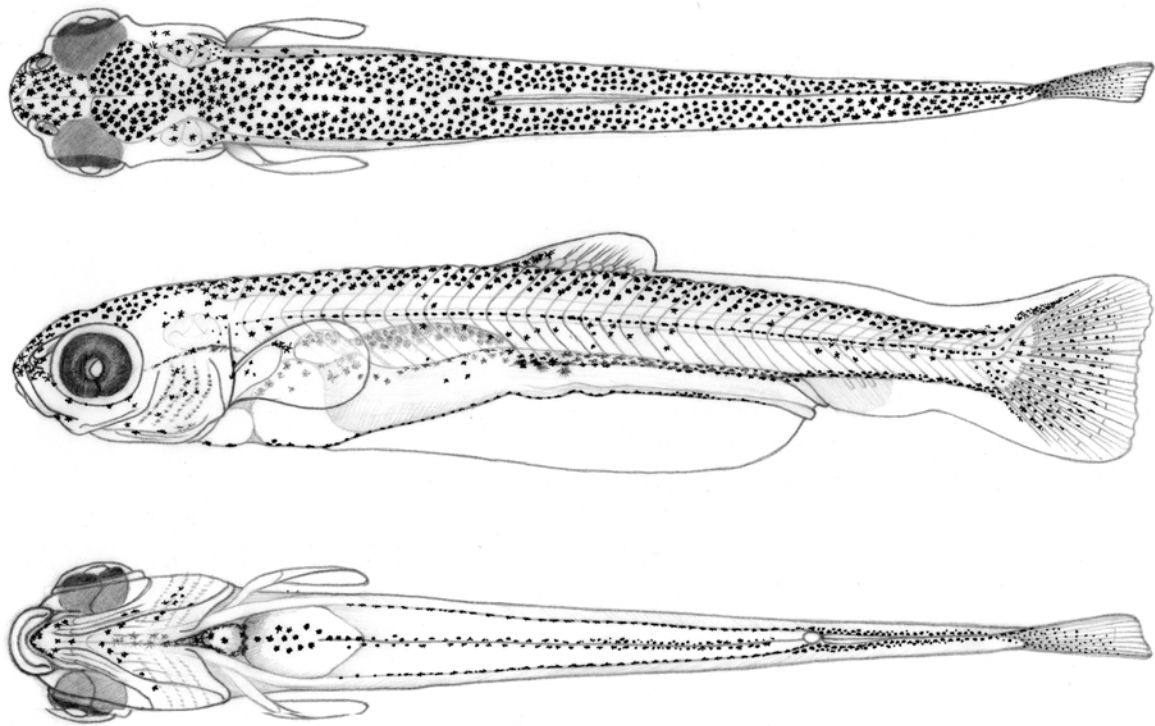


Figure 101. *Catostomus plebeius* postflexion mesolarva, 14.3 mm SL, 15.7 mm TL. (Collected in 1983–84 from Sapillo Creek, Gila River Drainage, New Mexico; LFL #67334. See Snyder 1998, Figure 14, for cultured variant with much less pigmentation.)

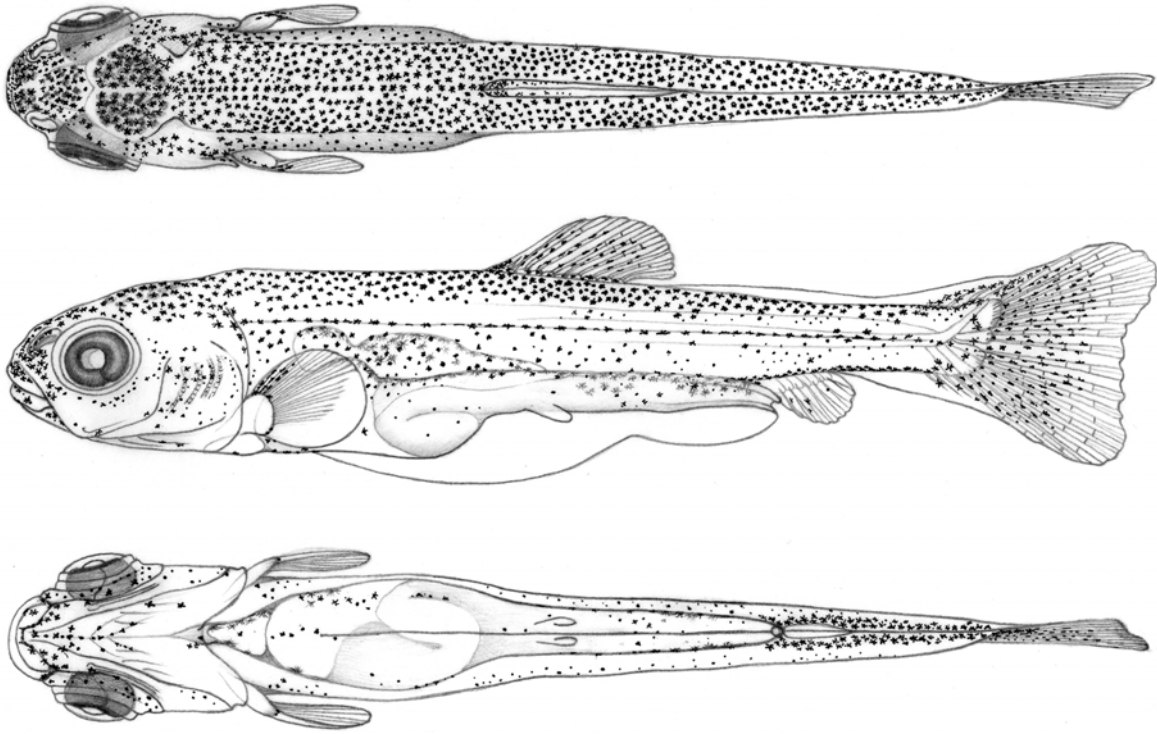


Figure 102. *Catostomus plebeius* metalarva, recently transformed, 16.9 mm SL, 19.6 mm TL. (Collected in 1982–85 from Sapillo Creek, Gila River Drainage, or Mimbres River, New Mexico; LFL #67342.)

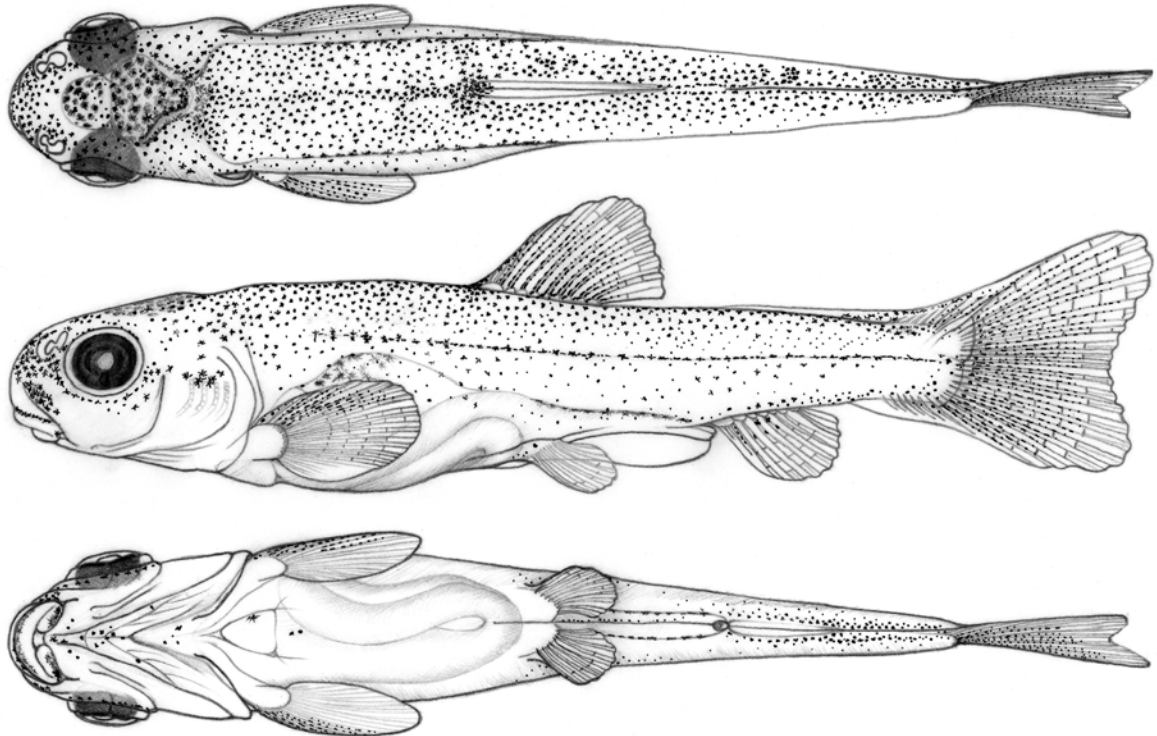


Figure 103. *Catostomus plebeius* metalarva, 19.9 mm SL, 23.5 mm TL. (Cultured in 1995 by Colorado Division of Wildlife Bellvue Fish Hatchery with stock from Hot Creek, Rio Grande Drainage, Conejos County, Colorado; LFL #67314.)

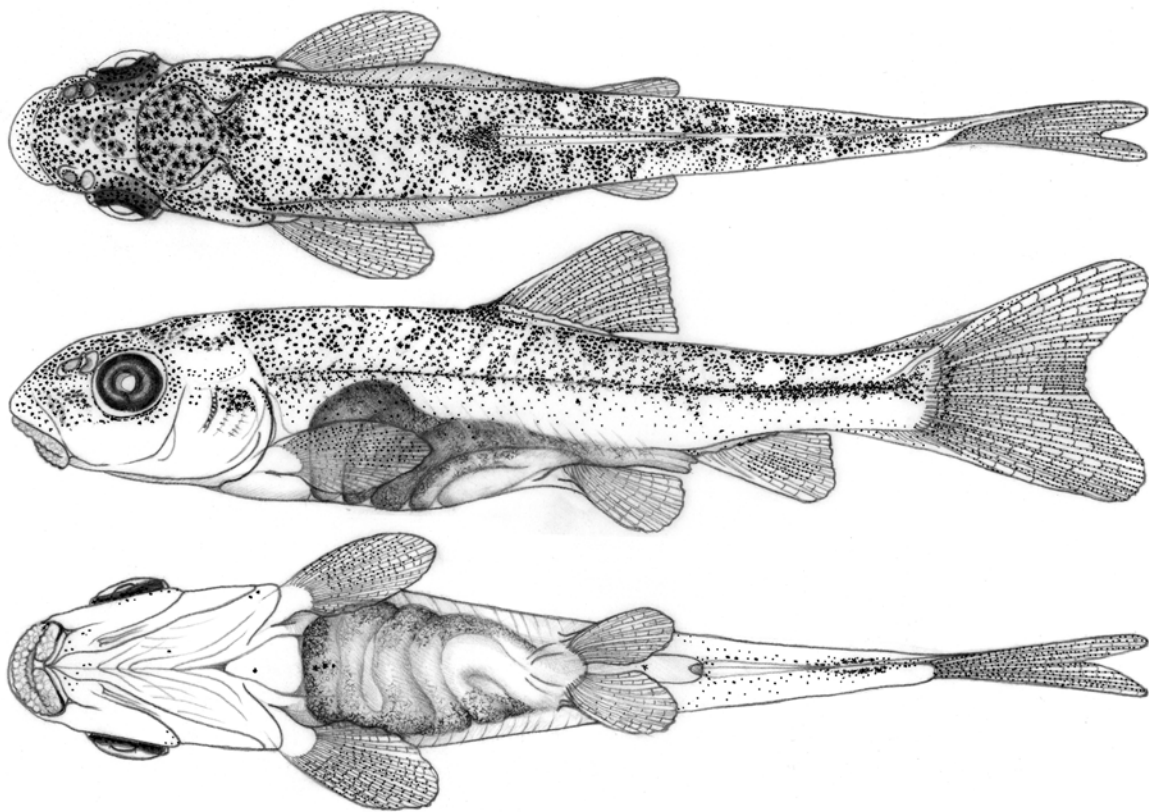


Figure 104. *Catostomus plebeius* juvenile, recently transformed, 23.1 mm SL, 27.4 mm TL. (Collected in 1984 from Sapillo Creek, Gila River Drainage, NM; LFL #67349. See Snyder 1998, Fig. 13, for variant with less pigmentation.)

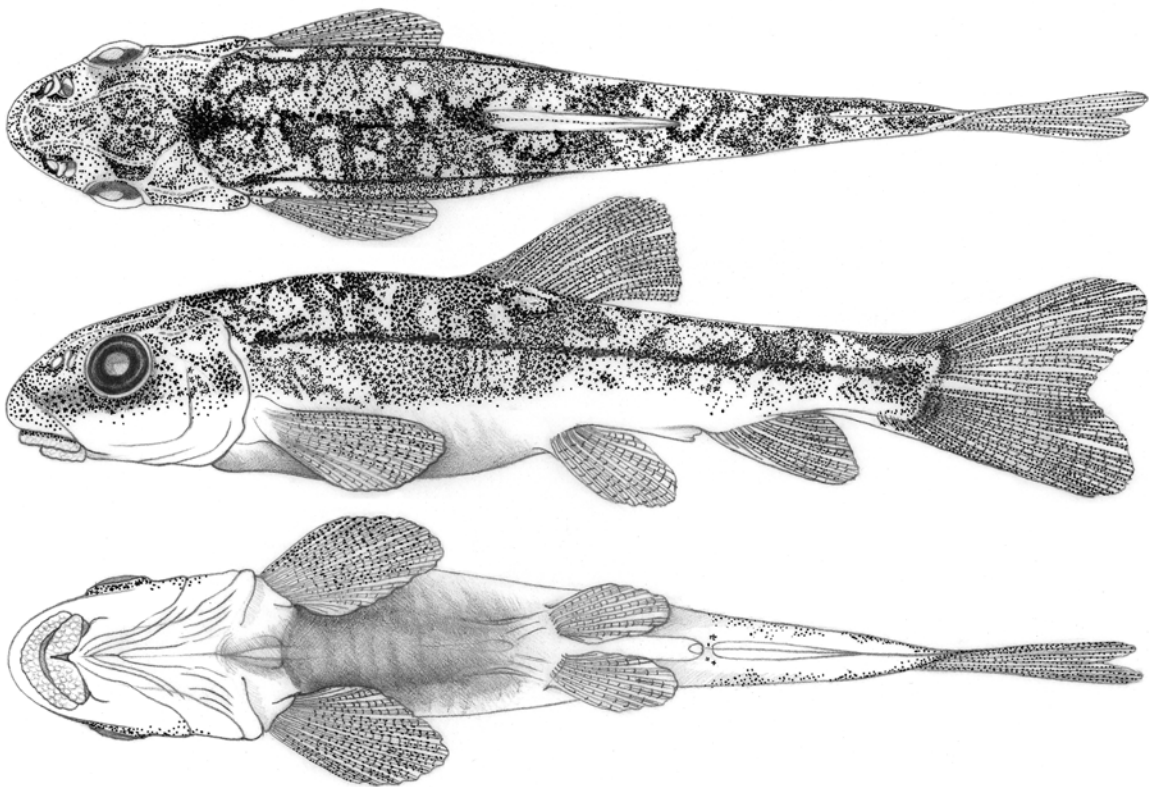


Figure 105. *Catostomus plebeius* juvenile, 31.4 mm SL, 37.8 mm TL. (Collected in 1983 from Sapillo Creek, Gila River Drainage, New Mexico; LFL #67350.)

Species Account – *Carpiodes carpio*, River Carpsucker

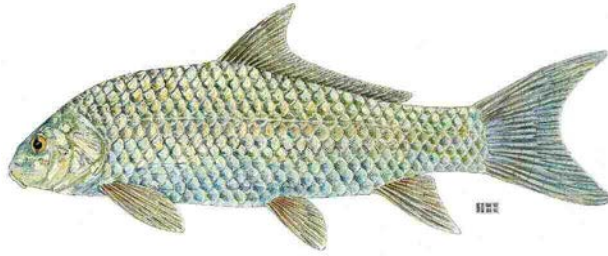


Figure 106. *Carpiodes carpio* adult (© W. H. Brandenburg).

Adult Description: Usually 30–38 cm TL, up to 64 cm. Body deep; back arched with a long, falcate dorsal fin ending behind vent. Anterior fontanelle open. Snout short, blunt; eyes moderately large, forward on head. Mouth inferior, usually ending below eye; lips weakly plicate, lower often with a small, knob-like projection at its tip. Subopercle broadest below middle with somewhat angular outer margin. Pharyngeal arches thinly compressed. Gut intricately coiled. Back brownish to greenish, sides silvery with large dark-edged scales, undersides whitish, caudal and dorsal fins dusky, lower fins clear or lightly pigmented. (Also, Table 42.)

Reproduction: Non-guarding, open-substrate lithopelagophil. Intermittently broadcast spawn in stream or reservoir shallows over firm sand to silt substrates, sometimes roots or rushes, in early spring to mid-summer at 18–27°C, late April to mid-July in Middle Rio Grande. Mature mostly at ages 3–5. Breeding fish have very small tubercles on top and sides of head, anterior back, and upper surfaces of fins; no special colors. Fecundity up to 274,000. Water-hardened eggs 1.7–2.1 mm diameter (mean 1.8 mm), demersal, and adhesive.

Young: Hatch in 3–15 d, in 4 d at 15–21°C. Swim up immediately after hatching, remain near surface by day 1, and form schools at 8 mm TL. Juveniles congregate in embayments and tributary mouths. Feed in water column until ~20 mm, then on bottom, primarily on zooplankton, algae, nematodes, and dipteran larvae.

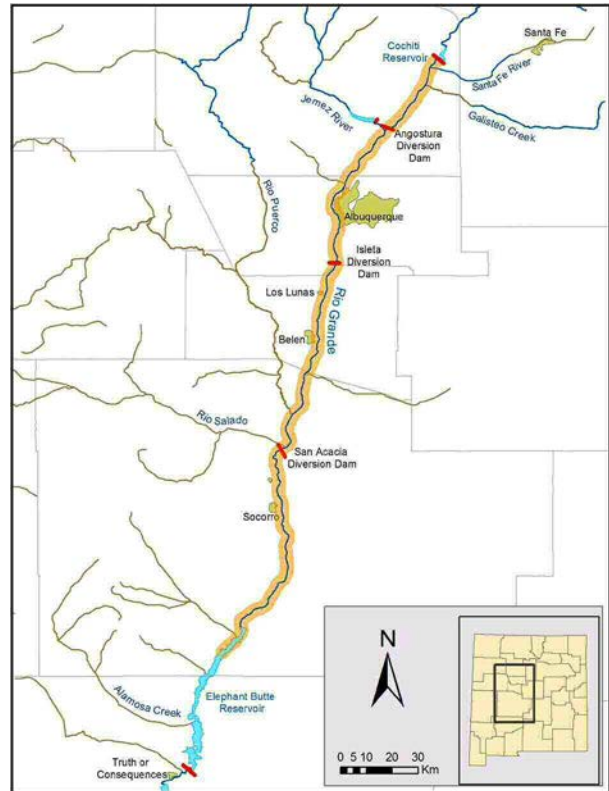


Figure 107. Distribution of *Carpiodes carpio* in the Middle Rio Grande, New Mexico, 2005–2015.

Table 42. Selected juvenile and adult meristics for *Carpiodes carpio*. (P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Gill rakers for exterior row of first arch, specimens >70 mm SL. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

| Character | Original | Literature | Character | Original | Literature |
|----------------------|----------|-------------------|-----------------------|----------|----------------|
| Dorsal-fin rays - P: | – | (23)24–27–30 | Dorsal-fin rays - R: | – | 3 ^a |
| Anal-fin rays - P: | – | 7–8–9 | Anal-fin rays - R: | – | 2 ^a |
| Caudal-fin rays - P: | – | (17)18(19) | Caudal-fin rays - RD: | – | 5 ^a |
| Pectoral-fin rays: | – | 15– <u>16</u> –18 | Caudal-fin rays - RV: | – | 5 ^a |
| Pelvic-fin rays: | – | 8– <u>9</u> –10 | Lateral scales: | – | (33)34–36(37) |
| Vertebrae: | – | (34–)36–37(–39) | Gill rakers: | – | – |

^a As shown in Yeager (1980) juvenile drawing, but illustrated count might not be accurate.

Table 43. Size at onset of selected developmental events for *Carpiodes carpio*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. Rare values in parentheses.)

| Event or structure | Onset or formation | | Fin rays or scales | First formed | | Last formed | |
|--------------------|--------------------|-------|--------------------|--------------|-------|-------------|------------|
| | mm SL | mm TL | | mm SL | mm TL | mm SL | mm TL |
| Hatched: | 5 | 5(6) | Dorsal - P: | 11(12) | 13 | 15(16) | 19 |
| Eyes pigmented: | * | * | Anal - P: | 13 | 16 | 15(16) | 18–19 |
| Yolk assimilated: | 7–8 | 8 | Caudal - P: | 9 | 10 | (11)12–13 | (12–)14–15 |
| Finfold absorbed: | 18 | 23 | Caudal - R: | 11–13 | 12–15 | > 16 | > 21 |
| Pectoral-fin buds: | * | * | Pectoral: | 12 | 14 | 17–18 | 22–23 |
| Pelvic-fin buds: | 11 | 12–13 | Pelvic: | 14 | 17 | 16–18 | 21–23 |
| * before hatching | | | Scales: | 16 | 20 | 21–22 | 27–29 |

References: Becker 1983; Cross 1967; Fuiman 1982a; Holland-Bartels et al. 1990; Jester 1972; Kansas Fishes Committee 2014; Kay et al. 1994; Pflieger 1997; Simon 1998; Sublette et al. 1990; Yeager 1980.

Account (and other larval descriptions): Except for adult description, distribution, and meristics, extracted or calculated from description by and illustrations in Yeager 1980, photographs in May and Gasaway 1967, and accounts based mostly on Yeager 1980 by Fuiman 1982a, Holland-Bartels et al. 1990, and Kay et al. 1994.

Table 44. Size at developmental interval (left) and gut phase (right) transitions for *Carpiodes carpio*. (See Figure 5 for phases of gut folding. Rare values in parentheses.)

| Transition to | mm SL | mm TL | Transition to | mm SL | mm TL |
|------------------------|-----------|------------|------------------------|------------|------------|
| Flexion mesolarva: | 9 | 10 | 2 - 90° bend: | 11–12 | 13 |
| Postflexion mesolarva: | (11)12–13 | (12–)14–15 | 3 - Full loop: | (14–)16–18 | (17–)19–23 |
| Metalarva: | 15(16) | 19 | 4 - Partial crossover: | ? | ? |
| Juvenile: | 18 | 23 | 5 - Full cross over: | ? | ? |

Table 45. Summary of morphometrics and myomere counts by developmental phase for *Carpiodes carpio*. (See Figure 4 for abbreviations and methods of measurement and counting. Standard deviation [SD] of 0 represents a value < 0.5.)

| | Protolarvae (N = 18 ^a) | | Flexion mesolarvae (N = 14 ^a) | | Postflexion mesolarvae (N = 20 ^a) | | Metalarvae (N = 13 ^a) | | Juveniles (N = 9 ^a) | | |
|--------------------|------------------------------------|-------------------------|---|------------------------|---|--------------------------|-----------------------------------|------------------------|---------------------------------|------------------------|--|
| | \bar{x} | \pm SD Range | \bar{x} | \pm SD Range | \bar{x} | \pm SD Range | \bar{x} | \pm SD Range | \bar{x} | \pm SD Range | |
| SL, mm | 7 | 1 5 – 9 | 11 | 1 9 – 12 | 14 | 1 ^j 11 – 15 | 17 | 1 15 – 18 | 20 | 2 18 – 24 | |
| TL, mm | 7 | 1 5 – 10 | 12 | 1 10 – 14 | 15 | 2 12 – 19 | 21 | 1 19 – 23 | 25 | 2 23 – 30 | |
| <u>Lengths %SL</u> | | | | | | | | | | | |
| AS to AE | 3 | 1 2 – 5 | 4 | 1 3 – 5 | 5 | 0 5 – 6 | 5 | 0 5 – 6 | 6 | 0 5 – 7 | |
| PE | 10 | 1 9 – 11 | 11 | 1 10 – 13 | 13 | 0 11 – 14 | 13 | 0 13 – 14 | 14 | 0 13 – 15 | |
| OP1 | 20 | 2 ^b 16 – 22 | 22 | 1 ^g 21 – 23 | 25 | 1 ^d 23 – 27 | 29 | ^h 29 | 28 | ^h 28 | |
| OP2 | | | | | 54 | 2 ^c 52 – 55 | 55 | ^h 55 | 54 | ^h 54 | |
| PY | 67 | 10 ^c 55 – 73 | | | | | | | | | |
| OPAF | 42 | 17 ^c 30 – 61 | 36 | ^h 36 | 45 | 8 ^d 34 – 54 | 63 | ^h 63 | | | |
| ODF | 40 | 2 36 – 44 | 46 | 1 ⁱ 42 – 48 | 46 | 0 ^k 46 – 46 | | | | | |
| OD | | | | | 48 | 1 ⁱ 46 – 50 | 48 | 1 47 – 49 | 48 | 1 47 – 49 | |
| ID | | | | | | | 81 | ^h 81 | 80 | ^h 80 | |
| PV | 76 | 1 75 – 77 | 78 | 1 75 – 80 | 79 | 1 77 – 82 | 77 | 1 76 – 78 | 77 | 1 74 – 79 | |
| OA | | | | | 78 | 0 ^k 78 – 78 | 77 | ^h 77 | 76 | ^h 76 | |
| IA | | | | | 84 | ^h 84 | 86 | ^h 86 | 85 | ^h 85 | |
| AFC | | | | | 112 | 1 ^c 110 – 113 | 118 | ^h 118 | 114 | ^h 114 | |
| PC | 105 | 1 103 – 107 | 111 | 4 105 – 117 | 120 | 3 ^j 113 – 125 | 128 | 2 124 – 130 | 129 | 1 127 – 132 | |
| Y | 26 | 27 ^d 0 – 54 | | | | | | | | | |
| P1 | 10 | 4 ^c 5 – 13 | 12 | ^h 12 | 14 | 0 ^k 14 – 15 | 24 | ^h 24 | 21 | ^h 21 | |
| P2 | | | | | 6 | 1 ^k 5 – 7 | 14 | ^h 14 | 19 | ^h 19 | |
| D | | | | | | | 36 | ^h 36 | 41 | ^h 41 | |
| A | | | | | 10 | ^h 10 | 13 | ^h 13 | 17 | ^h 17 | |
| <u>Depths %SL</u> | | | | | | | | | | | |
| at BPE | 12 | 1 11 – 18 | 14 | 1 12 – 16 | 17 | 1 13 – 18 | 18 | 0 18 – 20 | 19 | 0 19 – 20 | |
| OP1 | 13 | 3 ^c 11 – 16 | 15 | ^h 15 | 18 | 2 ^d 15 – 21 | 25 | ^h 25 | 25 | ^h 25 | |
| OD | 12 | 3 ^c 9 – 16 | 12 | ^h 12 | 16 | 4 ^d 11 – 22 | 26 | ^h 26 | 27 | ^h 27 | |
| BPV | 7 | 1 ^c 6 – 8 | 7 | ^h 7 | 10 | 2 ^d 7 – 12 | 17 | ^h 17 | 20 | ^h 20 | |
| AMPM | 4 | 0 ^c 3 – 4 | 5 | ^h 5 | 8 | 1 ^d 6 – 10 | 12 | ^h 12 | 14 | ^h 14 | |
| Max. Yolk | 5 | 8 ^d 0 – 20 | | | | | | | | | |
| <u>Widths %SL</u> | | | | | | | | | | | |
| at BPE | 12 | 1 ^c 11 – 13 | 15 | 1 ⁱ 13 – 16 | 17 | 1 ^c 16 – 18 | 18 | 0 ^m 18 – 18 | 19 | 0 ⁿ 18 – 19 | |
| OP1 | | | | | | | | | | | |
| OD | | | | | | | | | | | |
| BPV | | | | | | | | | | | |
| AMPM | | | | | | | | | | | |
| Max Yolk | | | | | | | | | | | |
| <u>Myomeres</u> | | | | | | | | | | | |
| to PY | 26 | 5 ^c 21 – 31 | | | | | | | | | |
| OPAF | 13 | 7 ^c 7 – 21 | 10 | ^h 10 | 15 | 5 ^k 11 – 18 | 22 | ^h 22 | | | |
| OP2 | | | | | 18 | 1 ^k 17 – 18 | 17 | ^h 17 | | | |
| ODF | 11 | 1 ^f 10 – 12 | 12 | ^h 12 | 14 | 1 ^k 13 – 14 | | | | | |
| OD | | | | | 15 | 1 ^k 14 – 15 | 13 | ^h 13 | | | |
| PV | 30 | 1 28 – 32 ^o | 30 | 1 29 – 31 | 29 | 1 ^l 27 – 31 | 29 | 0 ^f 28 – 29 | | | |
| Total | 38 | 1 36 – 41 ^o | 37 | 1 35 – 38 | 36 | 1 ^l 34 – 38 | 35 | 1 ^f 34 – 36 | | | |
| After PV | 8 | 1 7 – 10 | 7 | 1 5 – 9 | 6 | 1 ^l 5 – 8 | 7 | 0 ^f 6 – 7 | | | |

^aIncludes up to 5 calculated values for measurement means, means - SD, and means + SD from Yeager (1980), and myomere count modes, minimums, and maximums from Kay et al. (1994), in 1-mm-TL intervals, 10 specimens per interval; remaining data based on drawings in Yeager (1980) and photographs of postflexion mesolarvae in May and Gasaway (1967). ^bN = 9. ^cN = 3. ^dN = 5. ^eN = 15. ^fN = 6. ^gN = 7. ^hN = 1. ⁱN = 13. ^jN = 19. ^kN = 2. ^lN = 17. ^mN = 12. ⁿN = 8. ^oMaximum myomeres to PV and total are based on drawings in Yeager (1980) and 1 and 2 units greater, respectively, than summarized by Yeager and others.

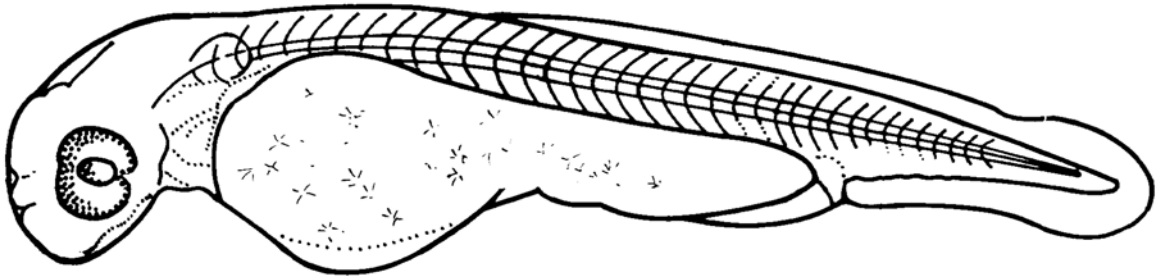


Figure 108. *Carpiodes carpio* protolarva, recently hatched, 5.0 mm SL, 5.2 mm TL. (Cultured in 1979 with stock from Holston River, Tennessee. From Yeager 1980, Figure 3a, with author permission, as reprinted by Fuiman 1982a, Figure 139a.)

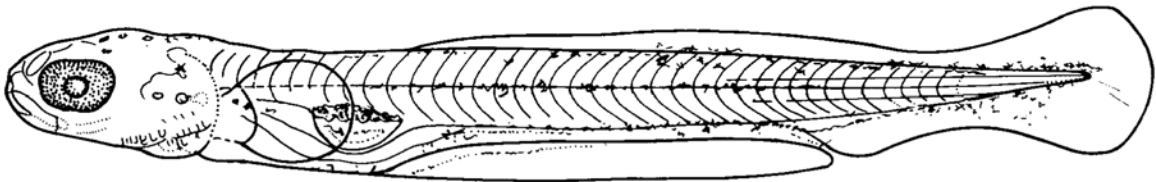
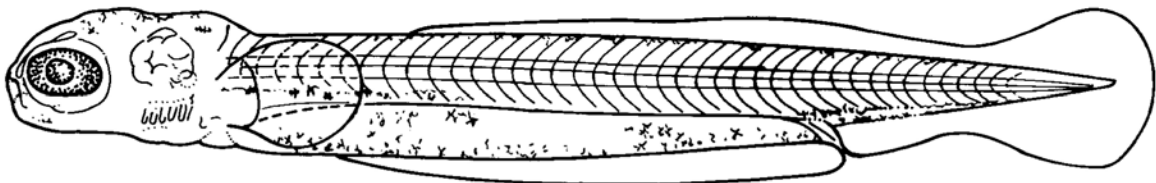


Figure 109. *Carpiodes carpio* protolarvae, 7.4 mm SL, 7.6 mm TL (top) and 7.9 mm SL, 8.3 mm TL (bottom). (Cultured in 1979 with stock from Holston River, Tennessee. From Yeager 1980, Figures 4a and 5a, with author permission, as reprinted by Fuiman 1982a, Figures 139b and c.)

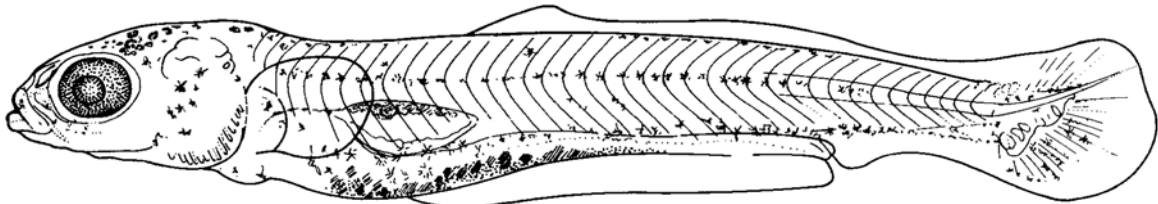


Figure 110. *Carpiodes carpio* flexion mesolarva, 10.9 mm SL, 11.4 mm TL. (Cultured in 1979 with stock from Holston River, Tennessee. From Yeager 1980, Figure 7a, with author permission, as reprinted by Fuiman 1982a, Figure 139d.)

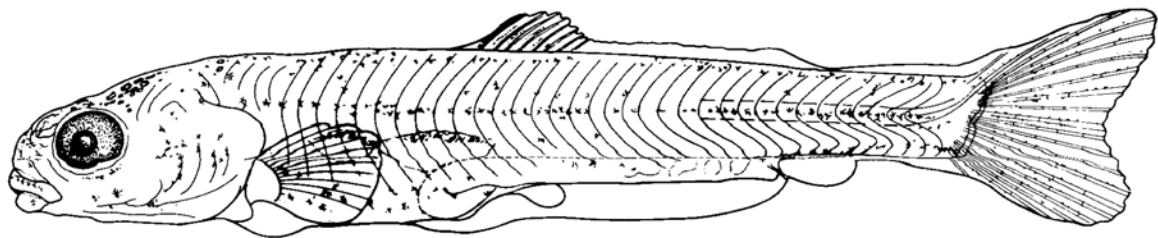


Figure 111. *Carpiodes carpio* postflexion mesolarva, 12.9 mm SL, 15.1 mm TL. (Cultured in 1979 with stock from Holston River, Tennessee. From Yeager 1980, Figure 8a, with author permission, as reprinted by Fuiman 1982a, Figure 139e.)

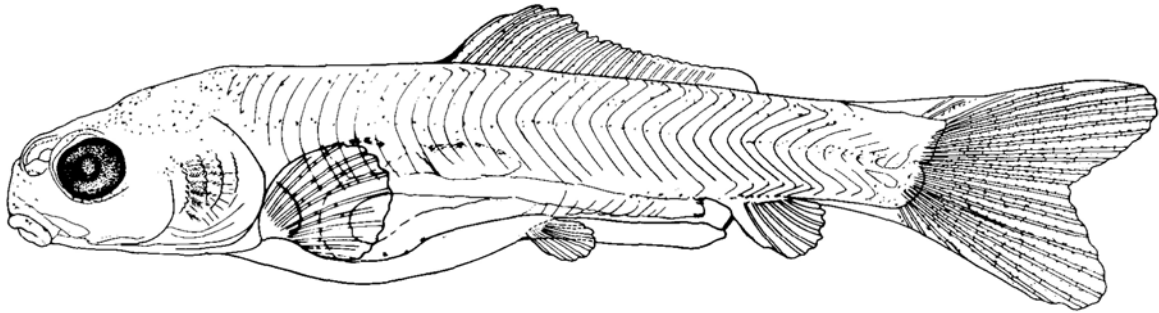


Figure 112. *Carpiodes carpio* postflexion mesolarva, almost metalarva (last principal dorsal fin rays not yet formed), 14.4 mm SL, 17.6 mm TL. (Cultured in 1979 with stock from Holston River, Tennessee. From Yeager 1980, Figure 9a, with author permission, as reprinted by Fuiman 1982a, Figure 140a.)

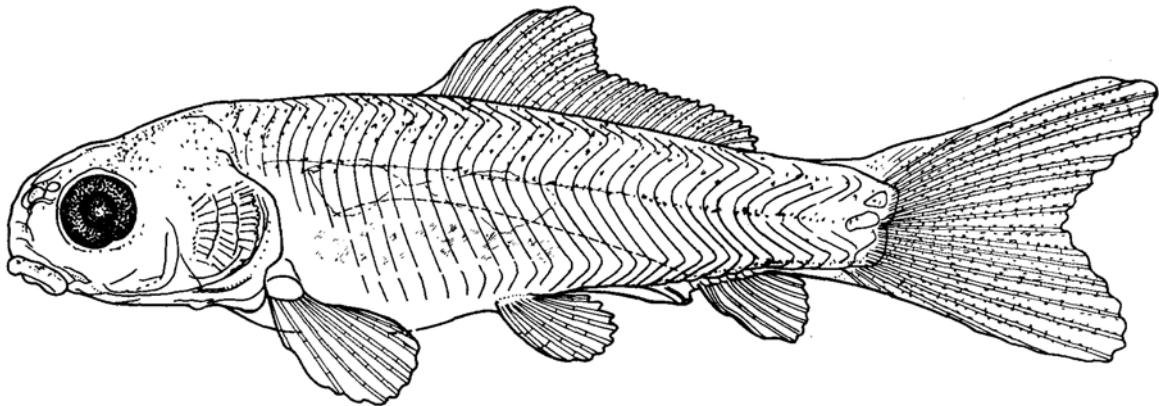


Figure 113. *Carpiodes carpio* metalarva, 16.4 mm SL, 21.1 mm TL. (Cultured in 1979 with stock from Holston River, Tennessee. From Yeager 1980, Figure 10a, with author permission, as reprinted by Fuiman 1982a, Figure 140b.)

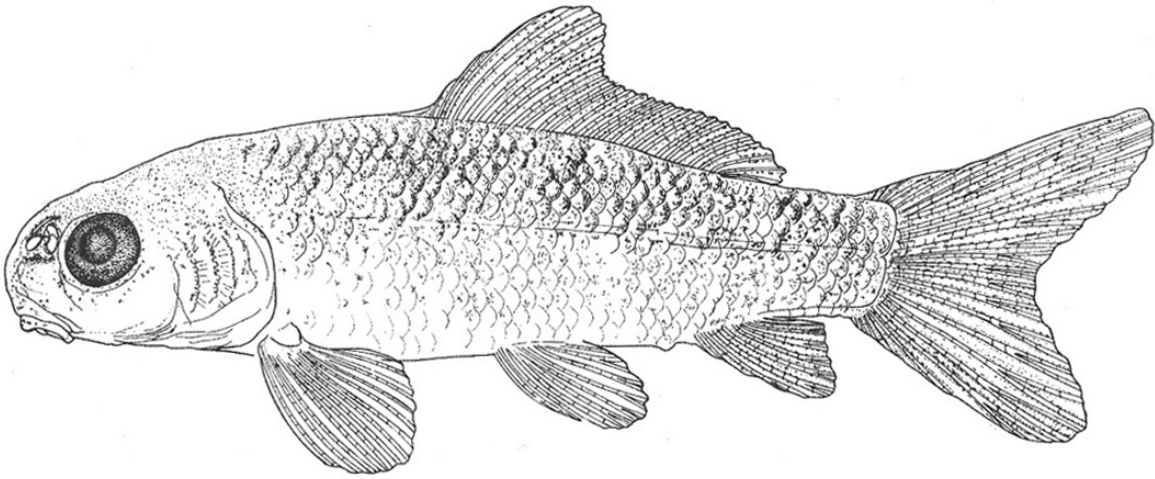


Figure 114. *Carpiodes carpio* juvenile, recently transformed, 23.7 mm SL, 30.1 mm TL. (Cultured in 1979 with stock from Holston River, Tennessee. From Yeager 1980, Figure 11a, with author permission, as reprinted by Fuiman 1982a, Figure 140c.)

