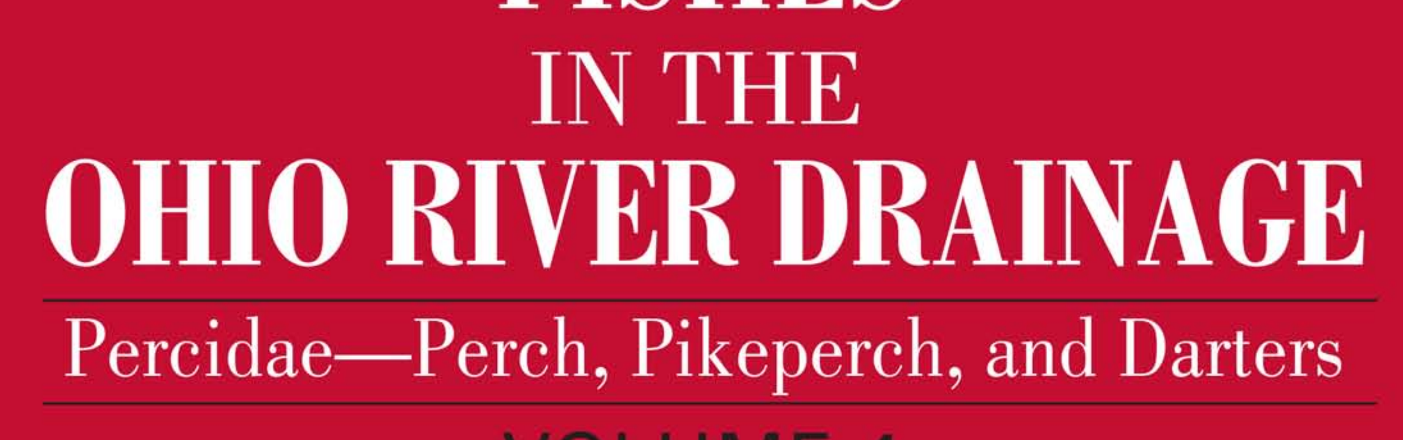
REPRODUCTIVE BIOLOGY AND EARLY LIFE HISTORY OF FISHES IN THE OHIO RIVER DRAINAGE

Percidae—Perch, Pikeperch, and Darters

VOLUME 4



Thomas P. Simon
Robert Wallus

CRC Taylor & Francis
Taylor & Francis Group

REPRODUCTIVE BIOLOGY
AND
EARLY LIFE HISTORY
OF
FISHES
IN THE
OHIO RIVER DRAINAGE

Percidae—Perch, Pikeperch, and Darters

VOLUME 4

REPRODUCTIVE BIOLOGY AND EARLY LIFE HISTORY OF FISHES IN THE OHIO RIVER DRAINAGE

Percidae—Perch, Pikeperch, and Darters

VOLUME 4

Thomas P. Simon
Robert Wallus

CRC
Taylor & Francis
Taylor & Francis Group
Boca Raton London New York

A CRC title, part of the Taylor & Francis imprint, a member of the Taylor & Francis Group, the academic division of T&F Informa plc.

Published in 2006 by
CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number-10: 0-8493-1920-X (Hardcover)
International Standard Book Number-13: 978-0-8493-1920-4 (Hardcover)
Library of Congress Card Number 2003055777

Library of Congress Cataloging-in-Publication Data

Simon, Thomas P.
Reproductive biology and early life history of fishes in the Ohio River drainage / Thomas P. Simon and Robert Wallus.
p. cm.
Rev. ed. of Reproductive biology and early life history of fishes in the Ohio River drainage / principal authors, Robert Wallus, Bruce L. Yeager. 1990.
Description based on: v. 3 published in 2003.
Includes bibliographical references (p.).
ISBN 0-8493-1920-X (alk. paper)
1. Fishes--Ohio River--Reproduction. 2. Fishes--Ohio River--Development. I. Wallus, Robert. II. Wallus, Robert. Reproductive biology and early life history of fishes in the Ohio River drainage. III. Title.

QL628.O33S56 2003
571.8'17--dc22 2003055777

Taylor & Francis Group is the Academic Division of Informa plc.

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the CRC Press Web site at
http://www.crcpress.com

SPONSORED BY

Tennessee Valley Authority
Nashville District, U.S. Army Corps of Engineers
American Electric Power Service Corporation

DEDICATION

In memory of Thomas P. Simon II

May 14, 1931–July 1, 1990

Father, friend, and mentor

ODE TO AN ICHTHYOLOGIST
OR
HOW 'BOUT THAT RIFFLE-KICKER

by

Robert Wallus
(with apologies to Mason Williams)

How 'bout that riffle-kicker
ain't he a Son?
A stompin and a slippin'
and a bustin' his buns!

Searchin' fer a madtom
or darter in disguise,
Wonder and excitement
ablazin' in his eyes.

Kickin' fer a rainbow,
stompin' fer a Johnny,
that silly ichthyologist
shore looks funny!

Ways to catch a darter,
Lord, he'll create 'em,
stompin' in the Smokies
fer a rufilineatum.

Early in the Spring,
he'll get a hankerin'
to shiver in the Pigeon
fer chlorobranchium

He makes it to the Buffalo
in middle Tennessee.
He'll catch himself a blenny darter',
it'll set him free!

albater and flavater
euzonum and juliae,
the Buffalo in Arkansas
drives him plum squirelly!

South to the Caddo,
madtoms galore!
He found himself a new one,
named it after Taylor.

How to be a riffle-kicker?
He knows how to lick it!
Just find himself a rocky stream
roar off and kick it!

With thanks to Dr. Neil H. Douglas,
my favorite riffle-kicker.

FOREWORD

This comprehensive, multivolume series, which originated more than a decade ago, is a much needed taxonomic aid, complete with keys, diagnostic criteria, and illustrated descriptions for identification of the eggs, larvae, and early juveniles of most of about 285 fishes in the Ohio River Basin. It is also an equally needed compendium of information on the ecology of those early life stages, as well as a summary of the distribution, habitat, and reproductive biology of their parents. The descriptive and early life history information in this single series complements a multitude of state and regional guides that emphasize only adult descriptions, distributions, and biology. Each volume has been anxiously awaited by many fish biologists throughout the central U.S., and wherever else the covered species are found.

The early life stages of most fishes represent developmental intervals that are ecologically distinct from each other and especially from their later juvenile and adult counterparts. Knowledge of their changing ecological requirements and limitations, population dynamics, and behavior facilitates more effective monitoring and management of fish populations and habitats. It is also crucial to the evaluation of environmental impacts and recovery of endangered species.

Early life history investigations in fresh waters of the U.S. received their greatest boost in the 1960s and 1970s in response to federal laws that require assessments or monitoring of adverse environmental impacts on the country's waters, aquatic communities, and endangered fishes. The effects of chemical discharges from industry, thermal effluents from and entrainment in power-plant cooling systems, transport through hydroelectric and pumped-storage turbines, impoundments, water diversions, other habitat changes, and introductions of non-native species on the early life stages of fish were, and in many cases remain, significant concerns across the country.