Species Account – *Ictiobus bubalus*, Smallmouth Buffalo

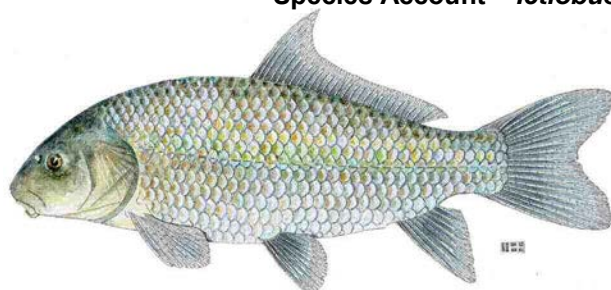


Figure 115. *Ictiobus bubalus* adult (© W. H. Brandenburg).

Adult Description: Usually 38–76 cm TL, up to 104 cm. Body deep; back arched, sometimes keel-like anteriorly, with a long falcate dorsal fin ending behind vent. Anterior fontanelle closed. Snout short, blunt; eyes forward on head. Mouth small, subterminal to inferior, ending before eyes; lips plicate, upper thick. Subopercle broadest at middle with evenly rounded outer margin. Pharyngeal arches stout. Gut coils linearly long. Large scales, not darkly edged. Back dark, sides brassy to grey, belly whitish; all fins dusky to dark (pelvics densely speckled), lower fins with whitish margins. (Also, Table 46.)

Reproduction: Non-guarding, open-substrate lithopelagophil (or phytolithophil). Broadcast spawn in little or no current over a wide variety of substrates including shoals, debris, plants, or recently flooded shoreline vegetation, mostly in spring at 15–18°C (but as late as September and up to 28°C), late May to June in Middle Rio Grande. Mature mostly in 4–8 years. Breeding males slightly darker with small tubercles over head, body, and fins. Fecundity up to 500,000. Eggs 1.6–2.4 mm diameter, demersal, and adhesive.

Young: Hatch in 1–8 d at 16–23°C, up to 10 d. Swim up immediately after hatching, free-swimming by 3.5 d, then rapidly disperse in current. Juveniles congregate in deep reservoir or headwater stream habitats. Begin bottom feeding in 2 weeks, mostly bottom feeding by 5 weeks. Feed mostly on zooplankton and algae.

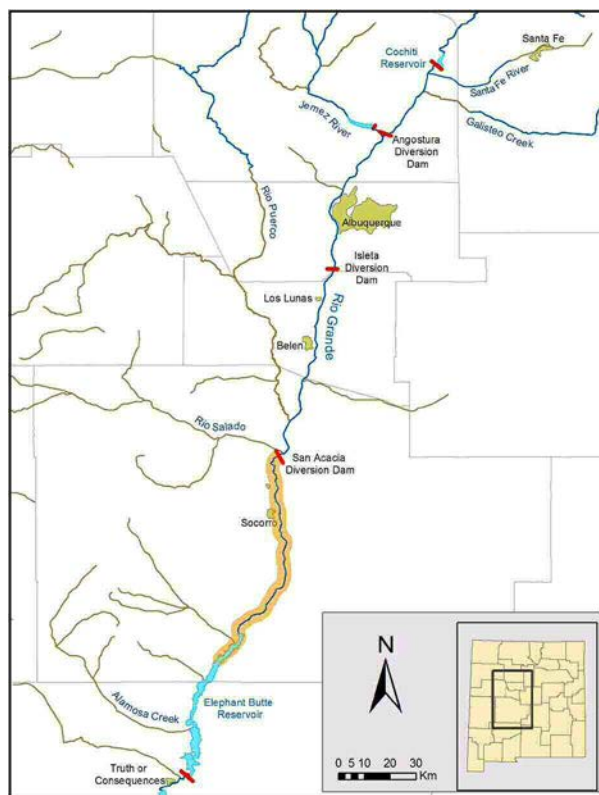


Figure 116. Distribution of *Ictiobus bubalus* in the Middle Rio Grande, New Mexico, 2005–2015.

Table 46. Selected juvenile and adult meristics for *Ictiobus bubalus*. (P = principal rays; R = rudimentary rays; D = dorsal; V = ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Gill rakers for exterior row of first arch, specimens >70 mm SL. Mean or modal values underlined if known and noteworthy; rare values in parentheses.)

| Character | Original | Literature | Character | Original | Literature |
|----------------------|----------|------------------------|-----------------------|----------|----------------|
| Dorsal-fin rays - P: | – | (24–)26–28–30(31) | Dorsal-fin rays - R: | – | 2 ^a |
| Anal-fin rays - P: | – | (7)8–9(–11) | Anal-fin rays - R: | – | 2 ^a |
| Caudal-fin rays - P: | – | 16–17–18–19(20) | Caudal-fin rays - RD: | – | 5 ^a |
| Pectoral-fin rays: | – | 15– <u>16</u> –17(–19) | Caudal-fin rays - RV: | – | 6 ^a |
| Pelvic-fin rays: | – | (8) <u>9</u> –11 | Lateral scales: | – | (33–)36–38(39) |
| Vertebrae: | – | (34–)36–37(–41) | Gill rakers: | – | < 35 |

^a As shown in Yeager and Baker (1982) juvenile drawing, but illustrated count might not be accurate.

Table 47. Size at onset of selected developmental events for *Ictiobus bubalus*. (As apparent under low power magnification. P = principal rays; R = rudimentary rays. Scales are lateral series. SL data approximated by calculation. Rare values in parentheses. If substantially different, TL data mostly from Wrenn and Grinstead 1971 and Yeager and Baker 1982 separated respectively by a slash.)

| Event or structure | Onset or formation | | Fin rays or scales | First formed | | Last formed | |
|--------------------|--------------------|---------------|--------------------|--------------|-----------|---------------|---------------|
| | mm SL | mm TL | | mm SL | mm TL | mm SL | mm TL |
| Hatched: | 5–6 | 5–6 | Dorsal - P: | 11–13 | 13–15 | 14–16 / 17–19 | 17–20 / 22–24 |
| Eyes pigmented: | * | * | Anal - P: | (12)13–15 | (14)15–18 | 13–14 / 16–19 | 15–17 / 21–24 |
| Yolk assimilated: | 7(8) | 7–8 | Caudal - P: | 9 | (9)10 | 11–12 | 13–14 |
| Finfold absorbed: | 16–17 / 22–24 | 18–22 / 28–31 | Caudal - R: | < 14 | < 16 | > 17 | > 21 |
| Pectoral-fin buds: | * | * | Pectoral: | – / (14)15 | – / 18 | 13–14 / 22–24 | 15–17 / 28–31 |
| Pelvic-fin buds: | (10)11–12 | 12–14 | Pelvic: | 13 / 15 | 16 / 18 | 14 / 19–20 | 17 / 24–26 |
| * before hatching | | | Scales: | 17–18 | 22–23 | (19)20 | 25–26 |

References: Becker 1983; Cross 1967; Eddy and Underhill 1974; Fuiman 1982a; Holland-Bartels et al. 1990; Hoyt et al. 1979; Jester 1973; Kansas Fishes Committee 2014; Kay et al. 1994; Pflieger 1997; Scheidegger 1990; Simon 1998; Sublette et al. 1990; Wrenn and Grinstead 1971; Yeager and Baker 1982. **Account (and other larval descriptions):** Except for adult description, distribution, and meristics, extracted or calculated from descriptions by and illustrations in Wrenn and Grinstead 1971 and Yeager and Baker 1982, accounts based mostly on those descriptions by Fuiman 1982a, Holland-Bartels et al. 1990, and Kay et al. 1994, and brief descriptions by Hoyt et al. 1979 and Scheidegger 1990.

Table 48. Size at developmental interval (left) and gut phase (right) transitions for *Ictiobus bubalus*. (If substantially different, TL data mostly from Wrenn and Grinstead 1971 and Yeager and Baker 1982 separated respectively by a slash. See Figure 5 for phases of gut folding. Rare values in parentheses.)

| Transition to | mm SL | mm TL | Transition to | mm SL | mm TL |
|------------------------|---------------|---------------|------------------------|-----------|-----------------|
| Flexion mesolarva: | 9 | (9)10 | 2 - 90° bend: | 13–15 | 16–18 |
| Postflexion mesolarva: | 11–12 | 13–14 | 3 - Full loop: | 14–15 | 17–19 |
| Metalarva: | 14–16 / 17–19 | 17–20 / 22–24 | 4 - Partial crossover: | ? (15–16) | ? (20: 2 loops) |
| Juvenile: | 16–17 / 22–24 | 18–22 / 28–31 | 5 - Full cross over: | ? | ? |

Table 49. Summary of morphometrics and myomere counts by developmental phase for *Ictiobus bubalus*. (See Figure 4 for abbreviations and methods of measurement and counting. Standard deviation [SD] of 0 represents a value < 0.5.)

| | Protolarvae (N = 11 ^a) | | Flexion mesolarvae (N = 6 ^b) | | Postflexion mesolarvae (N = 14 ^c) | | Metalarvae (N = 6 ^d) | | Juveniles (N = 2) | |
|--------------------|------------------------------------|----------------------------------|--|----------------------|---|------------------------|----------------------------------|----------------------|-------------------|----------------|
| | \bar{x} | \pm SD Range | \bar{x} | \pm SD Range | \bar{x} | \pm SD Range | \bar{x} | \pm SD Range | \bar{x} | \pm SD Range |
| SL, mm | 7 | 1 5–9 | 10 | 1 9–11 | 14 | 2 11–17 | 18 | 2 15–20 | 23 | 1 22–23 |
| TL, mm | 8 | 1 6–10 | 11 | 1 10–13 | 17 | 3 13–22 | 24 | 2 20–26 | 29 | 0 29–29 |
| <u>Lengths %SL</u> | | | | | | | | | | |
| AS to AE | 3 | 1 2–4 | 3 | 0 2–3 | 5 | 1 4–6 | 6 | 1 4–7 | 7 | 1 7–8 |
| PE | 10 | 1 9–12 | 11 | 1 9–12 | 13 | 1 11–15 | 15 | 1 12–15 | 15 | 1 15–16 |
| OP1 | 19 | 1 ^e 17–21 | 21 | 2 18–23 | 25 | 2 ^g 22–28 | 27 | 1 27 | 29 | 1 28–29 |
| OP2 | | | | | 50 | 2 ^l 47–51 | 52 | 1 52 | 52 | 1 52–53 |
| PY | 73 | 2 ^f 72–75 | | | | | | | | |
| OPAF | 34 | 5 ^g 26–39 | 32 | 3 ^f 29–35 | 35 | 1 ^j 32–36 | 52 | 1 52 | | |
| ODF | 42 | 1 40–44 | 43 | 2 39–45 | 47 | 2 ⁿ 40–48 | | | | |
| OD | | | | | 48 | 2 ^l 45–50 | 47 | 1 45–48 | 49 | 1 48–50 |
| ID | | | | | 83 | 1 83 | 80 | 1 80 | 84 | 2 82–85 |
| PV | 76 | 2 73–78 | 79 | 2 76–80 | 80 | 2 78–83 | 77 | 1 75–78 | 75 | 0 75–75 |
| OA | | | | | 80 | 2 ⁱ 79–82 | 74 | 1 74 | 75 | 1 75–76 |
| IA | | | | | 88 | 1 ^l 88–89 | 85 | 1 85 | 85 | 1 84–86 |
| AFC | | | | | 113 | 1 ^j 111–115 | 115 | 1 115 | 115 | 2 113–116 |
| PC | 105 | 1 104–108 | 112 | 3 109–117 | 122 | 3 116–127 | 128 | 1 126–130 | 127 | 1 126–128 |
| Y | 19 | 27 ^h 0–56 | | | | | | | | |
| P1 | 10 | 2 ^g 7–13 | 14 | 1 14 | 16 | 1 ^f 15–17 | | | 16 | 0 16–16 |
| P2 | | | | | 7 | 3 ^j 4–12 | 11 | 1 11 | 13 | 1 12–14 |
| D | | | | | 38 | 1 38 | 38 | 1 38 | 38 | 0 38–38 |
| A | | | | | 12 | 1 12 | 12 | 1 12 | 15 | 1 14–16 |
| <u>Depths %SL</u> | | | | | | | | | | |
| at BPE | 13 | 1 12–16 | 14 | 1 11–15 | 17 | 1 14–19 | 19 | 1 17–20 | 21 | 1 20–22 |
| OP1 | 14 | 1 ^g 13–16 | 16 | 3 ^f 12–18 | 20 | 2 ^l 17–23 | 20 | 1 20 | 27 | 0 27–28 |
| OD | 11 | 2 ^g 9–16 | 13 | 2 ^f 11–15 | 19 | 3 ^j 15–23 | 22 | 1 22 | 28 | 2 27–30 |
| BPV | 6 | 1 ^g 5–7 | 7 | 1 ^f 6–8 | 11 | 3 ^j 9–15 | 12 | 1 12 | 19 | 1 18–19 |
| AMPM | 4 | 1 ^g 3–5 | 6 | 2 ^f 5–7 | 9 | 1 ^j 7–11 | 11 | 1 11 | 12 | 0 12–13 |
| Max. Yolk | 4 | 6 ^h 0–15 | | | | | | | | |
| <u>Widths %SL</u> | | | | | | | | | | |
| at BPE | 12 | 1 ^e 11–14 | 14 | 0 ^f 14–14 | 16 | 1 ^o 15–17 | 17 | 0 ^j 17–18 | | |
| OP1 | 8 | 2 ⁱ 6–10 | | | | | | | | |
| OD | 7 | 2 ⁱ 6–8 | | | | | | | | |
| BPV | 3 | 1 ⁱ 3–4 | | | | | | | | |
| AMPM | 2 | 0 ⁱ 1–2 | | | | | | | | |
| Max Yolk | 2 | 5 ^j 0–10 ^l | | | | | | | | |
| <u>Myomeres</u> | | | | | | | | | | |
| to PY | 28 | 2 ^f 26–29 | | | | | | | | |
| OPAF | 8 | 4 ^g 3–13 | 5 | 1 5 | 5 | 1 ^f 4–6 | | | | |
| OP2 | | | | | 14 | 1 ^f 14–15 | | | | |
| ODF | 12 | 2 ^h 9–15 | 11 | 1 11 | 13 | 1 ⁱ 12–13 | | | | |
| OD | | | | | 13 | 1 ^f 12–14 | | | | |
| PV | 30 | 1 ^k 28–31 | 30 | 0 ^m 30–31 | 30 | 1 ^p 28–32 | | | | |
| Total | 37 ^a | 1 ^k 35–39 | 37 | 1 ^m 36–38 | 35 | 1 ^p 34–37 | | | | |
| After PV | 8 | 1 ^k 5–9 | 7 | 0 ^m 6–7 | 5 | 1 ^p 4–7 | | | | |

^aIncludes 5 morphometric means and myomere count modes, minimums and maximums for 35 specimens in ~1 mm intervals from Yeager and Baker (1982) (remaining data from drawings). ^bIncludes 3 . . . for 12 specimens ^cIncludes 9 morphometric means for 48 specimens and 8 myomere count modes, minimums and maximums for 42 specimens ^dIncludes 5 morphometric means for 38 specimens ^eN = 7. ^fN = 3. ^gN = 6. ^hN = 8. ⁱN = 2. ^jN = 5. ^kN = 19. ^lN = 1. ^mN = 10. ⁿN = 12. ^oN = 9. ^pN = 27. ^qMode of 38 reported by Yeager and Baker (1982). ^rMinimums of 25 reported by Wrenn and Grinstead (1971) and 27 by Hoyt et al. (1979) and Scheidegger (1990). ^sMinimum of 33 reported by Wrenn & Grinstead (1971) and Yeager (1980). ^tMaximum yolk width would be notably greater if data were available for recently hatched larvae.

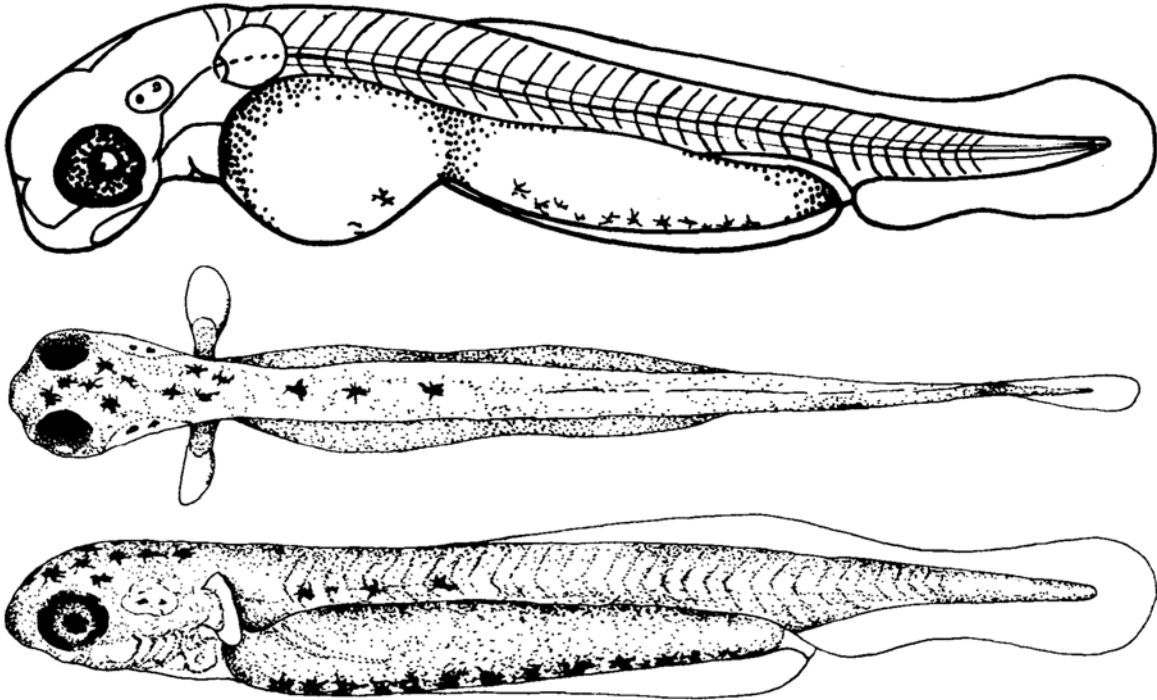


Figure 117. *Ictiobus bubalus* protolarvae, recently hatched, 5.4 mm SL, 5.6 mm TL (top,) and 3-d posthatch, 7.2 mm SL, 7.6 mm TL (lower dorsal and lateral views). (Cultured, respectively, in 1979 with stock from Cache River, Arkansas, and in 1968 with stock from Tennessee River, Alabama. From, respectively, Yeager and Baker 1982, Figure 1a, and Wrenn and Grinstead 1971, Figure 1b, with author permissions, as reprinted by Fuiman 1982a, Figures 164a and 165a.)

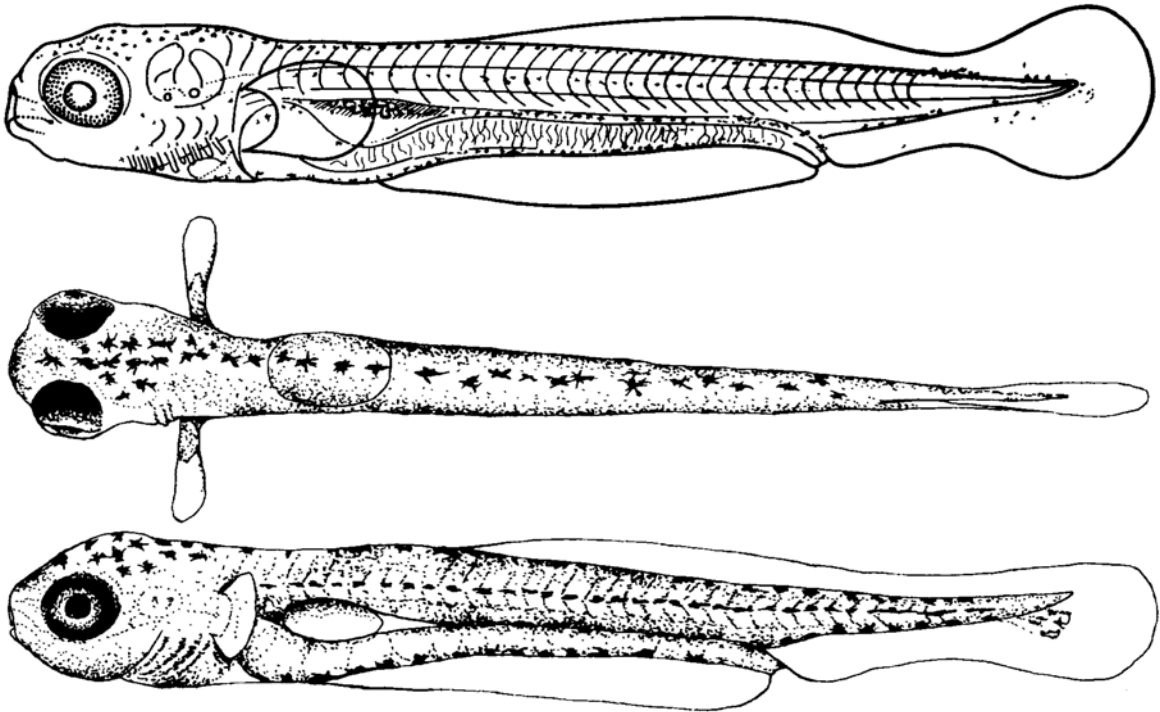


Figure 118. *Ictiobus bubalus* protolarvae, 7.2 mm SL, 7.7 mm TL (top), and 8.4 mm SL, 9.0 mm TL (lower dorsal and lateral views). (Cultured, respectively, in 1979 with stock from Cache River, Arkansas, and in 1968 with stock from Tennessee River, Alabama. From, respectively, Yeager and Baker 1982, Figure 1b [c in legend], and Wrenn and Grinstead 1971, Figure 1c, with author permissions, as reprinted by Fuiman 1982a, Figures 165b and c.)

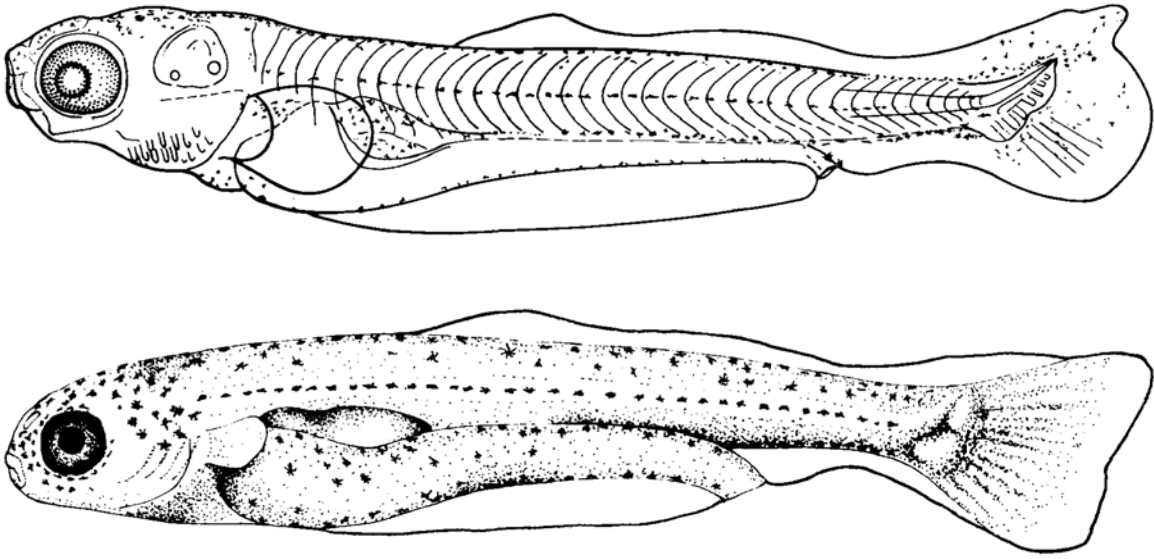


Figure 119. *Ictiobus bubalus* flexion mesolarvae, 9.6 mm SL, 10.4 mm TL (top), and 9.4 mm SL, 11.0 mm TL (bottom; caudal-fin rays not accurately represented). (Cultured, respectively, in 1979 with stock from Cache River, Arkansas, and in 1968 with stock from Tennessee River, Alabama. From, respectively, Yeager and Baker 1982, Figure 1d, and Wrenn and Grinstead 1971, Figure 2a, with author permissions, as reprinted by Fuiman 1982a, Figures 165d and 166a.)

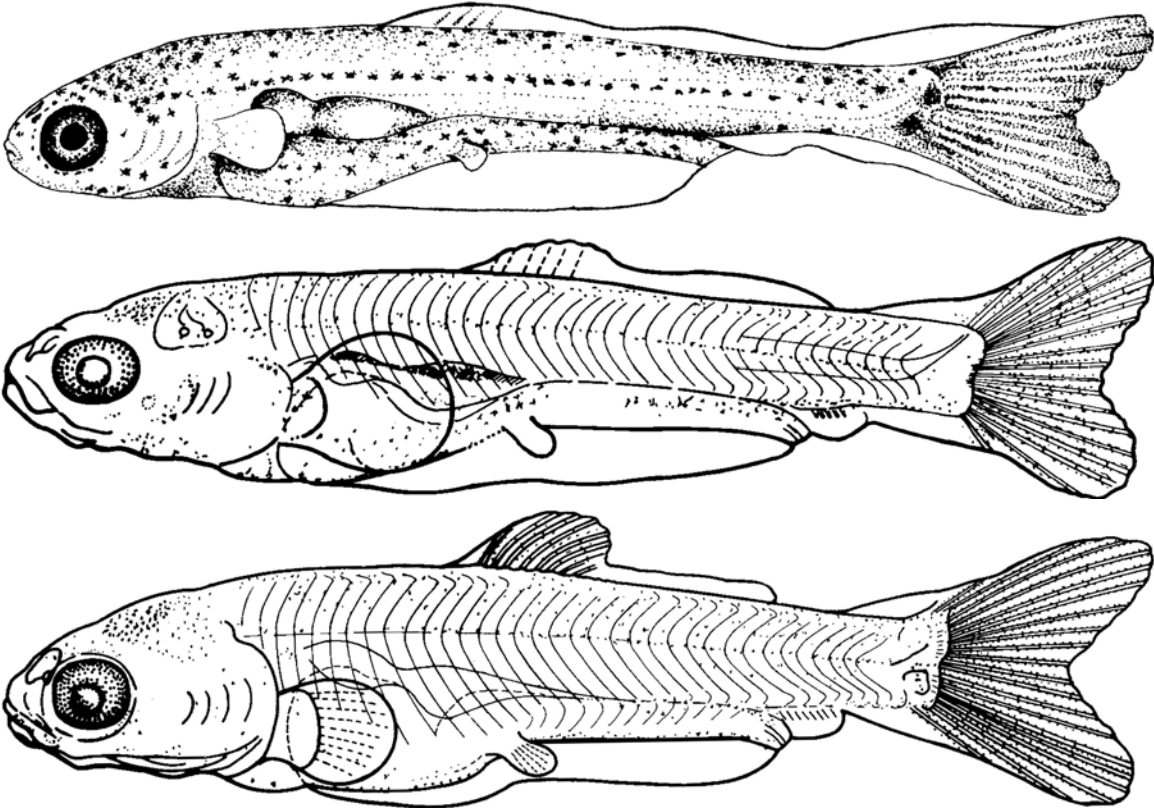


Figure 120. *Ictiobus bubalus* postflexion mesolarvae, 10.7 mm SL, 13.0 mm TL (top; caudal-fin rays not accurately represented), 13.8 mm SL, 16.2 mm TL (middle), and 14.6 mm SL, 17.8 mm TL (bottom). (Cultured in 1968 [top] and 1979 [rest] as for above figures. From Wrenn and Grinstead 1971, Figure 2b [top], and Yeager and Baker 1982, Figures 1e and f [rest], with author permissions, as reprinted by Fuiman 1982a, Figures 166b, c, and d.)

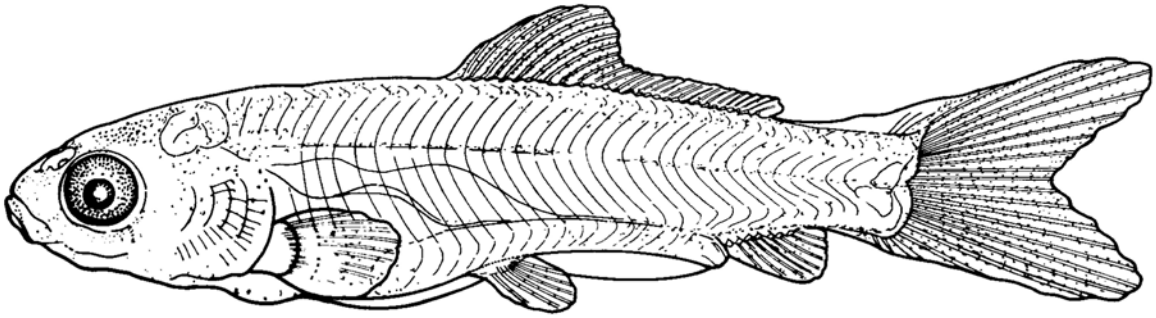


Figure 121. *Ictiobus bubalus* postflexion mesolarva, almost metalarva (last principal dorsal fin rays not yet formed), 17.1 mm SL, 21.5 mm TL. (Cultured in 1979 with stock from Cache River, Arkansas. From Yeager and Baker 1982, Figure 1g, with author permission, as reprinted by Fuiman 1982a, Figure 167a.)

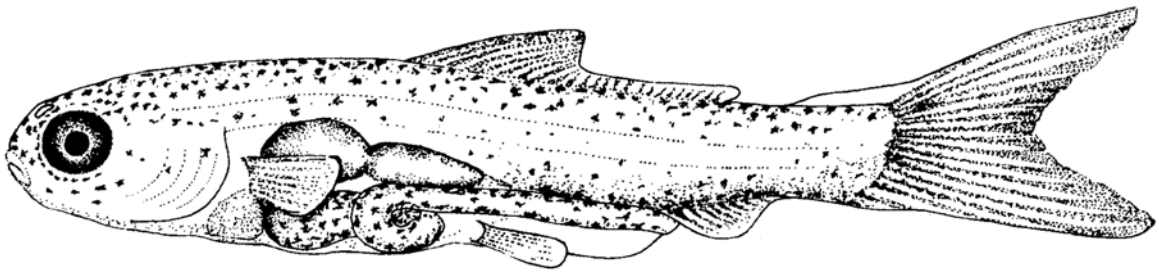


Figure 122. *Ictiobus bubalus* metalarva, recently transformed, 15.1 mm SL, 19.5 mm TL. (Cultured in 1968 with stock from Tennessee River, Alabama. From Wrenn and Grinstead 1971, Figure 2d, with author permission, as reprinted by Fuiman 1982a, Figures 166e.)

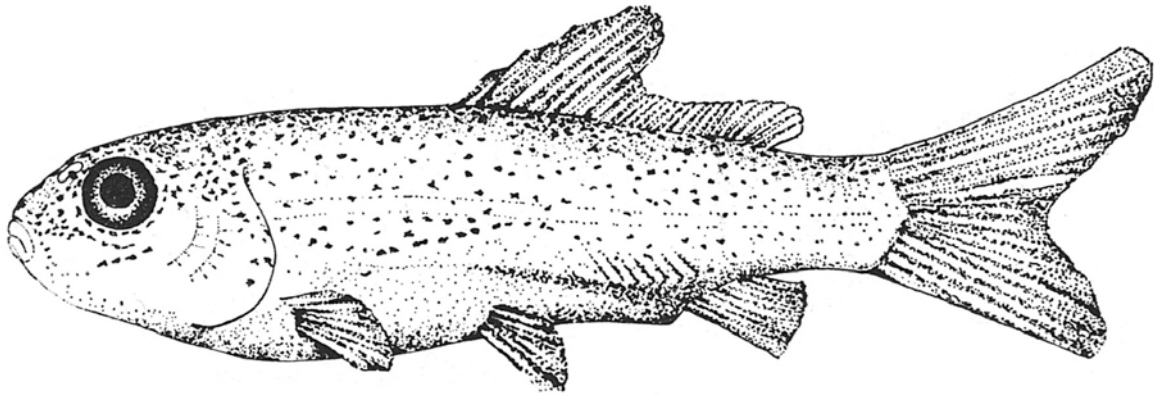


Figure 123. *Ictiobus bubalus* juvenile, recently transformed, 22.3 mm SL, 28.5 mm TL. (Cultured in 1968 with stock from Tennessee River, Alabama. From Wrenn and Grinstead 1971, Figure 2e, with author permission.)

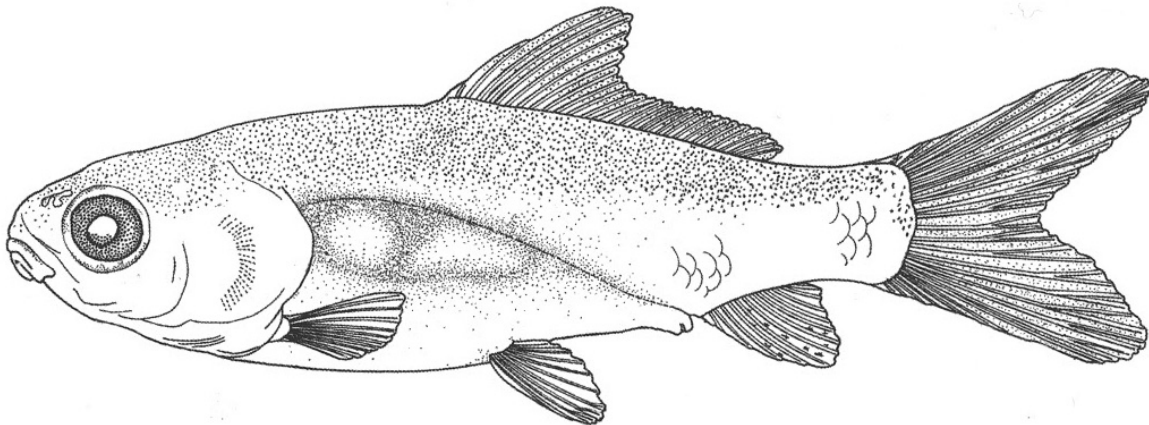


Figure 124. *Ictiobus bubalus* juvenile, recently transformed, 23.1 mm SL, 29.1 mm TL. (Cultured in 1979 with stock from Cache River, Arkansas. From Yeager and Baker 1982, Figure 1h, with author permission, as modified by original artist, M. V. Graser, for Kay et al. 1994, Figure 49e.)

Comparative Summary Tables

The following tables summarize the more diagnostically useful data in the species accounts in a convenient comparative format and supplement the species accounts with comparative information for special characters and pigmentation. They are organized in sets of three for the larger adult cyprinids, smaller adult cyprinids, and catostomids covered by this guide. These sets of tables compare: size at the onset of selected developmental events (Tables 50–52), selected meristics (Tables 53–55), the more diagnostically useful morphometrics (Tables 56–58), selected eye, mouth, and fin-position characters (Tables 59–61), size relative to pigmentation of the eyes and body in protolarvae and peritoneal pigmentation in metalarvae and early juveniles (Tables 62–64), and selected melanophore pigmentation patterns coded by developmental phase (Tables 65–67).

Size relative to developmental state

Table 50. Comparison of size of water-hardened eggs (mm diameter) and larvae or early juveniles (mm SL) at onset of or transition to developmental intervals, gut phases, and other developmental events for larger adult cyprinids in the Middle Rio Grande Basin. (Rare values in parentheses. NA = not applicable.)

| Character | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> ^c |
|-------------------------------------|--|---------------------|----------------------------|--|
| Egg diameter | 1.3–2.1 | 2.3–2.6 | 1.8–2.9 | 2.0–2.7 |
| Phase/period transitions | | | | |
| Embryo to larva | (4)5 | 7 | 5–6(7) | (4)5[–6] ^c |
| Protolarva to mesolarva | 7–8 | 8(9) | 7(8) | 7[–9] |
| Flexion to postflexion mesolarva | (8)9(10) | 9–10 | (8)9(10) | 8(9) |
| Mesolarva to metalarva | 12–13 | 11–12 | (9)10 | 10(11) |
| Larva to juvenile | (17)18–19 | 18–19 | (13–)15–16(–18) | (14)15(16) |
| Gut phase transitions | | | | |
| 1 to 2 (90° bend) | 11–12 | 12(13) | 10–11 | 11 |
| 2 to 3 (full loop) | 12–15 | 16–18 | 17–18 | (21–)25(26) |
| 3 to 4 (partial crossover) | 19–27 | NA | NA | NA |
| 4 to 5 (full crossover) | 27–31(32) | NA | NA | NA |
| Onset of selected events | | | | |
| Eyes pigmented | b | b | b | 4(5) ^b [4–6 ^b] |
| Yolk assimilated | 6–7 | 8–9 | (7)8–9 | 7[–9] |
| Finfold absorbed | (17)18–19 | 18–19 | (13–)15–16(–18) | (14)15(16) |
| Pectoral-fin buds | b | b | b | b |
| Pelvic-fin buds | (10)11 | 10–11 | (8)9(10) | 8(9)[–11] |
| Dorsal spine formation ^a | 20–21 (serrated) | NA | NA | NA |
| Maxillary barbels | 14–15(–20) (corner) 25–28(–39) (anterior) | NA | 18–22(–26) | 17(18) |
| Fin rays first observed | | | | |
| Dorsal, principal | 9–10(11) | 9(10) | (7)8–9 | 8 |
| Anal, principal | 11(12) | 9–10 | (8)9–10 | 9 |
| Caudal, principal | 7–8 | 8(9) | 7(8) | 7[–9] |
| Caudal, rudimentary | 9–10(11) | 11 | (8)9–10 | 9–10 |
| Pectoral | (10)11–12 | 11 | 9–10 | 9(10) |
| Pelvic | (11)12 | 12 | 9–10 | 10 |

(continued)

Table 50. Continued.

| Character | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> ^c |
|---|----------------------------|-------------------------|--------------------------------|--|
| Full fin-ray counts first observed | | | | |
| Dorsal, principal | 12–13 | 11–12 | (9)10 | 10 |
| Anal, principal | (11)12(13) | 11–12 | (9)10 | 10(11) |
| Caudal, principal | (8)9(10) | 9–10 | (8)9(10) | 8(9) |
| Caudal, rudimentary | (13)14–16(17) | (17)18(19) | 13–14(–18) | 14 |
| Pectoral | (13)14–16(17) | (15)16(17) | 13–16(–18) | (12)13–14 |
| Pelvic | (12)13–16(17) | (15)16 | (12)13–14 | 14–15 |
| Scales, lateral series | | | | |
| First observed | 14–15 | 21–23 | 18–19 | 17–19 |
| Full series first observed | (15–)17–18 | 22–27 | 19–20 | (18–)20–22(–25) |

^a Transformation of first principal dorsal-fin ray (thickening with serrations forming along posterior margin) to a distinctive spine or spine-like structure.

^b (Or) before hatching.

^c Bracketed data from descriptions for eastern US populations where larvae were notably larger relative to respective developmental events.