However, field research on fish eggs, larvae, and early juveniles depends on accurate identification of at least the targeted species among collected specimens. Morphological identification requires knowledge of the appearance of not only the targeted species, but all potentially similar-looking species in the waters sampled and the diagnostic criteria for segregating them. For the early life stages of most species, morphological criteria for identification change dramatically as the fish grow and develop, making diagnosis especially difficult and complicated.

This series will prove invaluable as research on, and management of, the fishes and aquatic ecosystems of the Ohio River Basin (and the rest of the Mississippi River System) continue in the new millennium. The authors and many of the contributors have dedicated much of their lives to advancing our knowledge of the eggs, larvae, and early juveniles of North America's freshwater fishes. As a result of their effort, the original, report-embedded, and previously published information compiled in each volume of this guide goes a long way toward filling immense gaps in our knowledge for future research and management. But, as evidenced by the information that is still missing, much remains to be learned. Even with the completion of this guide, the vast majority of North America's approximately 800 species of freshwater and anadromous fishes (perhaps two thirds of them, but only about one sixth of those in the Ohio River Basin) remain inadequately described as larvae for identification purposes. It must be impressed upon the sponsors of early life history research that descriptive biology and the development of taxonomic aids remain a vital part of that research and need to be funded and published accordingly.

Darrel E. Snyder

Larval Fish Laboratory

Colorado State University

PREFACE

Knowledge of early developmental stages of fishes is obviously fundamental to proper understanding of many aspects of fishery biology and ichthyology. It is paradoxical, then, that eggs, larvae, and juveniles of so many species of fishes remain completely or essentially unknown and undescribed.

— Mansueti and Hardy, 1967

Prior to the present day environmental movement, which began in the late 1960s, scientific attention to early life histories of fishes was limited to a handful of investigators possessing the insight, patience, and occupational privilege to pursue such an important but little known aspect of fisheries science. In recent decades, however, water resource issues have emerged as a top priority worldwide. It has been in this atmosphere of public concern and environmental enlightenment that the number of scientific voids has become apparent. In the arena of reproductive biology and early life ecology of fishes, so little had been investigated that larvae of most fish species could not be identified. Even less was known about behavior, ecology, and habitat requirements of young fish.

Regulatory requirements in recent years have resulted in the advancement of scientists' abilities to collect, identify, and quantify larval and juvenile fishes. However, knowledge of such important matters as spawning habitat requirements, reproductive behavior, and ecological relationships during the first few months of life, for even the most common species of fishes, lags well behind. New information has been and is currently being collected, but because so much recent research has been a direct result of regulatory requirements, it is often necessary to use the knowledge gained only to fulfill a reporting requirement. The importance to environmental biologists of disseminating advances in the state of the art to the remainder of the scientific community often becomes secondary to getting on with the next challenges at hand.

It is against this backdrop that the need for a compendium of acquired information was recognized and this particular project was spawned. What first formed an updated guide to identification of early life stages of fishes in the Tennessee River ultimately developed into a resource document on the reproductive biology and early life ecology of the fishes of the Ohio River Basin. The persistence and dedication of the authors, contributors, researchers, and supporters of this project cannot be overstated. Certainly there is more information in existence than has been discovered and incorporated herein. Unfortunately, that will always be the case. What has been provided, however, is the most complete treatise on early life histories of freshwater fishes in North America to date.

The information in this treatise is based on thorough field collections of early life phases and propagation and culture activities throughout the study area. We have added new information on the reproductive biology and early life histories for many species in the Ohio River drainage that previously was unknown. The Ohio River drainage contains a diverse fauna. Approximately 285 species are recognized from the system, including 54 endemic species. Currently, 6 species are federally listed as endangered, 5 are listed as threatened, and an additional 18 species are candidates for listing.

This series is divided into seven volumes that represent the inland ichthyofauna of the majority of eastern North America. Each volume contains distinguishing characteristics and a pictorial guide to the families of fishes present in the Ohio River drainage followed by family chapters. Family chapters are organized into species accounts arranged alphabetically within genus and sometimes higher taxonomic groupings (e.g., subgenera). The level of taxonomy presented is dependent on larval diagnostic traits within the family. Where possible, dichotomous keys to species or higher taxa within families are provided. When useful, schematic drawings of characters supplement key couplets. Each species account is divided into a variety of subtopics.

The information contained in this series will be invaluable to fisheries managers. They will be able to use the information to better protect and restore fishery resources. Resource planners and environmental scientists will use the information to validate the predicted effects of their decisions and to aid them in mitigating the impacts of their decisions. It is our intention to present the information in a format that will facilitate wide use. Our goal is to produce a resource document that will help a biologist identify a single larval fish, as well as provide a resource for the environmental manager concerned with the health and condition of his watershed jurisdiction. This series is the current state-of-the-art resource for reproductive biology and early life history of North American freshwater fishes.

Robert Wallus

Thomas P. Simon

ACKNOWLEDGMENTS

This project began in 1981, when Lawrence M. Page introduced Thomas P. Simon to the fascinating world of darters. As a recent graduate from the University of Michigan, he began studying the reproductive biology and early life stages of fishes in the Mississippi River during his masters work at the University of Wisconsin and doctoral work at the University of Illinois. The communications with Lawrence M. Page and Brooks M. Burr encouraged him further into this field, and for nearly the next two decades he worked on this project in an attempt to gain a complete basic knowledge of the early life history of darters. Without the mentoring, moral support, and assistance of Lawrence M. Page and Brooks M. Burr, this project would never have been completed. Their contributions can be seen throughout this book with the liberal use of their life history, taxonomic studies, and illustrations. My family, especially my wife Beth, has given support and encouragement throughout the years. To my children, Thomas P. IV, Cameron, Lia, and Zachary, who asked numerous times, "Is it done yet?" Thank you for your patience and love as I put this work together. The late Nancy Garcia, former North American Native Fishes Association board member, was instrumental in spawning and rearing ontogenetic series. There was not a single species we worked with that she had not spawned. Her hard work enabled the propagation of many specimens in this volume along with the Tennessee Valley Authority (TVA) biologists who provided invaluable assistance in the field and laboratory. D.A. Etnier and N.H. Douglas provided much assistance on darter taxonomy, reproductive biology, and information on species distribution. N.H. Douglas and his students provided laboratory support on fecundity analysis at Northeast Louisiana University. The following colleagues provided specimens, data, technical assistance, publications, manuscript review, and other professional courtesies that were helpful in the completion of this volume: D.J. Faber, L.A. Fuiman, J. Baker, J. Dorr III, D. Jude, J.B. Kaskey, E. Tyberghein, R.D. Hoyt, N.H. Douglas, K.B. Floyd, S.R. Layman, K. Cummins, B.E. Fisher, G.K. Weddle, R.M. Mayden, J.T. Hatch, G. Seegert, C.E. Saylor, L.K. Kay, and N.A. Auer. The original graphic and schematic illustrations in this volume were prepared by Ron Clayton, Murrie V. Graser, and Beth Simon. Their excellent artwork and attention to detail will be long-lasting contributions to our field. We thank the TVA, the Nashville District of the U.S. Army Corps of Engineers (USACE), and the American Electric Power Service Corporation (AEP) for sponsoring this work. Agency support for a project of this magnitude is gained through the committed support from the individuals of these organizations. We acknowledge the dedicated work of W.L. Poppe, W.B. Wrenn, R.J. Pryor, C. Massey, and W.G. Ruffner of TVA, H.J. Cathey and C.T. Swor of the Nashville District USACE, and R. Reash of AEP. We are also appreciative to associate editors Johnny P. Buchanan, H. Joe Cathey, Gordan E. Hall, Carl T. Swor, Clyde W. Voigtlander, and William B. Wrenn for their insights during the conceptualization of the project and development of the format. There are others who assisted us along the way; our apologies to those who have not been mentioned.

LIST OF ABBREVIATIONS

ABD	Air bladder depth
ADFL	Adipose fin length
BDA	Body depth at anus
BDE	Body depth at eyes
BDP1	Body depth at pectoral fin
CFL	Caudal fin length
CFS	Cubic feet per second
ChiBL	Chin barbel length
cm	Centimeter
CPD	Caudal peduncle depth
DFL	Dorsal fin length
ED	Eye diameter
EM	Early maturing ova
FL	Fork length
g	Gram
GD	Greatest depth
GSI	Gonadosomatic index
ha	Hectare
HD	Head depth
HL	Head length
HRM	Hinds Creek River Mile
HW	Head width
kg	Kilogram
km	Kilometer
LA	Latent ova
LM	Late maturing ova
m	Meter
MA	Mature ova
MaxBL	Maxillary barbel length
MBL	Mandibular barbel length
mm	Millimeter
MPosAD	Mid-postanal depth
MR	Mature ripe ova
N	Number
ORM	Ohio river mile
P1	Pectoral fin
P1L	Pectoral fin length
P2	Pelvic fin
P2L	Pelvic fin length
PosAL	Postanal length
PreAFI	Preadipose fin insertion length
PreAFO	Preadipose fin origin length
PreAL	Preanal length
PreDFFL	Predorsal finfold length
PreDFL	Predorsal fin length
RE	Ripe ova
RM	River mile
s	Second
SD	Shoulder depth
SL	Standard length
SnL	Snout length
sq	Square
TL	Total length
TRM	Tennessee river mile
TVA	Tennessee Valley Authority
UJL	Upper jaw length
YSD	Yolk-sac depth
YSL	Yolk-sac length

GLOSSARY OF TERMS

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

Actinotrichia Fin supports which are precursors of fin rays or spines; also called *lepidotrichia*.

Adherent Attached or joined together, at least at one point.

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.

Adipose fin A fleshy, rayless median dorsal structure, located posterior to the true dorsal fin.

Adnate Congenitally united; conjoined; keel-like.

Adnexed Flaglike.

Adult Sexually mature as indicated by production of gametes.

Alevin A term applied to juvenile catfish, trout, and salmon after yolk absorption; exhibiting no post yolk-sac larval phase.

Allopatric Having separate and mutually exclusive areas of geographical distribution.

Anadromous Fishes which ascend rivers from the sea to spawn.

Anal Pertaining to the anus or vent.

Anal fin Unpaired median fin immediately behind anus or vent.

Anlage Rudimentary form of an anatomical structure; primordium; incipient.

Antero-hyal Anterior bone to which branchiostegal rays attach; formerly ceratohyal.

Anus External orifice of the intestine; vent.

Auditory vesicle Sensory anlage from which the ear develops; clearly visible during early development.

Axillary process Enlarged accessory scale attached to the upper or anterior base of pectoral or pelvic fins.

Barbel Tactile structure arising from the head of various fishes.

Basibranchials Three median bones on the floor of the gill chamber, joined to the ventral ends of the five gill arches.

Blastula A hollow ball of cells formed early in embryonic development.

Body depth at anus Vertical depth of body at anus, not including finfolds.

Branched ray Soft fin ray with two or more branches distally.

Branchial arches Bony or cartilaginous structures supporting the gills, filaments, and rakers; gill arches.

Branchial region The pharyngeal region where branchial arches and gills develop.

Branchiostegals Struts of bone inserting on the hyoid arch and supporting, in a fanwise fashion, the branchiostegal membrane; branchiostegal rays.

Buoyant egg An egg which floats free within the water column; pelagic.

Caeca Finger-like outpouchings at boundary of stomach and intestine.

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

Catadromous Fishes which go to sea from rivers to spawn.

Caudal fin Tail fin.

Caudal peduncle Area lying between posterior end of anal fin base and base of caudal fin.

Cement glands Discrete or diffuse structures which permit a larva to adhere to a substrate.

Cephalic Pertaining to the head.

Cerotohyal See antero-hyal.

Cheek Lateral surface of head between eye and opercle, usually excluding preopercle.

Chorion Outer covering of egg; egg capsule.

Choroid fissure Line of juncture of invaginating borders of optic cup; apparent in young fish as a trough-like area below lens.

Chromatophores Pigment-bearing cells; frequently capable of expansions and contractions which change their size, shape, and color.

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

Cleithrum Prominent bone of pectoral girdle, clearly visible in many fish larvae.

Coelomic Pertaining to the body cavity.

Confluent Coming together to form one.

Ctenoid scale Scale with comb-like margin; bearing cteni or needle-like projections.

Cycloid scale Scale with evenly curved, free border, without cteni.

Demersal egg An egg which remains on the bottom, either free or attached to substrate.

Dentary Major bony element of the lower jaw, usually bearing teeth.

Dorsal fins Median, longitudinal, vertical fins located on the back.

Early embryo Stage in embryonic development characterized by formation of embryonic axis.

Egg capsule Outermost, encapsulating structure of the egg, consisting of one or more membranes; the protective shell.

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.

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

Emarginate Notched but not definitely forked, as in the shallowly notched caudal fins of some fishes.

Emergence The act of leaving the substrate and beginning to swim; swim-up.

Epaxial Portion of the body dorsal to the horizontal or median myoseptum.

Epurals Modified vertebrae elements which lie above the vertebrae and support part of the caudal fin.

Erythrophores Red or orange chromatophores.

Esophagus Alimentary tract between pharynx and stomach.

Eye diameter Horizontal measurement of the iris of the eye.

Falcate Deeply concave as a fin with middle rays much shorter than anterior and posterior rays.

Fin insertion Posterior-most point at which the fin attaches to the body.

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

Finfold Median fold of integument which extends along body of developing fishes and from which median fins arise.