Table 51. Comparison of size of water-hardened eggs (mm diameter) and larvae or early juveniles (mm SL) at onset of or transition to developmental intervals, gut phases, and other developmental events for smaller adult cyprinids in the Middle Rio Grande Basin. (Rare values in parentheses. NA = not applicable.)

| Character | <i>Cyprinella lutrensis</i> | <i>Hybognathus amarus</i> | <i>Pimephales promelas</i> | <i>Pimephales vigilax</i> |
|-------------------------------------|-----------------------------|---------------------------|----------------------------|---------------------------|
| Egg diameter | (1.0–)1.2– 1.3 (1.4) | (2.5)2.6– 3.9(–4.2) | (1.1–)1.3– 1.5(1.6) | 1.0–1.6 |
| Phase/period transitions | | | | |
| Embryo to larva | 3–4 | (3)4(5) | 4(5) | (4)5 |
| Protolarva to mesolarva | 5 | 5–6 | 6–7 | (5)6 |
| Flexion to postflexion mesolarva | 6 | (6)7(8) | 7–8 | (7)8 |
| Mesolarva to metalarva | (7)8 | 9(10) | 8–10(11) | 9–10 |
| Larva to juvenile | 10(–12) | 13–14 | 14–15 | (12)13 |
| Gut phase transitions | | | | |
| 1 to 2 (90° bend) | 8–9 | (7–)9 | 9–10 | 12–13 |
| 2 to 3 (full loop) | 12–13 | 9 | 11–14 | 16–17 |
| 3 to 4 (partial crossover) | NA | 9–10(11) | (15)16 | NA |
| 4 to 5 (full crossover) | NA | (11)12 | 16 | NA |
| Onset of selected events | | | | |
| Eyes pigmented | b | (4)5 | b | b |
| Yolk assimilated | (4)5 | 5 | 5(6) | (5)6 |
| Finfold absorbed | 10(–12) | 13–14 | 14 | (12)13 |
| Pectoral-fin buds | b | 4 ^b | b | b |
| Pelvic-fin buds | 7(8) | 9(10) | 8(9) | 8 |
| Dorsal spine formation ^a | NA | NA | NA | NA |
| Maxillary barbels | NA | NA | NA | NA |
| Fin rays first observed | | | | |
| Dorsal, principal | 6 | (6)7(8) | 7–8 | 7(8) |
| Anal, principal | 7 | (7)8 | 8 | 8 |
| Caudal, principal | 5 | 5–6 | 6–7 | (5)6 |
| Caudal, rudimentary | 7 | 7–8 | 7–8 | 8 |
| Pectoral | 7(8) | 9(10) | 8–10(11) | 9 |
| Pelvic | 8–9 | 9–10 | 11–12 | 9–10 |

(continued)

Table 51. Continued.

| Character | <i>Cyprinella lutrensis</i> | <i>Hybognathus amarus</i> | <i>Pimephales promelas</i> | <i>Pimephales vigilax</i> |
|---|---------------------------------|-------------------------------|--------------------------------|-------------------------------|
| Full fin-ray counts first observed | | | | |
| Dorsal, principal | 7(8) | (7)8 | 8–9 | (8)9 |
| Anal, principal | 7–8 | 9(10) | 8–10(11) | 9–10 |
| Caudal, principal | 6 | (6)7(8) | 7–8 | (7)8 |
| Caudal, rudimentary | 10(11) | (11–)13 | 14–15 | 12(13) |
| Pectoral | (8–)10(11) | (11)12(13) | 14–15 | 11–12 |
| Pelvic | (9)10(11) | 11–13 | 12–13 | 11–12 |
| Scales, lateral series | | | | |
| First observed | (12)13 | (14)15 | (14)15 | 15 |
| Full series first observed | 14–15 | 15–18 | (15)16 | (15)16 |

^a Transformation of first principal dorsal-fin ray (thickening with serrations forming along posterior margin) to a distinctive spine or spine-like structure.

^b (Or) before hatching.

Table 52. Comparison of size of water-hardened eggs (mm diameter) and larvae or early juveniles (mm SL) at onset of or transition to developmental intervals, gut phases, and other developmental events for catostomids in the Middle Rio Grande Basin. (Rare values in parentheses. NA = not applicable.)

| Character | <i>Catostomus commersonii</i> | <i>Catostomus plebeius</i> | <i>Carpiodes carpio</i> | <i>Ictiobus bubalus</i> |
|-------------------------------------|-------------------------------|----------------------------|-------------------------|----------------------------|
| Egg diameter | 2.6–3.3 | 2.0–3.2 | 1.7–2.1 | 1.6–2.4 |
| Phase/period transitions | | | | |
| Embryo to larva | (7)8–10 | (6)7–9 | 5 | 5–6 |
| Protolarva to mesolarva | 10–12(13) | 10 | 9 | 9 |
| Flexion to postflexion mesolarva | (12)13–15 | 11 | (11)12–13 | 11–12 |
| Mesolarva to metalarva | 15–16(17) | 15–17 | 15(16) | 14–16 / 17–19 ^c |
| Larva to juvenile | (17–)19–20 | 23–25 | 18 | 16–17 / 22–24 ^c |
| Gut phase transitions | | | | |
| 1 to 2 (90° bend) | 14–15(16) | 14–15 | 11–12 | 13–15 |
| 2 to 3 (full loop) | (16)17–18 | 16–18 | (14–)16–18 | 14–15 |
| 3 to 4 (partial crossover) | 19–20(21) | 18–20 | ? | ? (15-16) |
| 4 to 5 (full crossover) | (20)21–25 | 22–23 | ? | ? |
| Onset of selected events | | | | |
| Eyes pigmented | (7)8 ^b | 7 ^b | b | b |
| Yolk assimilated | 10–12(–14) | 10–11 | 7–8 | 7(8) |
| Finfold absorbed | (17–)19–20 | 23–25 | 18 | 16–17 / 22–24 ^c |
| Pectoral-fin buds | (7)8 ^b | b | b | b |
| Pelvic-fin buds | 13–15 | 12–14 | 11 | (10)11–12 |
| Dorsal spine formation ^a | NA | NA | NA | NA |
| Maxillary barbels | NA | NA | NA | NA |
| Fin rays first observed | | | | |
| Dorsal, principal | 12–14(15) | 12 | 11(12) | 11–13 |
| Anal, principal | 14–16 | 14 | 13 | (12)13–15 |
| Caudal, principal | 10–12(13) | 10 | 9 | 9 |
| Caudal, rudimentary | 13–15 | 12 | 11–13 | <14 |
| Pectoral | 14–16 | 14 | 12 | – / (14)15 ^c |
| Pelvic | 15–16 | 15–17 | 14 | 13 / 15 ^c |

(continued)

Table 52. Continued.

| Character | <i>Catostomus commersonii</i> | <i>Catostomus plebeius</i> | <i>Carpiodes carpio</i> | <i>Ictiobus bubalus</i> |
|---|-------------------------------|----------------------------|-------------------------|----------------------------|
| Full fin-ray counts first observed | | | | |
| Dorsal, principal | 14–16 | 13–15 | 15(16) | 14–16 / 17–19 ^c |
| Anal, principal | 15–16(17) | 15–17 | 15(16) | 13–14 / 16–19 ^c |
| Caudal, principal | (12)13–15 | 11 | (11)12–13 | 11–12 |
| Caudal, rudimentary | (17)18 | 22–23 | >16 | >17 |
| Pectoral | 16(–20) | 19–20 | 17–18 | 13–14 / 22–24 ^c |
| Pelvic | 16–18 | 19–20 | 16–18 | 14 / 19–20 ^c |
| Scales, lateral series | | | | |
| First observed | 22(23) | 23–25 | 16 | 17–18 |
| Full series first observed | 29–31 | 27–29 | 21–22 | (19)20 |

^a Transformation of first principal dorsal-fin ray (thickening with serrations forming along posterior margin) to a distinctive spine or spine-like structure.

^b (Or) before hatching.

^c Data calculated from Wrenn and Grinstead (1971) and sometimes Hoyt et al. (1979) / from Yeager and Baker (1982).

Selected meristics

Table 53. Comparison of selected meristics for larvae and early juveniles of larger adult cyprinids in the Middle Rio Grande Basin. (Character range is followed by the mean, mode, or more typical range. See Figure 4 for methods of counting myomeres and fin rays. ODF = origin of dorsal finfold, OD = origin of dorsal fin, OP2 = origin of pelvic buds or fins, and PV = posterior margin of the vent. Vertebra counts include four for the Weberian complex; dorsal- and anal-fin-ray counts are of principal rays; scale counts are of the lateral line or series. Data previously published by other authors are given in parentheses; sources are listed in corresponding species accounts.)

| Character | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> |
|--------------------------|----------------------------|-------------------------|-----------------------------------|-----------------------------------|
| Myomeres to ODF | | | | |
| Protolarvae | 9–12, 10 | 12–14, 13 | 12–17, 14 | 12–15, 13 |
| Flexion mesolarvae | 10–13, 11 | 13–16, 14 | 14–18, 15 | 13–16, 14 |
| Postflexion mesolarvae | 10–12, 12 | 12–15, 14 | 14–17, 16 | 14–16, 15 |
| Myomeres to OD | | | | |
| Postflexion mesolarvae | 11–13, 12 | 18–20, 19 | 15–18, 17 | 17–19, 18 |
| Metalarvae | 10–13, 11 | 18–20, 19 | 15–17, 16 | 15–19, 17 |
| Myomeres to OP2 | | | | |
| Postflexion mesolarvae | 13–15, 14 | 16–17, 16 | 15–17, 16 | 15–17, 16 |
| Metalarvae | 11–14, 13 | 16–18, 17 | 15–18, 17 | 14–17, 16 |
| Myomeres to PV | | | | |
| Proto- & mesolarvae | 23–28, 26–27 | 28–31, 29–30 | 26–29, 27–28 | 24–27, 25–27 |
| Metalarvae | 25–28, 26 | 27–30, 29 | 26–29, 28 | 24–27, 25 |
| All larvae | 23–28, 26–27 | 27–31, 29–30 | 26–29, 27–28 | 24–27, 25–27 |
| Myomeres after PV | | | | |
| Proto- & mesolarvae | 10–12, 11 | 11–14, 13 | 11–14, 13 | 11–15, 13 |
| Metalarvae | 10–12, 11 | 12–15, 14 | 12–14, 12 | 12–15, 13 |
| All larvae | 10–12, 11 | 11–15, 13–14 | 11–14, 12–13 | 11–15, 13 |
| Myomeres, total | | | | |
| Proto- & mesolarvae | 35–39, 37–38 | 41–44, 42–43 | 39–43, 40–41 | 36–40, 38–39 |
| Metalarvae | 36–39, 37 | 42–43, 43 | 39–41, 40 | 37–40, 39 |
| All larvae | 35–39, 37–38 | 41–44, 42–43 | 39–43, 40–41 | 36–40, 38–39 |
| Vertebrae | 37–38 (32–39, 35–36) | – (40–44, 41–43) | – (40–47, 40–43 ^b) | – (37–42, 38–40) |

(continued)

Table 53. Continued.

| Character | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> ^c |
|----------------------------|---|-------------------------|---------------------------------------|--|
| Dorsal-fin rays | 17–21, 19–20 ^a (15–24, 18–22) | 8–10, 8 (7–9, 8) | 8 (7–9, 8) | 8 (7–9, 8) |
| Anal-fin rays | 5–7, 6 ^a (4–8, 6) | 7–9, 8 (7–9, 8) | 8 (7–9, 8) | 7 (6–9, 7) |
| Lateral-line scales | 34–40 (32–41, 35–38) | 53–61 (51–68, 56–65) | 43–48 (42–59, 42–49 ^b) | 62–69, 64 (55–77, 58–72) |

^a The serrated spine at the beginning of juvenile and adult *Cyprinus carpio* dorsal and anal fins are hardened lepidotrichia (first principal rays) rather than true spines and, as such, are not separated in counts by use of Roman numerals (as in spinous-rayed fishes).

^b Usual values for Rio Grande, Pecos, Arkansas, and N. Platte basin populations described as *H. g. gulonella* by Olund and Cross (1961).

Table 54. Comparison of selected meristics for larvae and early juveniles of smaller adult cyprinids in the Middle Rio Grande Basin. (Character range is followed by the mean, mode, or more typical range. See Figure 4 for methods of counting myomeres and fin rays. ODF = origin of dorsal finfold, OD = origin of dorsal fin, OP2 = origin of pelvic buds or fins, and PV = posterior margin of the vent. Vertebra counts include four for the Weberian complex; dorsal- and anal-fin-ray counts are of principal rays; scale counts are of the lateral line or series. Data previously published by other authors are given in parentheses; sources are listed in corresponding species accounts.)

| Character | <i>Cyprinella lutrensis</i> | <i>Hybognathus amarus</i> | <i>Pimephales promelas</i> | <i>Pimephales vigilax</i> |
|--------------------------|---------------------------------|-------------------------------|--------------------------------|-------------------------------|
| Myomeres to ODF | | | | |
| Protolarvae | 6–11, 10 | 12–16, 14 | 10–15, 12 | 10–13, 11 |
| Flexion mesolarvae | 10–14, 12 | 12–16, 14 | 13–14, 14 | 12–14, 13 |
| Postflexion mesolarvae | 11–15, 13 | 13–16, 15 | 12–15, 14 | 12–15, 14 |
| Myomeres to OD | | | | |
| Postflexion mesolarvae | 14–16, 15 | 16–18, 17 | 15–16, 16 | 14–16, 16 |
| Metalarvae | 13–17, 15 | 15–18, 16 | 15–16, 15 | 15–16, 15 |
| Myomeres to OP2 | | | | |
| Postflexion mesolarvae | 12 ^a | 16–17, 17 | 15–15, 15 | 14–16, 14 |
| Metalarvae | 12–15, 14 | 16–19, 17 | 14–17, 15 | 15–16, 15 |
| Myomeres to PV | | | | |
| Proto- & mesolarvae | 20–24, 21–23 | 26–29, 27 | 21–27, 23–25 | 23–26, 24–25 |
| Metalarvae | 19–24, 22 | 25–27, 26 | 24–25, 25 | 24–25, 25 |
| All larvae | 19–24, 21–23 | 25–29, 26–27 | 21–27, 23–25 | 23–26, 24–25 |
| Myomeres after PV | | | | |
| Proto- & mesolarvae | 11–15, 13–14 | 9–12, 10–11 | 10–15, 11–13 | 12–14, 13–14 |
| Metalarvae | 12–15, 14 | 9–11, 10 | 10–13, 11 | 12–14, 13 |
| All larvae | 11–15, 13–14 | 9–12, 10–11 | 10–15, 11–13 | 12–14, 13–14 |
| Myomeres, total | | | | |
| Proto- & mesolarvae | 31–37, 35 | 35–39, 37–38 | 35–38, 36–37 | 37–39, 38 |
| Metalarvae | 34–37, 35 | 35–37, 36 | 34–37, 36 | 37–39, 37 |
| All larvae | 31–37, 35 | 35–39, 36–38 | 34–38, 36–37 | 37–39, 37–38 |
| Vertebrae | | | | |
| | 35–36 (32–36, 35) | 36–37 (35–37) | – (35–38, 37) | – (37–39) |

(continued)

Table 54. Continued.

| Character | <i>Cyprinella lutrensis</i> | <i>Hybognathus amarus</i> | <i>Pimephales promelas</i> | <i>Pimephales vigilax</i> |
|----------------------------|---------------------------------|-------------------------------|--------------------------------|-------------------------------|
| Dorsal-fin rays | 7-9, 8 (6-9, 8) | 7-8, 8 (7-9, 8) | 7-9, 8 (7-9, 8) | 8-9, 8 (7-9, 8) |
| Anal-fin rays | 8-10, 9 (7-13, 9) | 7-8, 8 (7-9, 8) | 7 (7) | 6-7, 7 (7-8, 7) |
| Lateral-line scales | 34-38, 36-38 (30-40, 32-37) | 34-38, 36 (31-44, 37) | 43-51, 48 (40-60, 44-48) | 39-44, 43 (37-49, 39-44) |

^a N = 1.

Table 55. Comparison of selected meristics for larvae and early juveniles of catostomids in the Middle Rio Grande Basin. (Character range is followed by the mean, mode, or more typical range. See Figure 4 for methods of counting myomeres and fin rays. ODF = origin of dorsal finfold, OD = origin of dorsal fin, OP2 = origin of pelvic buds or fins, and PV = posterior margin of the vent. Vertebra counts include four for the Weberian complex; dorsal- and anal-fin-ray counts are of principal rays; scale counts are of the lateral line or series. Data previously published by other authors, or extracted from their illustrations, are given in parentheses; sources are listed in corresponding species accounts.)

| Character | <i>Catostomus commersonii</i> | <i>Catostomus plebeius</i> | <i>Carpionodes carpio</i> | <i>Ictiobus bubalus</i> |
|--------------------------|-------------------------------|----------------------------|---------------------------|-------------------------|
| Myomeres to ODF | | | | |
| Protolarvae | 12–14, 13 | 12–18, 15 | (10–12, 11) | (9–15, 12) |
| Flexion mesolarvae | 12–17, 14 | 13–17, 14 | (12) ^b | (11) ^b |
| Postflexion mesolarvae | 12–17, 15 | 12–16, 15 | (13–14, 14) | (12–13, 13) |
| Myomeres to OD | | | | |
| Postflexion mesolarvae | 17–20, 19 | 16–19, 18 | (14–15, 15) | (12–14, 13) |
| Metalarvae | 16–19, 17 | 15–19, 17 | (13) ^b | – |
| Myomeres to OP2 | | | | |
| Postflexion mesolarvae | 19–22, 21 | 19–21, 20 | (17–18, 18) | (14–15, 14) |
| Metalarvae | 20–23, 21 | 19–22, 20 | (17) ^b | – |
| Myomeres to PV | | | | |
| Proto- & mesolarvae | 34–40, 37–38 | 33–36, 34–35 | (27–32, 29–30) | (28–32, 30) |
| Metalarvae | 34–37, 35 | 31–37, 33 | (28–29, 29) | – |
| All larvae | 34–40, 35–38 | 31–37, 33–35 | (27–32, 29–30) | (28–32, 30) |
| Myomeres after PV | | | | |
| Proto- & mesolarvae | 7–11, 9 | 6–10, 8 | (5–10, 6–8) | (4–9, 5–8) |
| Metalarvae | 8–12, 10 | 8–11, 10 | (6–7, 7) | – |
| All larvae | 7–12, 9–10 | 6–11, 8–10 | (5–10, 6–8) | (4–9, 5–8) |
| Myomeres, total | | | | |
| Proto- & mesolarvae | 43–49, 46–47 | 41–45, 43 | (34–41, 36–38) | (34–39, 35–37) |
| Metalarvae | 44–47, 45 | 42–45, 43 | (34–36, 35) | – |
| All larvae | 43–49, 45–47 | 41–45, 43 | (34–41, 35–38) | (34–39, 35–37) |
| Vertebrae | | | | |
| | 45–48, 46 (44–48) | (42–46, 43–44) | (34–39, 36–37) | (34–41, 36–37) |

(continued)

Table 55. Continued.

| Character | <i>Catostomus commersonii</i> | <i>Catostomus plebeius</i> | <i>Carpiodes carpio</i> | <i>Ictiobus bubalus</i> |
|----------------------------|--------------------------------|---------------------------------------|-------------------------|-------------------------|
| Dorsal-fin rays | 10–13, 11–12 (9–15, 10–13) | 8–10, 9 (8–11, 9) | (23–30, 27) | (24–31, 26–28) |
| Anal-fin rays | 5–8, 7 (6–8, 7) | 6–9, 7 (7–8, 7) | (7–9, 8) | (7–11, 8–9) |
| Lateral-line scales | 56–72, 59–68 (53–85, 56–70) | 73–91 ^a (70–103, 75–95) | (33–37, 34–36) | (33–39, 36–38) |

^a ~73–75 tentative counts for specimens reared from Hot Creek, Co, parental stock , n = 3, 33–38 mm TL; 85–91 for wild specimens captured from Rio Bonito and Jemez River, NM, n = 5, 45 and 90–135 mm TL.

^b N = 1.

Selected morphometrics

Table 56. Comparison of the more diagnostic differences in morphometrics for larvae and juveniles (≤ 40 mm SL) of larger adult cyprinids in the Middle Rio Grande Basin. (Except as indicated, all data are percentages of standard length, % SL, presented as ranges followed by means. HL = head length measured to the origin of the pectoral fin, AS to OP1. See Figure 4 for other abbreviations and methods of measurement.)

| Developmental Phase Character | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> |
|----------------------------------|----------------------------|-------------------------|--------------------------------|-----------------------------------|
| Protolarvae | | | | |
| Eye diameter ^a | 6–8, 7 | 6–8, 7 | 5–6, 6 | 7–9, 8 |
| AS-to-PE length | 9–13, 11 | 10–11, 11 | 9–11, 10 | 10–12, 11 |
| AS-to-ODF length | 37–47, 42 | 38–44, 40 | 40–49, 45 | 39–48, 44 |
| AS-to-PV length | 70–75, 72 | 67–73, 69 | 67–70, 68 | 64–69, 67 |
| Yolk length ^b | 0–59, 42 | 38–57, 49 | 0–55, 43 | 29–57, 46 |
| Pectoral-fin length ^c | 4–14, 11 | 4–9, 8 | 4–14, 9 | 4–11, 7 |
| Depth at OD ^{b, d} | 11–16, 13 | 12–16, 14 | 9–14, 12 | 11–18, 14 |
| Width at OD ^{b, d} | 5–10, 7 | 7–8, 7 | 5–8, 7 | 6–10, 8 |
| Max. yolk depth ^b | 0–23, 11 | 5–12, 9 | 0–21, 11 | 4–21, 13 |
| Max. yolk width ^b | 0–25, 11 | 7–18, 12 | 0–22, 13 | 7–24, 15 |
| Flexion mesolarvae | | | | |
| Eye diameter, % HL ^a | 29–33, 31 | 30–38, 34 | 26–30, 29 | 33–40, 37 |
| AS-to-AE length | 4–7, 5 | 3–4, 3 | 3–6, 5 | 3–5, 4 |
| AS-to-PE length | 11–15, 13 | 9–12, 10 | 9–12, 10 | 11–14, 12 |
| AS-to-OP1 length | 22–26, 24 | 19–22, 20 | 20–22, 21 | 20–23, 21 |
| AS-to-OPAF length | 31–45, 37 | 27–31, 29 | 34–38, 36 | 32–36, 34 |
| AS-to-ODF length | 44–49, 46 | 35–43, 40 | 43–49, 46 | 40–46, 44 |
| AS-to-PV length | 70–75, 74 | 65–67, 66 | 67–69, 69 | 64–69, 65 |
| Yolk length | 0 | 0–13, 6 | 0–24, 9 | 0 |
| Pectoral-fin length | 12–15, 14 | 11–13, 12 | 12–14, 13 | 13–14, 14 |
| Depth at OP1 | 16–20, 18 | 12–14, 14 | 13–15, 14 | 15–17, 15 |
| Depth at OD ^d | 11–16, 12 | 10–13, 11 | 10–12, 11 | 11–12, 12 |
| Depth at BPV | 6–8, 7 | 8–9, 8 | 7–8, 8 | 8–9, 8 |
| Width at BPE | 13–16, 15 | 13–15, 13 | 13–15, 13 | 13–16, 14 |
| Width at OP1 | 10–13, 11 | 10–11, 10 | 9–12, 11 | 11–13, 12 |
| Width at OD ^d | 5–8, 7 | 6–6, 6 | 5–7, 6 | 5–7, 6 |
| Max. yolk depth | 0 | 0–3, 1 | 0–4, 1 | 0 |
| Max. yolk width | 0 | 0–4, 2 | 0–6, 2 | 0 |
| Postflexion mesolarvae | | | | |
| Eye diameter, % HL ^a | 25–33, 29 | 29–37, 32 | 25–30, 28 | 30–37, 34 |
| AS-to-AE length | 5–7, 6 | 4–6, 5 | 4–7, 5 | 3–5, 4 |

(continued)

Table 56. Continued.

| Developmental Phase Character | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> |
|--|------------------------|---------------------|----------------------------|-------------------------------|
| AS-to-PE length | 13–17, 15 | 11–14, 12 | 10–14, 12 | 10–13, 12 |
| AS-to-OP1 length | 26–33, 29 | 21–26, 23 | 21–27, 24 | 20–25, 23 |
| AS-to-OP2 length | 49–55, 52 | 46–50, 49 | 47–50, 49 | 45–48, 46 |
| AS-to-OPAF length | 35–57, 43 | 30–34, 32 | 36–42, 38 | 31–41, 34 |
| AS-to-PV length | 74–78, 76 | 68–71, 69 | 69–74, 71 | 63–70, 67 |
| Pectoral-fin length | 10–18, 13 | 12–14, 14 | 13–15, 14 | 11–16, 14 |
| Dorsal-fin-base length ^{e, f} | – | 9–11, 10 | 8–10, 9 | 8–11, 9 |
| Depth at OP1 | 19–27, 23 | 15–20, 17 | 14–17, 16 | 16–18, 17 |
| Depth at OD | 13–25, 20 | 12–15, 13 | 11–13, 12 | 11–14, 13 |
| Depth at BPV | 7–15, 11 | 8–11, 9 | 8–10, 9 | 8–11, 9 |
| Width at BPE | 15–20, 18 | 13–16, 15 | 14–17, 15 | 14–16, 15 |
| Width at OP1 | 11–17, 15 | 11–15, 13 | 11–13, 12 | 11–14, 13 |
| Width at OD | 7–15, 11 | 6–10, 8 | 6–9, 7 | 6–8, 7 |
| Metalarvae | | | | |
| Eye diameter, % HL ^a | 24–32, 27 | 25–34, 29 | 22–28, 25 | 28–32, 31 |
| AS-to-AE length | 6–9, 7 | 5–7, 6 | 5–8, 6 | 4–8, 5 |
| AS-to-PE length | 13–18, 16 | 12–16, 13 | 11–15, 13 | 11–16, 13 |
| AS-to-OP1 length | 29–35, 32 | 25–29, 27 | 25–30, 27 | 23–28, 25 |
| AS-to-OP2 length | 50–55, 52 | 48–53, 51 | 48–54, 52 | 48–51, 50 |
| AS-to-OD length | 47–52, 49 | 53–55, 54 | 48–52, 50 | 50–53, 52 |
| AS-to-ID length | 79–83, 81 | 63–65, 64 | 60–65, 62 | 62–64, 63 |
| AS-to-PV length | 72–77, 75 | 66–71, 68 | 67–74, 71 | 66–69, 67 |
| AS-to-IA length | 80–84, 83 | 75–79, 77 | 77–82, 80 | 74–77, 75 |
| Caudal-fin length ^g | 18–27, 22 | 16–24, 21 | 14–27, 22 | 16–23, 20 |
| Pectoral-fin length | 12–17, 14 | 13–17, 16 | 15–22, 17 | 14–17, 16 |
| Pelvic-fin length | 8–13, 10 | 5–13, 9 | 5–13, 10 | 6–13, 9 |
| Dorsal-fin-base length ^f | 30–36, 32 | 10–12, 11 | 11–13, 12 | 9–12, 11 |
| Depth at BPE | 20–24, 22 | 16–19, 17 | 13–17, 15 | 15–18, 16 |
| Depth at OP1 | 24–30, 27 | 18–21, 20 | 17–21, 19 | 18–22, 19 |
| Depth at OD | 23–30, 27 | 12–20, 17 | 15–20, 17 | 13–20, 17 |
| Depth at BPV | 13–17, 15 | 9–15, 12 | 9–14, 11 | 9–14, 13 |
| Depth at AMPM | 8–12, 10 | 7–10, 9 | 7–10, 8 | 7–11, 9 |
| Width at BPE | 19–20, 20 | 15–17, 16 | 16–19, 17 | 16–17, 16 |
| Width at OP1 | 16–21, 18 | 14–19, 16 | 14–19, 16 | 13–18, 16 |
| Width at OD | 11–17, 15 | 7–14, 11 | 8–14, 11 | 7–13, 10 |
| Width at BPV | 8–12, 9 | 6–10, 8 | 6–9, 7 | 5–9, 8 |
| Width at AMPM | 3–6, 5 | 3–5, 4 | 3–5, 4 | 4–5, 4 |

(continued)

Table 56. Continued.

| Developmental Phase Character | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> |
|-------------------------------------|------------------------|---------------------|----------------------------|-------------------------------|
| Juveniles ≤40 mm SL | | | | |
| Eye diameter, % HL ^a | 22–31, 26 | 25–31, 28 | 20–27, 24 | 19–34, 25 |
| AS-to-AE length | 7–11, 9 | 5–8, 6 | 6–8, 7 | 6–10, 8 |
| AS-to-PE length | 14–19, 17 | 12–16, 13 | 12–14, 13 | 13–16, 14 |
| AS-to-OP1 length | 29–34, 31 | 25–30, 27 | 24–28, 26 | 23–27, 26 |
| AS-to-OP2 length | 48–56, 53 | 49–53, 52 | 48–54, 51 | 46–54, 50 |
| AS-to-OD length | 46–51, 49 | 51–55, 53 | 45–52, 49 | 51–55, 53 |
| AS-to-ID length | 80–86, 82 | 63–67, 65 | 58–64, 61 | 62–65, 64 |
| AS-to-PV length | 72–77, 75 | 64–69, 66 | 64–70, 68 | 63–67, 65 |
| AS-to-IA length | 80–86, 83 | 76–80, 77 | 76–82, 79 | 72–77, 75 |
| AS-to-AFC length | 109–116, 112 | 113–116, 115 | 113–118, 115 | 114–118, 115 |
| Caudal-fin length ^g | 17–27, 23 | 22–27, 24 | 23–28, 25 | 21–27, 23 |
| Pectoral-fin length | 12–19, 16 | 16–20, 18 | 17–22, 20 | 17–23, 19 |
| Pelvic-fin length | 11–17, 14 | 13–17, 14 | 11–18, 14 | 13–16, 14 |
| Dorsal-fin length | 35–41, 38 | 19–26, 22 | 20–25, 22 | 19–24, 21 |
| Anal-fin length | 14–19, 17 | 17–20, 18 | 16–20, 18 | 15–21, 19 |
| Dorsal-fin-base length ^f | 31–37, 34 | 10–14, 12 | 10–15, 12 | 9–13, 11 |
| Depth at BPE | 21–25, 23 | 16–19, 17 | 14–17, 16 | 14–18, 16 |
| Depth at OP1 | 28–35, 31 | 20–23, 21 | 18–21, 20 | 17–23, 20 |
| Depth at OD | 30–37, 33 | 20–23, 22 | 19–23, 21 | 18–26, 20 |
| Depth at BPV | 17–23, 20 | 14–17, 15 | 13–16, 14 | 14–19, 15 |
| Depth at AMPM | 11–13, 12 | 9–11, 10 | 9–11, 10 | 9–13, 11 |
| Width at BPE | 18–21, 19 | 15–18, 16 | 16–18, 17 | 14–18, 16 |
| Width at OP1 | 18–24, 21 | 16–19, 17 | 16–19, 18 | 17–22, 19 |
| Width at OD | 16–22, 19 | 13–16, 15 | 13–18, 15 | 11–21, 15 |
| Width at BPV | 8–17, 12 | 9–13, 11 | 8–12, 10 | 8–14, 11 |
| Width at AMPM | 3–9, 6 | 4–6, 5 | 3–6, 4 | 5–7, 5 |

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

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

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

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

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

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

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

Table 57. Comparison of the more diagnostic differences in morphometrics for larvae and juveniles (≤ 40 mm SL) of smaller adult cyprinids in the Middle Rio Grande Basin. (Except as indicated, all data are percentages of standard length, % SL, presented as ranges followed by means. HL = head length measured to the origin of the pectoral fin, AS to OP1. See Figure 4 for other abbreviations and methods of measurement.)

| Developmental Phase Character | <i>Cyprinella lutrensis</i> | <i>Hybognathus amarus</i> | <i>Pimephales promelas</i> | <i>Pimephales vigilax</i> |
|----------------------------------|---------------------------------|-------------------------------|--------------------------------|-------------------------------|
| Protolarvae | | | | |
| Eye diameter ^a | 6–8, 7 | 7–8, 7 | 7–8, 7 | 6–7, 6 |
| AS-to-PE length | 8–12, 10 | 9–11, 10 | 8–12, 10 | 8–10, 10 |
| AS-to-ODF length | 33–49, 41 | 38–45, 42 | 38–45, 41 | 37–40, 38 |
| AS-to-PV length | 61–70, 64 | 69–72, 71 | 60–68, 65 | 62–67, 64 |
| Yolk length ^b | 0–57, 23 | 0–58, 22 | 0–54, 28 | 25–56, 45 |
| Pectoral-fin length ^c | 6–17, 11 | 6–12, 11 | 4–15, 10 | 8–16, 13 |
| Depth at OD ^{b, d} | 10–14, 12 | 10–12, 11 | 10–12, 11 | 11–13, 12 |
| Width at OD ^{b, d} | 5–9, 6 | 4–8, 6 | 5–7, 6 | 5–7, 6 |
| Max. yolk depth ^b | 0–22, 6 | 0–10, 3 | 0–20, 8 | 3–17, 10 |
| Max. yolk width ^b | 0–23, 9 | 0–13, 5 | 0–18, 8 | 3–18, 11 |
| Flexion mesolarvae | | | | |
| Eye diameter, % HL ^a | 32–43, 36 | 32–40, 35 | 31–41, 36 | 29–36, 32 |
| AS-to-AE length | 2–5, 3 | 3–4, 3 | 2–4, 3 | 4–4, 4 |
| AS-to-PE length | 9–13, 10 | 10–12, 11 | 10–12, 11 | 10–11, 11 |
| AS-to-OP1 length | 19–23, 21 | 20–23, 21 | 20–21, 20 | 20–23, 21 |
| AS-to-OPAF length | 34–41, 37 | 30–37, 32 | 30–34, 32 | 37–44, 40 |
| AS-to-ODF length | 38–49, 45 | 42–49, 45 | 41–44, 43 | 38–44, 41 |
| AS-to-PV length | 61–67, 64 | 70–75, 72 | 64–66, 65 | 63–67, 64 |
| Yolk length | 0 | 0 | 0 | 0–19, 4 |
| Pectoral-fin length | 10–15, 13 | 10–13, 12 | 11–12, 12 | 12–16, 13 |
| Depth at OP1 | 11–14, 13 | 13–16, 15 | 12–15, 13 | 12–14, 13 |
| Depth at OD ^d | 10–15, 12 | 10–13, 11 | 9–13, 11 | 11–15, 12 |
| Depth at BPV | 8–13, 9 | 6–8, 7 | 7–8, 8 | 7–9, 8 |
| Width at BPE | 12–14, 13 | 12–14, 13 | 12–13, 12 | 11–13, 12 |
| Width at OP1 | 9–13, 10 | 8–12, 10 | 8–10, 9 | 9–11, 10 |
| Width at OD ^d | 5–8, 6 | 5–8, 7 | 5–8, 6 | 5–7, 6 |
| Max. yolk depth | 0 | 0 | 0 | 0–2, 0 |
| Max. yolk width | 0 | 0 | 0 | 0–3, 1 |
| Postflexion mesolarvae | | | | |
| Eye diameter, % HL ^a | 29–38, 34 | 29–38, 32 | 31–39, 34 | 28–32, 30 |
| AS-to-AE length | 3–5, 4 | 3–5, 4 | 3–5, 4 | 4–5, 4 |

(continued)

Table 57. Continued.

| Developmental Phase Character | <i>Cyprinella lutrensis</i> | <i>Hybognathus amarus</i> | <i>Pimephales promelas</i> | <i>Pimephales vigilax</i> |
|--|-----------------------------|---------------------------|----------------------------|---------------------------|
| AS-to-PE length | 11–13, 12 | 10–12, 11 | 10–13, 12 | 11–12, 12 |
| AS-to-OP1 length | 21–24, 23 | 20–23, 22 | 21–24, 23 | 23–24, 24 |
| AS-to-OP2 length | 48 ^h | 51–52, 51 | 48–49, 49 | 46–48, 47 |
| AS-to-OPAF length | 29–40, 37 | 25–37, 32 | 35–39, 36 | 42–48, 45 |
| AS-to-PV length | 65–67, 66 | 72–75, 74 | 68–72, 70 | 67–70, 68 |
| Pectoral-fin length | 11–16, 14 | 11–14, 13 | 11–14, 12 | 11–12, 11 |
| Dorsal-fin-base length ^{e, f} | 11–14, 12 | 8–10, 9 | 10–13, 12 | 11–14, 13 |
| Depth at OP1 | 14–16, 15 | 15–19, 16 | 15–19, 17 | 15–17, 16 |
| Depth at OD | 12–15, 13 | 12–17, 13 | 11–17, 15 | 14–16, 15 |
| Depth at BPV | 9–12, 10 | 7–11, 9 | 8–11, 9 | 9–11, 10 |
| Width at BPE | 12–15, 13 | 13–17, 15 | 13–15, 14 | 13–14, 13 |
| Width at OP1 | 10–11, 10 | 11–16, 13 | 10–13, 12 | 11–13, 12 |
| Width at OD | 6–8, 7 | 6–11, 9 | 6–10, 8 | 7–10, 8 |
| Metalarvae | | | | |
| Eye diameter, % HL ^a | 30–40, 33 | 26–36, 30 | 27–37, 31 | 23–30, 27 |
| AS-to-AE length | 4–7, 5 | 4–6, 5 | 4–5, 5 | 4–6, 5 |
| AS-to-PE length | 12–15, 13 | 11–13, 12 | 11–15, 13 | 11–13, 12 |
| AS-to-OP1 length | 22–28, 25 | 22–28, 25 | 25–28, 26 | 24–26, 25 |
| AS-to-OP2 length | 47–51, 49 | 53–58, 55 | 49–53, 51 | 48–50, 49 |
| AS-to-OD length | 49–53, 52 | 52–56, 54 | 51–56, 52 | 48–51, 50 |
| AS-to-ID length | 63–67, 65 | 61–65, 63 | 63–69, 65 | 62–64, 63 |
| AS-to-PV length | 61–68, 65 | 71–76, 74 | 67–71, 69 | 65–69, 67 |
| AS-to-IA length | 74–78, 76 | 78–83, 81 | 74–78, 76 | 74–76, 75 |
| Caudal-fin length ^g | 15–26, 20 | 16–24, 20 | 14–22, 18 | 14–21, 17 |
| Pectoral-fin length | 11–18, 14 | 12–17, 14 | 11–15, 13 | 11–14, 12 |
| Pelvic-fin length | 3–13, 8 | 2–11, 7 | 4–12, 7 | 5–9, 7 |
| Dorsal-fin-base length ^f | 11–17, 13 | 8–11, 10 | 12–14, 13 | 12–15, 13 |
| Depth at BPE | 12–18, 15 | 15–18, 17 | 14–18, 16 | 13–15, 14 |
| Depth at OP1 | 14–21, 17 | 14–23, 19 | 17–22, 20 | 16–18, 17 |
| Depth at OD | 14–19, 16 | 14–23, 19 | 13–22, 17 | 16–19, 17 |
| Depth at BPV | 11–15, 13 | 10–14, 12 | 9–14, 12 | 11–14, 12 |
| Depth at AMPM | 7–10, 8 | 6–9, 7 | 7–10, 9 | 7–10, 8 |
| Width at BPE | 12–16, 15 | 13–17, 16 | 15–19, 16 | 13–15, 14 |
| Width at OP1 | 11–14, 12 | 11–18, 15 | 11–18, 15 | 12–15, 13 |
| Width at OD | 8–11, 9 | 8–16, 12 | 9–13, 11 | 9–13, 11 |
| Width at BPV | 6–9, 8 | 7–10, 8 | 6–9, 8 | 7–9, 8 |
| Width at AMPM | 2–5, 4 | 3–6, 4 | 4–6, 5 | 3–5, 4 |

(continued)

Table 57. Continued.

| Developmental Phase Character | <i>Cyprinella lutrensis</i> | <i>Hybognathus amarus</i> | <i>Pimephales promelas</i> | <i>Pimephales vigilax</i> |
|-------------------------------------|-----------------------------|---------------------------|----------------------------|---------------------------|
| Juveniles ≤40 mm SL | | | | |
| Eye diameter, % HL ^a | 21–38, 31 | 23–28, 25 | 25–34, 29 | 26–34, 28 |
| AS-to-AE length | 4–8, 6 | 4–6, 5 | 4–7, 5 | 5–7, 6 |
| AS-to-PE length | 11–15, 13 | 10–13, 12 | 11–15, 13 | 12–15, 13 |
| AS-to-OP1 length | 22–28, 25 | 23–28, 26 | 23–27, 25 | 23–26, 25 |
| AS-to-OP2 length | 46–51, 48 | 54–59, 56 | 49–55, 52 | 48–51, 49 |
| AS-to-OD length | 47–52, 50 | 52–56, 53 | 49–54, 51 | 47–52, 49 |
| AS-to-ID length | 60–67, 63 | 63–66, 65 | 63–66, 64 | 60–65, 63 |
| AS-to-PV length | 60–64, 62 | 70–74, 72 | 65–69, 67 | 63–69, 66 |
| AS-to-IA length | 73–78, 76 | 79–83, 81 | 73–78, 75 | 72–77, 75 |
| AS-to-AFC length | 111–118, 114 | 112–120, 116 | 110–117, 114 | 110–114, 111 |
| Caudal-fin length ^g | 20–29, 25 | 22–31, 27 | 18–26, 22 | 18–26, 21 |
| Pectoral-fin length | 15–23, 19 | 14–22, 18 | 13–20, 16 | 12–21, 16 |
| Pelvic-fin length | 11–17, 14 | 11–17, 14 | 9–17, 13 | 8–17, 11 |
| Dorsal-fin length | 20–24, 22 | 19–24, 22 | 18–24, 21 | 19–25, 21 |
| Anal-fin length | 17–23, 20 | 14–17, 16 | 13–18, 15 | 12–17, 14 |
| Dorsal-fin-base length ^f | 10–16, 12 | 10–12, 11 | 11–14, 13 | 13–16, 14 |
| Depth at BPE | 14–18, 16 | 14–19, 16 | 16–19, 17 | 13–17, 15 |
| Depth at OP1 | 17–24, 20 | 18–23, 21 | 19–24, 22 | 16–20, 18 |
| Depth at OD | 17–25, 20 | 18–25, 22 | 18–25, 21 | 17–24, 20 |
| Depth at BPV | 13–20, 17 | 13–18, 16 | 12–17, 14 | 13–17, 15 |
| Depth at AMPM | 8–12, 10 | 8–12, 10 | 9–12, 10 | 9–12, 11 |
| Width at BPE | 12–16, 14 | 13–18, 15 | 14–16, 15 | 13–15, 14 |
| Width at OP1 | 11–16, 14 | 15–19, 17 | 14–19, 16 | 13–17, 15 |
| Width at OD | 9–17, 12 | 12–18, 15 | 11–18, 14 | 10–16, 13 |
| Width at BPV | 8–14, 10 | 8–13, 10 | 7–12, 10 | 8–12, 10 |
| Width at AMPM | 3–7, 4 | 3–5, 4 | 4–6, 5 | 3–6, 4 |

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

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

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

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

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

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

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

^h N = 1.