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

Fork length Distance measured from the anterior-most point of the head to the end of the central caudal rays.

Frenum A fold of skin that limits movement of the upper jaw.

Ganoid scales Diamond- or rhombic-shaped scales consisting of bone covered with enamel.

Gas bladder Membranous, gas-filled organ located between the kidneys and alimentary canal in teleosts; air bladder or swim bladder.

Gastrula Stage in embryonic development between blastula and embryonic axis.

Gill arches See branchial arches.

Gill rakers Variously shaped bony projections on anterior edge of the gill arches.

Granular yolk Yolk consisting of discrete units of finely to coarsely granular material.

Greatest body depth Greatest vertical depth of the body excluding fins and finfolds.

Guanophores White chromatophores; characterized by presence of iridescent crystals of guanine.

Gular fold Transverse membrane across throat.

Gular plate Ventral bony plate on throat, as in *Amia calva*.

Gular region Throat.

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

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.

Head width Greatest dimension between opercles.

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

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.

Horizontal myoseptum Connective tissue dividing epaxial and hypaxial regions of the body; median myoseptum.

Hypaxial That portion of the body ventral to the horizontal myoseptum.

Hypochord A transitional rod of cells which develops under the notochord in the trunk region of some embryos.

Hypochordal Below the notochord; referring to the lower lobe of the caudal fin.

Hypurals Expanded, fused, haemal spines of last few vertebrae that support the caudal fin.

Incipient Becoming apparent.

Incubation period Time from fertilization of egg to hatching.

Inferior mouth Snout projecting beyond the lower jaw.

Integument An enveloping layer or membrane.

Interorbital Space between eyes over top of head.

Interradial Area between the fin rays.

Interspaces Spaces between parr marks of salmonids.

Iridocytes Crystals of guanine having reflective and iridescent qualities.

Isocercal Tail in which vertebral axis terminates in median line of fin, as in Gadiformes.

Isthmus The narrow area of flesh in the jugular region between gill openings.

Jugular Pertaining to the throat; gular.

Juvenile Young fish after attainment of minimum adult fin-ray counts and complete absorption of the median finfold and before sexual maturation.

Keeled With a ridge or ridges.

Larva Young fish between time of hatching and attainment of juvenile characteristics.

Late embryo Stage prior to hatching in which the embryo has developed external characteristics of its hatching stage.

Lateral line Series of sensory pores and/or tubes extending backward from head along sides.

Lateral line scales Pored or notched scales associated with the lateral line.

Lepidotrichia See actinotrichia.

Mandible Lower jaw, comprising three bones: dentary, angular, and articular.

Maxillary The dorsal-most of the two bones in the upper jaw.

Meckel's cartilage Embryonic cartilaginous axis of the lower jaw in bony fishes; forms the area of jaw articulation in adults.

Melanophores Black chromatophores.

Mental Pertaining to the chin.

Myomeres Serial muscle bundles of the body.

Myosepta Connective tissue partitions separating myomeres.

Nares Nostrils, openings leading to the olfactory organs.

Narial Pertaining to the nares.

Nasal Pertaining to region of the nostrils, or to the specific bone in that region.

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

Notochord length Straight-line distance from anterior- most part of head to posterior tip of notochord; used prior to and during notochord flexion.

Obtuse With a blunt or rounded end; an angle greater than 90 degrees.

Occipital region Area on dorsal surface of head, beginning above or immediately behind eyes and extending backward to end of head; occiput.

Oil globules Discrete spheres of fatty material within the yolk.

Olfactory buds Incipient olfactory organs.

Ontogenetic Related to biological development.

Opercle Large posterior bone of the operculum.

Operculum Gill cover.

Optic vesicles Embryonic vesicular structures which give rise to the eyes.

Otoliths Small, calcareous, secreted bodies within the inner ear.

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

Palatine teeth Teeth on the paired palatine bones in the roof of the mouth of some fishes.

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

Pectoral fins Paired fins behind head, articulating with pectoral girdle.

Peduncle Portion of body between anal and caudal fins.

Pelagic Floating free in the water column; not necessarily near the surface.

Pelvic bud Swelling at site of future pelvic fin; anlage of pelvic fin.

Pelvic fins Paired fins articulating with pelvic girdle; ventral fins.

Pericardium Cavity in which the heart lies.

Peritoneum Membranous lining of abdominal cavity.

Perivitelline space Fluid-filled space between egg proper and egg capsule.

Pharyngeal teeth Teeth on the pharyngeal bones of the branchial skeleton.

Physoclistic Having no connection between the esophagus and the pneumatic duct; typical of perciform fishes.

Physostomus Having the swim bladder connected to the esophagus by the pneumatic duct; typical of cypriniform fishes.

Plicae Wrinkle-like folds found on the lips of some catostomids.

Postanal length Distance from posterior margin of anus to the tip of the caudal fin.

Postanal myomeres Myomeres posterior to an imaginary vertical line through the body at the posterior margin of the anus; the first postanal myomere is the first myomere behind and not touched by the imaginary line.

Postero-hyal Posterior bone to which branchiostegal rays attach, formerly epihyal.

Postorbital length Distance from posterior margin of eye to posterior edge of opercular membrane.

Preanal length Distance from anterior-most part of head to posterior margin of anus.

Preanal myomeres The number of myomeres between the anterior-most myoseptum and an imaginary vertical line drawn at the posterior margin of anus, including any bisected by the line.

Predorsal scales Scales along dorsal ridge from occiput to origin of dorsal fin.

Prejuvenile Developmental stage 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.

Premaxillary The ventral-most of the two bones included in the upper jaw.

Primordium Rudimentary form of an anatomical structure; anlage.

Principal caudal ray Caudal rays inserting on hypural elements; the number of principal rays is generally defined as the number of branched rays plus two.

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.

Pronephic ducts Ducts of pronephic kidney of early development stages.

Pterygiophores Bones of the internal skeleton supporting the dorsal and anal fins.

Redd An excavated area or nest into which trout spawn.

Retrorse Pointing backward.

Rostrum Snout.

Scute A modified, thickened scale, often spiny or keeled.

Semibuoyant Referring to eggs which neither float nor sink, but remain suspended in the water column.

Sigmoid heart The S-shaped heart which develops from the primitive heart tube.

Soft rays Bilaterally paired, usually segmented fin supports.

Squamation Covering of scales.

Spines Unpaired, unsegmented, unbranched fin supports, usually (but not always) stiff and pungent.

Standard length In larvae, straight-line distance from anterior-most part of head to the most posterior point of the notochord or hypural complex.

Stellate Referring to a melanophore which is expanded into a starlike shape.

Stomodeum Primitive invagination of the ectoderm which eventually gives rise to the mouth.

Superior mouth Condition when the lower jaw extends upward and the mouth opens dorsally.

Sympatric Species inhabiting the same or overlapping geographic areas.

Teleosts Bony fishes.

Terminal mouth Condition when lower and upper jaws are equal in length and the mouth opens terminally.

Total length Straight-line distance from anterior-most part of head to tip of tail; all older literature references not stated differently are assumed to be total length.

Truncate Terminate abruptly as if the end were cut off.

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; usually modified for caudal fin support.

Vent Anus.

Vermiculate Having wormlike markings.

Vitelline vessels Arteries and veins of yolk region.

Water-hardening Expansion and toughening of egg capsule due to absorption of water into the perivitelline space.

Weberian apparatus First four vertebrae of cypriniform fishes modified for sound amplification.

Width of perivitelline space Distance between yolk and outer margin of egg capsule.

Xanthophores Yellow chromatophores.

Yearling A fish in its second year.

Yolk Food reserve of embryonic and early larval stages, usually seen as a yellowish sphere diminishing in size as development proceeds.

Yolk diameter Greatest diameter of yolk; more accurately measurable prior to embryo formation.

Yolk sac A baglike ventral extension of the primitive gut containing the yolk.

Yolk-sac larva A larval fish characterized by the presence of a yolk sac.

Yolk-sac length Horizontal distance from most anterior to most posterior margin of yolk sac.

Yolk-sac depth Greatest vertical depth of yolk sac.

CONTENTS

Reproductive Biology and Early Life History of Fishes in the Ohio River Drainage:

An Introduction to the Series

Thomas P. Simon and Robert Wallus

Although numerous descriptions of the ontogeny of individual fish species have been published, and a few studies have summarized the existing knowledge of the early life histories of fishes present in particular areas or regions, information is still lacking for many species (Mansueti and Hardy, 1967; Simon, 1985). Important geographical works on the early life histories of fishes have come from coastal regions (Mansueti and Hardy, 1967; Jones et al., 1978; Wang and Kernehan, 1979) and the Great Lakes (Auer, 1982). However, no resource document of this type exists for the large, inland freshwater drainages of the U.S.

Fisheries biologists have become acutely aware of this void with their increased need for reproductive biology and early life history information in their conduct of required ecological studies and in the development of management techniques. Information on distribution and abundance of eggs and larvae is useful in determining spawning and nursery areas, spawning seasons, reproductive success, year-class strength, and in some instances relative abundance of adult populations. The conditions and behaviors associated with spawning, as well as the sensitivity of fish eggs and larvae to environmental impacts are a concern and the cause for assessments and monitoring programs, i.e., 316(b) demonstrations, now required of most industries and utilities.

SERIES OBJECTIVES

The principal objective of this book is to provide an illustrated resource document for biologists who study the reproductive biology and early life history of fishes that occur in the Ohio River or its tributaries. Comprehensive reviews of the literature, as well as presentations of original data, are included. This text has three primary purposes: the advancement and evaluation of larval fish taxonomy, the identification of gaps in the knowledge of reproductive biology and early life history of fishes within the study area, and the stimulation of further research in areas lacking information. The diversity of species in the Ohio River drainage should make this document useful to fisheries biologists throughout the eastern and central U.S.

STUDY AREA

The Ohio River originates at the confluence of the Allegheny and Monongahela Rivers at Pittsburgh (ORM 0) and generally flows southwest for 981 miles (1578 km) before entering the Mississippi River near Cairo, IL (ORM 981). After flowing from PA, the Ohio River delineates the geographical boundaries between OH and WV, OH and KY, IN and KY, and IL and KY (Figure 1). Most of the tributaries in the system drain water from these states including headwater tributaries, which flow from NY, MD, and VA.

The southern portion of the Ohio River system is drained by two of its largest tributaries, the Cumberland and Tennessee Rivers (Table 1). The mouth of the Cumberland River enters the Ohio River at ORM 925. Its tributaries are confined to KY and TN. The Tennessee River is the largest tributary system in the Ohio River, accounting for approximately 20% of the watershed. The drainage lies mostly in the state of TN, but its headwaters are in the mountains of VA, western NC, eastern TN, and northern GA (Figure 1). From the confluence of the Holston and French Broad Rivers near Knoxville, TN, the Tennessee River flows approximately 652 miles (1049 km) before entering the Ohio River. Its course takes it southwest across TN into AL and then west across northern AL; it turns north at the northeast corner of the State of MS and flows back across TN and western KY to enter the Ohio River near Paducah, KY (ORM 940).

The Wabash River is the second largest Ohio River tributary system (Table 1) and the largest northern tributary (Figure 1). It encompasses approximately 16% of the total watershed and drains most of IN and portions of southeastern IL before its confluence with the Ohio River (ORM 850). The Wabash River is the largest free-flowing tributary of the Ohio River.

The Ohio River drainage contains one of the world's greatest coal-producing regions, several large metropolitan areas (e.g., Pittsburgh, Cincinnati, Louisville, Lexington, Knoxville, Chattanooga, and Nashville), and numerous power plants and large industries. Dams have been built on most of the larger rivers, including the mainstem Ohio, to provide flood control, navigation, hydroelectric power, water supply, and recreation.

The Ohio River system contains a diverse ichthyofauna (Pearson and Krumholz, 1984). Approximately 285 species are recognized from the system (Lee et al., 1980), including 54 endemic species (Table 2). This represents about 40% of the North American fauna. Currently, nine species are federally listed as endangered and ten are listed as threatened (Table 3).

FORMAT

This document is presented as a series of volumes containing family chapters. Information is not presented in phylogenetic sequence. Volume 1 included the families Acipenseridae through Esocidae (Wallus et al., 1990). Volume 2 represented the single family Catostomidae (Kay et al., 1994). Volume 3 contains information on the catfishes, family Ictaluridae. Information for additional families will be compiled in the remainder of the seven volumes. Common and scientific names follow Americam Fisheries Society (AFS) Special Publication series. Exceptions are noted in the introduction to each volume.

Each volume contains distinguishing characteristics and a pictorial guide to the families of fishes present in the Ohio River drainage followed by family chapters. Family chapters are organized into species accounts arranged alphabetically within genus and sometimes higher taxonomic groupings, i.e., subgenera and subfamilies. The level of taxonomy is dependent on larval diagnostic traits within the family. Where possible, dichotomous keys to species or higher taxa within families are provided. When useful, schematic drawings of characters supplement key couplets. Each species account is divided into the following major divisions.