Table 58. Comparison of the more diagnostic differences in morphometrics for larvae and juveniles (≤ 40 mm SL) of catostomids in the Middle Rio Grande Basin. (Except as indicated, all data are percentages of standard length, % SL, presented as ranges followed by means. HL = head length measured to the origin of the pectoral fin, AS to OP1. See Figure 4 for other abbreviations and methods of measurement.)

| Developmental Phase Character | <i>Catostomus commersonii</i> | <i>Catostomus plebeius</i> | <i>Carpionodes carpio</i> | <i>Ictiobus bubalus</i> |
|----------------------------------|-----------------------------------|--------------------------------|-------------------------------|-----------------------------|
| Protolarvae | | | | |
| Eye diameter ^a | 5–7, 6 | 7–9, 8 | 6–8, 7 | 7–8, 7 |
| AS-to-PE length | 8–9, 8 | 9–11, 10 | 9–11, 10 | 9–12, 10 |
| AS-to-ODF length | 34–42, 37 | 38–49, 43 | 36–44, 40 | 40–44, 42 |
| AS-to-PV length | 76–82, 78 | 77–84, 79 | 75–77, 76 | 73–78, 76 |
| Yolk length ^b | 26–63, 51 | 43–64, 52 | 0–54, 26 | 0–56, 19 |
| Pectoral-fin length ^c | 2–12, 7 | 3–11, 8 | 5–13, 10 | 7–13, 10 |
| Depth at OD ^{b, d} | 8–13, 10 | 8–18, 11 | 9–16, 12 | 9–16, 11 |
| Width at OD ^{b, d} | 5–9, 6 | 5–13, 8 | – | 6–8, 7 ⁱ |
| Max. yolk depth ^b | 1–11, 6 | 1–13, 7 | 0–20, 5 | 0–15, 4 |
| Max. yolk width ^b | 1–10, 6 | 2–14, 8 | – | 0–10, 2 |
| Flexion mesolarvae | | | | |
| Eye diameter, % HL ^a | 28–38, 34 | 32–40, 37 | 31–34, 33 | 31–39, 36 |
| AS-to-AE length | 2–3, 2 | 2–4, 3 | 3–5, 4 | 2–3, 3 |
| AS-to-PE length | 7–10, 8 | 8–11, 10 | 10–13, 11 | 9–12, 11 |
| AS-to-OP1 length | 16–20, 18 | 18–22, 19 | 21–23, 22 | 18–23, 21 |
| AS-to-OPAF length | 23–27, 25 | 23–28, 26 | 36 ^h | 29–35, 32 |
| AS-to-ODF length | 35–43, 38 | 39–44, 41 | 42–48, 46 | 39–45, 43 |
| AS-to-PV length | 76–81, 79 | 76–81, 78 | 75–80, 78 | 76–80, 79 |
| Yolk length | 0–50, 18 | 0–49, 14 | 0 | 0 |
| Pectoral-fin length | 10–12, 11 | 10–13, 11 | 12 ^h | 14 ^h |
| Depth at OP1 | 10–13, 11 | 11–15, 13 | 15 ^h | 12–18, 16 |
| Depth at OD ^d | 8–10, 9 | 8–12, 10 | 12 ^h | 11–15, 13 |
| Depth at BPV | 5–6, 5 | 6–8, 7 | 7 ^h | 6–8, 7 |
| Width at BPE | 9–12, 10 | 10–13, 12 | 13–16, 15 | 14–14, 14 |
| Width at OP1 | 6–8, 7 | 7–10, 9 | – | – |
| Width at OD ^d | 5–6, 5 | 5–7, 6 | – | – |
| Max. yolk depth | 0–3, 1 | 0–5, 1 | 0 | 0 |
| Max. yolk width | 0–4, 1 | 0–5, 1 | 0 | 0 |
| Postflexion mesolarvae | | | | |
| Eye diameter, % HL ^a | 24–34, 31 | 29–39, 33 | 28–33, 30 | 30–35, 32 |
| AS-to-AE length | 2–6, 4 | 3–7, 4 | 5–6, 5 | 4–6, 5 |

(continued)

Table 58. Continued.

| Developmental Phase Character | <i>Catostomus commersonii</i> | <i>Catostomus plebeius</i> | <i>Carpoides carpio</i> | <i>Ictiobus bubalus</i> |
|--|-------------------------------|----------------------------|-------------------------|-------------------------|
| AS-to-PE length | 9–14, 11 | 10–15, 12 | 11–14, 13 | 11–15, 13 |
| AS-to-OP1 length | 19–25, 22 | 20–27, 23 | 23–27, 25 | 22–28, 25 |
| AS-to-OP2 length | 52–54, 53 | 51–55, 53 | 52–55, 54 | 47–51, 50 |
| AS-to-OPAF length | 25–33, 30 | 26–38, 31 | 34–54, 45 | 32–36, 35 |
| AS-to-PV length | 78–81, 80 | 76–83, 79 | 77–82, 79 | 78–83, 80 |
| Pectoral-fin length | 11–14, 12 | 12–17, 14 | 14–15, 14 | 15–17, 16 |
| Dorsal-fin-base length ^{e, f} | 12–14, 13 | 9–12, 10 | – | 36 ^h |
| Depth at OP1 | 14–18, 16 | 14–20, 17 | 15–21, 18 | 17–23, 20 |
| Depth at OD | 9–16, 12 | 10–19, 14 | 11–22, 16 | 15–23, 19 |
| Depth at BPV | 6–9, 7 | 6–9, 8 | 7–12, 10 | 9–15, 11 |
| Width at BPE | 11–15, 13 | 13–17, 14 | 16–18, 17 | 15–17, 16 |
| Width at OP1 | 8–12, 10 | 9–13, 11 | – | – |
| Width at OD | 5–9, 7 | 5–11, 8 | – | – |
| Metalarvae | | | | |
| Eye diameter, % HL ^a | 25–34, 30 | 27–31, 29 | 31 ^h | 30 ^h |
| AS-to-AE length | 4–8, 6 | 5–8, 6 | 5–6, 5 | 4–7, 6 |
| AS-to-PE length | 12–15, 14 | 12–15, 14 | 13–14, 13 | 12–15, 15 |
| AS-to-OP1 length | 20–30, 26 | 23–27, 25 | 29 ^h | 27 ^h |
| AS-to-OP2 length | 54–59, 56 | 52–59, 55 | 55 ^h | 52 ^h |
| AS-to-OD length | 48–53, 51 | 48–52, 50 | 47–49, 48 | 45–48, 47 |
| AS-to-ID length | 61–67, 65 | 59–64, 61 | 81 ^h | 80 ^h |
| AS-to-PV length | 75–79, 77 | 74–81, 76 | 76–78, 77 | 75–78, 77 |
| AS-to-IA length | 83–86, 85 | 82–87, 83 | 86 ^h | 85 ^h |
| Caudal-fin length ^g | 16–26, 21 | 15–21, 17 | 24–30, 28 | 26–30, 28 |
| Pectoral-fin length | 12–19, 15 | 15–21, 17 | 24 ^h | – |
| Pelvic-fin length | 4–16, 9 | 4–13, 8 | 14 ^h | 11 ^h |
| Dorsal-fin-base length ^f | 12–15, 14 | 10–12, 11 | 32 ^h | 35 ^h |
| Depth at BPE | 14–19, 16 | 16–19, 17 | 18–20, 18 | 17–20, 19 |
| Depth at OP1 | 16–20, 18 | 18–21, 20 | 25 ^h | 20 ^h |
| Depth at OD | 13–20, 16 | 14–21, 19 | 26 ^h | 22 ^h |
| Depth at BPV | 7–11, 9 | 8–13, 10 | 17 ^h | 12 ^h |
| Depth at AMPM | 5–8, 7 | 6–9, 7 | 12 ^h | 11 ^h |
| Width at BPE | 13–17, 15 | 15–17, 16 | 18–18, 18 | 17–18, 17 |
| Width at OP1 | 11–14, 13 | 12–17, 15 | – | – |
| Width at OD | 8–14, 10 | 9–15, 12 | – | – |
| Width at BPV | 4–8, 6 | 6–9, 7 | – | – |
| Width at AMPM | 2–4, 3 | 3–5, 4 | – | – |

(continued)

Table 58. Continued.

| Developmental Phase Character | <i>Catostomus commersonii</i> | <i>Catostomus plebeius</i> | <i>Carpiodes carpio</i> | <i>Ictiobus bubalus</i> |
|-------------------------------------|-------------------------------|----------------------------|-------------------------|---------------------------|
| Juveniles ≤40 mm SL | | | | |
| Eye diameter, % HL ^a | 22–28, 25 | 23–27, 25 | 30 ^h | 28–29, 29 ⁱ |
| AS-to-AE length | 6–10, 8 | 7–10, 8 | 5–7, 6 | 7–8, 7 ⁱ |
| AS-to-PE length | 13–16, 15 | 13–17, 15 | 13–15, 14 | 15–16, 15 ⁱ |
| AS-to-OP1 length | 24–29, 28 | 23–29, 26 | 28 ^h | 28–29, 29 ⁱ |
| AS-to-OP2 length | 52–59, 57 | 56–60, 57 | 54 ^h | 52–53, 52 ⁱ |
| AS-to-OD length | 48–53, 51 | 49–51, 50 | 47–49, 48 | 48–50, 49 ⁱ |
| AS-to-ID length | 61–68, 65 | 61–62, 62 | 80 ^h | 82–85, 84 ⁱ |
| AS-to-PV length | 72–78, 76 | 72–77, 74 | 74–79, 77 | 75–75, 75 ⁱ |
| AS-to-IA length | 79–86, 84 | 82–85, 83 | 85 ^h | 84–86, 85 ⁱ |
| AS-to-AFC length | 113–117, 115 | 113–117, 115 | 114 ^h | 113–116, 115 ⁱ |
| Caudal-fin length ^g | 19–24, 22 | 18–22, 20 | 27–32, 29 | 26–28, 27 ⁱ |
| Pectoral-fin length | 15–20, 17 | 16–22, 19 | 21 ^h | 16–16, 16 ⁱ |
| Pelvic-fin length | 10–15, 12 | 11–16, 14 | 19 ^h | 12–14, 13 ⁱ |
| Dorsal-fin length | 18–24, 20 | 18–23, 20 | 41 ^h | 38–38, 38 ⁱ |
| Anal-fin length | 10–16, 13 | 13–20, 16 | 17 ^h | 14–16, 15 ⁱ |
| Dorsal-fin-base length ^f | 13–16, 14 | 11–13, 12 | 33 ^h | 34–35, 35 ⁱ |
| Depth at BPE | 16–19, 17 | 15–19, 17 | 19–20, 19 | 20–22, 21 ⁱ |
| Depth at OP1 | 18–22, 20 | 18–23, 21 | 25 ^h | 27–28, 27 ⁱ |
| Depth at OD | 17–22, 19 | 19–25, 22 | 27 ^h | 27–30, 28 ⁱ |
| Depth at BPV | 10–14, 11 | 11–14, 13 | 20 ^h | 18–19, 19 ⁱ |
| Depth at AMPM | 7–9, 8 | 8–9, 8 | 14 ^h | 12–13, 12 ⁱ |
| Width at BPE | 14–18, 16 | 15–18, 16 | 18–19, 19 | – |
| Width at OP1 | 13–20, 16 | 14–20, 17 | – | – |
| Width at OD | 10–16, 13 | 13–20, 16 | – | – |
| Width at BPV | 7–10, 8 | 7–11, 8 | – | – |
| Width at AMPM | 4–5, 4 | 3–6, 5 | – | – |

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

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

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

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

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

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

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

^h N = 1.

ⁱ N = 2.

Selected eye, mouth, and fin position characters

Table 59. Comparison of selected eye, mouth, and fin-position characters for larvae and juveniles (≤ 40 mm SL) of larger adult cyprinids in the Middle Rio Grande Basin. (Key to characters and their states is given below. Rare character states are enclosed in parentheses.)

| Character | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> |
|----------------------------------|----------------------------|-------------------------|--------------------------------|-----------------------------------|
| Eye Shape | | | | |
| Protolarvae | 2–3 | 1–2 | 1 | (1),2 |
| Flexion Mesolarvae | 2–3 | (1),2–3 | 1–2 | 2 |
| Postflexion Mesolarvae | (2),3 | 2–3 | 1–2 | 2,(3) |
| Mouth Position | | | | |
| Protolarvae | 2–5 | 4–5 | 4–5 | 4–5 |
| Flexion Mesolarvae | 2–3 | 4 | (3),4 | 4 |
| Postflexion Mesolarvae | 2–3 | (2),4 | (2–3),4 | (2),4 |
| Metalarvae | 2–3 | 2–4 | (2),4 | 4 |
| Juveniles | 2–3 | 2(–4) | 4 | 4 |
| Posterior Corner of Mouth | | | | |
| Protolarvae | 2–4 | 3–4 | 3–4 | 3–4 |
| Flexion Mesolarvae | (1),2–3 | 3 | 2–3 | 3 |
| Postflexion Mesolarvae | (1),2,(3) | 3 | 2–3 | 3 |
| Metalarvae | 1–2 | (2),3 | 2–3 | 3 |
| Juveniles | 1 | (1),2,(3) | 2–3 | 1–3 |
| Frenum | | | | |
| Postflexion Mesolarvae | 3 | 2–3 | 3 | 2 |
| Metalarvae | 3 | 3 | 3 | 2 |
| Juveniles | 3 | 3 | 3 | 2 |
| Origin of Dorsal Fin | | | | |
| Metalarvae | 1–2 | 3 | 1,(2–3) | (2),3 |
| Juveniles | 1,(2) | (2),3 | 1,(2) | (2),3 |
| Insertion of Dorsal Fin | | | | |
| Metalarvae | 3 | 1 | 1 | 1 |
| Juveniles | 3 | 1–2 | 1 | 1–2 |

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

Eye shape [pr–pm]

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

(continued)

Table 59. Continued.

Mouth position [all]

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

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

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

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

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

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

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

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

Table 60. Comparison of selected eye, mouth, and fin-position characters for larvae and juveniles (≤ 40 mm SL) of smaller adult cyprinids in the Middle Rio Grande Basin. (See Table 59 for key to characters and their states. Rare character states are enclosed in parentheses.)

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

Table 61. Comparison of selected eye, mouth, and fin-position characters for larvae and juveniles (≤ 40 mm SL) of catostomids in the Middle Rio Grande Basin. (See Table 59 for key to characters and their states. Rare character states are enclosed in parentheses. U = unknown—not reported or illustrated.)

| Character | <i>Catostomus commersonii</i> | <i>Catostomus plebeius</i> | <i>Carpiodes carpio</i> | <i>Ictiobus bubalus</i> |
|----------------------------------|-------------------------------|----------------------------|-------------------------|-------------------------|
| Eye Shape | | | | |
| Protolarvae | 2–3 ^a | 2–3 ^a | 1–2 | (1 ^a),2–3 |
| Flexion Mesolarvae | 2–3 ^a | 2–3 ^a | 1 ^a | 3 ^a |
| Postflexion Mesolarvae | 2–3 ^a | 2–3 ^a | (1),2,(3) ^a | (1),3 ^a |
| Mouth Position | | | | |
| Protolarvae | 2,4–5 ^a | 2,4–5 ^a | 2,(3–4),5 | 2,(3–4),5 |
| Flexion Mesolarvae | 2 ^a | 2,(4) ^a | 2,(3) | 2 |
| Postflexion Mesolarvae | 2,(3) ^a | 2–3,(4) ^a | (2),3 | 2 ^a ,3–4 |
| Metalarvae | 2–3,(4) | 2–4 | 3 ^a ,4 | 2 ^a ,3–4 |
| Juveniles | 3–4 | (3),4–5 | 4 | 2–3 ^a ,4 |
| Posterior Corner of Mouth | | | | |
| Protolarvae | 2–4 ^a | 2–4 ^a | 2–4 ^a | 1–4 ^a |
| Flexion Mesolarvae | 1–3 ^a | 2–3 ^a | 2–3 ^a | 1–2 ^a |
| Postflexion Mesolarvae | 1–2 ^a | 1–2 ^a | U,2–3 ^a | 1–2 ^a |
| Metalarvae | 1,(2) ^a | 1,(2) ^a | 2–3 | 1 ^a |
| Juveniles | 1,(2) ^a | 1,(2) ^a | 2–3 | 1 ^a |
| Frenum | | | | |
| Postflexion Mesolarvae | 2–3 ^a | 2–3 ^a | U,3 ^a | 2–3 ^a |
| Metalarvae | 3 | 3 | 3 | 3 |
| Juveniles | 3 | 3 | 3 | 3 |
| Origin of Dorsal Fin | | | | |
| Metalarvae | 1 | 1 | 1 ^a | 1 ^a |
| Juveniles | 1 | 1 | 1 ^a | 1 ^a |
| Insertion of Dorsal Fin | | | | |
| Metalarvae | 1 | 1 | 3 ^a | 3 ^a |
| Juveniles | 1 | 1 | 3 ^a | 3 ^a |

^a As assessed from illustrations herein or previously published.

Size relative to acquisition of eye, body, and peritoneal pigmentation

Table 62. Comparison of size (mm SL) relative to melanophore pigmentation in the eyes, and on the bodies for protolarvae, and on the lateral to ventral peritoneum for metalarvae (M) and juveniles (J, ≤ 40 mm SL) of larger adult cyprinids in the Middle Rio Grande Basin. (For peritoneal pigmentation, size is preceded by initials for the applicable developmental intervals. Rare values are given in parentheses.)

| Character | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> |
|--|------------------------|---------------------|----------------------------|-------------------------------|
| Eye pigmentation, protolarvae | | | | |
| Unpigmented | a | a | a | 4(5) ^a |
| Light to moderate, in general patterned | (4–5) ^a | (7) ^a | – | (4–6) ^a |
| Dark | – | – | 5–6(7) ^{a, b} | (4)5(6) ^{a, b} |
| | $\geq(4)5^a$ | $\geq 7^a$ | $\geq(6)7$ | $\geq(5)6$ |
| Body pigmentation, protolarvae | | | | |
| Unpigmented | a | a | 5–6 ^a | 4–5(6) ^a |
| Sparsely to moderately pigmented with ≤ 12 melanophores on dorsum | (4) ^a | a | 6–7 | (4)5(6) ^a |
| Moderately to well pigmented with ≥ 13 melanophores on dorsum | $\geq(4)5^a$ | $\geq 7^a$ | $\geq(6)7$ | $\geq(5)6$ |
| Peritoneal pigmentation, metalarvae and juveniles^c | | | | |
| Lateral aspects | | | | |
| Absent | – | (M ≤ 13) | M | M 10(11) |
| Sparse or patchy | MJ $\leq 20(-23)$ | MJ ≤ 27 | MJ ≤ 26 | MJ ≤ 26 |
| Uniformly speckled | J (21)22(-24) | MJ 16–23(-27) | (J 15–19) | (M 14–16) |
| Uniformly light | – | – | – | – |
| Uniformly dark | – | – | – | – |
| Obscured by overlying tissues | (M)J $\geq(15-)21$ | MJ $\geq(19-)24$ | J ≥ 24 | J $\geq(25-)27$ |
| Ventrolateral aspects | | | | |
| Absent | (J 22–24) | M ≤ 14 | MJ $\leq 22(-23)$ | M $\leq 11(12)$ |
| Sparse, patchy, or uniformly speckled | MJ $\leq 23(24)$ | MJ 15–31(-34) | MJ ≤ 26 | MJ ≤ 26 |
| Uniformly light | – | – | – | – |
| Uniformly dark | – | – | – | – |
| Obscured by overlying tissues | J $\geq(21-)24$ | J ≥ 30 | J ≥ 24 | J $\geq(25-)27$ |

(continued)

Table 62. Continued.

| Developmental Phase Character | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> |
|--|----------------------------|-------------------------|--------------------------------|-----------------------------------|
| Ventral aspects | | | | |
| Absent | MJ \leq 22(-29) | MJ \leq 27 | MJ \leq 26 | MJ \leq 16(-26) |
| Sparse, patchy, or uniformly speckled | MJ (13)14–22(-29) | MJ 15–31(-34) | (J 17–26) | MJ 14–26 |
| Uniformly light | – | – | – | – |
| Uniformly dark | – | – | – | – |
| Obscured by overlying tissues | J \geq (22)23 | J \geq 30 | J \geq 24 | J \geq (25–)27 |

^a (Or) before hatching.

^b Pigment forming or most intense as a diagonal band across the eye.

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

Table 63. Comparison of size (mm SL) relative to melanophore pigmentation in the eyes, and on the bodies for protolarvae, and on the lateral to ventral peritoneum for metalarvae (M) and juveniles (J, ≤ 40 mm SL) of smaller adult cyprinids in the Middle Rio Grande Basin. (For peritoneal pigmentation, size is preceded by initials for the applicable developmental intervals. Rare values are given in parentheses.)

| Character | <i>Cyprinella lutrensis</i> | <i>Hybognathus amarus</i> | <i>Pimephales promelas</i> | <i>Pimephales vigilax</i> |
|--|---------------------------------|-------------------------------|--------------------------------|-------------------------------|
| Eye pigmentation, protolarvae | | | | |
| Unpigmented | a | 3–4(5) a | a | a |
| Light to moderate, in general | 3(4) a | (4)5 | (4) a | a |
| patterned | – | – | – | – |
| Dark | $\geq(3)4$ | ≥ 5 | ≥ 4 a | $\geq(4)5$ a |
| Body pigmentation, protolarvae | | | | |
| Unpigmented | 3–4 a | 3–5 a | a | a |
| Sparsely to moderately Pigmented with ≤ 12 melanophores on dorsum | 4–5 b | 5 | 4–5(6) a | $\geq(4)5$ a, c |
| Moderately to well pigmented with ≥ 13 melanophores on dorsum | – b | $\geq(5)6$ | ≥ 5 –6 | – c |
| Peritoneal pigmentation, metalarvae and juveniles d | | | | |
| Lateral aspects | | | | |
| Absent | M $\leq 9(10)$ | (M ≤ 12) | M ≤ 10 | M $\leq 10(11)$ |
| Sparse or patchy | MJ (9)10–12(–14) | M(J ≤ 26) | MJ ≤ 16 | MJ ≤ 25 |
| Uniformly speckled | (M)J 12–25(–29) | MJ ≤ 15 | (J ≤ 32) | J (19)20–26 |
| Uniformly light | J (25–)29–33(–35) | – | (M)J (11–)16–20(–22) | – |
| Uniformly dark | – | J $\leq 25(–30)$ | J $\leq 38(39)$ | – |
| Obscured by overlying tissues | J $\geq(15–)18$ | J $\geq(21–)26$ | J $\geq(15–)19$ | J ≥ 27 |
| Ventrolateral aspects | | | | |
| Absent | M $\leq 9(10)$ | M | M(J) $\leq 12(–15)$ | MJ ≤ 16 |
| Sparse, patchy, or uniformly speckled | MJ (9)10–25(–29) | MJ ≤ 18 | MJ (8–)11–27(–32) | MJ ≤ 26 |
| Uniformly light | J (25–)29–33(–35) | – | (M)J (11–)15–24 | – |
| Uniformly dark | – | J $\leq 25(–40)$ | J 19–34(–39) | – |
| Obscured by overlying tissues | J $\geq(15–)18$ | J ≥ 26 | J $>(24)25$ | J ≥ 27 |

(continued)

Table 63. Continued.

| Developmental Phase Character | <i>Cyprinella lutrensis</i> | <i>Hybognathus amarus</i> | <i>Pimephales promelas</i> | <i>Pimephales vigilax</i> |
|---------------------------------------|-----------------------------|---------------------------|----------------------------|---------------------------|
| Ventral aspects | | | | |
| Absent | MJ \leq 14 | M | MJ \leq 16 | MJ \leq 29 |
| Sparse, patchy, or uniformly speckled | J (14)15–33(–35) | J \leq 18 | MJ 11–27(–32) | (J 16–29) |
| Uniformly light | – | – | J (16)17–33(34) | – |
| Uniformly dark | – | J \geq 15 | J 25–34(–39) | – |
| Obscured by overlying tissues | J \geq (15–)18 | (J \geq 27) | J \geq (34)35 | J \geq 30 |

^a (Or) before hatching.

^b Most sparsely pigmented 4-mm and some 5-mm-SL protolarvae without melanophores on dorsum, and when present often only on dorsum of head; all 5-mm and some 6-mm-SL flexion mesolarvae with some but still fewer than 13 melanophores on dorsum (sometimes also only over head).

^c All examined and previously described protolarvae and some recently transformed flexion mesolarvae (6–7 mm SL) lack melanophore pigmentation on the dorsal surface, but are sparsely to moderately pigmented elsewhere.

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

Table 64. Comparison of size (mm SL) relative to melanophore pigmentation in the eyes, and on the bodies for protolarvae, and on the lateral to ventral peritoneum for metalarvae (M) and juveniles (J, ≤ 40 mm SL) of catostomids in the Middle Rio Grande Basin. (For peritoneal pigmentation, size is preceded by initials for the applicable developmental intervals. Rare values are given in parentheses. U = unknown—not reported or illustrated.)

| Character | <i>Catostomus commersonii</i> | <i>Catostomus plebeius</i> | <i>Carpionodes carpio</i> | <i>Ictiobus bubalus</i> |
|--|-------------------------------|-----------------------------------|---------------------------|-------------------------|
| Eye pigmentation, protolarvae | | | | |
| Unpigmented | 7 ^a | 6–7 ^a | a | a |
| Light to moderate, in general patterned | 7–10 ^a | 7–9 ^a | 5(6) ^a | a |
| Dark | ≥ 8 ^a | $\geq (8)9$ | $\geq (5)6$ | $\geq 5-6$ ^a |
| Body pigmentation, protolarvae | | | | |
| Unpigmented | 7–9 ^a | 6–9 ^a | a | a |
| Sparsely to moderately pigmented with ≤ 12 melanophores on dorsum | 7–9 ^a | 8–9 | 5–6(7) ^a | 5–7 ^a |
| Moderately to well pigmented with ≥ 13 melanophores on dorsum | ≥ 8 ^a | $\geq (8)9$ | $\geq 6-7$ | $\geq 6-7$ |
| Peritoneal pigmentation, metalarvae and juveniles^b | | | | |
| Lateral aspects | | | | |
| Absent | M ≤ 18 | M $\leq 19(-23)$ | – | – |
| Sparse or patchy | MJ ≤ 29 | MJ $\leq 27(-30)$ | M $\geq (15)16$; J U | – |
| Uniformly speckled | – | (MJ $\leq 27(-30)$) ^c | M $\geq (15)16$; J U | MJ 15–U |
| Uniformly light | – | MJ $\leq 27(-30)$ | J U | MJ U |
| Uniformly dark | – | MJ $\geq (17-)20-27(-30)$ | J U | MJ U |
| Obscured by overlying tissues | J ≥ 30 | J $\geq (28-)30$ | J U ≥ 24 | MJ U |
| Ventrolateral aspects | | | | |
| Absent | MJ ≤ 37 | MJ ≤ 27 | M $\geq (15)16$; J U | – |
| Sparse, patchy, or uniformly speckled | MJ 16–37 | MJ ≤ 27 | M $\geq (15)16$; J U | MJ 15–U |
| Uniformly light | (J 35–37) | MJ (17–)20–27(–33) | J U | MJ U |
| Uniformly dark | – | MJ (24–)31–34(–36) | J U | MJ U |
| Obscured by overlying tissues | J ≥ 38 | J $\geq (35-)37$ | J U ≥ 24 | MJ U |

(continued)

Table 64. Continued.

| Developmental Phase Character | <i>Catostomus commersonii</i> | <i>Catostomus plebeius</i> | <i>Carpiodes carpio</i> | <i>Ictiobus bubalus</i> |
|--|-----------------------------------|--------------------------------|-----------------------------|-----------------------------|
| Ventral aspects | | | | |
| Absent | MJ \leq 37 | MJ \leq 27(-31) | MJ U | MJ U |
| Sparse, patchy, or uniformly speckled | J 22–37 | MJ \geq 17–34(-36) | MJ U | MJ 15–U |
| Uniformly light | (J 35–37) | J \geq 23 | MJ U | MJ U |
| Uniformly dark | – | J \geq (24–)31 | MJ U | MJ U |
| Obscured by overlying tissues | J \geq 38 | – | MJ U | MJ U |

^a (Or) before hatching.

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

^c State of “uniformly speckled” not originally assessed for catostomids, but in this case was specifically noted for one 25 mm SL juvenile and is likely an intermediate state between “sparse or patchy” and “uniformly light” for some late metalarvae and recently transformed juveniles.

Selected melanophore pigmentation patterns

Table 65. Comparison of selected melanophore pigmentation patterns for larvae and juveniles (≤ 40 mm SL) of larger adult cyprinids in the Middle Rio Grande Basin. (Key to characters and their states is given below; character numbers correspond to those used in the computer-interactive key. Rare character states are enclosed in parentheses. NA = not applicable.)

| Character number | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> |
|--|------------------------|---------------------|----------------------------|-------------------------------|
| Protolarvae (after pigment is well established) | | | | |
| 25. | 1-2 | 1 | 1 | 1 |
| 26. | 2 | 1-2 | 1-2 | 1-2 |
| 27. | 1,(2) | 1-2 | NA,1,(4) | NA,1 |
| 28. | 1-2 | 2-3 | NA,1-2,(3) | NA,2,(3,5) |
| 29. | (2),3,(4) | 3-4 | NA,2-3 | NA,4 |
| 35. | 1,3 | 1-3 | 1-2 | 1-2,(3) |
| 38. | 1,(2) | 2,(3) | 2-3,(5) | 1,(2),3 |
| 39. | 4-6 | 3,6 | 2-3,6 | 1,(2),3,6 |
| 43. | (1),2-3 | 2,(6),7,(8) | 1-2,7 | 1-2,(5),6 |
| 51. | 1,(2) | 1 | 1 | 1 |
| 52. | 1 | 1 | 1 | 1 |
| 53. | 1,(2) | 1 | 1 | 1 |
| 54. | 1-2 | 1 | 1 | 1-2 |
| 55. | 1-2 | 1-3 | 1-2,(3-4) | 1,3 |
| 56. | 1-2 | 1,4 | 1-2,(4) | 1,(2),4,(5) |
| 57. | NA,(2),3-4 | NA | NA,(3-4) | NA,(2) |
| 58. | NA | NA | NA | NA,(1,6) |
| 59. | NA | NA,2 | NA,(2) | NA,(1-2),3 |
| Flexion mesolarvae | | | | |
| 24. | 3 | 1-3 | 1-3 | 1(2) |
| 25. | 1-3 | 1-2 | (1),2 | 1-2 |
| 26. | 2 | 2 | 2 | 2 |
| 27. | 1-3 | 1-2 | 1,(4) | 1 |
| 28. | NA,1-2 | 2-3 | 1-4 | (1),2,(4) |
| 29. | NA,3-4 | 3-4 | 2-4 | 4 |
| 35. | 3 | 3-4 | 2-3 | (1),2-3 |
| 37. | 2-3 | 2-3 | 1-3 | (2),3 |
| 38. | 1-2,4 | 2-4 | (2),3-4 | 3-4 |
| 39. | 4-5 | 6 | (1-3),6 | 6 |
| 40. | 1-2 | 1-2 | 1 | 1,(2) |
| 41. | 1-3 | 1-2 | 1 | 1 |
| 42. | 1-3 | 1 | 1 | 1 |
| 43. | 2-3,5,7-8 | 4,6-7 | (4-5),6-8 | (2),5-6 |

(continued)

Table 65. Continued.

| Character number | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> |
|-------------------------------|------------------------|---------------------|----------------------------|-------------------------------|
| 44. | 1-3 | 1-3 | 1-3 | 1-2 |
| 51. | 1-2 | 1-3 | 1,(3) | 1,(2) |
| 52. | 1 | 1-3 | 1 | 1,(2-3) |
| 53. | 1 | 1 | 1-2 | 1-2 |
| 54. | 1 | 1-2 | 1 | 1-2 |
| 55. | 1-2 | 3-4 | (2),3,(4-5) | (3),5 |
| 56. | 2 | 2,4,6-7 | 1,4-5,(6) | 1,(3),4-5 |
| 57. | 3 | NA,1-2 | NA,(4) | NA |
| 58. | NA | NA,6 | NA,(1),6 | NA,5 |
| 59. | NA | NA,2-3 | NA,2-3 | NA,3 |
| Postflexion mesolarvae | | | | |
| 24. | 3 | 1,3 | 2-3 | 3 |
| 25. | 2-3 | 1-2 | 2-3 | 2-3 |
| 27. | 2-3 | 1-2 | 1 | 1-3 |
| 28. | NA,2,5 | 2-3,(4-5) | (1),5 | 1-3,(5) |
| 29. | NA,2,4 | 2-4 | (1),4 | 3-4 |
| 35. | 1,3 | (2),3,(4) | 1-2 | (1),2-3 |
| 37. | 3 | (2),3 | (2),3 | (2),3 |
| 38. | 2,4-5 | 2-4,(5) | 4-5 | 4-5 |
| 39. | 1,5 | (1),6 | (1),6 | 6 |
| 40. | 1-3 | 1 | 1-2 | 1-2 |
| 41. | 3 | 1-2,(3) | 1-2,(3) | (1),2-3 |
| 42. | 3 | 1-2 | 1,(2) | 1-2 |
| 43. | 1,3,5 | 4,6-8 | (2,4),5-6,(8) | (4),5-6,(7) |
| 44. | 3 | 2-3 | 2-3 | 1-2,(3) |
| 45. | 1-3 | 1 | 1 | 1,(2) |
| 47. | 1 | 1 | 1 | 1 |
| 51. | 2 | 1 | 1-2 | 1-3 |
| 52. | 1-3 | 1-2 | 1 | 1-3 |
| 53. | 1 | 1 | 1-2 | 1-2 |
| 54. | 1 | 1-2 | 1 | 1,(2) |
| 55. | 2-3 | 3 | (2),3-4 | 3-5 |
| 56. | 1-2 | 1,(2),4,6 | (4),5-6,(7) | (1-2),4-5,(6) |
| 57. | NA,3 | NA,(2),4 | NA,(1),4 | NA,(2,4) |
| 58. | NA | NA,1 | (NA),1,6 | NA,(1),5 |
| 59. | NA | NA,2-3 | 2-4 | NA,3 |
| 63. | 1-3 | 1 | 1 | 1-2,(3) |
| 64. | 1-2 | 1,(2) | 1 | 1 |
| 65. | 1-2 | 1-2 | 1-2 | 1-2 |

(continued)

Table 65. Continued.

| Character number | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> |
|-------------------|------------------------|---------------------|----------------------------|-------------------------------|
| Metalarvae | | | | |
| 30. | 1 | 1,(3) | 1,3 | 1,(3) |
| 31. | 1 | 1 | 1 | 1 |
| 32. | 2 | 1-2,(3),4 | 1-2 | (2),3-4 |
| 33. | 5 | 4-5 | 5 | (2),5-6 |
| 34. | 5 | 4-5 | 5-6 | 5 |
| 36. | 1 | 1 | 1 | 2 |
| 37. | 3 | 3 | 3 | 3 |
| 38. | 4-5 | 4-5 | (2),4-5 | 4-6 |
| 41. | 3 | 2-3 | (1-2),3 | (2),3 |
| 42. | 3 | (1),2-3 | (1),2-3 | 2-3 |
| 44. | 2-3 | 1-3 | 1-3 | 1,(2) |
| 45. | 1(3) | 1 | 1-2 | (1),2-3 |
| 46. | 1 | 1 | 1 | 1 |
| 47. | 1 | 1,(2-3) | 1,(3) | 1,3,(5) |
| 51. | 1-2 | 1-3 | 1,(3) | 1-2,(3) |
| 52. | 1 | 1,(2-3) | 1 | 1-3 |
| 53. | 1 | 1 | 1 | 1 |
| 54. | 1 | 1-2 | 1 | 1-2 |
| 55. | 1,(2-3) | 1,(2),3 | 1-2 | 1,3,(4),5 |
| 56. | 1,(2) | 1-2,6,(7) | 1,4,7 | 1,(2-3),4-5,(6) |
| 57. | NA,(2) | NA,(2),4 | NA,(1,4) | NA,2 |
| 58. | NA | NA,1,(6) | NA,(1,6) | NA,1,5 |
| 66. | 1-2 | 1 | 1,3 | 1 |
| 67. | (1),3 | 1,3 | 1-2 | 1-2 |
| 68. | 1,3 | 1 | 1-2 | 1,(5) |
| 69. | 1,(2),3 | 2-3 | 1-3 | 1-2 |
| 70. | 1 | 1,(2) | 1 | 1 |
| Juveniles | | | | |
| 30. | 1 | 1 | 1 | 1 |
| 31. | 1 | 1 | 1 | 1 |
| 32. | 2 | 2-3,(4) | 1-2 | 3-4 |
| 33. | 5 | 4-5 | 4-5 | 2,(4),6 |
| 34. | (1),5-6 | (1),(3),4-5,(6) | 1,(3),5-6 | 1-2,(4),5-6 |
| 36. | 1 | 1 | 1 | 2 |
| 45. | 1,(2-3) | 1-2 | 1-2 | (1),2-3 |
| 46. | 1 | 1 | 1 | 1 |
| 47. | 1 | 1-2 | 1-3 | (4),5 |
| 48. | 3 | 3 | 2-3 | 1,(2),3 |

(continued)

Table 65. Continued.

| Character number | <i>Cyprinus carpio</i> | <i>Gila pandora</i> | <i>Platygobio gracilis</i> | <i>Rhinichthys cataractae</i> |
|------------------|------------------------|---------------------|----------------------------|-------------------------------|
| 49. | 2–3 | 3 | 1,(2),3 | 1,(2),3 |
| 50. | 1–3 | 1–2,(3) | 1–2 | 1–3 |
| 51. | 1,(3) | 1,(2),3 | 1,(3) | 1,(2) |
| 52. | 1 | 1,(2) | 1 | 1,(2) |
| 53. | 1 | 1 | 1 | 1 |
| 54. | 1,(2) | 1 | 1,(2) | 1 |
| 55. | 1 | 1 | 1,(3,5) | 1,(3) |
| 56. | 1,(2) | 1–2,(7) | 1,(4,6–7) | 1,(4) |
| 57. | NA,(2) | NA,(2),4 | NA,(4) | NA |
| 58. | NA | NA,(6) | NA,(1,6) | NA |
| 66. | 2 | 1–2 | 1 | 1 |
| 67. | 3 | 3 | 1–3 | 1–3 |
| 68. | 3–4 | 1,4 | 1–2 | 1,(2,5) |
| 69. | 1–3 | 3 | 1,(2),3 | 1–3 |
| 70. | 1–2 | 1–2 | 1 | 1–2 |

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

24. Snout (above upper lip or margin of upper jaw and exclusive of nares) [fm–pm]
 1. unpigmented.
 2. pigmented with 1–5 melanophores.
 3. pigmented with 6 or more melanophores.
25. Pigmentation in or along margin of nares (nasal pits) [pr–pm]
 1. absent.
 2. sparse to moderate.
 3. extensive without strong emphasis on anterior and medial margins.
 4. extensive with strong emphasis on anterior and medial margins.
26. Dorsal surface of head [pr–fm]
 1. unpigmented or pigmented only over hindbrain (posterior to middle of eyes).
 2. pigmented over both mid- and hindbrain (anterior and posterior to middle of eyes).
27. Pigmentation across dorsal surface of body between head and last myomere (for specimens with greater than 12 melanophores on dorsal surface of body) [pr–pm]
 1. not scattered or sparsely scattered with at least a partial, distinct, lengthwise line or narrow band of melanophores on or lateral to dorsal midline.
 2. densely scattered over all or most of back with at least a partial, distinct, lengthwise line or narrow band of melanophores on or lateral to dorsal midline.
 3. densely scattered over all or most of back with no distinct, lengthwise lines or narrow bands of melanophores [characters 28 and 29 NA].