Range
A description of the reported distribution of the species is presented; the principal source for this

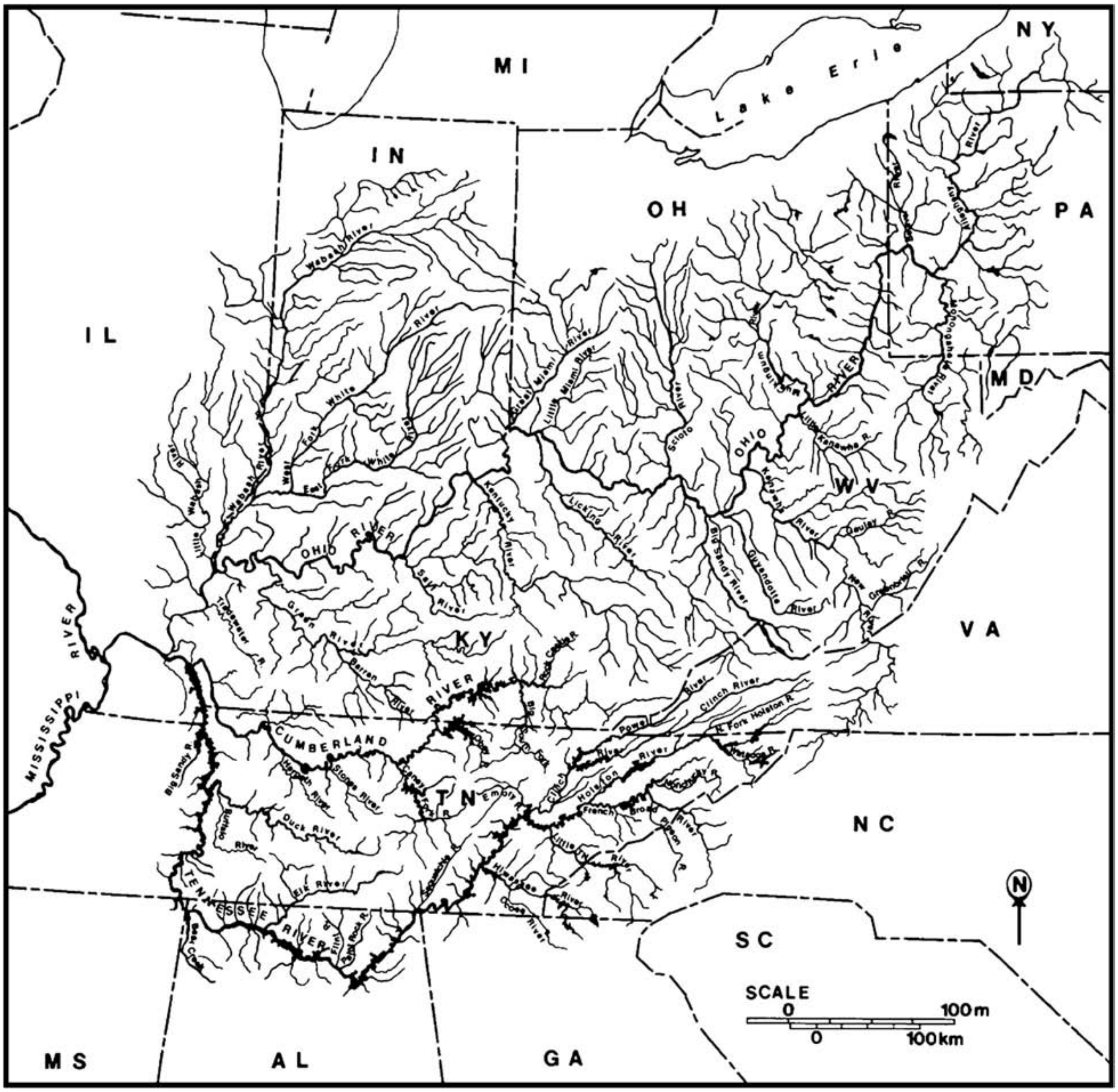


Figure 1 Map of Ohio River system.

information is Lee et al. (1980), although more recent references are used, if appropriate.

Habitat and Movement

A description of the habitats with which adults of the species are most often associated and a description of any movement patterns (e.g., diel, seasonal, pre-spawning, and post-spawning) associated with the life history of the species are provided.

Distribution and Occurrence in the Ohio River System

Information about the relative occurrence of the species within the study area comes from state or regional publications such as Gerking (1945), Burr and Warren (1986), Etnier and Starnes (1993), Pearson and Krumholz (1984), Smith (1985), Smith (1979), and Jenkins and Burkhead (1994).

Spawning

A description of reproductive characteristics is organized into sections including information on location (habitat), season, temperature, fecundity, sexual maturity (age and size), and spawning act.

Eggs

Information is given on the following:

Description — Characteristics of fertilized eggs, including shape, adhesiveness, buoyancy, color,

Table 1

Physical characteristics of the Ohio River system.

River Basin	Ohio River Mile	Approximate Drainage Area (km^2)
Allegheny	0	30,300
Monongahela	0	19,200
Beaver	25	8,100
Muskingum	172	20,800
Little Kanawha	185	6,000
Kanawha	266	31,600
Guyandotte	305	4,300
Big Sandy	317	11,100
Scioto	356	16,900
Little Miami	464	4,600
Licking	470	9,500
Great Miami	491	14,000
Kentucky	546	18,000
Salt	630	7,500
Wabash	848	85,700
Cumberland	920	46,400
Tennessee	940	106,000
Mainstem Ohio and smaller tributaries	—	64,100
		528,000

diameter, and sometimes internal characteristics; information on ovarian eggs may be provided, if little information is available for fertilized eggs.

Incubation — Time period in days or hours with associated temperatures.

Development — Reference is made to important embryological studies but little information is provided other than brief comments pertaining to embryonic distinctiveness. Drawings and descriptions of embryology are limited to the presentation of new information.

Development

Descriptions of development within each life phase (yolk-sac larvae, post yolk-sac larvae, and juvenile) arranged into the following subdivisions:

Size Range — Size encompassed by phase, if known.

Myomeres — Usually includes total, preanal, and postanal counts.

Morphology — Information further presented under length or length-range subheadings.

Morphometry — Where available, measurements are presented as percent total length or as percent head length.

Fin Development — Information usually presented under length or length-range subheadings, although individual fins may be used as subheadings with dynamic descriptions of development provided; finfold absorption and median and paired fin development are discussed.

Pigmentation — Information presented under length or length-range subheadings; emphasis placed on patterns of diagnostic importance.

Taxonomic Diagnosis

Fishes most likely to be confused with the species under discussion are listed and, if possible, taxonomic differences described for all life phases. Diagnostic discussions may be presented at the beginning of a family chapter along with keys.

Table 2

Diversity of fish populations in the Ohio River and its tributaries.

River Basin	Number of Native spp.	Number of Introduced spp.	Total	Number of Endemic spp.
Ohio River proper	102	9	111	0
Allegheny River	97	11	108	0
Monongahela River	93	12	105	0
Little Kanawha River	75	5	80	0
Kanawha River	125	10	135	6
Muskingum River	114	19	133	0
Guyandotte River	68	3	71	0
Big Sandy River	98	5	103	0
Scioto River	114	9	123	1
Little Miami River	95	4	99	0
Great Miami River	103	9	112	0
Licking River	98	5	103	0
Kentucky River	117	10	127	0
Salt River-Rolling Fork	81	2	83	0
Green River	146	5	151	5
Wabash River	151	2	153	0
Cumberland River	175	7	182	10
Tennessee River	220	11	231	32

Source: From C.H. Hocutt and Wiley, E.O., 1986.

Table 3

Listing of endangered and threatened fish species (as of August 1994) occurring in the Ohio River system.

Endangered	Threatened
Etheostoma (=*Catonotus*) *percnurum* duskytail darter	*Erimystax* (=*Hybopsis*) *cahni* slender chub
Etheostoma sp. bluemask darter (=jewel darter)	*Etheostoma boschungi* slackwater darter
Etheostoma chienense relict darter	*Cyprinella* (=*Notropis*) *caerulea* blue shiner
Etheostoma wapiti boulder darter (=Elk River darter)	*Cyprinella* (=*Hybopsis*) *monacha* spotfin chub (=turquoise shiner)
Notropis sp. palezone shiner	*Noturus flavipinnis* yellowfin madtom
Noturus baileyi smoky madtom	*Phoxinus cumberlandensis* blackside dace
Noturus stanauli pygmy madtom	*Percina tanasi* snail darter
Noturus trautmani Scioto madtom	*Percina macrocephala* longhead darter
Speoplatyrhinus poulsoni Alabama cavefish	*Percina squamata* olive darter
	Percina uranidea stargazing darter

Source: From the U.S. Fish and Wildlife Service, 1994.

Ecology of Early Life Phases

Occurence and Distribution — Spatial-temporal and other ecological information from the open and gray literature and original data are presented under egg, yolk-sac larval, post yolk-sac larval, larval, and juvenile subheadings.

Early Growth — Preadult growth information.

Feeding Habits — Preadult focus.

References
These include abbreviated citations to literature consulted for that species account. Complete citations appear in the Bibliography and Appendix at the end of each volume. Occasionally, we became aware of important literature after a species or family account had been completed. Such articles are listed in abbreviated citation form as "Other Important Literature" at the end of the appropriate species account and fully referenced in the master Bibliography or Appendix.

TERMINOLOGY

Key morphological attributes and examples of yolk-sac and post yolk-sac larval phases and anatomy are illustrated in Figure 2. Definitions and terms for the early development of fishes vary considerably. We have adopted the following developmental terminology based on Hubbs (1943); however, other terminology exists including Balon (1979, 1981) and Snyder (1976). We choose to use a simple approach that any fish biologist could quickly identify. Since the presence of yolk and fin rays is easily identified, we have only slightly modified Hubbs' (1943) terminology:

Yolk-sac larvae — Phase of development from the moment of hatching to complete absorption of the yolk.

Post yolk-sac larvae — 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.

Larvae — Includes both yolk-sac and post yolk-sac phases of development.

Juvenile — Phase beginning when an adult complement of rays is present in all fins and the median finfold is completely absorbed, and ending with the attainment of sexual maturity.

GENERAL COMMENTS ABOUT THE TEXT

Superscript numbers in each species account refer to the abbreviated literature citations at the end of each account. In some instances, a numbered, abbreviated citation is preceded by a capital *A*, denoting the referenced work as gray literature, e.g., internal agency reports, incomplete Dingel-Johnson (D-J) or other project reports, and, generally, unrefereed publications that contain useful information but are not widely circulated or available. Complete citations for journal and other refereed literature are in the References at the end of each volume; complete citations for gray (A) literature are in the Appendix. In the family, genera, or subgenera description prefaces, introductions, taxonomic accounts higher than species (i.e., genus and family), and tables encompassing information for more than one species, citations are given by author and date, rather than superscript. Citations are only presented in introductory sections when information is from literature not cited in subsequent species accounts. Each volume has its own References; no cumulative bibliography will be attempted.

Throughout the volume, original data are indicated by a superscript asterisk. Sources of original data are described at the end of the abbreviated literature list for each species. Reference material used for the description of species development was obtained from a variety of sources, including individual researchers, universities, and agencies. The location of specimens utilized for documentation of morphometric and meristic data and other developmental information is noted. Many developmental series of eggs and larvae were prepared by the Tennessee Valley Authority. This material along with many other specimens from this study are curated by the Indiana Biological Survey, Aquatic Research Center, Division of Fishes, Bloomington, IN.

When available, illustrations of development are presented as part of each species description. They vary in quality and source. Some have been reprinted from the literature; others have been redrawn from previously published figures or plates; and many are original illustrations. Illustrators of original drawings are listed in the acknowledgments for each volume and have initialed their work. In instances where more than one source of illustration was available, we used only those that best illustrated important developmental features.

Maps provided with each species account are most often used to indicate distribution of the species within the study area and to document reproduction

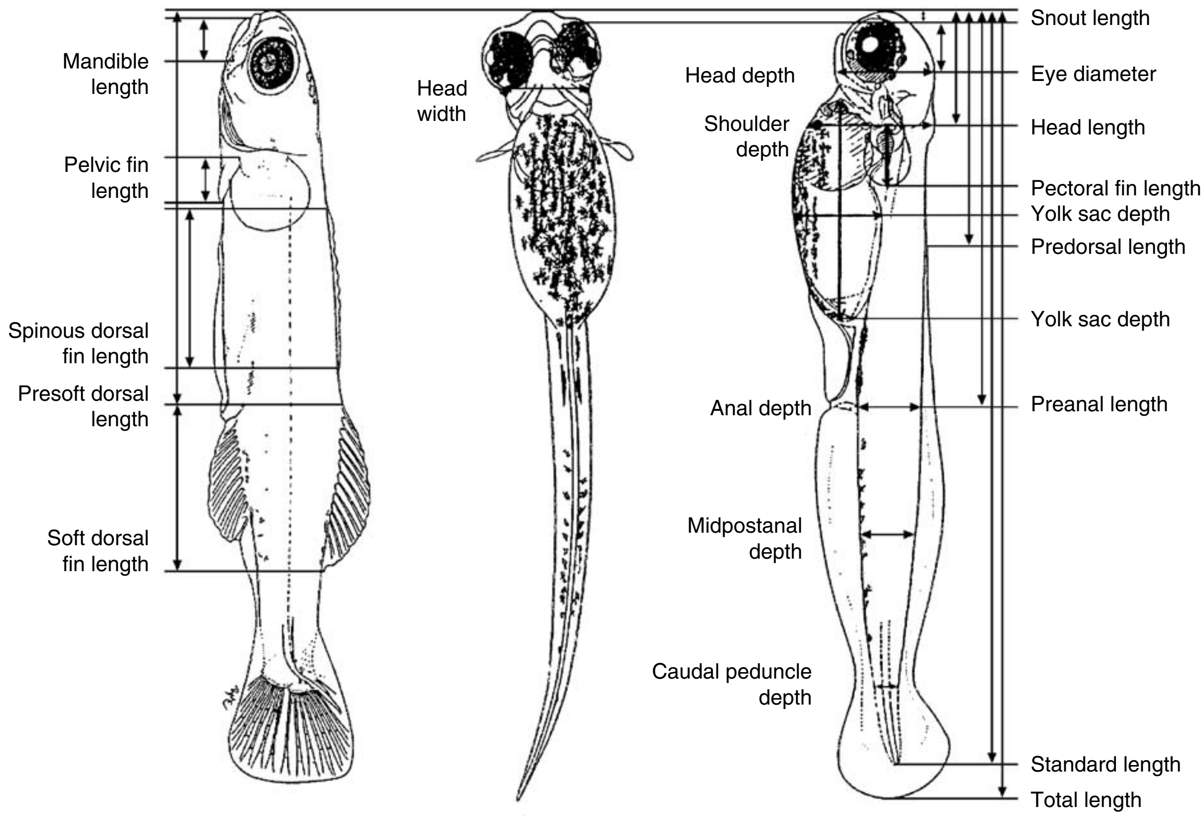


Figure 2 Diagrammatic representation of typical yolk sac and post yolk sac larval percid (Simon 1994).