(continued)

Table 65. Continued.

4. otherwise (e.g., sparsely scattered with no distinct lengthwise lines).
28. Pigmentation on , or distinctly visible subsurface pigment below, dorsal midline behind head to origin of the dorsal fin (first pterygiophore) or its approximate future origin (about half of standard length) (for specimens with >12 melanophores on dorsal surface of body) [pr–pm; NA if character 27 is state 3]
 1. absent.
 2. present only as sparsely to moderately scattered melanophores not forming a distinct midline of any length.
 3. present in a short but distinct, continuous or discontinuous line or series of several well-spaced melanophores extending to no more than half the distance.
 4. present in a distinct but discontinuous line or series of at least several well-spaced melanophores extending to or nearly to full length.
 5. present in a distinct continuous or nearly continuous line to or nearly to full length.
29. Pigmentation on dorsal surfaces lateral to midline from shortly behind head to about 2/3 distance to last myomeres (for specimens with >12 melanophores on dorsal surface of body) [pr–pm; NA if character 27 is state 3]
 1. absent.
 2. sparsely to densely scattered with no distinct, lengthwise lines or narrow bands of melanophores on either side.
 3. scattered or not but with a distinct, short or discontinuous (well separated segments) line or narrow band of melanophores along one or both sides of dorsal midline.
 4. scattered or not but with a distinct, continuous or nearly continuous, full-length line or narrow band of melanophores along each side.
30. Pigmentation on dorsal surface of body between head and last myomere [mt–ej]
 1. scattered more or less evenly (with or without emphasis on distinct lines of melanophores or melanophore clusters on or lateral and parallel to dorsal midline).
 2. scattered in a blotchy or mottled pattern (with or without emphasis on distinct lines of melanophores or melanophore clusters on or lateral and parallel to dorsal midline).
 3. not notably scattered, mostly in two or three lines or narrow bands down the back.
31. Distinct spot or aggregation of pigment at origin of dorsal fin [mt–ej]
 1. absent (or indistinct).
 2. prominent.
32. Pigment on or between pterygiophores of dorsal fin [mt–ej]
 1. absent or not obvious (essentially white).
 2. obvious (light to strong) without a distinct spot or dash.
 3. with an obvious spot or dash over posterior two-thirds to half of pterygiophores with some scattered pigment before and/or after.
 4. with an obvious spot or dash over posterior two-thirds to half of pterygiophores with obvious unpigmented spot or area immediately before and/or after.
33. Pigmentation under or immediately along base of dorsal fin [mt–ej]
 1. absent.
 2. present only under or along middle portion, often forming a distinctive "dash" of pigment.
 3. present only under or along middle and posterior portions.

(continued)

Table 65. Continued.

4. present under or along posterior two-thirds to full length of base with greater intensity and concentration at posterior end.
 5. present full length.
 6. otherwise.
34. Pigmentation under or immediately along base of anal fin [mt–ej]
1. absent.
 2. present only under or along middle portion, often forming a distinctive "dash" of pigment.
 3. present only under or along middle and posterior portion.
 4. present under or along posterior two-thirds to full length of base with greater intensity and concentration at posterior end.
 5. present full length.
 6. otherwise.
35. Pigmentation around end of notochord or urostyle (uroneural) [pr–pm]
1. absent.
 2. present but sparse—just a few melanophores.
 3. moderate but not prominent—does not stand out.
 4. present with a prominent series of melanophores along dorsal side only.
 5. present with a prominent series of melanophores along dorsal side, around end, and ventral side.
36. Dark bar of pigment on lateral surface of snout anterior to eye [mt–ej]
1. absent.
 2. present (usually as a continuation of an intense lateral band from eye to tail).
37. Lateral surface of head posterior to eyes [fm–mt]
1. unpigmented.
 2. pigmented with 1–5 melanophores.
 3. pigmented with more than 5 melanophores.
38. Pigmentation of horizontal myoseptum [pr–mt]
1. absent.
 2. sparse.
 3. moderate to strong line only along middle of body.
 4. moderate to strong line only along middle and posterior body.
 5. moderate to strong line along entire body (except sometimes immediately behind head).
 6. moderate to strong narrow band along entire body (except sometimes immediately behind head; precursor of a broader lateral band).
 7. mostly or entirely obscured by or incorporated in a moderate to wide lateral band.
39. Line or narrow band of internal to near-surface pigment over dorsal and dorsolateral surfaces of posterior gut and air bladder (if present), as visible from lateral view [pr–pm]
1. absent, obscure, or indistinct (can't tell), except possibly over air bladder (if present).
 2. does not extend anteriorly to head.
 3. continues anteriorly to head but not beyond.
 4. continues anteriorly in head to or towards anterior margin of auditory vesicle behind eye and has obvious horizontal-y-forming branch extending down behind base of pectoral fin or bud then forward to throat region.

(continued)

Table 65. Continued.

5. continues anteriorly in head beyond anterior margin of auditory vesicle towards eye and has obvious horizontal-y-forming branch.
6. continues anteriorly in head to or towards anterior margin of auditory vesicle behind eye but without obvious horizontal-y-forming branch.
7. continues anteriorly in head beyond anterior margin of auditory vesicle towards eye but without obvious horizontal-y-forming branch.
40. Internal to near-surface pigmentation over dorsal to dorsolateral surfaces of gut or visceral cavity under air bladder as visible from lateral view [fm–pm]
 1. absent.
 2. sparse, up to several melanophores.
 3. moderate in coverage or intensity.
 4. continuous and dark.
41. Lateral surface of body above horizontal myoseptum (lateral midline) and below dorsolateral surface (exclusive of pigmentation associated with horizontal myoseptum) [fm–mt]
 1. unpigmented.
 2. pigmented with 1–5 melanophores.
 3. pigmented with more than 5 melanophores.
42. Lateral surface of body below horizontal myoseptum (or lateral midline) but anteriorly above gut and visceral cavity (exclusive of pigmentation associated with horizontal myoseptum and air bladder) [fm–mt]
 1. unpigmented.
 2. pigmented with 1–5 melanophores.
 3. pigmented with more than 5 melanophores.
43. Pigmentation on lateral surface over visceral cavity (exclusive of, but often posteriorly overlying, internal near-surface pigment on dorsal and dorsolateral surfaces of gut) [pr–pm]
 1. absent.
 2. sparsely scattered, up to 5 melanophores not forming a line.
 3. moderately scattered with no distinct line or band.
 4. scattered anteriorly to below middle of air bladder with a line or narrow band extending along lateral to dorsal aspect of posterior gut from below posterior portion of air bladder (if present), or shortly behind, to or near vent.
 5. scattered or not, but with a continuous or discontinuous line or series of melanophores extending nearly horizontally from behind pectoral fin to under posterior portion of air bladder, then extending as a line or narrow band along lateral to dorsal aspect of posterior gut to or near vent.
 6. scattered or not, but with a continuous or discontinuous line or series of melanophores under posterior air bladder, continuing a diagonal series from heart on ventral or ventrolateral surface, and extending posteriorly as a line or narrow band along lateral to dorsal aspects of gut to or near vent.
 7. absent or sparsely scattered anteriorly with a line or narrow band extending along lateral to dorsal aspects of posterior gut from below posterior portion of air bladder, or shortly behind, to or near vent.

(continued)

Table 65. Continued.

8. otherwise.
44. Basicaudal spot (distinctive pigment spot on lower hypural bones) [fm–mt]
 1. absent.
 2. faint, or light.
 3. dark and prominent.
45. Caudal spot (distinctive spot of pigment at the middle base of the caudal fin, about the size of the pupil or larger, sometimes present as the enlarged end of the lateral band, sometimes extending onto the base of the middle caudal rays) [pm–ej]
 1. absent.
 2. faint, or light.
 3. dark and prominent.
46. Distinctive, large, square melanophores on lateral surface of body [mt–ej]
 1. absent.
 2. present (coverage few to extensive).
47. Lateral band of pigment from head to tail [pm–ej]
 1. absent.
 2. faint to dark and narrow on posteriorly, absent anteriorly.
 3. faint to moderate intensity, sometimes broadening anteriorly, not continuing on lateral surface of head.
 4. dark and narrow posteriorly, becoming much broader (diffuse) and slightly lighter to faint (dusky) anteriorly.
 5. dark and consistently wide for full body length, beginning on lateral surface of head, sometimes ending posteriorly in a slightly wider or disjunct caudal spot.
48. Pigmentation on lateral surfaces of body above bottom-of-eye level and anterior to vent (exclusive of melanophores associated with horizontal myoseptum, air bladder, visceral cavity peritoneum, or gut) [ej]
 1. scattered only partially down to the horizontal myoseptum (lateral midline) or lateral band if present, leaving an unpigmented zone above all or most of the horizontal myoseptum or lateral band.
 2. scattered fully and evenly down to the horizontal myoseptum or lateral band with few if any melanophores below the myoseptum or band.
 3. scattered evenly or in mottled pattern (continuous with dorsal and dorsolateral surface pattern) down to horizontal myoseptum or lateral band and at least partially below to bottom-of-eye level.
49. Pigmentation on lateral to ventrolateral surfaces of body below bottom-of-eye level (exclusive of melanophores associated with horizontal myoseptum, air bladder, visceral cavity peritoneum, or gut) [ej]
 1. absent including caudal peduncle.
 2. absent except on caudal peduncle.
 3. present.
50. Pigmentation outlining scales (presence) [ej]
 1. absent.
 2. light (barely evident).

(continued)

Table 65. Continued.

3. moderate.
4. bold.
51. Pigmentation under chin (mid-ventral region of lower jaw) [pr–ej]
 1. absent.
 2. present with one melanophore or more but not in a midline row.
 3. present with two or more melanophores in a midline row.
52. Melanophores on ventral to ventrolateral surfaces or margins of preopercles or opercles over branchiostegal rays (below to behind posterior half of eyes) [pr–ej]
 1. absent.
 2. present, but not consisting of or including a distinct oblique row of 3 or more melanophores near or along the margin of either preopercle.
 3. consisting of or including a distinct oblique row of 3 or more melanophores near or along the margin of one or both preopercles.
53. Melanophores on ventral surface anterior to heart in branchial (gular) region (between opercles and branchiostegal membranes) [pr–ej]
 1. absent.
 2. present.
54. Melanophores on ventral surface of heart region exclusive of outer margins [pr–ej]
 1. absent.
 2. present.
55. Internal (subsurface) pigmentation outlining heart cavity [pr–ej]
 1. absent (or obscured).
 2. sparse, or light with ≤ 5 melanophores.
 3. moderate, at least laterally.
 4. bold along lateral margins only.
 5. bold along lateral and posterior margins.
56. Pigmentation on ventral surface between heart and vent [pr–ej]
 1. absent [characters 57, 58, and 59 NA].
 2. present only as scattered melanophores over all or part of surface [characters 58 and 59 NA].
 3. present only as a partial to continuous line, narrow band, or series of well-spaced melanophores along the ventral midline [characters 57 and 59 NA].
 4. present only as partial to continuous lines, narrow bands, or linear series of well-spaced melanophores laterally outlining at least the anterior visceral cavity from behind or lateral to the heart and extending posteriorly onto ventrolateral to lateral surfaces [characters 57 and 58 NA].
 5. present only as partial to continuous lines, narrow bands, or linear series of well-spaced melanophores both on the ventral midline and laterally outlining the anterior visceral cavity [character 57 NA].
 6. present as combination of scattered melanophores with a partial to continuous line, narrow band, or well-spaced linear series of melanophores on the ventral midline and/or outlining the anterior visceral cavity.
 7. otherwise.

(continued)

Table 65. Continued.

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

(continued)

Table 65. Continued.

67. Pigmentation in anal fin (melanophores are sometimes very linear along margins of fin rays and easily overlooked) [mt–ej]
1. absent.
 2. present but very light with 5 or fewer melanophores.
 3. present but more prominent with 6 or more melanophores.
68. Pigmentation in caudal fin [mt–ej]
1. present to extensive along principal fin rays with few, if any, melanophores on membranes between principal rays (but might be present on membranes between branches of rays).
 2. extensive along principal fin rays and notably present (more than just a few melanophores) to extensive only on proximal portions of membranes between at least some principal rays (often part of caudal spot on or extending onto base of rays).
 3. extensive along principal fin rays and notably present (more than just a few melanophores) to extensive on middle or (and) distal portions of membranes between some or all principal rays (might also be present on membranes between branches).
 4. extensive along principal fin rays and notably present (more than just a few melanophores) to extensive over most of membranes (proximal to distal portions) between at least some principal rays.
 5. extensive along entire middle rays, and sometimes on membranes between, but only along, and sometimes between, middle to distal portions of principal rays above and below (proximal portions of these mostly unpigmented).
69. Pigmentation in pectoral fins [mt–ej]
1. absent.
 2. present but very light with up to 5 melanophores.
 3. present but more prominent with greater than 5 melanophores.
70. Pigmentation in pelvic fins [mt–ej]
1. absent.
 2. present (but seldom with more than a few melanophores).
-

Table 66. Comparison of selected melanophore pigmentation patterns for larvae and juveniles (≤ 40 mm SL) of smaller adult cyprinids in the Middle Rio Grande Basin. (See Table 65 for key to characters and their states; character numbers are those used in the computer-interactive key. Rare character states are enclosed in parentheses. NA = not applicable.)

| Character number | <i>Cyprinella lutrensis</i> | <i>Hybognathus amarus</i> | <i>Pimephales promelas</i> | <i>Pimephales vigilax</i> |
|--|-----------------------------|---------------------------|----------------------------|---------------------------|
| Protolarvae (after pigment is well established) | | | | |
| 25. | 1 | 1-2 | 1,(2) | 1 |
| 26. | 1 | 1-2 | 1-2 | 1 |
| 27. | NA | NA,1-2 | NA,1 | NA |
| 28. | NA | NA,1-3 | NA,1,(2) | NA |
| 29. | NA | NA,(1-2),3-4 | NA,3,(4) | NA |
| 35. | 1-2 | 1 | 1-3 | 1,(2) |
| 38. | 1,3 | 1,(2-3),4-5 | (1),2,(3),4,(5) | 1-2 |
| 39. | 1-2 | 1-3,(5),6 | (1),2 | 1-2 |
| 43. | 2,6-8 | 1 | 2-3,(7) | (1),2,(3,7),8 |
| 51. | 1 | 1,(2) | 1 | 1 |
| 52. | 1 | 1,(3) | 1,(2),3 | 1 |
| 53. | 1-2 | 1 | 1 | 1 |
| 54. | 1 | 1-2 | 1,(2) | 1 |
| 55. | 1-3 | 1-2 | 1,(2-4) | 1-2,(3) |
| 56. | 2,4 | 1 | (1),2,6 | 2,6,(7) |
| 57. | NA,3-4 | NA | (NA),3-4 | (1),4 |
| 58. | NA | NA | NA,1,(4) | NA,(1-2),6 |
| 59. | NA,2 | NA | NA,2 | NA,2,4 |
| Flexion mesolarvae | | | | |
| 24. | 1 | 1-2 | 1-3 | 1-2 |
| 25. | 1 | 1-2 | 1-2,(3) | 1-2 |
| 26. | 1-2 | (1),2 | 1-2 | 1-2 |
| 27. | NA,1 | 1-2 | NA,1,(2) | NA,1 |
| 28. | NA,3 | 2-3 | NA,(2-4) | NA,1-2 |
| 29. | NA,4 | (3),4 | NA,4 | NA,3 |
| 35. | 1-2 | 1-2,(3,5) | 1-2,(3) | 1-2 |
| 37. | 1-2 | (1),2 | 2-3 | 2-3 |
| 38. | 2-4 | 2,(3),4-5 | (4),5 | 2-3,(4) |
| 39. | 1-2 | 2-3,5-6 | 2-3 | (1),2 |
| 40. | 1 | 1 | 1 | 1 |
| 41. | 1 | 1,(2) | 1,(2),3 | 1 |
| 42. | 1 | 1,(2) | 1 | 1 |
| 43. | 7 | 1-2,(3) | 2,(3,6) | (6),7-8 |
| 44. | 1 | 1,(2) | 1,(2-3) | 1-2 |
| 51. | 1-2 | 1,(2) | 1-2,(3) | 1-3 |

(continued)

Table 66. Continued.

| Character number | <i>Cyprinella lutrensis</i> | <i>Hybognathus amarus</i> | <i>Pimephales promelas</i> | <i>Pimephales vigilax</i> |
|-------------------------------|-----------------------------|---------------------------|----------------------------|---------------------------|
| 52. | 1 | 1-2,(3) | 3 | 1-2 |
| 53. | 1-2 | 1,(2) | 1-2 | 1,(2) |
| 54. | 1 | 1-2 | 1,(2) | 1,(2) |
| 55. | 2-4 | 1-2 | 2,(3),4 | (2),3 |
| 56. | 2,4 | 1-2,(3) | (4),6 | 6 |
| 57. | NA,2 | NA,2,4 | (NA),3,(4) | (2),3-4 |
| 58. | NA | NA,(6) | (NA),1 | 1,4,6 |
| 59. | NA,2-3 | NA | 2,(3) | (1),2-3,(4) |
| Postflexion mesolarvae | | | | |
| 24. | 1 | 1-3 | 1-3 | 2-3 |
| 25. | 1 | 1-2 | 1-2 | (1),2 |
| 27. | 1 | 1-2 | 1-3 | 1 |
| 28. | 3 | 2-3 | 1-3 | (1),2-4 |
| 29. | 1-3 | (3),4 | 2-4 | 3-4 |
| 35. | 1 | (1),2-3,(5) | 1-2 | 1-2 |
| 37. | 1-3 | (1),2-3 | 2-3 | 2-3 |
| 38. | 2-4 | 4-5 | 4-5 | 3-4,(5) |
| 39. | 1 | (1-2),3,6 | 1-3,6 | (1),2 |
| 40. | 1 | 1,(2) | 1 | 1 |
| 41. | 1 | 1-3 | 1-3 | 1 |
| 42. | 1 | 1 | 1-2 | 1 |
| 43. | 7 | (1),2-3 | 1-4,6 | (2-3),4-6,(8) |
| 44. | 1-3 | 1,(2) | 1-3 | (1),2 |
| 45. | 1 | 1 | 1 | 1-2 |
| 47. | 1 | 1 | 1 | 1 |
| 51. | 1-2 | 1-2 | 2-3 | (2),3 |
| 52. | 1-2 | 1-2 | 2-3 | 1-2 |
| 53. | 1-2 | 1-2 | 1-2 | 1-2 |
| 54. | 1 | 1-2 | 1-2 | 1,(2) |
| 55. | 2-3 | 1-2,(3) | 1,3-5 | (1),2-3 |
| 56. | 2,4 | 1-2,(3) | 2,6-7 | 2,4,6 |
| 57. | NA,2 | NA,2,4 | 1,3 | NA,4 |
| 58. | NA | NA,(2,6) | NA,1,6 | NA,1,6 |
| 59. | NA,2 | NA | NA,2-3 | NA,(1),2-3,(4) |
| 63. | 1 | 1,(2) | 1-3 | 1-2,(3) |
| 64. | 1 | 1,(2) | 1-2 | 1 |
| 65. | 1 | 1 | 1-2 | 1 |

(continued)

Table 66. Continued.

| Character number | <i>Cyprinella lutrensis</i> | <i>Hybognathus amarus</i> | <i>Pimephales promelas</i> | <i>Pimephales vigilax</i> |
|-------------------|-----------------------------|---------------------------|----------------------------|---------------------------|
| Metalarvae | | | | |
| 30. | 3 | 1,3 | 1,3 | 1,3 |
| 31. | 1 | 1 | 1 | 1 |
| 32. | 1,(2) | 1 | 1-2 | (1-2),3-4 |
| 33. | 1,5-6 | 5 | 1,(3),5 | 3-4 |
| 34. | 5 | 5 | 5 | 5 |
| 36. | 1 | 1 | 1 | 1 |
| 37. | (1)2-3 | (1),2-3 | 3 | 3 |
| 38. | (3),4 | 4,(5) | 4-5 | 4-5 |
| 41. | 1 | 1-3 | 1,(2),3 | 1-3 |
| 42. | 1 | 1 | 1-3 | 1,3 |
| 44. | 1-2,(3) | 1,(2) | 1-2 | 2-3 |
| 45. | 1 | 1 | 1 | 1,(2) |
| 46. | 1 | 1 | 1 | 1 |
| 47. | 1 | 1 | 1 | 1,(3) |
| 51. | 1-3 | 1-2 | 1-3 | (2),3 |
| 52. | 1,(2) | 1-2 | (1-2),3 | 1-2,(3) |
| 53. | 1-2 | 1-2 | 1-2 | 1-2 |
| 54. | 1 | 1,(2) | 1-2 | 1-2 |
| 55. | 1-3 | 1,(3) | 1,(2),3 | 1-3 |
| 56. | (1),4,(6-7) | 1-2,(3) | 1-2,6 | 2,6 |
| 57. | NA,(1-2) | NA,2,(4) | NA,(2),3-4 | (2),4 |
| 58. | NA,1 | NA,(2) | NA,1 | NA,1,4,(6) |
| 66. | 1 | 1,(3) | 1 | 1,3 |
| 67. | 1-2,(3) | 1,(2) | 1-3 | 1-3 |
| 68. | 1 | 1 | 1 | 1 |
| 69. | 1,(3) | 1,(2) | 1,(2),3 | 1-2 |
| 70. | 1 | 1 | 1,(2) | 1 |
| Juveniles | | | | |
| 30. | 1,3 | 1,(3) | 1 | 1,3 |
| 31. | 1 | 1 | 1 | 1 |
| 32. | 1-2 | 1 | (1),2-3 | (2),3-4 |
| 33. | 5,(6) | 5 | 3-5 | (3),4,(5) |
| 34. | (1),5 | 1,5 | 1,3,5,(6) | 4-5 |
| 36. | 1 | 1 | 1 | 1 |
| 45. | 1 | 1 | 1-2,(3) | 1-3 |
| 46. | 1 | 1 | 1 | 1,(2) |
| 47. | 1-2 | 1-2,(3) | 1,(2),3,5 | (2),3 |
| 48. | 1,(2),3 | (1),2-3 | 1,(2),3 | 1,(2),3 |

(continued)

Table 66. Continued.

| Character number | <i>Cyprinella lutrensis</i> | <i>Hybognathus amarus</i> | <i>Pimephales promelas</i> | <i>Pimephales vigilax</i> |
|------------------|-----------------------------|---------------------------|----------------------------|---------------------------|
| 49. | 1,3 | 1,(2),(3) | 1,(2),3 | 1,3 |
| 50. | 1,(2),3-4 | 1-3 | 1-3,(4) | 1-3,(4) |
| 51. | 1-3 | 1,(2-3) | 1-3 | (1),2-3 |
| 52. | 1 | 1,(2) | 1-2,(3) | 1-2 |
| 53. | 1,(2) | 1,(2) | 1-2 | 1-2 |
| 54. | 1 | 1,(2) | 1,(2) | 1,(2) |
| 55. | 1 | 1 | 1,(2-3,5) | 1,(2) |
| 56. | 1,(2,7) | 1,(2) | 1-2 | 1-2,(6),7 |
| 57. | NA,(1,4) | NA,(2) | NA,3,(4) | NA,4 |
| 58. | NA,(6) | NA | NA | NA,(1,2,6) |
| 66. | 1,(2) | 1,(3) | 1 | 1,(2),3 |
| 67. | 1-2,(3) | 1,(2) | 1,(2),3 | 1-3 |
| 68. | 1 | 1,(2) | 1 | 1-2 |
| 69. | 1,(2),3 | 1,(2),3 | (1-2),3 | 1-3 |
| 70. | 1,(2) | 1,(2) | 1-2 | 1,(2) |

Table 67. Comparison of selected melanophore pigmentation patterns for larvae and juveniles (≤ 40 mm SL) of catostomids in the Middle Rio Grande Basin. (Key to characters and their states is given below. Rare or questionable data are enclosed in parentheses. NA = not applicable. U = unknown—not reported or illustrated, or if only illustrated, those states appended, but others still possible.)

| Character number | <i>Catostomus commersonii</i> | <i>Catostomus plebeius</i> | <i>Carpionodes carpio</i> | <i>Ictiobus bubalus</i> |
|--|-------------------------------|----------------------------|---------------------------|-------------------------|
| Protolarvae (after pigment is well established) | | | | |
| 22. | 1–2 | (1),2 | 1–2 | (1),2 |
| 23. | 1 | 1–3 | NA,1 | NA,1 |
| 24. | 2–3 | 1 | NA,U | NA,1,(2–3) |
| 25. | 2–3 | 1 | NA,(1–2),3 | NA,(1–2),3 |
| 38. | 1 | 1 | U | U |
| 39. | 1–2,(3) | 1–2 | U | 1–2,(3) |
| 40. | 1–2 | 1 | 1–2 | 1–2 |
| 41. | 4–5 | 1–4,(5 ^a) | (2),3–5 | (2),3–5 |
| 54. | 1 | 1–2 | U | U |
| Flexion Mesolarvae | | | | |
| 21. | (1–2),3 | 1,(2) | 2–3 | 2–3 |
| 22. | 2 | 2 | 2 | 2 |
| 23. | 1 | (1),2–3 | 1 | 1 |
| 24. | 1–3 | 1,(2) | U | 1–3 |
| 25. | 1–3 | 1 | (2),3 | (1–2),3 |
| 26. | NA,1–2 | NA | 1 | NA,U,1 |
| 31. | 2–3 | 1–3 | 2–3 | (1),2–3 |
| 32. | 1–2 | 1–3 | U,1–2 | (1),2–3 |
| 33. | 1–2 | 1–3 | U,1–2 | U,1 |
| 38. | 1–2 | 1–2 | U | U |
| 39. | 1–3 | 1–3 | (1),2–3 | 1–3 |
| 40. | 2 | 1–2 | 2 | 2 |
| 41. | 4–5 | 1–4,(5) | 2–4 | 3–5 |
| 54. | 1–2 | 1–2 | U | U |
| 55. | U,2 | U,2 | U,2–3 | 1–4 |
| Postflexion Mesolarvae | | | | |
| 21. | 3 | (1),2–3 | (2),3 | (1–2),3 |
| 23. | 1–3 | (1),2–3 | 1–2 | 1–2,(3) |
| 24. | (1),2,(3) | 1,(2) | U | 2–3 |
| 25. | 1,(2–3) | 1 | 3 | 2–3 |
| 26. | NA,(1–2) | NA | 1 | U,1 |
| 27. | 2 | 1–2 | U,1 | U,1 |
| 31. | (2),3 | 1–3 | (1),2–3 | 2–3 |

(continued)

Table 67. Continued.

| Character number | <i>Catostomus commersonii</i> | <i>Catostomus plebeius</i> | <i>Carpiodes carpio</i> | <i>Ictiobus bubalus</i> |
|-------------------|-------------------------------|----------------------------|-------------------------|-------------------------|
| 32. | (1),2-3 | (2),3 | 1-3 | 2-3 |
| 33. | 1-3 | 1-3 | U,1-2 | 1-3 |
| 38. | (1),2 | 1-2 | U | U |
| 39. | (1),2-3 | 1-3 | 1-3 | 2-3 |
| 40. | 2 | 1-2 | (1),2 | 2 |
| 41. | (4),5 | 1-4,(5) | 2-4 | (1),2-5 |
| 45. | 2 | 1-2 | 1-2 | 1-2 |
| 46. | 1-2 | 1 | U,1 | 1-2 |
| 47. | (1),2 | 1-2 | 1 | 1-2 |
| 53. | 1 | 1-2 | 1 | 1,(2) |
| 54. | 2 | (1),2 | U | U |
| 55. | U,1 | 2-4 | U,1 | 1-4 |
| Metalarvae | | | | |
| 28. | 1 | 1-2 | 1 | 1 |
| 29. | 1 | (1),2 | U | U |
| 30. | 2 | 1-2 | U | U |
| 31. | 3 | 3 | 3 | 3 |
| 32. | 3 | 3 | 3 | 3 |
| 33. | (1-2),3 | 3 | 2-3 | 1-3 |
| 34. | 1,(4) | 1 | 1 | 1 |
| 38. | (1),2 | (1),2 | U | U |
| 39. | 1-3 | 1-3 | U,1 | U,1 |
| 40. | 2 | 1-2 | U,2 | U,1 |
| 41. | 4-5 | 1-4,(5) | U,1 | 1,(2-5) |
| 48. | 1,(2) | 1 | 1-2 | 1 |
| 49. | 1-2,(3) | (1),2-3 | (2),3 | 3 |
| 50. | 1 | 1,(3) | 1,(2) | 1 |
| 51. | 1-2,(3) | 1-3 | 1 | 3 |
| 52. | 1,(2) | 1,(2) | 1 | U |
| 53. | 1 | 1-2 | 1 | 1,(2) |
| 54. | (1),2 | (1),2 | U | U |
| Juveniles | | | | |
| 28. | 1-2 | 1-2 | U,2 | 1 |
| 29. | 1,(2) | 2 | U | U |
| 30. | 2 | 1-2 | U,1 | U |
| 34. | 1,(2),4 | 1-2 | 1 | 1 |
| 35. | (2),3 | 3 | U,3 | 3 |
| 36. | 1-2,(3) | 1-3 | U,3 | U,3 |

(continued)

Table 67. Continued.

| Character number | <i>Catostomus commersonii</i> | <i>Catostomus plebeius</i> | <i>Carpionodes carpio</i> | <i>Ictiobus bubalus</i> |
|------------------|-------------------------------|----------------------------|---------------------------|-------------------------|
| 37. | 1–2 | 1–2 | U,1 | U,1 |
| 38. | 1–2 | 1–2 | U | U |
| 39. | 1–2,(3) | 1–2,(3 ^b) | U,1 | U |
| 40. | 1–2 | 1–2 | U | U,1 |
| 41. | (1–2),3–5 | 1–3,(4–5 ^{a,b}) | U,1 | U,1 |
| 48. | 1–2 | 1 | 1–2 | U,2 |
| 49. | 1–2,(3) | (1–2),3 | 2–3 | U,3 |
| 50. | 1,(2) | 1,3 | 1–2 | U,2 |
| 51. | 1–2,(3) | 3 | 1–2 | U,3 |
| 52. | 1,(2) | 1,(2 ^b) | 1 | U,1 |
| 53. | 1 | (1),2 | 1 | 1 |
| 54. | 1–2 | 1,(2) | U | U |

^a Based on presence in some flexion and postflexion mesolarvae.

^b Based on presence in some metalarvae.

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

21. Snout [fm–pm]
 1. unpigmented.
 2. pigmented with 1–5 melanophores.
 3. pigmented with 6 or more melanophores.
22. Dorsal surface of head [pr–fm]
 1. unpigmented or pigmented only over hindbrain (posterior to middle of eyes).
 2. pigmented over both mid- and hindbrain (anterior and posterior to middle of eyes).
23. Pigmentation on dorsal surface of body between head and last myomere (for specimens with >12 melanophores on dorsal surface) [pr–pm]
 1. not scattered or sparsely scattered with at least a partial distinct lengthwise line or narrow band of melanophores (sometimes in oblique pairs or clusters) on or lateral to dorsal midline.
 2. densely scattered over all or most of back with at least a partial distinct lengthwise line or narrow band of melanophores (sometimes in oblique pairs or clusters) on or lateral to dorsal midline.
 3. densely scattered over all or most of back with no distinct lengthwise lines or narrow bands of melanophores.
24. Dorsal midline from shortly behind head to near last myomeres [pr–pm]
 1. with ≤24 melanophores in a short, discontinuous, or well-spaced line, or (rarely) with no distinct line of melanophores.

(continued)

Table 67. Continued.

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.
25. Pigmentation on dorsal surfaces lateral to midline from shortly behind head to about 2/3 distance to last myomeres [pr–pm]
 1. absent, sparsely scattered, or densely scattered over back with no distinct lengthwise lines or narrow bands of melanophores along either side of dorsal midline [character 26 NA].
 2. scattered or not with a distinct short or discontinuous (well separated segments) line or narrow band of melanophores (sometimes in oblique pairs or clusters) along one or both sides of dorsal midline.
 3. scattered or not with a distinct continuous or nearly continuous, full-length line or narrow band of melanophores (sometimes in oblique pairs or clusters) along each side of dorsal midline.
26. Melanophores in lines lateral (and parallel) to dorsal midline between head and 2/3 distance to last myomeres mostly [fm–pm; NA if character 25 is state 1]
 1. in single file.
 2. in obliquely oriented pairs or clusters resulting in a herringbone pattern down the back.
27. Dorsal surface of end of urostyle (uroneural) [pm]
 1. with few to no melanophores (pigmentation not distinctly greater than elsewhere in vicinity).
 2. with a prominent series of melanophores.
28. Pigmentation on dorsal surface of body between head and last myomere [mt–ej]
 1. scattered more or less evenly (with or without emphasis on distinct lines of melanophores 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).
29. Distinct spot or aggregation of pigment at origin of dorsal fin [mt–ej]
 1. absent or obscure.
 2. prominent.
30. Pigment on or between pterygiophores of dorsal fin [mt–ej]
 1. absent or not obvious (essentially white).
 2. obvious (light to strong).
31. Lateral surface of head posterior to eyes [fm–mt]
 1. unpigmented.
 2. with 1–5 melanophores.
 3. pigmented with ≥ 6 melanophores.
32. Lateral surface of body above horizontal myoseptum (lateral midline) and below dorso-lateral surface (exclusive of pigmentation associated with horizontal myoseptum, air bladder, or visceral-cavity peritoneum) [fm–mt]
 1. unpigmented.
 2. with 1–5 melanophores.
 3. with ≥ 6 melanophores.

(continued)

Table 67. Continued.

33. Lateral surface of body below horizontal myoseptum (or lateral midline, exclusive of pigmentation associated with horizontal myoseptum, air bladder, gut, or visceral-cavity peritoneum) [fm–mt]
 1. unpigmented.
 2. with 1–5 melanophores.
 3. with ≥ 6 melanophores.
34. Mid-lateral surface of body (pigmentation, large spots) [mt–ej]
 1. with no distinct, near-eye-size spots of pigment.
 2. with 1 distinct, near-eye-size spot of pigment on caudal peduncle near base of caudal fin.
 3. with 2 distinct, near-eye-size spots of pigment, one between head and dorsal fin and the other between pelvic and anal fins (sometimes with very faint or indistinct third near-eye-size spot near base of tail).
 4. with 3 distinct, near-eye-size spots of pigment, one between head and dorsal fin, the second between pelvic and anal fins, and the third on the caudal peduncle near the base of the tail.
 5. with 1 or more distinct, near-eye-size spots of pigment, but otherwise.
35. Pigmentation on lateral surfaces of body above bottom-of-eye level and anterior to vent (exclusive of melanophores associated with horizontal myoseptum, air bladder, visceral-cavity peritoneum, or gut) [ej]
 1. scattered only partially down to the horizontal myoseptum (lateral midline).
 2. scattered fully and evenly down to the horizontal myoseptum with few if any melanophores below the myoseptum.
 3. scattered evenly or in mottled pattern (continuous with dorsal and dorso-lateral surface pattern) down to horizontal myoseptum and at least partially to bottom-of-eye level below.
36. Pigmentation on lateral to ventro-lateral surfaces of body below bottom-of-eye level (exclusive of melanophores associated with horizontal myoseptum, air bladder, visceral cavity peritoneum, or gut) [ej]
 1. absent including caudal peduncle.
 2. absent except on caudal peduncle.
 3. present.
37. Pigmentation outlining scales [ej]
 1. absent or light.
 2. bold.
38. Melanophores under chin (anterior ventral surface of lower jaw) [pr–ej]
 1. absent.
 2. present.
39. Melanophores over ventral to ventro-lateral surfaces of preopercles and opercles (gill covers) [pr–ej]
 1. absent.
 2. present but not consisting of or including a distinct oblique row of 3 or more melanophores near or along margin of either preopercle.

(continued)

Table 67. Continued.

3. consisting of or including a distinct oblique row of 3 or more melanophores near or along margin of one or both preopercles.
40. Melanophores on ventral surface of heart region [pr–ej]
 1. absent.
 2. present.
41. Ventral midline from shortly behind heart region to near vent [pr–ej]
 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 so, full-length line or narrow band.
45. Pigmentation in developing dorsal fin [pm]
 1. absent or sparse with few 5 or fewer melanophores.
 2. at least moderate with 6 or more melanophores.
46. Pigmentation in developing anal fin [pm]
 1. absent.
 2. present.
47. Pigmentation in developing pectoral fins [pm]
 1. absent.
 2. present.
48. Pigment in dorsal fin [mt–ej]
 1. present to extensive along principal fin rays with few, if any, melanophores on membranes between principal rays (but might be present on membranes between branches of rays).
 2. extensive along principal fin rays and notably present (more than just a few melanophores) to extensive on at least a portion of membranes between some or all principal fin rays (might also be present on membranes between branches of rays).
49. Pigment in anal fin [mt–ej]
 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).
50. Pigment in caudal fin [mt–ej]
 1. present to extensive along principal fin rays with few, if any, melanophores on membranes between principal rays (but might be present on membranes between branches of rays).
 2. extensive along principal fin rays and notably present (more than just a few melanophores) to extensive on most or at least the middle or distal portion of membranes between some or all principal fin rays (might also be present on membranes between branches of rays).
 3. extensive along principal fin rays and notably present (more than just a few melanophores) to extensive only on proximal portions of membranes between at least some principal fin rays.
51. Pigment in pectoral fin [mt–ej]
 1. absent.

(continued)

Table 67. Continued.

2. present but very light with only a few (≤ 5) melanophores.
 3. present but more prominent with many (≥ 6) melanophores.
 52. Pigmentation in pelvic fins [mt–ej]
 1. absent.
 2. present (but seldom with more than a few melanophores).
 53. Pigment along and in horizontal myoseptum [pm–ej]
 1. not notably more intense than other lateral pigmentation.
 2. notably more intense than other lateral pigmentation.
 54. Melanophores on ventral surface anterior to heart in branchial (gular) region (between opercles or branchiostegal membranes) [all]
 1. absent.
 2. present.
 55. Pigmentation over dorsal surface of gut under air bladder as apparent from lateral view [fm–pm]
 1. absent.
 2. present covering less than a quarter of the distance.
 3. present covering a quarter to three-quarters of distance.
 4. present covering greater than three-quarters of distance.
-

Computer-Interactive Keys

Computer-interactive keys to the eggs, larvae, and early juveniles of MRG cyprinids and catostomids covered herein (Snyder and Seal 2019 and Snyder 2019) can be downloaded from the Internet as instructed below or accessed from the USB memory stick or card provided in a pocket on the inside rear cover of the print publication version of this guide. Likewise for a similar key to all families of fish in the basin, except Loricariidae (Snyder and Seal 2008 onwards; also covers families for most other freshwater and anadromous fishes in the United States and Canada). These keys consist of data sets with associated image, text, and controlling files for use with the DELTA program, *Intkey* (Dallwitz et al. 1993 onwards, 1995 onwards). The current version of the host program, *Intkey5* (also downloadable from the Internet or provided on the USB stick) runs under Microsoft *Windows 95* and later *Windows* operating systems. A color display with at least 800 x 600 pixel resolution (SVGA) is recommended (higher resolutions are preferred), but 640 x 480 pixel resolution (VGA) will work (less text is displayed without scrolling).

Intkey has been one of the longer-standing, more highly evolved, and more widely used programs for interactive keys on personal computers (Dallwitz 1993). Many other interactive-key programs are available (e.g., *IdentifyIt*, *LucID*, *MEKA*, *Navkey*, *ONLINE*, *PollyClave*, and *XID*—Dallwitz 1996 onwards), and some may have worked as well for these keys. However, we successfully used *Intkey* for earlier keys to larvae of the UCRB and Gila River Basin (Snyder 2003 onwards for Snyder and Muth 2004, and Snyder and Seal 2004a and 2004b onwards for Snyder et al. 2005), and data for some species covered herein were already incorporated in the *DELTA Editor* databases for those keys. Accordingly, it was decided to build on that experience and those databases and continue to use *Intkey* as the host program for the keys associated with this guide, as well as those for concurrently developed guides to cyprinid larvae of the UCRB (Snyder and Seal 2015 onwards for Snyder et al. 2016) and the middle and lower Pecos River (Brandenburg et al. 2018b for Brandenburg et al. 2018a). Also, on the condition that it is not used or distributed for financial gain, *Intkey* is available free over the Internet—an important consideration for potential users of this keys. In addition to its function as an interactive key, *Intkey* has a vast array of other options for information retrieval, including output of full or partial "natural-language" descriptions of, or differential comparisons among selected taxon-items. Once installed, use of *Intkey* is not limited to the data sets associated with this guide or referenced above. It can be used also with data sets for published keys to a wide array of other taxa (e.g., salamanders, crustaceans, beetles, butterflies, polychaetes, flowering plants, grasses, viruses) as listed at <https://www.delta-intkey.com/> under "Data" or "References."

Installation

If the USB memory stick or card included with a print version of this guide is available (hereafter referenced only as the USB stick), the keys can be used directly from the "Delta" directory (folder) thereon. Alternatively, they can be installed on your computer's hard-drive using the compressed *Intkey* program (Intk32.exe, a self-extracting file), an optional but recommended test update of the *Intkey* program and two associated files (intkey.zip, to be used after original program installation), and the data set distribution files (Cyp-mrg.zip, Cat-mrg.zip, and Fam-na.zip) on the USB stick. Installation of *Intkey* on your hard drive is recommended if (or when) you anticipate downloading and using future updates of these data sets or data sets for

other taxa (such as those referenced above). The "Delta" directory on the USB stick can be copied to and used from your computer's hard drive (or other computer-memory device), and additional key data sets can be added as Delta subdirectories, 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.

To install *Intkey* on your computer, double click on "Intk32.exe" from the USB stick and follow on-screen instructions. Installation in a directory (folder) named "Delta" under either the computer's root directory or "Program Files" is recommended. In addition to the program and an array of bitmap and other files used by *Intkey*, the distribution file also includes and installs a "doc" subdirectory for the user's guide (intkey.doc, a Microsoft *Word* document, but readable by most other word processors) and separate text files regarding installation (install.txt), conditions of use (use.txt), and registration (register.txt—*Intkey* can be used without registration, but remains subject to other conditions of use). The full set of program and related files will require about 2.4 Mb of storage memory (plus ~1.7 Mb for an included sample data set). After this initial installation, the recommended program update files can be extracted from "intkey.zip" (double click or right click and select "Extract All") to your Delta directory, overwriting three originally installed files.

Once *Intkey* is installed, extract the key data sets from the distribution files "Cyp-mrg.zip," "Cat-mrg.zip," and "Fam-na.zip" to your "Delta" directory. They expand respectively as subdirectories "Cyp-mrg," "Cat-mrg," and "Fam-na," each including five files and two further subdirectories containing "images" and rich-text files (RTF) used by or accessible via the *Intkey* program (also a "readme" file with instructions similar to these). The three data sets and associated files require about 4.5 Mb of storage memory.

In the absence of the USB stick, the updated *Intkey* program and associated files can be downloaded from the Internet at <<https://www.delta-intkey.com/>> (select "Installing and running the programs" and follow instructions therein). Likewise, the data sets for use with *Intkey* can be downloaded at <<https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/>> (under "Pecos River and Rio Grande basins," select "Key to the Cyprinids—Middle Rio Grande" and "Key to the Catostomids—Middle Rio Grande," and under "North America," select "Key to the Families"). Install the compressed files, as instructed above.

Future updates of the data sets for this guide will likely be available only over the Internet. Users should periodically check the LFL website download page for subsequently updated copies of the data sets in compressed folders (zip-files), as indicated by a "r" appended to the file name or a later file date or revision number.

Use

As noted above, the *User's Guide to Intkey* (Dallwitz et al. 1995 onwards) is included as "intkey.doc" in the folder "delta/doc" on the USB stick included with printed versions of this guide, as well as in the *Intkey* distribution package on the Internet. A more recent PDF version of the user's guide (intkey-ug.pdf) is also included on the USB stick for your reference or available online at <https://www.delta-intkey.com/> under "Documentation." 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 a key directly from the USB stick (or a copy on your hard drive), open the "Delta" directory and double click on "intkey5.exe." *Intkey* should open with

the data-set names listed in an index window (startup dialog box); just select the key of interest and click on "OK" to open the data set. If not listed, click on "Browse" and in the appropriate Delta subdirectory (Cyp-mrg, Cat-mrg, or Fam-na) click on and open the corresponding startup file (intkey-cyp-mrg.ink, intkey-cat-mrg.ink, or intkey-fam.ink).

To run *Intkey* after it is installed on your computer's hard drive, press the *Windows* "Start" button, then select "Programs," "Delta," and "Intkey" (for convenience, a startup icon can be placed on your *Windows* desktop). The startup index window will be displayed. If the desired data-set name is listed, select it and click on "OK" to open the data set. If the data-set name is not yet listed in the index window (as upon first use after installation), browse for the appropriate subdirectory (e.g., Cyp-mrg) and select and open the corresponding startup file (e.g., Intkey-cyp-mrg.ink); upon closing the data set or program, you will be given an opportunity to add the data set to the startup index (you can later modify the descriptive name for the data set, or make other changes to the startup index, from within the *Intkey* program by selecting "advanced mode" in the file menu and then selecting "edit index").

Upon opening a data set, a startup image with the name of the key and author(s) 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 overlaid initially with introductory and instructional text windows. After reading their contents, close or minimize the text windows (if closed, they can be redisplayed by selecting the desired text file from the "information" index—click on the book icon in the top left corner of the screen beneath "File"). Upon closing the text files, the standard screen will be revealed with its main menu, character and taxon-item toolbars, and four integral windows (available or best-remaining characters in upper left, used characters in lower left, remaining taxon items in upper right, and eliminated or non-matching taxon items in lower right). The relative size of the four windows can be changed at any time by moving the dividers between them.

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

Before beginning identification, limit taxon possibilities (candidate species in the cyprinid or catostomid key, or families in the family key) by selecting a pertinent predefined subset of taxa, only the species (or families) likely to be present in the waters sampled, or just those remaining if you've already eliminated some possibilities. 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. For example, in the family key, select "Families in the Middle Rio Grande" for all families therein. Taxa to be considered in the keys can be changed at any time with results to that point updated accordingly.

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 morphometric characters if the user is unable to make such measurements). To select or deselect subsets of characters, click on the "use subset of characters" button (yellow oval icon, second from right in the "Best Characters" or "Available Characters" toolbar, upper left window). Proceed with identification as per basic instructions (click on the "help" (\?), then "restart" buttons).

Except in a couple circumstances, all characters in these keys (except number of vertebrae) are based on external or externally visible morphology and pigmentation and can be assessed without dissection or destructive treatment. For the cyprinid and catostomid keys, character states were extracted from the descriptive species accounts and comparative summary tables of this guide. When likely to be observed, myomere count ranges for some developmental phases were extended, for purposes of the key, to those of adjacent phases. Pigmentation characters used in these keys (and referenced in comparative summary tables) refer only to the black or brown pigment of melanophores (melanin-bearing cells). The pigment of most other chromatophores is difficult to preserve and has not been assessed. However, in living, freshly euthanized, and alcohol-preserved metalarvae and juveniles (not first fixed in formalin), melanophore pigmentation of the peritoneum (membrane lining the visceral cavity), as well as the degree of gut coiling, is often obscured by a layer of silvery iridophores. Similarly, in later juveniles, these characters may be obscured by muscle or thicker skin and scales, regardless of preservative. 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 cyprinid and catostomid keys are generally limited to specimens 40 mm or less in SL. However, some larger early (young-of-the-year) juveniles can be successfully identified with these keys by treating them as 40-mm-SL juveniles. Meristic characters such as fin-ray and scale counts in these keys are also applicable to all later juveniles and adults but may not be sufficient for definitive identification of these larger fish. The family key covers only the larval period.

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

Taxonomic keys are tools for specimen identification, but the responsibility for accurate determinations remains with the user. Computer-interactive keys are simply easier-to-use and much more flexible tools than traditional printed keys, but as such they should facilitate more accurate identifications by the user. In the case of the cyprinid catostomid keys, even with their extensive character sets, the identity of closely related fish larvae of similar developmental state and size cannot always be resolved to a single species; and even when it is, the results may not necessarily be conclusive because true character ranges may extend beyond those observed for descriptions herein, and because of possible errors by the author or user. As noted earlier in this guide, the possibility of hybrids among candidate taxa can further confound or reduce confidence in the resulting identification. Upon resolution of identity to a single taxon or if no matches are found, *Intkey* provides a help file with suggestions for confirming identity or allowing for some mismatches (increasing error tolerance—click on “~” icon on right side of “Best Characters” toolbar) and continuing with the key. By allowing for a couple mismatches, even when identity is resolved to a single species, the user can base his or her identification on more characters and be more confident of the results. To further confirm the identity suggested by the key, users should also critically compare the specimen in question with descriptive information and

illustrations in the species accounts and comparative summary tables in this guide (or for the family key, the pictorial guide to families, Appendix IV) and, if available, with preserved reference specimens. As noted earlier, identities that cannot be resolved with reasonable certainty should be either treated tentatively as the most likely species with a question mark following the determination (and perhaps with an explanatory footnote) or identified conservatively only to genus or family (e.g., *Pimephales* sp. or unidentified Cyprinidae).

Please report any problems, discrepancies, errors, or observed character-range extensions for future updates of these computer-interactive-key data sets directly to: Darrel E. Snyder, Larval Fish Laboratory, Colorado State University, 1474 Campus Delivery, Fort Collins, Colorado 80523-1474 (Phone: 970-491-5295, Fax: 970-491-5091, E-mail: Darrel.Snyder@ColoState.edu).

If these keys are to be referenced separately from their inclusion in this guide, the suggested citations using the American Fisheries Society Publication Style Guide (American Fisheries Society 2013) are (and replacing the date in parentheses at the end of each citation with the date you personally last accessed the site and verified presence of the file):

Snyder, D. E., S. C. Seal, and W. H. Brandenburg. 2019 onwards. Computer-interactive key to eggs, larvae, and early juveniles of cyprinid fishes in the Middle Rio Grande, New Mexico (data set for use with DELTA *Intkey*). Larval Fish Laboratory, Colorado State University, Fort Collins, and American Southwest Ichthyological Researchers, L.L.C., Albuquerque, New Mexico. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (to be posted in November 2019).

Snyder, D. E. 2019 onwards. Computer-interactive key to eggs, larvae, and early juveniles of catostomid fishes in the Middle Rio Grande, New Mexico (data set for use with DELTA *Intkey*). Larval Fish Laboratory, Colorado State University, Fort Collins. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (to be posted in November 2019).

Snyder, D. E., and S. C. Seal. 2008 onwards. Computer-interactive key to families of larval fishes in freshwaters of the United States and Canada (data set for use with DELTA *Intkey*). Larval Fish Laboratory, Colorado State University, Fort Collins. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (November 2018).

CONCLUSIONS AND RECOMMENDATIONS

Building on information, species accounts, and keys already assembled for Snyder (1981), Snyder and Muth (1990, 2004), and Snyder et al. (2005), and other information and illustrations from the literature, this project, begun in late 2008, has resulted in a comprehensive guide to the cypriniform larvae and early juveniles of the MRG (and for shared species, helped complete a similar guide to cyprinids of the UCRB—Snyder et al. 2016). Pending finalization of this updated report and a proposal with cost estimates for formal print and digital publication, we recommend formal publication of this guide, possibly along with a companion guide that was concurrently prepared for cyprinid larvae of the middle and lower Pecos River (Brandenburg et al. 2018a).

LITERATURE CITED

- Ahlstrom, E. H., J. L. Butler, and B. Y. Sumida. 1976. Pelagic stromateoid fishes (Pisces, Perciformes) of the eastern Pacific: kinds, distributions, and early life histories and observations on five of these from the northwest Atlantic. *Bulletin of Marine Science* 26:285–402.
- American Fisheries Society. 2013. A guide to AFS publications style. American Fisheries Society, Bethesda, Maryland.
- Andrews, A. K. 1970. Squamation chronology of the Fathead Minnow, *Pimephales promelas*. *Transactions of the American Fisheries Society* 99:429–432.
- Andrews, A. K., and S. A. Flickinger. 1974. Spawning requirements and characteristics of the Fathead Minnow. *Proceedings of the Annual Conference of Southeastern Association of Game and Fish Commissioners* 27(1973):759–766.
- Arvidson, L. G., and J. B. Alber. 2013. A handbook to help identify Hudson River fish larvae. Larry G. Arvidson, publisher, Rosendale, NY. Available: <http://www.amazon.com/Handbook-Identify-Hudson-River-Larvae/dp/1492260398> (November 2018).
- Auer, N. A., editor. 1982. Identification of larval fishes of the Great Lakes Basin with emphasis on the Lake Michigan Drainage. Great Lakes Fishery Commission, Special Publication 82-3, Ann Arbor, Michigan.
- Balon, E. K. 1958. Development of the Danube Wild Carp (*Cyprinus carpio carpio* L.) in time of prelarval phase and the larval period. *Biologicke Prace* 4:5–54.
- Balon, E. K. 1975a. Reproductive guilds of fishes: a proposal and definition. *Journal of the Fisheries Research Board of Canada* 32:821–864.
- Balon, E. K. 1975b. Terminology of intervals in fish development. *Journal of the Fisheries Research Board of Canada* 32:1663–1670.
- Balon, E. K. 1981. Additions and amendments to the classification of reproductive styles in fishes. *Environmental Biology of Fishes* 6:377–389.
- Balon, E. K. 1984. Reflections on some decisive events in the early life of fishes. *Transactions of the American Fisheries Society* 113:178–185.
- Bartnik, V. G. 1970. Reproductive isolation between two sympatric dace, *Rhinichthys atratulus* and *R. cataractae*, in Manitoba. *Journal of the Fisheries Research Board of Canada* 27:2125–2141.
- Battle, H. I. 1940. The embryology and larval development of the Goldfish (*Carassius auratus* L.) from Lake Erie. *Ohio Journal of Science* 40(2):82–93.
- Baxter, G. T., and J. R. Simon. 1970. Wyoming fishes. Wyoming Game and Fish Department, Bulletin 4 (revised), Cheyenne.
- Baxter, G. T., and M. D. Stone. 1995. Fishes of Wyoming. Wyoming Game and Fish Department, Cheyenne.
- Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison.
- Beckman, W. C. 1952. Guide to the fishes of Colorado. University of Colorado Museum Leaflet 11, Boulder.
- Behnke, R. J. 1988. Phylogeny and classification of cutthroat trout. Pages 1–7 in R. E. Gresswell, editor. Status and management of interior stocks of cutthroat trout. American Fisheries Society, Symposium 4, Bethesda, Maryland.
- Behnke, R. J. 1992. Native trout of western North America. American Fisheries Society, Monograph 6, Bethesda, Maryland.

- Berry, F. H., and W. J. Richards. 1973. Characters useful to the study of larval fishes. Pages 48–65 in A. L. Pacheco, editor. Proceedings of a workshop on egg, larval, and juvenile stages of fish in Atlantic coast estuaries. U.S. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Middle Atlantic Coastal Fisheries Center, Technical Publication 1, Highlands, New Jersey.
- Bestgen, K. R., R. I. Compton, and K. A. Zelasko. 2003. Distribution and status of Rio Grande Chub in Colorado. Final Report of the Colorado State University Larval Fish Laboratory to the Colorado Division of Wildlife, Fort Collins. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/contribution-series/#135>; November 2018).
- Bestgen, K. R., H. J. Crockett, M. R. Haworth, and R. M. Fitzpatrick. 2016. Production of non-adhesive eggs by flathead chub and implications for downstream transport and conservation. *Journal of Fish and Wildlife Management* 7:434–443.
- Bestgen, K. R., and S. P. Platania. 1990. Extirpation and notes on the life history of *Notropis simus simus* and *Notropis orca* (Cypriniformes: Cyprinidae) from the Rio Grande, New Mexico. *Occasional Papers of the Museum of Southwestern Biology* 6:1–8.
- Bestgen, K. R., and S. P. Platania. 1991. Status and conservation of the Rio Grande Silvery Minnow, *Hybognathus amarus*. *The Southwestern Naturalist* 36:225–232.
- Bestgen, K. R., and D. L. Propst. 1996. Redescription, geographic variation, and taxonomic status of the Rio Grande Silvery Minnow, *Hybognathus amarus* (Girard 1856). *Copeia* 1996:41–55.
- Bond, C. E. 1996. *Biology of fishes*, 2nd edition. Saunders College Publishing, Harcourt Brace and Company, Orlando, Florida.
- Bookstein, F. L., B. Chernoff, R. L. Elder, J. M. Humphries, G. R. Smith, and R. E. Strauss. 1985. Morphometrics in evolutionary biology: the geometry of size and shape change with examples from fishes. *Academy of Natural Sciences of Philadelphia Special Publication* 15.
- Bragensky, R. Y. 1960. Early development of the Carp. Pages 129–149 in C. G. Krevanowski, editor. Works on the early development of bony fishes [in Russian]. Soviet Academy of Sciences, Studies the A.N. Stevertsov Institute of Animal Morphology 28.
- Brandenburg, W. H., D. E. Snyder, S. P. Platania, and K. R. Bestgen. 2018a. Cyprinid fish larvae and early juveniles of the middle and lower Pecos River and Rio Grande—morphological descriptions, comparisons, illustrations, and computer-interactive key. Report of American Southwest Ichthyological Researchers to U.S. Bureau of Reclamation, Albuquerque, New Mexico. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (November 2018).
- Brandenburg, W. H., D. E. Snyder, and S. C. Seal. 2018b. Computer-interactive key to cyprinid fish eggs, larvae, and early juveniles of the middle and lower Pecos River and Rio Grande (data set for use with DELTA *Intkey*). American Southwest Ichthyological Researchers, L.L.C., Albuquerque, New Mexico, and Larval Fish Laboratory, Colorado State University, Fort Collins. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (November 2018).
- Butler J. L. 1960. Development of the Weberian apparatus of a catostomid fish. *Proceedings of the Iowa Academy of Science* 67:532–543.

- Buynak, G. L., and H. W. Mohr, Jr. 1978. Larval development of the White Sucker (*Catostomus commersoni*) from the Susquehanna River. *Proceedings of the Pennsylvania Academy of Science* 52:143–145.
- Buynak, G. L., and H. W. Mohr, Jr. 1979a. Larval development of the Blacknose Dace (*Rhinichthys atratulus*) and Longnose Dace (*Rhinichthys cataractae*) from a Susquehanna River tributary. *Proceedings of the Pennsylvania Academy of Science* 53:56–60.
- Buynak, G. L., and H. W. Mohr, Jr. 1979b. Larval development of the Bluntnose Minnow (*Pimephales notatus*) and Fathead Minnow (*Pimephales promelas*) from northeast Pennsylvania. *Proceedings of the Pennsylvania Academy of Science* 53:172–176.
- Buynak, G. L., and H. W. Mohr, Jr. 1980a. Larval development of Golden Shiner and Comely Shiner from Northeastern Pennsylvania. *The Progressive Fish-Culturist* 42(4):206–211.
- Buynak, G. L., and H. W. Mohr, Jr. 1980b. Larval development of Stoneroller, Cutlips Minnow, and River Chub with diagnostic keys, including four additional cyprinids. *The Progressive Fish-Culturist* 42(3):127–135.
- Carlander, K. D. 1969. *Handbook of freshwater fishery biology*, volume 1. Iowa State University Press, Ames.
- Carlson, C. A., C. G. Prewitt, D. E. Snyder, E. J. Wick, E. L. Ames, and W. D. Fronk. 1979. Fish and macroinvertebrates of the White and Yampa Rivers, Colorado. U.S. Bureau of Land Management, Biological Sciences Series 1, Denver.
- Chernoff, B., R. R. Miller, and C. R. Gilbert. 1982. *Notropis orca* and *Notropis simus*, cyprinid fishes from the American Southwest, with description of a new subspecies. *Occasional Papers of the Museum of Zoology, University of Michigan* 698:1–49.
- Clay, W. M. 1975. *The fishes of Kentucky*. Kentucky Department of Fish and Wildlife Resources, Frankfort.
- Coburn, M. M. 1986. Egg diameter variation in eastern North American minnows (Pisces: Cyprinidae): correlation with vertebral number, habitat, and spawning behavior. *Ohio Journal of Science* 86(3):110–120.
- Conner, J. V., R. P. Gallagher, and M. F. Chatry. 1980. Larval evidence for natural reproduction of the Grass Carp (*Ctenopharyngodon idella*) in the lower Mississippi River. Pages 1–19 in Fuiman, editor. *Proceedings of the fourth annual Larval Fish Conference*. U.S. Fish and Wildlife Service FWS/OBS-80/43.
- Conrow, R., and A. V. Zale. 1985. Early life history stages of fishes of Lake Orange, Florida—an illustrated identification manual. Florida Cooperative Fish and Wildlife Research Unit Technical Report 15, University of Florida, Gainesville.
- Contreras-Balderas, S., P. Almada-Villela, M. L. Lozano-Vilano, and M. E. Garcia-Ramirez. 2003. Freshwater fish at risk or extinct in Mexico. *Reviews in Fish Biology and Fisheries* 12:241–251.
- Cooper, J. E. 1978. Egg, larval, and juvenile development of the Longnose Dace, *Rhinichthys cataractae* (Valenciennes), and the River Chub, *Nocomis micropogon* (Cope), (Pisces: Cyprinidae) with notes on their hybridization. Master's thesis. Frostburg State College, Frostburg, Maryland.
- Cooper, J. E. 1980. Egg, larval and juvenile development of Longnose Dace, *Rhinichthys cataractae*, and River Chub, *Nocomis micropogon*, with notes on their hybridization. *Copeia* 1980:469–478.

- Cowley, D. E. 2006. Strategies of ecological restoration of the Middle Rio Grande in New Mexico and recovery of the endangered Rio Grande Silvery Minnow. *Reviews in Fisheries Science* 14:169–186.
- Cowley, D. E., P. D. Shirey and M. D. Hatch. 2006. Ecology of the Rio Grande Silvery Minnow (Cyprinidae: *Hybognathus amarus*) inferred from specimens collected in 1874. *Reviews in Fisheries Science* 14: 111–125.
- Cowley, D. E., R. C. Wissmar, and R. Sallenave. 2007. Fish assemblages and seasonal movements of fish in irrigation canals and river reaches of the Middle Rio Grande, New Mexico. *Ecology of Freshwater Fish* 16:548–558.
- CPW (Colorado Parks and Wildlife). 2015. State wildlife action plan. CPW, Denver.
- Crawford, D. R. 1923. The significance of food supply in the larval development of fishes. *Ecology* 4:147–153.
- Cross, F. B. 1967. Handbook of fishes of Kansas. Museum of Natural History Miscellaneous Publication 45, University of Kansas, Lawrence.
- Dallwitz, M. J. 1974. A flexible computer program for generating identification keys. *Systematic Zoology* 23:50–57.
- Dallwitz, M. J. 1980. A general system for coding taxonomic descriptions. *Taxon* 29:41–6.
- Dallwitz, M. J. 1993. DELTA and INTKEY. Pages 287–296 in R. Fortuner, editor. *Advances in computer methods for systematic biology: artificial intelligence, databases, computer vision*. The Johns Hopkins University Press, Baltimore, Maryland.
- Dallwitz, M. J. 1996 onwards. Programs for interactive identification and information retrieval. Commonwealth Scientific and Industrial Research Organization Department of Entomology. Available: <http://www.delta-intkey.com/>, under "Methodology" (October 2019).
- Dallwitz, M. J. 2000 onwards. A comparison of interactive identification programs. Commonwealth Scientific and Industrial Research Organization Department of Entomology. Available: <https://www.delta-intkey.com/>, under "Methodology" (October 2019).
- Dallwitz, M. J., and T. A. Paine. 1986. User's guide to the DELTA System: a general system for processing taxonomic descriptions. Commonwealth Scientific and Industrial Research Organization Department of Entomology Report 13, Canberra, Australia.
- Dallwitz, M. J., T. A. Paine, and E. J. Zurcher. 1993 (onwards). User's guide to the DELTA System: a general system for processing taxonomic descriptions, 4th edition. Commonwealth Scientific and Industrial Research Organization Department of Entomology. Available: <https://www.delta-intkey.com/>, under "Documentation" (October 2019).
- 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: <https://www.delta-intkey.com/>, under "Documentation" (October 2019).
- Dallwitz, M. J., T. A. Paine, and E. J. Zurcher. 1999 (onwards). User's guide to the DELTA Editor. Commonwealth Scientific and Industrial Research Organization Department of Entomology. Available: <https://www.delta-intkey.com/>, under "Documentation" (October 2019).

- Dallwitz, M. J., T. A. Paine, and E. J. Zurcher. 2000 (onwards). Principles of interactive keys. Commonwealth Scientific and Industrial Research Organization Department of Entomology. Available: <https://www.delta-intkey.com/>, under "Methodology" (October 2019).
- Drewry, G. E. 1979. A punch card key to the families of yolk sac larval fishes of the Great Lakes region. V. I. D. Publishing Company, Waldorf, Maryland.
- Dudley, R. K., and S. P. Platania. 1999. Imitating the physical properties of drifting semibuoyant fish (Cyprinidae) eggs with artificial eggs. *Journal of Freshwater Ecology* 14(4):423–430.
- Dudley, R. K., and S. P. Platania. 2007. Flow regulation and fragmentation imperil pelagic-spawning riverine fishes. *Ecological Applications* 17:2074–2086.
- Dudley, R. K., S. P. Platania, and G. C. White. 2016. Rio Grande Silvery Minnow reproductive monitoring during 2016 in the Rio Grande and selected irrigation canals. Report of American Southwest Ichthyological Researchers to U.S. Bureau of Reclamation, Albuquerque.
- Dudley, R. K., S. P. Platania, and G. C. White. 2019. Rio Grande Silvery Minnow population monitoring during 2018 in the Rio Grande and selected irrigation canals. Report of American Southwest Ichthyological Researchers LLC to U.S. Bureau of Reclamation, Albuquerque.
- Dunn, J. R. 1983. The utility of developmental osteology in taxonomic and systematic studies of teleost larvae: a review. U.S. National Oceanic and Atmospheric Administration Technical Report, National Marine Fisheries Service Circular 450.
- Dunn, J. R. 1984. Developmental osteology. Pages 48–50 in H. G. Moser, W. J. Richards, D. M. Cohen, M. P. Fahay, A. W. Kendall, Jr., and S. L. Richardson, editors. *Ontogeny and systematics of fishes*. American Society of Ichthyologists and Herpetologists Special Publication 1, Lawrence, Kansas.
- Eddy, S., and J. C. Underhill. 1974. *Northern fishes*. University of Minnesota Press, Minneapolis.
- Edwards, R. 2017. Biological monitoring of the reintroduction efforts of the Rio Grande Silvery Minnow into the Big Bend region of Texas and Mexico. Final performance report, Texas Parks and Wildlife Department, Austin.
- Ehrenbaum, E. 1909. Eier und larven von fischen des nordischen planktons (Part 2) [Eggs and larvae of fish in Nordic (or northern) plankton]. Pages 217–413 in *Nordisches Plankton, Zoologischer Teil, Erster Band*. Lipsius und Tischer, Kiel und Leipzig. (In German; reprinted in 1964 by Neudruck A. Asher and Company, Amsterdam).
- Ellis, M. M. 1914. *Fishes of Colorado*. The University of Colorado Studies 11(1), Boulder.
- Etnier, D. A., and W. C. Starnes. 1993. *The Fishes of Tennessee*. University of Tennessee Press, Knoxville.
- Faber, D. J. 1980. Observations of the life of the Golden Shiner, *Notemigonus crysoleucas* (Mitchell), in Lac Heney, Quebec. Pages 69–78 in L. A. Fuiman, editor. *Proceedings of the fourth annual Larval Fish Conference*, U.S. Fish and Wildlife Service FWS/OBS-80/43.
- Faber, D. J. 2006 onwards. *Baby fishes of Canada*. Website—<http://fishbabies.ca> (March 2015).
- Feeney, R. F., and C. C. Swift. 2008. Description and ecology of larvae and juveniles of three native cypriniforms of coastal southern California. *Ichthyological Research* 65:65–77.

- Fish, M. P. 1929. Contributions to the early life histories of Lake Erie fishes. *Bulletin of the Buffalo Society of Natural Sciences* 14(3):136–187.
- Fish, M. P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. *Bulletin of the U.S. Bureau of Fisheries* 47(10):293–398.
- Fowler, W. H. 1945. A study of the fishes of the southern piedmont and coastal plain. *Monographs of the Academy of Natural Sciences of Philadelphia* 7:1–408.
- Fuiman, L. A. 1978. Descriptions and comparisons of northeastern catostomid fish larvae. Master's thesis. Cornell University, Ithaca, New York.
- Fuiman, L. A. 1979. Descriptions and comparisons of catostomid fish larvae: northern Atlantic drainage species. *Transactions of the American Fisheries Society* 108:560–603.
- Fuiman, L. A. 1982a. Catostomidae. Pages 345–435 in N. A. Auer, editor. Identification of larval fishes of the Great Lakes Basin with emphasis on the Lake Michigan Drainage. Great Lakes Fishery Commission, Special Publication 82-3, Ann Arbor, Michigan.
- Fuiman, L. A. 1982b. Correspondence of myomeres and vertebrae and their natural variability during the first year of life in Yellow Perch. Pages 56–59 in C. F. Bryan, J. V. Conner, and F. M. Truesdale, editors. The fifth annual Larval Fish Conference. Louisiana Cooperative Fishery Research Unit and School of Forestry and Wildlife Management, Louisiana State University, Baton Rouge.
- Fuiman, L. A., J. V. Conner, B. A. Lathrop, G. L. Buynak, D. E. Snyder, and J. J. Loos. 1983. State of the art of identification for cyprinid fish larvae from eastern North America. *Transactions of the American Fisheries Society* 112:319–332.
- Fuiman, L. A., and L. Corazza. 1979. Morphometry and allometry: implications for larval fish taxonomy. Pages 1–19 in R. Wallus and C. W. Voigtlander, editors. Proceedings of a Workshop on Freshwater Larval Fishes. Tennessee Valley Authority, Norris, Tennessee.
- Fuiman, L. A., and J. J. Loos. 1977. Identifying characters of the early development of the daces *Rhinichthys atratulus* and *R. cataractae* (Osteichthyes: Cyprinidae). *Proceedings of the Academy of Natural Science, Philadelphia* 129(2):23–32.
- Fuiman, L. A. and J. R. Trojnar. 1980. Factors affecting egg diameter of White Suckers (*Catostomus commersoni*). *Copeia* 1980:699–704.
- Gale, W. F. 1986. Indeterminate fecundity and spawning behavior of captive red shiners—fractional, crevice spawners. *Transactions of the American Fisheries Society* 115:429–437.
- Gale, W. F. and G. L. Buynak. 1982. Fecundity and spawning frequency of the Fathead Minnow—A fractional spawner. *Transactions of the American Fisheries Society* 111:35–40.
- Geen, G. H., T. G. Northcote, G. F. Hartman, and C. C. Lindsey. 1966. Life histories of two species of catostomid fishes in Sixteenmile Lake, British Columbia, with particular reference to inlet stream spawning. *Journal of the Fisheries Research Board of Canada* 23:1761–1788.
- Gerlach, J. M. 1983. Characters for distinguishing larvae of Carp, *Cyprinus carpio*, and Goldfish, *Carassius auratus*. *Copeia* 1983:116–121.
- Gould, W. 1985. Aspects of the biology of the Flathead Chub (*Hybopsis gracilis*) in Montana. *Great Basin Naturalist*. 45(2):332–336.

- Hardy, J. D., Jr., G. E. Drewry, R. A. Fritzsche, G. D. Johnson, P. W. Jones, and F. D. Martin. 1978. Development of fishes of the Mid-Atlantic Bight, an atlas of egg, larval and juvenile stages (6 volumes). U.S. Fish and Wildlife Service FWS/OBS-78/12.
- Haworth, M. R. 2015. Reproduction and recruitment dynamics of Flathead Chub *Platygobio gracilis* relative to flow and temperature regimes in Fountain Creek, Colorado. Master's Thesis. Department of Fish, Wildlife, and Conservation Biology, Colorado State University, Fort Collins.
- Haworth, M. R., and K. R. Bestgen. 2017. Flow and water temperature affect reproduction and recruitment of a Great Plains cyprinid. *Canadian Journal of Fisheries and Aquatic Sciences* 74:853–863.
- Hendrickson, D. A., and A. E. Cohen. 2015a. Fishes of Texas Project Database (Version 2.0) [online database, doi:10.17603/C3WC70]—*Pimephales vigilax*. Texas Advanced Computing Center, University of Texas, Austin. Available: <http://www.fishesoftexas.org/taxa/pimephales-vigilax> (July 2019).
- Hendrickson, D. A., and A. E. Cohen. 2015b. Fishes of Texas Project Database (Version 2.0) [online database, doi:10.17603/C3WC70]—*Platygobio-gracilis*. Texas Advanced Computing Center, University of Texas, Austin. Available: <http://www.fishesoftexas.org/taxa/platygobio-gracilis> (July 2019).
- Heufelder, G. R., and L.A. Fuiman. 1982. Cyprinidae. Pages 174–344 in N. A. Auer, editor. Identification of larval fishes of the Great Lakes Basin with emphasis on the Lake Michigan Drainage. Great Lakes Fishery Commission, Special Publication 82-3, Ann Arbor, Michigan.
- Hikita, T. 1956. On the anatomy and development of the Carp in Hokkaido. *Scientific Reports of the Hokkaido Fish Hatchery* 11:65–95.
- Hoda, S. M. S., and H. Tsukahara. 1971. Studies on the development and relative growth of Carp, *Cyprinus carpio* (Linne). *Kyushu University Journal of the Faculty of Agriculture* 16(4):387–509.
- Hogue Jr., J. J., R. Wallus, and L. K. Kay. 1976. Preliminary guide to the identification of larval fishes in the Tennessee River. Tennessee Valley Authority Technical Note B19, Norris Tennessee.
- Holland-Bartels, L. E., S. K. Littlejohn, and M. L. Hustin. 1990. A guide to larval fishes of the upper Mississippi River. U.S. Fish and Wildlife Service National Fisheries Research Center, La Crosse, Wisconsin, and Minnesota Extension Service and Sea Grant, University of Minnesota, Saint Paul.
- Hoyt, R. D., G. J. Overmann, and G. A. Kindschi. 1979. Observations on the larval ecology of the Smallmouth Buffalo. Pages 1–16 in R. D. Hoyt, editor. Proceedings of the third symposium on larval fish. Western Kentucky University, Bowling Green.
- Hubbs, C. L. 1958. *Dikellorhynchus* and *Kanazawaichthys*: nominal fish genera interpreted as based on prejuveniles of *Malacanthus* and *Antennarius*, respectively. *Copeia* 1958:282–285.
- Hubbs, C. L., L. C. Hubbs, and R. E. Johnson. 1943. Hybridization in nature between species of catostomid fishes. *Contributions from the Laboratory of Vertebrate Biology of the University of Michigan* 22.
- Hubbs, C. L., and K. F. Lagler. 1958. Fishes of the Great Lakes region. *Cranbrook Institute of Science Bulletin* 26.

- Hubbs, C. L., K. F. Lagler, and G. R. Smith. 2004. Fishes of the Great Lakes region, revised edition. University of Michigan Press, Ann Arbor.
- Humphries, J. M., F. L. Bookstein, B. Chernoff, G. R. Smith, R. L. Elder, and S. G. Poss. 1981. Multivariate discrimination by shape in relation to size. *Systematic Zoology* 30:291–308.
- Itazawa, Y. 1963. The ossification sequences of the vertebral column in the Carp and the snakehead fish. *Bulletin of the Japanese Society of Scientific Fisheries* 29(7):667–674.
- Jester, D. B. 1972. Life history, ecology, and management of the River Carpsucker, *Carpionodes carpio* (Rafinesque), with reference to Elephant Butte Lake. New Mexico State University, Agricultural Experiment Station, Research Report 243, Las Cruces.
- Jester, D. B. 1973. Life history, ecology, and management of the Smallmouth Buffalo, *Ictiobus bubalus* (Rafinesque), with reference to Elephant Butte Lake. New Mexico State University, Agricultural Experiment Station, Research Report 261, Las Cruces.
- Jones, P. W., F. D. Martin, and J. D. Hardy, Jr. 1978. Acipenseridae through Ictaluridae. Volume 1 in J. D. Hardy, Jr., G. E. Drewry, R. A. Fritzsche, G. D. Johnson, P. W. Jones, and F. D. Martin. 1978. Development of fishes of the Mid-Atlantic Bight, an atlas of egg, larval and juvenile stages (6 volumes). U.S. Fish and Wildlife Service FWS/OBS-78/12.
- Jordan, D. S., and B. W. Evermann. 1896. The fishes of north and middle America (4 volumes). U.S. National Museum Bulletin 47.
- Jude, D. J., G. R. Heufelder, H. T. Tin, N. A. Auer, S. A. Kinger, P. J. Schneeberger, T. L. Rutecki, C. P. Madenjian and P. J. Rago. 1979. Adult, juvenile and larval fish in the vicinity of the J. H. Campbell Power Plant, Eastern Lake Michigan, 1978. Great Lakes Research Division Special Report 73, University of Michigan, Ann Arbor, Michigan.
- Jumawan, J. C., A. A. Herrera, and B. Vallejo, Jr. 2014. Embryonic and larval development of the Suckermouth Sailfin Catfish *Pterygoplichthys pardalis* from Marikina River, Philippines. *EurAsian Journal of BioSciences* [online serial] 8:38-50.
- Kansas Fishes Committee, editors. 2014. Kansas fishes. University Press of Kansas, Lawrence.
- Kay, L. K., R. Wallus, and B. L. Yeager. 1994. Reproductive biology and early life history of fishes in the Ohio River drainage, Volume 2: Catostomidae. Tennessee Valley Authority, Chattanooga, Tennessee.
- Kelso, W. E., M. D. Kaller, and D. A. Rutherford. 2012. Collection, processing, and identification of fish eggs and larvae and zooplankton. Pages 363–452 (Chapter 9) in A. V. Zale, D. L. Parrish, and T. M. Sutton, editors. *Fisheries techniques*, third edition. American Fisheries Society, Bethesda, Maryland.
- Kelso, W. E., and D. A. Rutherford. 1996. Collection, preservation, and identification of fish eggs and larvae. Pages 255–302 (Chapter 9) in B. R. Murphy and D. W. Willis, editors. *Fisheries techniques*, second edition. American Fisheries Society, Bethesda, Maryland.
- Kendall, A. W., Jr., E. H. Ahlstrom, and H. G. Moser. 1984. Early life history stages of fishes and their characters. Pages 11–22 in H. G. Moser, W. J. Richards, D. M. Cohen, M. P. Fahay, A. W. Kendall, Jr., and S. L. Richardson, editors. *Ontogeny and systematics of fishes*. American Society of Ichthyologists and Herpetologists Special Publication 1, Lawrence, Kansas.
- Khan, M. H. 1929. Early stages in the development of the Goldfish (*Carassius auratus*). *Journal of the Bombay Natural History Society* 33:614–617.
- Korwin-Kossakowski, M. 2008. The influence of temperature during the embryonic period on larval growth and development in Carp, *Cyprinus carpio* L., and Grass Carp

- Ctenopharyngodon idella* (Val.): theoretical and practical aspects. Archives of Polish Fisheries 16:231–314.
- Koster, W. J. 1957. Guide to the fishes of New Mexico. University of New Mexico Press, Albuquerque.
- Kraatz, W. C. 1924. The intestine of the minnow *Campostoma anomalum* (Rafinesque), with special reference to the development of its coiling. Ohio Journal of Science 24(6): 265–298.
- La Rivers, I. 1962. Fishes and fisheries of Nevada. Nevada State Fish and Game Commission. State Printing Office, Carson City.
- Lagasse, P. F. 1980. An assessment of the response of the Rio Grande to dam construction—Cochiti to Isleta reach. Technical report for the U.S. Army Engineer District, U.S. Army Corps of Engineers, Albuquerque, New Mexico.
- Lagler, K. F., J. E. Bardach, and R. R. Miller. 1962. Ichthyology. John Wiley and Sons, New York.
- Langlois, D., J. Alves, and J. Apker. 1994. Rio Grande Sucker recovery plan. Colorado Division of Wildlife, Montrose.
- Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. 1980. Atlas of North American freshwater fishes. North Carolina Biological Survey Publication 1980-12, North Carolina State Museum of Natural History, Raleigh.
- Lentsch, L. D., R. T. Muth, P. D. Thompson, B. G. Hoskins, and T. A. Crowl. 1996. Options for selective control of nonnative fishes in the Upper Colorado River Basin. Utah Division of Wildlife Resources Publication 96-14, Salt Lake City.
- Lipps, A. J., and R. L. Moran. 1974. Manual for identification of early developmental stages of fishes of the Potomac River Estuary. Maryland Department of Natural Resources Power Plant Siting Program PPSP-MP-13, Annapolis.
- Long, W. L., and W. W. Ballard. 1976. Normal embryonic stages of the white sucker, *Catostomus commersoni*. Copeia 1976:342–351.
- Loos, J. J., and L. A. Fuiman. 1978. Subordinate taxa of the genus *Notropis*: a preliminary comparative survey of their developmental traits. Pages 1–50 in L. L. Olmstead, editor. Proceedings of the first symposium on freshwater larval fish. Duke Power Company, Charlotte, North Carolina.
- Loos, J. J., L. A. Fuiman, N. R. Foster, and E. K. Jankowski. 1979. Notes on early life histories of cyprinoid fishes of the upper Potomac River. Pages 93–139 in R. Wallus and C. W. Voigtlander, editors. Proceedings of a workshop on freshwater larval fishes. Tennessee Valley Authority, Norris, Tennessee.
- McAllister, D. E. 1968. Evolution of branchiostegals and classification of teleostome fishes. National Museum of Canada Bulletin 221.
- McCrimmon, H. R., and U. B. Swee. 1967. Scale formation as related to growth and development of young Carp, *Cyprinus carpio* L. Journal of the Fisheries Board of Canada 24:47–51.
- McElman, J. F., and E. K. Balon. 1980. Early ontogeny of White Sucker, *Catostomus commersoni*, with steps of saltatory development. Environmental Biology of Fishes 5:191–224.
- McGowan, E. G. 1984. An identification guide for selected larval fishes from Robinson Impoundment, South Carolina. Carolina Power and Light Company Environmental Services Section Biology Unit, New Hill, North Carolina.

- McGowan, E. G. 1988. An illustrated guide to larval fishes from three North Carolina Piedmont impoundments. Carolina Power and Light Company Environmental Services Section Biology Unit, New Hill, North Carolina.
- Mansueti, A. J., and J. D. Hardy, Jr. 1967. Development of fishes of the Chesapeake Bay region, an atlas of egg, larval, and juvenile stages, part 1. Natural Resources Institute, University of Maryland, Cambridge. (Subsequently updated by Jones et al. 1978 as volume 1 of Hardy et al. 1978).
- Markus, H. C. 1934. Life history of Blackhead Minnow (*Pimephales promelas*). *Copeia* 1934(3):116–122.
- Martinez, A. M. 1983. Identification of Brook, Brown, Rainbow and Cutthroat Trout larvae. Master's thesis. Colorado State University, Fort Collins.
- Martinez, A. M. 1984. Identification of Brook, Brown, Rainbow, and Cutthroat Trout larvae. *Transactions of the American Fisheries Society* 113:252–259.
- May, E. B., and C. R. Gasaway. 1967. A preliminary key to the identification of larval fishes of Oklahoma with particular reference to Canton Reservoir, including a selected bibliography. Oklahoma Department of Wildlife, Conservation Bulletin 5, Oklahoma City.
- Miller, R. R. 1952. Bait fishes of the lower Colorado River from Lake Mead, Nevada, to Yuma, Arizona, with a key for their identification. *California Fish and Game* 38:7–42.
- Miller, R. R., and C. L. Hubbs. 1960. The spiny-rayed cyprinid fishes (Plagopterini) of the Colorado River system. *Miscellaneous Publication of the Museum of Zoology, University of Michigan* 115:1–39.
- Miller, R. R., and C. Hubbs. 1962. *Gila pandora*, a cyprinid new to the Texas fish fauna. *Texas Journal of Science* 14(1):111–113.
- Minckley, W. L. 1973. Fishes of Arizona. Arizona Game and Fish Department, Phoenix.
- Moore, G. A. 1968. Fishes. Pages 22–165 in W. F. Blair, A. P. Blair, P. Brodkorb, F. R. Cagle, and G. A. Moore. *Vertebrates of the United States*. McGraw-Hill Book Co., New York.
- Moser, H. G., and E. H. Ahlstrom. 1970. Development of lanternfishes (family Myctophidae) in the California current, part 1, species with narrow-eyed larvae. *Bulletin of the Los Angeles County Museum of Natural History Science* 7.
- Moyle, P. B. 1976. *Inland fishes of California*. University of California Press, Berkeley.
- Muth, R. T. 1990. Ontogeny and taxonomy of Humpback Chub, Bonytail, and Roundtail Chub larvae and early juveniles. Doctoral dissertation. Colorado State University, Fort Collins.
- Muth, R. T., and D. E. Snyder. 1995. Diets of young Colorado Squawfish and other small fish in backwaters of the Green River, Colorado and Utah. *The Great Basin Naturalist* 55:95–104.
- Nakamura, M. 1969. [Cyprinid fishes of Japan—studies on the life history of cyprinid fishes of Japan]. Research Institute of Natural Resources, Special Publication 4, Tokyo, Japan. (In Japanese.)
- Nakatani, K., A. A. Agostinho, G. Baumgartner, A. Bialecki, P. V. Sanches, M. C. Markrakis and C. Pavanelli. 2001. *Ovos e larvas de peixe de água doce: desenvolvimento e manual de identificação*. [Eggs and larvae of freshwater fish: development and identification manual.] Maringá, Eduem/Nupelia. EDUEM (Editora da Universidade Estadual de Maringá), Maringá, Paraná, Brazil. (In Portuguese.)

- Nielsen, L. A., and D. L. Johnson, editors. 1983. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.
- NMDGF (New Mexico Department of Game and Fish). 2016a. State wildlife action plan for New Mexico. NMDGF, Santa Fe.
- NMDGF. 2016b. Rio Grande Cutthroat Trout. NMDGF, Santa Fe. Available: <http://www.wildlife.state.nm.us/fishing/native-new-mexico-fish/rio-grande-cutthroat-trout/> (November 2018).
- NMDGF. 2016c. Cold water species. NMDGF, Santa Fe. Available: <http://www.wildlife.state.nm.us/fishing/game-fish/cold-water/> (November 2018).
- NMDGF. 2018. Threatened and endangered species of New Mexico, 2018 biennial review (draft, 23 August 2018). NMDGF, Santa Fe.
- Nordqvist, H. 1914. Bidrag till kannedomen om vara sotvattensfiskars larvstadier. [Contributions to knowledge of the larval stage in our freshwater fish.] Arkiv for Zoologi 9(4):1–49. (In Swedish; English translation in library of the National Museum of Canada, Ottawa.)
- Okada, Y. 1960. [Studies on the freshwater fishes of Japan.] Prefectural University of Mie. Otanimachi, Tsu, Mie Prefecture, Japan. 4(2):267–588. (In Japanese.)
- Olund, L. J., and F. B. Cross. 1961. Geographic variation in the North American cyprinid fish *Hybopsis gracilis*. University of Kansas Publications, Museum of Natural History 13(7):323–348.
- Orton, G. L. 1953. Development and migration of pigment cells in some teleost fishes. Journal of Morphology 93:69–99.
- Page, L. M., and B. M. Burr. 1991. A field guide to freshwater fishes, North America north of Mexico. The Peterson Field Guide Series, Houghton Mifflin Company, Boston, Massachusetts.
- Page, L. M., and P. A. Ceas, 1989. Egg attachment in *Pimephales* (Pisces: Cyprinidae). Copeia 1989:1074–1077.
- Page, L. M., H. Espinosa-Perez, L. T. Findley, C. R. Gilbert, R. N. Lea, N. E. Mandrak, R. L. Mayden, and J. S. Nelson. 2013. Common and scientific names of fishes from the United States, Canada, and Mexico, 7th edition. American Fisheries Society, Special Publication 34, Bethesda, Maryland.
- Parker, H. L., 1964. Natural history of *Pimephales vigilax* (Cyprinidae). Southwestern Naturalist, 8:228–235.
- Penaz, M., M. Prokes, J. Kouril, and J. Hamackova. 1983. Early development of the Carp, *Cyprinus carpio*. Acta Scientiarum Naturalium—Academiae Scientiarum Bohemoslovacae Brno 17 (2):1–39.
- Pennak, R. W. 1964. Collegiate dictionary of zoology. The Ronald Press Company, New York.
- Perry, L. G. 1979. Identification of nine larval cyprinids inhabiting small northern rivers. Master's thesis, part 1. Iowa State University, Ames.
- Perry, L. G., and B. W. Menzel. 1979. Identification of nine larval cyprinids inhabiting small northern rivers. Pages 141–173 in R. Wallus and C. W. Voigtlander, editors. Proceedings of a workshop on freshwater larval fishes. Tennessee Valley Authority, Norris, Tennessee.
- Pflieger, W. L. 1997. The fishes of Missouri, revised edition. Missouri Department of Conservation, Jefferson City.

- Pinder, A. C. 2001. Keys to larval and juvenile stages of coarse fishes from fresh waters in the British Isles. Freshwater Biological Association Scientific Publication 60, Ambleside, Cumbria, UK.
- Platania, S. P. 1991. Fishes of the Rio Chama and upper Rio Grande, New Mexico, with preliminary comments on their longitudinal distribution. *The Southwestern Naturalist* 36:186–193.
- Platania, S.P. 1993. The fishes of the Rio Grande between Velarde and Elephant Butte Reservoir and their habitat associations. Report to the New Mexico Department of Game and Fish (contract 516.6-74-23) and U.S. Bureau of Reclamation (cooperative agreement 0-FC-40-08(70)).
- Platania, S. P. 1995. Reproductive biology and early life-history of Rio Grande Silvery Minnow *Hybognathus amarus*. Final Report to the U.S. Army Corps of Engineers, Albuquerque, New Mexico.
- Platania, S. P. 1998. Imperiled fishes of the southwest. Pages 565–570 in M. J. Mac, P. A. Opler, C. E. Puckett-Haecker, and P. D. Duran, editors. Status and trends of the nation's biological resources (2 volumes). U. S. Geological Survey, Reston, Virginia.
- Platania, S. P. 2000. Effects of four water temperatures treatments on survival, growth, and developmental rates of Rio Grande Silvery Minnow, *Hybognathus amarus*, eggs and larvae. Final Report of American Southwest Ichthyological Research Foundation to the U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office, Albuquerque, New Mexico.
- Platania, S. P., and C. S. Altenbach. 1998. Reproductive strategies and egg types of seven Rio Grande Basin cyprinids. *Copeia* 1998:559–569.
- Platania, S. P., and R. K. Dudley. 2002. Spawning periodicity of Rio Grande Silvery Minnow, *Hybognathus amarus*, during 2001. Final Report of American Southwest Ichthyological Research Foundation to U. S. Bureau of Reclamation, Albuquerque, New Mexico.
- Prewitt, C. G. 1977. Catostomid fishes of the Yampa and White rivers, Colorado. Master's thesis. Colorado State University, Fort Collins.
- Propst, D. L., G. L. Burton, and B. H. Pridgeon. 1987. Fishes of the Rio Grande between Elephant Butte and Caballo Reservoir. *The Southwestern Naturalist* 32(3):408–411.
- Pyron, M. 2014. Bullhead Minnow, *Pimephales vigilax* (Baird and Girard 1853). Pages 240–241 in Kansas Fishes Committee, editors. Kansas Fishes. University Press of Kansas, Lawrence.
- Rahel, F. J., and L. A. Thel. 2004. Flathead Chub (*Platygobio gracilis*): a technical conservation assessment [Online]. USDA Forest Service, Rocky Mountain Region, Lakewood, Colorado. Available: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5182082.pdf (November 2018).
- Reed, R. 1958. The early life history of two cyprinids, *Notropis rubellus* and *Campostoma anomalum pullum*. *Copeia* 1958:325–327.
- Rees, D.E., R.J. Carr, and W.J. Miller. 2005. Rio Grande Chub (*Gila pandora*): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region, Lakewood, Colorado. Available: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5200374.pdf (November 2018).
- Reighard, J. 1920. The breeding behavior of the suckers and minnows—I, the suckers. *Biological Bulletin* (Woods Hole) 38(1):1–32.

- Remple, S., and D. F. Markle. 2005. Description and identification of larval and juvenile cyprinids (Fathead Minnow, Tui Chub, and Blue Chub) from Upper Klamath Lake, Oregon. *California Fish and Game* 91(2):83–99.
- Rinne, J. N. 1995. Reproductive biology of the Rio Grande Sucker, *Catostomus plebeius* (Cypriniformes), in a montane stream, New Mexico. *Southwestern Naturalist* 40:237–241.
- Rinne, J. N., and S. P. Platania. 1995. Fish fauna. Pages 165–175 in D. M. Finch, and J. A. Tainter, editors. *Ecology, diversity, and sustainability of the Middle Rio Grande Basin*. U. S. Forest Service General Technical Report RM-GTR-268, Fort Collins, Colorado.
- Rivas, L. R. 1956. Definitions and methods of measuring and counting in the billfishes (Istiophoridae, Xiphiidae). *Bulletin of Marine Science of the Gulf and Caribbean* 6(1):18–27.
- Ruppert, J. B., R. T. Muth, and T. P. Nesler. 1993. Predation on fish larvae by adult Red Shiner, Yampa and Green rivers, Colorado. *Southwestern Naturalist* 38:397–399.
- Saksena, V. P. 1962. The post-hatching stages of the Red Shiner, *Notropis lutrensis*. *Copeia* 1962:539–544.
- Sallenave, R., C. Carrasco, and D. E. Cowley. 2010 (updated 2018). Fishes in the middle and lower Rio Grande irrigation systems of New Mexico. New Mexico State University, College of Agricultural, Consumer, and Environmental Sciences, Cooperative Extension Service Circular 653, Las Cruces. Available: http://aces.nmsu.edu/pubs/_circulars/CR653/welcome.html (November 2018).
- Scheidegger, K. J. 1990. Appendix C—Descriptions and illustrations of the early life stages of select fishes from the Tallapoosa and Cahaba rivers. Pages 87–133 in K. J. Scheidegger. *Larval fish assemblage composition and microhabitat use in two southeastern rivers*. Master's thesis. Auburn University, Auburn, Alabama.
- Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. *Bulletin of the Fisheries Research Board of Canada* 184.
- Scripter, M. J. 2009. A manual for the identification of the larval fish of the St. Johns River. Department of Biological Sciences, Florida Institute of Technology, Melbourne, Florida (unpublished laboratory manual, available from author—e-mail: matts@ecological-associates.com).
- Siefert, R. E. 1969. Characteristics for separation of White and Black Crappie larvae. *Transactions of the American Fisheries Society* 98:326–328.
- Sigler, W. F., and R. R. Miller. 1963. *Fishes of Utah*. Utah Department of Fish and Game, Salt Lake City.
- Sigler, W. F., and J. W. Sigler. 1996. *Fishes of Utah, a natural history*. University of Utah Press, Salt Lake City.
- Simon, T. P. 1986. A listing of regional guides, keys, and selected comparative descriptions of freshwater and marine larval fishes. *American Fisheries Society Early Life History Section Newsletter* 7(1):10–15.
- Simon, T. P. 1998. Assessment of Balon's reproductive guilds with application to midwestern North American freshwater fishes. Pages 97–121 in Simon, T.P. (ed.). *Assessing the sustainability and biological integrity of water resources using fish communities*. CRC Press, Boca Raton, Florida.

- Simon, T. P., and R. Wallus. 2004. Reproductive biology and early life history of fishes in the Ohio River drainage, volume 3: Ictaluridae—catfishes and madtoms. CRC Press, Boca Raton, Florida.
- Simon, T. P., and R. Wallus. 2006. Reproductive biology and early life history of fishes in the Ohio River drainage, volume 4: Percidae—perch, pikeperch, and darters. CRC Press, Boca Raton, Florida.
- Simpson, J. C., and R. L. Wallace. 1978. Fishes of Idaho. University Press of Idaho, Moscow.
- Smallwood, W. M. and M. B. Derrickson. 1933. The development of the Carp, *Cyprinus carpio*. II. The development of the liver-pancreas, the Islands of Langerhans and the spleen. *Journal of Morphology* 55(1):15–28.
- Smallwood, W. M., and M. L. Smallwood. 1931. The development of the Carp, *Cyprinus carpio*. I. The larval life of the carp, with special reference to the development of the intestinal canal. *Journal of Morphology* 52:217–231.
- Smith, C. L. 1985. The inland fishes of New York. New York State Department of Environmental Conservation, Albany.
- Smith, G. R. 1966. Distribution and evolution of the North American catostomid fishes of the subgenus *Pantosteus*, genus *Catostomus*. *Miscellaneous Publications Museum of Zoology University of Michigan* 129.
- Smith, G. R., J. G. Hall, R. K. Koehn, and D. J. Innes. 1983. Taxonomic relationships of the Zuni Mountain Sucker, *Catostomus discobolus yarrowi*. *Copeia* 1983:37–48.
- Snyder, D. E. (chairperson). 1976a. Identification tools: what's available and what could be developed, report of working group 2. Pages 88–96 in J. Boreman, editor. Great Lakes fish egg and larvae identification, proceedings of a workshop. U.S. Fish and Wildlife Service, FWS/OBS-76/23.
- Snyder, D. E. 1976b. Terminologies for intervals of larval fish development. Pages 41–670 in J. Boreman, editor. Great Lakes fish egg and larvae identification, proceedings of a workshop. U.S. Fish and Wildlife Service FWS/OBS-76/23.
- Snyder, D. E. 1979. Myomere and vertebra counts of the North American cyprinids and catostomids. Pages 53–69 in R. D. Hoyt, editor. Proceedings of the third symposium on larval fish. Department of Biology, Western Kentucky University, Bowling Green.
- Snyder, D. E. 1981. Contributions to a guide to the cypriniform fish larvae of the Upper Colorado River System in Colorado. U.S. Bureau of Land Management Biological Sciences Series 3, Denver, Colorado. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/contribution-series/#009>; November 2018)
- Snyder, D. E. 1983. Fish eggs and larvae. Pages 165–197 (Chapter 9) in L. A. Nielsen and D. L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.
- Snyder, D. E. 1990. Fish larvae—ecologically distinct organisms. Pages 20–23 in M. B. Bain, editor. Ecology and assessment of warmwater streams: workshop synopsis. U.S. Fish and Wildlife Service Biological Report 90(5).
- Snyder, D. E. 1996. To the millennium and beyond: a commentary on early life history research. Stages, Newsletter of the American Fisheries Society Early Life History Section 16(3):17–19.
- Snyder, D. E. 1998. Catostomid larvae and early juveniles of the Rio Grande Basin in Colorado. Final Report of Colorado State University Larval Fish Laboratory to Colorado Division

- of Wildlife, Monte Vista. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/contribution-series/#102>; November 2018).
- 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: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (November 2018).
- Snyder, D. E. 2013. Middle Rio Grande larval fish identification guide. Final Report of Colorado State University Larval Fish Laboratory to U.S. Bureau of Reclamation, Salt Lake City, Utah. (Incomplete results; project and guide manuscript completed via revised final report herein.)
- Snyder, D. E. 2019 onwards. Computer-interactive key to eggs, larvae, and early juveniles of catostomid fishes in the Middle Rio Grande, New Mexico (data set for use with DELTA Intkey). Larval Fish Laboratory, Colorado State University, Fort Collins. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (to be posted in November 2019).
- Snyder, D. E., N. A. Auer, L. K. Kay, C. D. Kernehan, R. J. Kernehan, A. J. Lippson, R. C. Reyes, M. J. Scriptor, S. C. Seal, E. A. Sturm, and C. T. Wilcox. 2012. How well do we know the early life stages of our freshwater and anadromous fishes? Stages (Newsletter of the Early Life History Section of the American Fisheries Society) 33(2):6–10. (Extended abstract and tabulated summary of selected results from a paper presented at the 34th annual Larval Fish Conference, 31 May to 2 June 2010, Santa Fe, New Mexico—An initial assessment of descriptive information available for embryos, larvae, and early juveniles of fishes in fresh waters of the United States and Canada). Available: <https://earlylifehistory.fisheries.org/wp-content/uploads/2016/11/jun2012high.pdf> (November 2018).
- Snyder, D. E., K. R. Bestgen, and S. C. Seal. 2005. Native cypriniform fish larvae of the Gila River Basin—morphological descriptions, comparisons, and computer-interactive keys. Final Report of Colorado State University Larval Fish Laboratory to U.S. Bureau of Reclamation, Phoenix, Arizona. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (November 2018).
- Snyder, D. E., and S. C. Douglas. 1978. Description and identification of Mooneye, *Hiodon tergisus* protolarvae. Transactions of the American Fisheries Society 107:590–594.
- Snyder, D. E., and G. J. Holt. 1984. Terminology workshop report. Newsletter of the American Fisheries Society Early Life History Section 5(2):14–15.
- Snyder, D. E., and R. T. Muth. 1988. Description and identification of June, Utah, and Mountain Sucker larvae and early juveniles. Utah State Division of Wildlife Resources Publication 88-8, Salt Lake City. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/contribution-series/#037>; November 2018).
- Snyder, D. E., and R. T. Muth. 1990. Description and identification of Razorback, Flannelmouth, White, Utah, Bluehead, and Mountain Sucker larvae and early juveniles. Colorado Division of Wildlife Technical Publication 38. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/contribution-series/#038>; November 2018).
- Snyder, D. E., and R. T. Muth. 2004. Catostomid fish larvae and early juveniles of the Upper Colorado River Basin—morphological descriptions, comparisons, and computer-

- interactive key. Colorado Division of Wildlife Technical Publication 42. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (November 2018).
- Snyder, D. E., and S. C. Seal. 2004a onwards. Computer-interactive key to eggs, larvae, and early juveniles of native catostomid fishes in the Gila River Basin (data set for use with DELTA Intkey). Larval Fish Laboratory, Colorado State University, Fort Collins. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (November 2018).
- Snyder, D. E., and S. C. Seal. 2004b onwards. Computer-interactive key to eggs, larvae, and early juveniles of selected cyprinid fishes in the Gila River Basin (data set for use with DELTA Intkey). Larval Fish Laboratory, Colorado State University, Fort Collins. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (November 2018).
- Snyder, D. E., and S. C. Seal. 2008 onwards. Computer-interactive key to families of larval fishes in freshwaters of the United States and Canada (data set for use with DELTA Intkey). Larval Fish Laboratory, Colorado State University, Fort Collins. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (November 2018).
- Snyder, D. E., and S. C. Seal. 2015 onwards. Computer-interactive key to eggs, larvae, and early juveniles of cyprinid fishes in the Upper Colorado River Basin (data set for use with DELTA Intkey). Larval Fish Laboratory, Colorado State University, Fort Collins. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (November 2018).
- Snyder, D. E., S. C. Seal, and W. H. Brandenburg. 2019 onwards. Computer-interactive key to eggs, larvae, and early juveniles of cyprinid fishes in the Middle Rio Grande, New Mexico (data set for use with DELTA Intkey). Larval Fish Laboratory, Colorado State University, Fort Collins, and American Southwest Ichthyological Researchers, L.L.C., Albuquerque, New Mexico. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (to be posted in November 2019).
- Snyder, D. E., S. C. Seal, J. A. Charles, and C. L. Bjork. 2016. Cyprinid fish larvae and early juveniles of the Upper Colorado River Basin—morphological descriptions, comparisons, and computer-interactive key. Colorado Parks and Wildlife Technical Publication 47. Available: <https://warnercnr.colostate.edu/fwcb/larval-fish-laboratory/downloadable-keys-guides-bibliography/> (November 2018).
- Snyder, D. E., M. B. M. Snyder, and S. C. Douglas. 1977. Identification of Golden Shiner, *Notemigonus crysoleucas*, Spotfin Shiner, *Notropis spilopterus*, and Fathead Minnow, *Pimephales promelas*, larvae. *Journal of the Fisheries Research Board of Canada* 34:1397–1409.
- Stewart, N. H. 1926. Development, growth, and food habits of the White Sucker, *Catostomus commersoni* Le Sueur. *Bulletin of the U.S. Bureau of Fisheries* 42:147–184.
- Strauss, R. E. and F. L. Bookstein. 1982. The truss: body form reconstruction in morphometrics. *Systematic Zoology* 31:113–135.
- Sturm, E. A. 1988. Description and identification of larval fishes in Alaskan freshwaters. Master's thesis. University of Alaska, Fairbanks.

- Sturm, E. A. 2004. Identification of metalarval and juvenile fishes of Alaskan freshwaters. U.S. Geological Survey Alaska Cooperative Fish and Wildlife Research Unit, University of Alaska, Fairbanks.
- Sublette, J. E., M. D. Hatch, and M. Sublette. 1990. The fishes of New Mexico. University of New Mexico Press, Albuquerque.
- Suttkus, R.D., and R.C. Cashner. 1981. The intergeneric hybrid combination, *Gila pandora* x *Rhinichthys cataractae* (Cyprinidae), and comparisons with parental species. *Southwestern Naturalist* 26:78–81.
- Swee, U. B., and H. R. McCrimmon. 1966. Reproduction biology of the Carp, *Cyprinus carpio* L., in Lake St. Lawrence, Ontario. *Transaction of the American Fisheries Society* 95:372–380.
- Swift, S. M. 1996. Ecology and conservation of Rio Grande Sucker *Catostomus plebeius*. Master's thesis. Colorado State University, Fort Collins.
- Taber, C. A. 1969. The distribution and identification of larval fishes in the Buncombe Creek Arm of Lake Texoma with observations on spawning habits and relative abundance. Doctoral dissertation. University of Oklahoma, Norman.
- Tiemann, J. S. 2007. Reproductive traits in the Slim Minnow (*Pimephales tenellus*) and the Bullhead Minnow (*Pimephales vigilax*). *Transactions of the Kansas Academy of Science* 110:282–284.
- TPW (Texas Parks and Wildlife). 2011. Species of greatest conservation need. TPW, Austin. Available: https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/tcap/sgcn.phtml (November 2018).
- TPW. 2018. Federal and state listed species in Texas. TPW, Austin. Available: https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/listed-species/ (November 2018).
- Trautman, M. B. 1981. The fishes of Ohio with illustrated keys. Ohio State University Press, Columbus.
- Tucker, J. W., Jr., and J. L. Laroche. 1984. Radiographic techniques in studies of young fishes. Pages 37–39 in H. G. Moser, W. J. Richards, D. M. Cohen, M. P. Fahay, A. W. Kendall, Jr., and S. L. Richardson, editors. *Ontogeny and systematics of fishes*. American Society of Ichthyologists and Herpetologists Special Publication 1, Lawrence, Kansas.
- Twomey, K. A., K. L. Williamson, and P. C. Nelson. 1984. Habitat suitability index models and instream flow suitability curves: White Sucker. U.S. Fish and Wildlife Service FWS/OBS-82/10.64.
- Tyus, H. M., B. D. Burdick, R. A. Valdez, C. M. Haynes, T. A. Lytle, and C. R. Berry. 1982. Fishes of the Upper Colorado River Basin: distribution, abundance, and status. Pages 12–70 in W. H. Miller, H. M. Tyus, and C. A. Carlson, editors. *Fishes of the Upper Colorado River System: present and future*. American Fisheries Society, Western Division, Bethesda, Maryland.
- USDI (U.S. Department of Interior). 1994. Endangered and threatened wildlife and plants: final rule to list the Rio Grande Silvery Minnow as an endangered species. *Federal Register* 59: 138 (20 July 1994): 36988–36995.
- USFWS (U.S. Fish and Wildlife Service). 1999. Rio Grande Silvery Minnow Recovery Plan. USFWS, Albuquerque, New Mexico.
- USFWS. 2010. Rio Grande Silvery Minnow (*Hybognathus amarus*) Recovery Plan, First Revision. USFWS, Albuquerque, New Mexico.

- USFWS. 2014. Species status assessment report for the Rio Grande Cutthroat Trout. USFWS, Albuquerque, New Mexico.
- USFWS. 2018. Endangered species. USFWS, Falls Church, VA. Available: <https://www.fws.gov/endangered/species/us-species.html> (November 2018).
- Verma, P. 1970. Normal stages in the development of *Cyprinus carpio* Var. *communis* L. Acta Biologica Academiae Scientiarum Hungaricae 21(2):207–218.
- Wallus, R., and T. P. Simon. 2006. Reproductive biology and early life history of fishes in the Ohio River drainage, volume 5: Aphredoderidae through Cottidae, Moronidae and Sciaenidae. CRC Press, Boca Raton, Florida.
- Wallus, R., and T. P. Simon. 2008. Reproductive biology and early life history of fishes in the Ohio River drainage; volume 6: Elasmobranchidae and Centrarchidae. CRC Press, Boca Raton, Florida.
- Wallus, R., T. P. Simon, and B. L. Yeager. 1990. Reproductive biology and early life history of fishes in the Ohio River drainage, volume 1: Acipenseridae through Esocidae. Tennessee Valley Authority, Chattanooga.
- Wang, J. C. S. 1986. Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: A guide to the early life histories. California Department of Water Resources, Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Technical Report 9, Sacramento.
- Wang, J. C. S. 2007. Spawning, early life stages, and early life histories of the osmerids found in the Sacramento-San Joaquin Delta of California. Tracy Fish Facilities Studies, Volume 38. U.S. Bureau of Reclamation, Mid-Pacific Region, Byron, California, and Denver Technical Service Center, Denver, Colorado.
- Wang, J. C. S. 2010. Fishes of the Sacramento-San Joaquin River Delta and adjacent waters, California: a guide to early life histories. Tracy Fish Facility Studies, Volume 44—Special Publication. U.S. Bureau of Reclamation, Mid-Pacific Region, Byron, California, and Denver Technical Service Center, Denver, Colorado.
- Wang, J. C. S., and R. J. Kernehan. 1979. Fishes of the Delaware estuaries, a guide to the early life histories. Ecological Analysts, E. A. Communications, Towson, Maryland.
- Wang, J. C. S., and R. C. Reyes. 2007. Early life stages and life histories of cyprinid fish in the Sacramento-San Joaquin Delta, California: with emphasis on spawning by Splittail, *Pogonichthys macrolepidotus*. Tracy Fish Facility Studies, Volume 32. U.S. Bureau of Reclamation, Mid-Pacific Region, Byron, California.
- Wang, J. C. S., and R. C. Reyes. 2008. Early life stages and life histories of centrarchids in the Sacramento-San Joaquin River Delta System, California. Tracy Fish Facilities Studies, Volume 42. U.S. Bureau of Reclamation, Mid-Pacific Region, Byron, California, and Denver Technical Service Center, Denver, Colorado.
- Watson, J. M. 1939. The development of the Weberian ossicles and anterior vertebrae in the Goldfish. Proceedings of the Royal Society of London Series B Biological Sciences 123(849):452–472.
- Werner, R. G. 2004. Freshwater fishes of the northeastern United States. Syracuse University Press, Syracuse.
- Wheeler, C. A. 1997. Current distributions and distributional changes of fishes in Wyoming west of the continental divide. Master's thesis. University of Wyoming, Laramie.
- Widmer, A. M., L. L. Burckhardt, E. J. Gonzales, and M. D. Hatch. 2010. Fish community monitoring and fish sampling methodology evaluation final report: Task 1 report –

- assessment of current techniques to sample the fish assemblages of the Middle Rio Grande. Final Report of SWCA Environmental Consultants to U. S. Bureau of Reclamation Albuquerque Area Office, Albuquerque, New Mexico.
- Woodling, J. 1985. Colorado's little fish, a guide to the minnows and other lesser known fishes in the state of Colorado. Colorado Division of Wildlife, Denver, Colorado.
- Wrenn, W. B., and B. G. Grinstead. 1971. Larval development of the Smallmouth Buffalo, *Ictiobus bubalus*. Journal of the Tennessee Academy of Science 46:117–120.
- Wynne-Edwards, V. C. 1932. The breeding habits of the Black-headed Minnow (*Pimephales promelas* Raf.). Transactions of the American Fisheries Society 62:382–383.
- Yeager, B. L. 1980. Early development of the genus *Carpiodes* (Osteichthyes: Catostomidae). Master's thesis. University of Tennessee, Knoxville.
- Yeager, B. L., and J. M. Baker. 1982. Early development of the genus *Ictiobus* (Catostomidae). Pages 63–69 in C. F. Bryan, J. V. Conner, and F. M. Truesdale, editors. Fifth Annual Larval Fish Conference. Louisiana Cooperative Fishery Research Unit and The School of Forestry and Wildlife Management, Louisiana State University, Baton Rouge.
- Zuckerman, L. D. 1984. Rio Grande fishes management. Annual report, July 1983 to June 1984, of Colorado State University Department of Fishery and Wildlife Biology to Colorado Division of Wildlife, Denver.
- Zuckerman, L. D., and D. Langlois. 1990. Status of Rio Grande Sucker and Rio Grande Chub in Colorado. Colorado Division of Wildlife, Montrose. (Also earlier version, 1986: Pages 136–165 in J. Sartoris, editor. Collected papers from the 20th Annual Meeting, Colorado-Wyoming Chapter, American Fisheries Society (March 20–21, 1985), Laramie, Wyoming (publisher and publication location not given, assumed to be the same).

APPENDIX I

Glossary

(Reprinted from Snyder et al. 2016)

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

A – Abbreviation for anal fin.¹

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

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

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

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

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

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

Adnexed – Flaglike.³

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

Air bladder – See gas bladder; swim bladder.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

BL – Abbreviation for body length.¹

Blastocoel – Cavity of the blastula; segmentation cavity.¹

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

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

Blastomeres – Individual cells formed during cleavage.¹

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

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

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

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

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

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

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

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

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

C – Abbreviation for caudal fin.¹

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

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

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

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

Caudal fin – Tail fin.^{1,3}

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

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

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

Ceratohyal – See antero-hyal.³

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

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

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

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

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

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

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

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

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

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

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

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

D – Abbreviation for dorsal fin.¹

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

- Epihyal** – See postero-hyal.
- Epurals** – Modified vertebrae elements which lie above the vertebrae and support part of the caudal fin.^{2,3}
- Erythrophores** – Red or orange chromatophores.^{1,3}
- Esophagus** – Alimentary tract between pharynx and stomach.^{1,3}
- Eye diameter** – Horizontal measurement (distance) of the iris of the eye.^{2,3} [Horizontal diameter of the externally visible eye.]
- Falcate** – Deeply concave as a fin with middle rays much shorter than anterior and posterior rays.^{1,3} Scythe-shaped; referring to an anal fin.²
- Fin insertion** – [As used herein,] posterior-most point at which the fin attaches to the body.³ [More generally refers to entire margin of fin attachment to the body, the fin base.]
- Fin origin** – Anterior-most point at which the fin attaches to the body.³
- Finfold** – Median fold of integument which extends along body of developing fishes and from which median fins arise.^{1,3}
- FL** – Abbreviation for fork length.¹
- Flexion larva** – Phase between hatching and upward flexing of the tip of the notochord [or appearance of first caudal fin rays] (Ahlstrom et al. 1976).
- Flexion mesolarva** – Among fishes with homocercal tails, subphase of mesolarval development characterized by an incomplete adult complement of principal caudal-fin rays (posterior portion of notochord flexes upward and standard length measured to end of notochord) (Snyder and Muth 1988, 1990, 2004; see discussion on developmental interval terminology in introduction; presence of yolk indicated by an appropriate modifier).
- Focal point** – Location of a fish maintaining a stationary position on or off the substrate for at least a 10-second period.³
- Fontanelle** – A gap or space between bones in the roof of the skull covered only by a membrane.²
- Foramen** – An opening through a bone.²
- Fork length** – Distance measured from the anterior-most point of the head to the end of the central caudal rays.^{1,3} Distance from the most anterior point on the snout to the end of the shortest central caudal fin ray.²
- Frenum** – A fold of skin that limits movement of the upper jaw.^{2,3} [Bridge of tissue tightly connecting anterior portion of upper lip to fleshy portion of snout above (rather than being fully separated by a crease or groove between) and making premaxillaries non-protractile (upper lip not protrusible).]
- Ganoid scales** – Diamond- or rhombic-shaped scales consisting of bone covered with enamel.^{1,3}
- Gape** – The border of the mouth.² Distance between the tips of the open jaws of vertebrates (Pennak 1964). Width of gape is the greatest transverse distance across the opening of the mouth (Hubbs and Lagler 1958).
- Gas bladder** – Membranous, gas-filled organ located between the kidneys and alimentary canal [digestive tract or gut] in teleosts; air bladder or swim bladder.^{1,3}
- Gastrula** – Stage in embryonic development between blastula and embryonic axis.^{1,3}
- Germ ring** – The thickened rim of the blastoderm evident during late blastula and gastrula stages.¹
- Germinal disc** – The blastodisc.¹
- Gill arches** – See branchial arches.^{1,3}

- Gill rakers** – Various-shaped bony projections on anterior edge of the gill arches.^{1,3} Unless otherwise stated, counts are for all rakers on the first arch [external row] (Hubbs and Lagler 1958).
- Glossohyal** – A median bone of the tongue.²
- Granular yolk** – Yolk consisting of discrete units of finely to coarsely granular material.^{1,3}
- Greatest body depth** – Greatest vertical depth of the body excluding fins and finfolds.^{2,3}
- Guanophores** – White chromatophores; characterized by presence of iridescent crystals of guanine.^{1,3} [= iridophores.]
- Gular fold** – Transverse membrane across throat.^{1,3}
- Gular plate** – Ventral bony plate between anterior third of lower jaws, as in *Amia calva*.¹ Ventral bony plate on throat, as in *Amia calva*.³ Median ventral bony plate or plates located behind the chin and between the sides of the lower jaw.²
- Gular region** – Throat.³
- Haemal** – Relating to or situated on the side of the spinal cord where the heart and chief blood vessels are placed.³
- Head length** – Distance from anterior-most tip of head to posterior-most part of opercular membrane, excluding spine; prior to development of operculum, measured to posterior end of auditory vesicle.^{1,3} Distance from the most anterior point on the snout [including mouth] to the posterior edge of the auditory vesicle, cleithrum or opercle as each develop.² [As used herein, measured instead to the origin of the pectoral fin, or prior to formation of the pectoral fin buds, to the cleithrum.]
- Head width** – Greatest dimension between opercles.^{2,3} [Unless measured, as herein, at other specified locations such as middle of eye or just behind posterior margin of eye.]
- Heterocercal** – Tail in which the vertebral axis is flexed upward and extends nearly to tip of upper lobe of caudal fin; fin typically asymmetrical externally, upper lobe much longer than lower.^{1,3}
- HL** – Abbreviation for head length.¹
- Holoblastic** – Type of cleavage in which the entire egg, including the yolk, undergoes division.¹
- Homocercal** – Tail in which the vertebral axis terminates in a penultimate vertebra followed by a urostyle (the fusion product of several vertebral elements); fin perfectly symmetrical externally.^{1,3}
- Horizontal myoseptum** – Connective tissue dividing epaxial and hypaxial regions of the body;^{2,3} median myoseptum.³
- Hypaxial** – That portion of the body ventral to the horizontal myoseptum.^{2,3}
- Hypochord** – A transitional rod of cells which develops under the notochord in the trunk region of some embryos.^{1,3}
- Hypochordal** – Below the notochord; referring to the lower lobe of the caudal fin.^{2,3}
- Hypurals** – Expanded, fused, haemal spines of last few vertebrae which support the caudal fin.^{1,3} The expanded hemal spines of the posterior vertebrae which support most of the caudal fin.²
- Incipient** – Becoming apparent.^{2,3}
- Incubation period** – Time from fertilization of egg to hatching.^{1,3}
- Inferior mouth** – Snout projecting beyond the lower jaw.^{2,3} [As used herein, mouth that is horizontal (or nearly so) and distinctly on underside of head with lips well behind anterior margin of snout.]
- Insertion (of fin)** – See fin insertion.

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

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

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

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

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

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

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

Iridophores – See guanophores.

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

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

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

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

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

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

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

Larva – Young fish between time of hatching and attainment of minimum adult fin ray counts.¹ Young fish between time of hatching and attainment of juvenile characteristics.³ Encompasses both yolk-sac and post yolk-sac phases of development (Wallus et al. 1990). As used herein, period of fish development between hatching or birth and (1) acquisition of adult complement of fin spines and rays (principal and rudimentary) in all fins, and (2) loss beyond recognition of all finfold not retained by the adult (Snyder and Muth 1988, 1990, 2004; see discussion on developmental interval terminology in introduction; presence of yolk indicated by an appropriate modifier).

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

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

Lateral-line scales – Pored or notched scales associated with the lateral line.^{1,3} Count of pores in the lateral line, or the number of scales along the line in the position which would normally be occupied by a typical lateral line from the shoulder girdle to the structural base of the caudal fin (scales wholly on the caudal fin base not included in the count, even when well developed and pored) (Hubbs and Lagler 1958). [Second definition: lateral-series scales.]

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

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

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

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

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

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

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

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

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

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

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

Mesencephalon – Midbrain; serves optic functions.²

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

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

Metalarva – Phase of larval development characterized by presence of (1) adult complement of principal soft rays in all median fins and (2) pelvic-fin buds or pelvic fins (if present in adult) (Snyder and Muth 1988, 1990, 2004; see discussion on developmental interval terminology in introduction; presence of yolk indicated by an appropriate modifier; standard length measured to posterior end of axial skeleton, hypural elements or plates in fishes with homocercal tails).

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

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

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

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

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

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

Nape – Area immediately posterior to occipital region.¹

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

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

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

NL – Abbreviation of notochord length.¹

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

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

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

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

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

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

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

Opercle – Large posterior bone of the operculum.³

Operculum – Gill cover.³

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

Origin (or fin) – See fin origin.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Periblast – A layer of tissue between the yolk and cells of blastoderm which is observed as a thin border around blastula.¹

Pericardium – Cavity in which the heart lies.^{2,3}

Peritoneum – Membranous lining of abdominal cavity.^{1,2,3}

Perivitelline space – Fluid-filled space between egg proper and egg capsule.^{1,3} Fluid-filled space between the chorion and yolk material.²

Pharyngeal teeth – Teeth on the pharyngeal bones of the branchial skeleton.^{1,3} Bony tooth-like projections derived from the fifth (pharyngeal) gill arch.² In cyprinids, both left and right arches bear 1–3 rows of teeth; counts for each row and arch are given in a formula in order from left to right [rows separated by commas, arches by a dash] (Hubbs and Lagler 1958).

Physoclistic – Having no connection between the esophagus and the pneumatic duct [of the swim (air or gas) bladder]; typical of perciform fishes.³

Physostomus – Having the swim bladder connected to the esophagus by the pneumatic duct;^{2,3} typical of cypriniform fishes.³

Plicae – Wrinkle-like folds found on the lips of some catostomids.^{2,3}

Post yolk-sac larva – Phase beginning with complete absorption of the yolk and ending when a minimum adult complement of rays is present in all fins and the median finfold is completely absorbed (Wallus et al. 1990).

- Postanal length** – Distance from posterior margin of anus [or vent] to the tip of the caudal fin,^{2,3} or median finfold.²
- Postanal myomeres** – The number of myomeres between posterior margin of anus and the most posterior myoseptums.¹ Number of whole myomeres posterior to an imaginary vertical line at the most posterior point of the anus [vent],^{2,3} including one urostylar element; the first postanal myomere is the first myomere behind and not touched by the imaginary line.³ [The last myomere lies immediately anterior to the most posterior complete myoseptum.]
- Postero-hyal** – Posterior bone to which branchiostegal rays attach, formerly epihyal.^{2,3}
- Postflexion larva** – Phase following upward flexion of the tip of the notochord [more precisely considered to begin with formation of all principal caudal fin rays] (Ahlstrom et al. 1976).
- Postflexion mesolarva** – Among fishes with homocercal tails, subphase of mesolarval development characterized by adult complement of principal caudal-fin rays (notochord flexion essentially complete and standard length measured to posterior-most margin of hypural elements or plates) (Snyder and Muth 1988, 1990, 2004; see discussion on developmental interval terminology in introduction; presence of yolk indicated by an appropriate modifier).
- Postorbital length** – Distance from posterior margin of eye to posterior edge of opercular membrane.^{2,3} [Or to origin of pectoral fin, depending on criteria for head length.]
- Preanal length** – Method of measuring often not stated, assumed to be about equivalent to snout to vent length in larvae.¹ Distance from anterior-most part of head to posterior margin of anus.^{2,3} [Snout-to-vent length, herein measured to posterior margin of vent.]
- Preanal myomeres** – The number of myomeres between the anterior-most myoseptum^{1,3} and the posterior margin of anus¹ or an imaginary vertical line drawn at the posterior margin of anus, including any bisected by the line.³ Number of myomeres from the nape to, and including any myomeres bisected by an imaginary vertical line at the most posterior point of the anus.² [As used herein, the most anterior myomere, which is mostly an epaxial unit, is located immediately behind the occiput and often deltoid in shape (somewhat wider at the top), and the last is the most posterior myomere transected by a vertical line from the posterior margin of the vent.]
- Prebranchial length** – In petromyzontids, distance between the tip of the snout and the anterior margin of the first gill opening.²
- Predorsal length** – Distance from the most anterior point on the snout to the anterior margin of the base [origin] of the first dorsal fin ray when formed.²
- Predorsal myomeres** – Number of myomeres from nape to dorsal origin of median finfold.² [Or, to origin of the dorsal fin once anterior-most pterygiophores or fin rays are formed.]
- Predorsal scales** – Scales along dorsal ridge from occiput to origin of dorsal fin.^{1,3}
- Preflexion larva** – Phase between hatching and upward flexing of the tip of the notochord [or appearance of first caudal fin rays] (Ahlstrom et al. 1976).
- Preflexion mesolarva** – Among fishes with homocercal tails, subphase of mesolarval development characterized by absence of caudal-fin rays (posterior portion of notochord remains essentially straight and standard length measured to end of notochord; when first median-fin ray is a caudal ray, as in most fishes, larva progresses directly from protolarva to flexion mesolarva) (Snyder and Muth 1988, 1990, 2004; see discussion on

- developmental interval terminology in introduction; presence of yolk indicated by an appropriate modifier).
- Prejuvenile** – Developmental stage [phase] immediately following acquisition of minimum fin ray complement of adult and before assumption of adult-like body form; used only where strikingly different from juvenile^{1,3} (*cf.* Hubbs, 1958; *Tholichthys* stage of butterflyfishes, *querimana* stage of mullets, etc.).¹ [Transitional phase.]
- Premaxilla, premaxillary** – The ventral-most of the two bones included in the upper jaw.^{1,3}
Primary bone of the upper jaw in most fish, usually bearing teeth.²
- Preorbital** – Large bone anterior to the eye.²
- Primordium** – Rudimentary form of an anatomical structure; anlage.^{1,3}
- Principal anal- and dorsal-fin rays** – In certain fishes, particularly the Cyprinidae and Catostomidae, . . . the principal rays include the branched rays plus one unbranched ray [the anteriorly adjacent, usually longest, unbranched ray]; . . . the last two bases [branched rays, both of which articulate with the most posterior pterygiophore] are counted as one ray (Hubbs and Lagler 1958). [In traditional fin-ray count formulas, represented by Arabic numerals.]
- Principal caudal [-fin] rays** – Caudal rays inserting on hypural elements; the number of principal rays is generally defined as the number of branched rays plus two [adjacent unbranched rays, one above and one below the branched rays].^{1,3} [In traditional fin-ray count formulas, represented by Arabic numerals.]
- Procurrent caudal rays** – A series of much shorter rays anterior to the principal caudal rays, dorsally and ventrally, not typically included in the margin of the caudal fin.^{1,3}
[Rudimentary or secondary rays of the caudal-fin; in traditional fin-ray count formulas, represented by lower case Roman numerals (dorsal before and ventral after principal ray count, separated by commas.)]
- Pronephric ducts** – Ducts of pronephric kidney of early developmental stages.^{1,3}
- Protolarva** – Phase of larval development characterized by absence of dorsal-, anal-, and caudal-fin spines and rays (Snyder and Muth 1988, 1990, 2004; see discussion on developmental interval terminology in introduction; presence of yolk indicated by an appropriate modifier; standard length measured to end of notochord).
- Protractile** – Describing premaxillae which can be extended.² [Protrusible.]
- Pterygoid** – Dermal bone of the upper jaw.²
- Pterygiophores** – Bones of the internal skeleton supporting the dorsal and anal fins.^{2,3}
- Redd** – An excavated area or nest into which trout spawn.³
- Retrorse** – Pointing backward.³
- Rostrum** – Snout.³
- Rudimentary fin rays** – [In certain fishes, particularly the Cyprinidae and Catostomidae, size-graded series of shorter, unbranched soft rays anterior to the principal rays of the dorsal, anal, and caudal fins; also called secondary rays or, in the case of the caudal fin, procurrent rays; in traditional fin-ray count formulas, represented by lower case Roman numerals and separated from the principal ray count, in Arabic, by commas.]
- Saddle markings** – Pigment patterns which cover the dorsal and lateral aspects and give an overall appearance of a saddle.²
- Secondary fin rays** – See rudimentary fin rays, and with respect to the caudal fin, procurrent rays.
- Scute** – A modified, thickened scale, often spiny or keeled.^{1,3}

Semibuoyant – Referring to eggs which neither float nor sink, but remain suspended in the water column.^{2,3}

Sigmoid heart – The S-shaped heart which develops from the primitive heart tube.^{1,3}

SL – Abbreviation for standard length.¹

Snout – [Portion of head anterior to eyes and, as used herein, including the portion of the mouth anterior to the eyes (often used in reference only to the fleshy anterior extension of the head above the mouth including the nares).]

Snout-to-vent length – Distance from anterior-most part of head to posterior margin of anus [vent]; the precise method of measurement often not stated.¹ [See preanal length.]

Soft rays – Bilaterally paired, usually segmented, fin supports.^{1,3} [See lepidotrichia; in traditional fin-ray count formulas, principal soft rays of median fins or all rays of paired fins represented by Arabic numerals.]

Somites – Primitive, segmented, mesodermal tissue along each side of notochord.¹ [Consists in part of future myomeres.]

Spatulate – Having a rounded apex and tapering to a base; spoon-shaped.²

Spines – Unpaired [uniserial, not bilaterally divided], unsegmented, unbranched fin supports, usually (but not always) stiff and pungent.^{1,3} [In traditional fin-ray count formulas, represented by upper case Roman numerals, and if part of a fin with both spines and soft rays, separated from such by a comma, or if in a fully separated section of the fin (e.g., first dorsal fin of some perciform fishes), separated by a dash.]

Spinous rays – [In certain otherwise soft-rayed fish, soft rays that during embryonic or larval development are thickened, fused, and hardened into spine-like structures, sometimes with moderate to strong serrations or barbs along their posterior margins (e.g., spines at the anterior margins of the dorsal and pectoral fins in catfishes, order Siluriformes, dorsal and anal fins in Goldfish *Carassius auratus* and Common Carp *Cyprinus carpio*, and dorsal fins of the spiny-rayed cyprinids, tribe Plagopterini, for which the basal portions of certain other dorsal, pelvic, and pectoral fin rays also exhibit spine-like modifications—Hubbs and Lagler 1958, Lagler et al. 1962, and Miller and Hubbs 1960). In formulas for fin-ray counts, fully spinous rays may designated by Roman numerals like true spines.]

Squamation – Covering of scales.^{2,3}

Standard length – In larvae, straight-line distance from anterior-most part of head to end of hypural elements; not applicable to larvae prior to [or during] notochord flexion (in juveniles and adults measured from most anterior point of snout or upper lip.)¹ In larvae, straight-line distance from anterior-most part of head to the most posterior point of the notochord or hypural complex.^{2,3} [As used herein for fish with homocercal tails, includes notochord length prior to formation of all principal caudal fin rays which signals the end of notochord flexion.]

Stellate – Referring to a melanophore [with pigment] which is expanded into a starlike shape.^{2,3}

Stomodeum – Primitive invagination of the ectoderm which eventually gives rise to the mouth.^{1,3} Primordial mouth; the anterior pitted portion of the embryonic gut.²

Submandibular – Beneath the lower jaw; along the edge of the lower jaw.²

Subterminal mouth – [As used herein, mouth that is slightly oblique to horizontal with anterior margin of upper lip at or below bottom-of-eye level and lips slightly to moderately preceded or overhung by anterior margin of snout; between low-terminal and inferior positions.]

Superior mouth – Condition when the lower jaw extends upward and the mouth opens dorsally.^{2,3} [As used herein, mouth that is strongly oblique with anterior end of upper lip above middle-of-eye level and lower jaw usually the most anterior margin of snout.]

Supramaxilla – Small dermal bone attached posterior and dorsal to the maxilla.²

Supraoral – Above the mouth; referring to the teeth of the oral disc in lampreys which are anterior to the mouth opening.²

Supraoral tooth plate – In petromyzontids, tooth plate immediately anterior to esophageal opening.²

Swim bladder – See gas bladder.

Sympatric – Species inhabiting the same or overlapping geographic areas.³

Tail-bud stage – Stage of embryonic development characterized by a prominent caudal bulge and marked development of cephalic region.¹

Tail-free stage – Stage of embryonic development characterized by separation of the tail from the yolk.¹

Tail length – In petromyzontids, distance from cloacal slit to tip of caudal fin.²

Teleosts – Bony fishes.³

Terminal mouth – Condition when lower and upper jaws are equal in length and the mouth opens terminally.^{2,3} [As used herein, mouth that is moderately oblique with anterior end of upper lip above bottom-of-eye to middle-of-eye level, lips usually even with or the most anterior margin of snout (sometimes slightly behind anterior margin of snout).]

Tessellated – Markings or colors arranged into squares.²

TL – Abbreviation for total length.¹

Total length – Straight-line distance from anterior-most part of head to tip of tail.^{1,3} Distance from the most anterior point on the snout to the most posterior point on the caudal fin or finfold.²

Truncate – Ending abruptly along a vertical line.² Terminate abruptly as if the end were cut off.³

Trunk length – In petromyzontids, distance between posterior margin of last gill opening and cloacal slit.²

Trunk myomeres – In petromyzontids, myomeres between the most posterior gill opening and the cloacal slit.²

Urostyle – Terminal vertebral element in higher teleosts, derived from the fusion and loss of several of the most posterior centra of the more primitive forms;^{1,3} usually modified for caudal fin support.³ Final vertebral segment usually modified for caudal fin support.²

V [or P2] – Abbreviation for the ventral or pelvic fin.¹

Vent – Anus.^{1,3} [Cloacal aperture, includes both anus and end of the uro-genital duct.]

Ventral fins – Paired fins articulating with the pelvic girdle; pelvic fins.¹

Vermiculate – Having wormlike markings.^{2,3}

Villiform – In the form of finger-like projections.²

Vitelline membrane – After water hardening, the membrane surrounding the egg proper (animal and vegetal material).²

Vitelline vessels – Arteries and veins of yolk region.^{1,3}

Vomer – Anterior, median bone of the roof of the mouth (= prevomer).²

Water-hardening – Expansion and toughening of egg capsule due to absorption of water into the perivitelline space.^{1,3} Process of membrane delamination and fluid formation which forms the perivitelline space bordered by the chorion and vitelline membrane.²

Weberian vertebrae – First four vertebrae in cyprinids, catostomids, and ictalurids which are modified to connect the swim bladder to the inner ear.²

Width of perivitelline space – Distance between yolk and egg capsule expressed either as direct measurement or a ratio of the egg diameter.¹ Distance between yolk and outer margin of egg capsule.³ [Technically, measured instead to the inner surface of the chorion.]

Xanthophores – Yellow chromatophores.^{1,2,3}

Yearling – A fish in its second year.³

Yolk – Food reserve of embryonic and early larval stages, usually seen as a yellowish sphere diminishing in size as development proceeds.^{1,3}

Yolk diameter – Greatest diameter of yolk; more accurately measurable prior to embryo formation.^{1,3}

Yolk plug – Yolk within the blastopore.¹

Yolk sac – A bag-like ventral extension of the primitive gut containing the yolk.^{1,3}

Yolk-sac larva – A larval fish characterized by the presence of a yolk-sac.^{1,3} Phase of development from the moment of hatching to complete absorption of the yolk (Wallus et al. 1990).

Yolk-sac length – Horizontal distance from most anterior to most posterior margin of yolk sac.^{2,3}

Yolk-sac depth – Vertical distance from dorsum to venter of yolk sac.²

APPENDIX II

Prior Descriptions of Larvae for Cypriniform Fishes in the Middle Rio Grande

Prior descriptions, comparisons, or guides for larvae of cypriniform fishes currently known or possibly still present in the Middle Rio Grande are listed below by species and ordered by publication year. Species listed in bold type are covered and further described in this guide. In addition to the listed references, Snyder (1979) and Conner et al. (1980) summarized myomere and vertebra counts for many of these species.

Cyprinids

- Campostoma anomalum*, Central Stoneroller—Kraatz (1924), Fish (1932, wrong species), Reed (1958), May and Gasaway (1967), Hogue et al. (1976), Loos et al. (1979), Perry (1979), Perry and Menzel (1979), Buynak and Mohr (1980b), Heufelder and Fuiman (1982), and Fuiman et al. (1983).
- Carassius auratus*, Goldfish—Khan (1929), Watson (1939), Battle (1940), Okada (1960), Mansueti and Hardy (1967), May and Gasaway (1967), Nakamura (1969), Lippson and Moran (1974), Jones et al. (1978), Loos et al. (1979), Wang and Kernehan (1979), Heufelder and Fuiman (1982), Fuiman et al. (1983), Gerlach (1983), Wang (1986), Pinder (2001), Wang and Reyes (2007), and Arvidson and Alber (2013); others cited by some of these.
- Cyprinella lutrensis*, Red Shiner**—Saksena (1962), Taber (1969), Loos and Fuiman (1978), Perry (1979), Perry and Menzel (1979), Snyder (1981) Fuiman et al. (1983), Wang (1986), Holland-Bartels et al. (1990), Snyder et al. (2005), Wang and Reyes (2007), Feeney and Swift (2008), Snyder et al. (2016), and Brandenburg et al. (2018a).
- Cyprinus carpio*, Common Carp**—Ehrenbaum (1909), Nordqvist (1914), Smallwood and Smallwood (1931), Fish (1932), Smallwood and Derrickson (1933), Hikita (1956), Balon (1958), Bragensky (1960), Okada (1960), Itazawa (1963), Mansueti and Hardy (1967), May and Gasaway (1967), McCrimmon and Swee (1967), Nakamura (1969), Taber (1969), Verma (1970), Hoda and Tsukahara (1971), Lippson and Moran (1974), Hogue et al. (1976), Jones et al. (1978), Jude et al. (1979), Loos et al. (1979), Wang and Kernehan (1979), Conner et al. (1980), Snyder (1981), Heufelder and Fuiman (1982), Fuiman et al. (1983), Gerlach (1983), Penaz et al. (1983), Wang (1986), McGowan (1988), Holland-Bartels et al. (1990), Scheidegger (1990), Nakatani et al. (2001), Pinder (2001), Snyder et al. (2005), Faber (2006 onwards), Wang and Reyes (2007), Korwin-Kossakowski (2008), Arvidson and Alber (2013), Snyder et al. (2016), and Brandenburg et al. (2018a); others cited by some of these.
- Dionda espiscopa*, Roundnose Minnow—Brandenburg et al. 2018a.
- Gila pandora*, Rio Grande Chub**—not previously described.
- Hybognathus amarus*, Rio Grande Silvery Minnow**—Platania (1995, 2000), and Brandenburg et al. (2018a, modification of account herein).
- Notemigonus crysoleucas*, Golden Shiner—Fish (1932, wrong illustration), Fowler (1945), Mansueti and Hardy (1967), Lippson and Moran (1974), Hogue et al. (1976), Snyder et al. (1977), Jones et al. (1978), Loos et al. (1979), Wang and Kernehan (1979), Buynak and Mohr (1980a), Faber (1980), Heufelder and Fuiman (1982), Fuiman et al. (1983),

McGowan (1984), Conrow and Zale (1985), Wang (1986), McGowan (1988), Holland-Bartels et al. (1990), Scheidegger (1990), Faber (2006 onwards), Wang and Reyes (2007), Scriptor (2009, wrong embryo illustration), Arvidson and Alber (2013), Snyder et al. (2016), and Brandenburg et al. (2018a).

***Pimephales promelas*, Fathead Minnow**—Fish (1932), Andrews (1970); Hogue et al. (1976), Snyder et al. (1977), Buynak and Mohr (1979b), Perry (1979), Perry and Menzel (1979), Snyder (1981), Heufelder and Fuiman (1982), Fuiman et al. (1983), Wang (1986), Holland-Bartels et al. (1990), Remple and Markle (2005), Snyder et al. (2005), Wang and Reyes (2007), Feeney and Swift (2008), Snyder et al. (2016), and Brandenburg et al. (2018a).

***Pimephales vigilax*, Bullhead Minnow**—Taber (1969), Heufelder and Fuiman (1982), Fuiman et al. (1983), Holland-Bartels et al. (1990), and Scheidegger (1990).

***Platybio gracilis*, Flathead Chub**—not previously described.

***Rhinichthys cataractae*, Longnose Dace**—Fish (1932, *R. atratulus*), Bartnik (1970), Fuiman and Loos (1977), Cooper (1978, 1980), Buynak and Mohr (1979a), Loos et al. (1979), Snyder (1981), Heufelder and Fuiman (1982), Fuiman et al. (1983), and Snyder et al. (2016).

Catostomids

***Carpionodes carpio*, River Carpsucker**—May and Gasaway (1967), Yeager (1980), Fuiman (1982a), Holland-Bartels et al. (1990), and Kay et al. (1994).

***Catostomus commersonii*, White Sucker**—Crawford (1923), Stewart (1926), Fish (1929, 1932), Mansueti and Hardy (1967), Lippson and Moran (1974), Long and Ballard (1976), Buynak and Mohr (1978), Fuiman (1978), Jones et al. (1978), Fuiman (1979), Loos et al. (1979), Wang and Kernehan (1979), McElman and Balon (1980), Snyder (1981), Fuiman (1982a), Holland-Bartels et al. (1990), Snyder and Muth (1990), Kay et al. (1994), Snyder (1998), Snyder and Muth (2004), and Arvidson and Alber (2013).

***Catostomus plebeius*, Rio Grande Sucker**—Snyder (1998).

***Ictiobus bubalus*, Smallmouth Buffalo**—Wrenn and Grinstead (1971), Hoyt et al. (1979), Yeager (1980), Fuiman (1982a), Yeager and Baker (1982), Holland-Bartels et al. (1990), Scheidegger (1990), and Kay et al. (1994).

APPENDIX III

Specimens Analyzed for this Guide and Sources of Reared Developmental Series

The following is a list of the total number of specimens analyzed in detail for each species described herein (N, including drawing specimens, specimens analyzed for prior versions of the species accounts, and protolarvae with unpigmented eyes that were not included in account morphometric and meristic summaries) and, if catalogued or removed from catalogued lots, the associated Larval Fish Laboratory Collection (LFL) or Museum of Southwestern Biology (MSB) catalog numbers followed in parentheses by the number of analyzed specimens if more than one. Cataloged lots for or including primary drawing specimens are denoted by an asterisk, followed by a superscript number if more than one. Note that many cyprinid larvae analyzed for description (most for a few species) are part of recent developmental series reared or field collections made primarily for this project and were not yet to be cataloged as part of the LFL Collection at the time this list was prepared. Also listed are the sources of both older and more recently reared developmental series maintained by MSB or LFL for study and reference, including many from which specimens were used for descriptions in this guide.

Cyprinidae

Cyprinella lutrensis, Red Shiner—N = 115; LFL catalog numbers: 48862(2)*, 72788(3)*, 72789, 72791, 72793, 72794, 72796, 72804, 72822, 72824(2), 72828(4)*, 72831(2), 72833, 72848(2), 97880(2), 97881*, 97898(5)*². Developmental series were reared in-house (LFL) by Colorado State University (CSU) graduate student Michelle McGree from aquarium-spawned eggs through yolk absorption in 2006 and by LFL staff in 2007 and 2008 with parental stock from Cache la Poudre River east of Fort Collins, CO.

Cyprinus carpio, Common Carp—N = 84; LFL catalog numbers: 2974(2), 7218(2), 8515*, 11784, 23421, 26390, 31315*, 31319, 41010, 73048(2)*, 73050, 73051, 73052(2), 73055, 73061, 73063, 73064, 73069, 73077, 82258, 82354*, 82400, 87799*, 88897*. A developmental series was reared in-house in 2007 from naturally fertilized eggs collected locally at River Bend Ponds, Fort Collins, CO.

Gila pandora, Rio Grande Chub—N = 55; LFL catalog numbers: 80202, 80206(2), 80212, 80221, 80254, 89537, 89540, 89833*, 105726*, 105727–105729, 105731(2), 105732(2)*, 105735, 105736*, 105737, 105740, 105741, 105742(2)*, 105743–105746, 105748(2)*, 105749(2), 105751(2), 105752, 105754, 105755*. Developmental series were reared by Colorado Parks and Wildlife (CPW) Mumma Native Aquatic Species Restoration Facility (CPW-NASRF, Alamosa, CO) in 2007 with parental stock from Hot Creek (Rio Grande drainage), Conejos County, CO, and in-house in 2010 from live week-old and later larvae provided by CPW-NASRF (to complement the earlier series) with brood stock from a Rio Grande tributary (Hot Creek, Rio San Antonio, or Roaring Fork Pond) in Conejos or Mineral Co., CO.

Hybognathus amarus, Rio Grande Silvery Minnow—N = 89; MSB catalog number: 30824(4), 39153(4), 49967(64, reared series)*⁸; additional wild specimens from Rio Grande Silvery Minnow Population Monitoring collections, MSB Accession number 1993-VIII:27, field numbers: RKD06-118(3), RKD06-137(3), RKD07-076(9), RKD07-077(2), RKD08-046(3), RKD08-076(1). Developmental series were reared by MSB (Steven Platania) in

1994 with parental stock from the Rio Grande east of Socorro, NM, (MSB 49967) and, for LFL reference, by the U.S. Fish and Wildlife Service Dexter National Fish Hatchery and Technology Center, NM, (DNFHTC, now Southwestern Native Aquatic Resources and Recovery Center) in 2006 and juveniles in 2009 with brood stock from the Rio Grande; also a juvenile series by the Albuquerque Biological Park Rio Grande Silvery Minnow Rearing and Refugia Facility, NM, in 2009.

Pimephales promelas, Fathead Minnow—N = 42; LFL catalog numbers: 72860(3)*, 72865(4), 72869(2), 72876, 72877*, 72878(2), 72880(2), 72881, 72899, 72900, 72904, 72909, 72913, 72924, 72930, 72933, 72935, 72959, 72962(3), 72966, 72968, 72976, 82227*. A developmental series was reared in-house through early larvae in 2006 from fertilized eggs provided by Aquatic BioSystems, Inc., Fort Collins, CO.

Pimephales vigilax, Bullhead Minnow—N = 73; LFL catalog numbers: 43011(3)*. A developmental series was reared by DNFHTC in 2010 with parental stock from Elephant Butte Reservoir, Rio Grande, Sierra Co., NM.

Platygobio gracilis, Flathead Chub—N = 64; LFL catalog numbers: 80270*, 80787, 96324, 96377, 96405, 99685, 99727, 99727*, 99765. Developmental series were reared in-house (Kevin Bestgen) in 2009 with stock from Fountain Creek, El Paso Co., CO, and by DNFHTC in 2010 with stock from Lower San Juan Drain outfall to the Rio Grande, Sandoval Co., NM.

Rhinichthys cataractae, Longnose Dace—N = 59; LFL catalog numbers: 68648, 80190, 80215, 80239*, 80246, 89551(2), 99726, 99755, 99954(3), 99958, 102857. Developmental series were reared in-house in 2007 and 2008 from trough-spawned eggs with parental stock from Cache la Poudre River, Fort Collins, CO.

Catostomidae

Catostomus commersonii, White Sucker—per Snyder and Muth (2004): N = 79; LFL catalog numbers (study series, not all analyzed): 69104–69217, 69218*, 69219, 69220, 69221*, 69222–69224, 69225*, 69226, 69227, 69228*, 69229*. A developmental series was reared in-house by CSU graduate student Edmund Wick in 1979 with stock from a private pond (Louis Swift) near Fort Collins, CO.

Catostomus plebeius, Rio Grande Sucker—N = 81; LFL catalog numbers 102924, 102925, 102926*, 67279*, 67280–67313, 67314*, 67315–67321, 67322*, 67323, 67324, 67325*, 67326–67333, 67334*, 67335–67341, 67342*, 67343–67348, 67349*, 67350*, 67351; MSB catalog numbers: 9567(3), 13582(2). A developmental series was reared by the Colorado Division of Wildlife Bellvue Research Hatchery near Fort Collins in 1995 with parental stock from Hot Creek (Rio Grande drainage), Conejos Co., CO; also a series of recently hatched larvae was reared by CPW-NASRF in 2006 with stock from Rio de las Vacas, Sandoval Co., NM.

(No specimens analyzed for *Carpionodes carpio*, River Carpsucker, or *Ictiobus bubalus*, Smallmouth Buffalo—all data and illustrations extracted from prior descriptions by others based on specimens reared from Alabama or Arkansas stock. No reared developmental series were maintained by MSB or the LFL Collection.)

APPENDIX IV

Pictorial Guide to Families of Fish Larvae in the Middle Rio Grande, New Mexico

(Modified with permission from Wallus et al. 1990
for only extant families found in the Middle Rio Grande, New Mexico)

Larvae with yolk

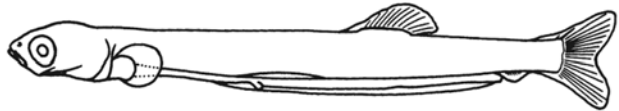
Larvae without yolk

CLUPEIDAE—herrings

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

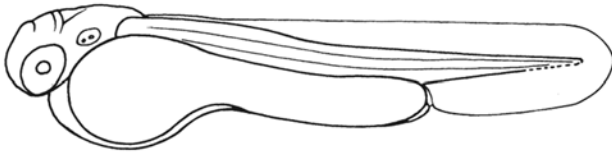


- slender, little pigment
- posterior vent
- anal fin posterior to dorsal fin
- [posterior gut vertically striated]

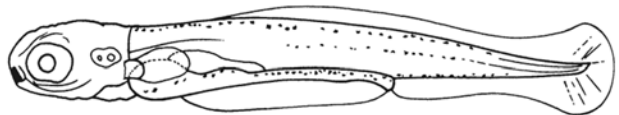


CYPRINIDAE—carps and minnows

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



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



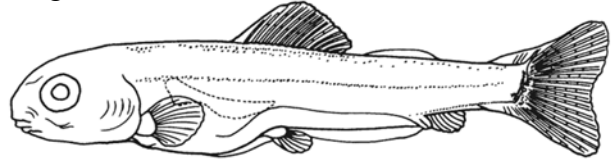
Larvae with yolk

Larvae without yolk

CATOSTOMIDAE—suckers

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

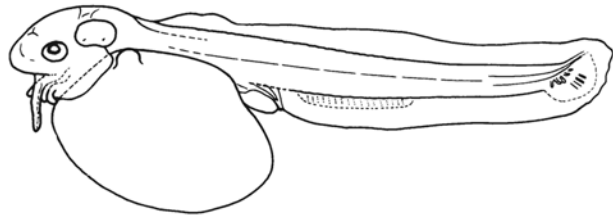
- mouth shape and position varies from terminal and oblique to inferior (later in development)
- pigment variable but often in three rows, dorsally, ventrally, and midlaterally; dorsal pigment may also be in 1–3 rows
- air bladder obvious
- single dorsal fin



ICTALURIDAE—North American catfishes (also LORICARIIDAE—suckermouth armored catfishes)

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

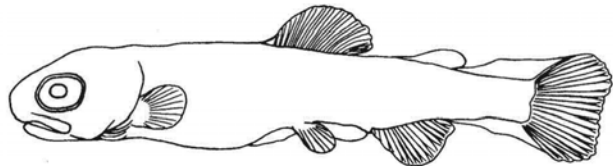
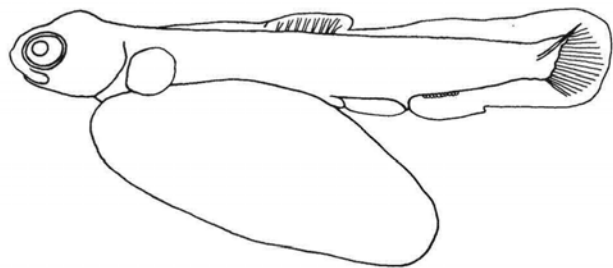
- [sometimes] no post yolk-sac larval phase [earliest juveniles of some still have yolk, but larvae of others may absorb all yolk before the adipose fin is fully differentiated from remnant finfold or all rudimentary caudal-fin rays are formed]



SALMONIDAE—trouts and salmons

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

- robust
- large, rounded head
- adipose fin



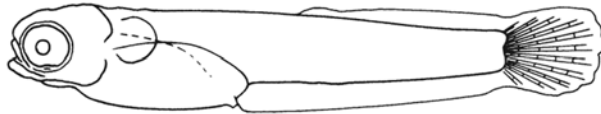
Larvae with yolk

Larvae without yolk

FUNDULIDAE—topminnows

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

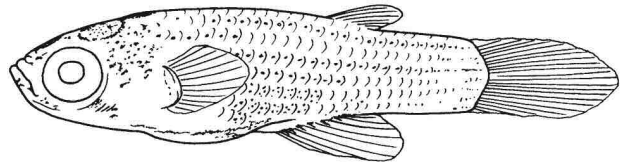
- large head
- superior mouth
- rounded caudal fin
- stocky caudal peduncle
- 10 or more dorsal rays [later larvae]



POECILIIDAE—livebearers

- inside female

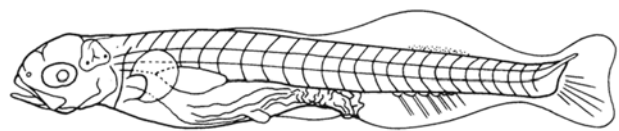
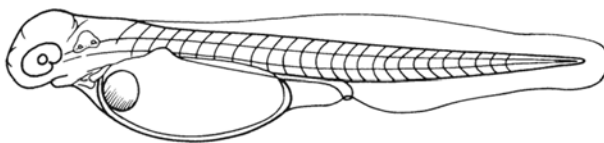
- scales present at birth
- rays in all fins at birth [except pelvic fins]
- superior mouth
- dorsal fin short, 7–8 rays



MORONIDAE—temperate basses

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

- S-shaped gut
- low myomere count
- late larvae with well developed mouth with teeth
- spinous dorsal fin develops secondarily [later larvae]

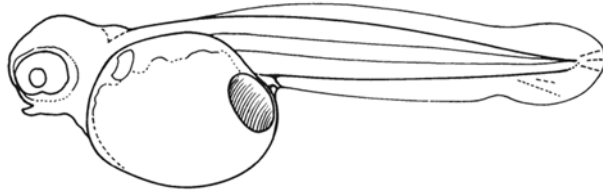


Larvae with yolk

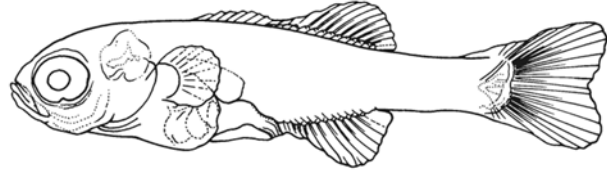
Larvae without yolk

CENTRARCHIDAE—sunfishes

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

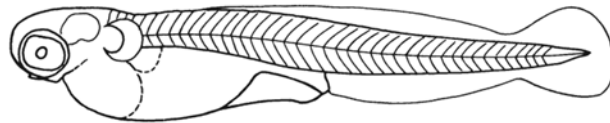


- usually robust with large head
- air bladder distinct
- gut short, coils with growth
- spinous and soft dorsal fins continuous [later larvae]

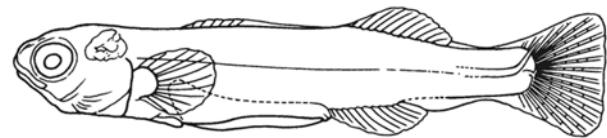


PERCIDAE—perches and darters

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



- large pectoral fins
- spinous dorsal separate from soft dorsal fin [later larvae]



USB MEMORY STICK OR CARD— COMPUTER-INTERACTIVE KEYS

[Inside back cover of printed versions of the guide]