by showing collection localities of early life history phases of that species. However, if the species is rare, or has limited distribution, the maps may only show localities of recent adult collections. We have noted this situation in the figure caption.

References to body length are presented as found in the literature, i.e., standard length (SL), fork length (FL), or total length (TL). No conversions to TL were attempted. If body length was presented as length only with no further definition, we presented the information in a similar manner.

LITERATURE CITED

Balon, E.K. 1979.
Balon, E.K. 1981.
Burr, B.M. and M.L. Warren, Jr. 1986.
Etnier, D.A. and W.C. Starnes. 1993.
Gerking, S.D. 1945.
Hocutt, C.H. and E.O. Wiley. 1986.
Hubbs, C.L. 1943.
Jenkins, R.E. and N.M. Burkhead. 1994.
Kay, L.K. et al. 1994.
Lee, D.S. et al . 1980.
Mansueti, A.J. and J.D. Hardy. 1967.
Pearson, W.D. and L.A. Krumholz. 1984.
Simon, T.P. 1985.
Smith, C.L. 1985.
Smith, P.W. 1979.
Snyder, D.E. 1976.
U.S. Fish and Wildlife Service. 1994.
Wallus, R. et al. 1990.

Distinguishing Characteristics

and Pictorial Guide to the Families of Fishes in the Ohio River Drainage

Robert Wallus and Thomas P. Simon

In all, 27 families of fishes occur in the Ohio River drainage. The following pictorial guide is based on distinguishing characteristics that are diagnostic to separate each of the families. Diagnostic characters for yolk-sac and post yolk-sac stages of development are highlighted for each family.

YOLK-SAC LARVAE	POST YOLK-SAC LARVAE

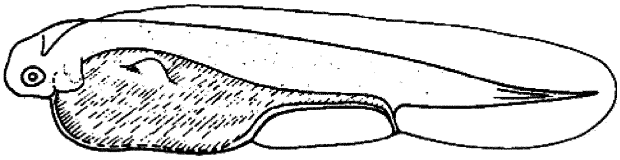
ACIPENSERIDAE — sturgeons

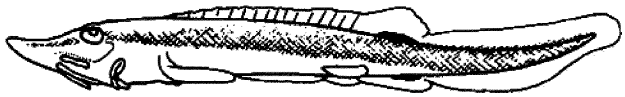
Yolk-sac larvae:

- Hatching size 7–12 mm TL
- No adhesive organ
- Large, dark yolk sac
- Anus posterior to midbody
- More than 50 total myomeres
- Preanal length of early yolk-sac larvae about 65% TL
- Length from tip of snout to dorsal finfold origin about 25% TL for early yolk-sac larvae

Post yolk-sac larvae:

- Extended snout with four ventral barbels
- Ventral mouth
- Heterocercal tail





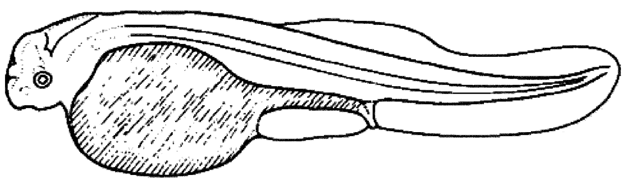
POLYODONTIDAE — paddlefishes

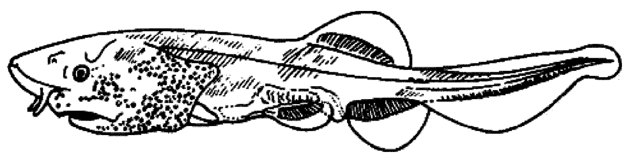
Yolk-sac larvae:

- Hatching size 8–9.5 mm TL
- Large, dark yolk sac
- More than 50 total myomeres
- No adhesive organ
- Anus posterior to midbody
- Small eye
- Preanal length of early, yolk-sac larvae about 60% TL
- Length from tip of snout to dorsal finfold origin about 35% TL for early, yolk-sac larvae

Post yolk-sac larvae:

- Rostrum develops with two ventral barbels
- Numerous sensory patches present on head and operculum
- Heterocercal tail





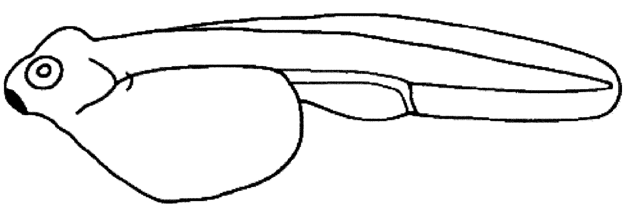
LEPISOSTEIDAE — gars

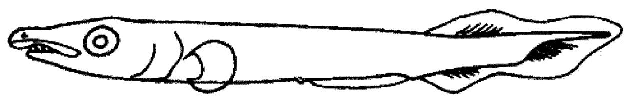
Yolk-sac larvae:

- Adhesive organ present
- Large, oval yolk sac
- More than 50 total myomeres

Post yolk-sac larvae:

- Elongate body
- Extended snout
- Anal fin origin anterior to dorsal fin origin
- Heterocercal tail





YOLK-SAC LARVAE	POST YOLK-SAC LARVAE

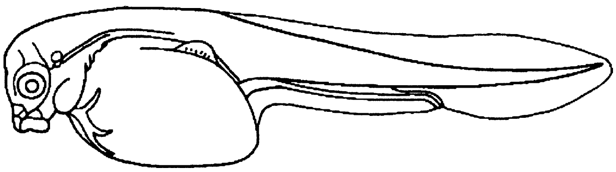
AMIIDAE — bowfins

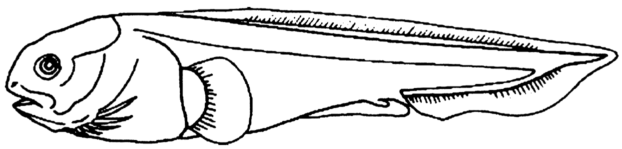
Yolk-sac larvae:

- Hatching size 3–7 mm TL
- Adhesive organ present
- Total myomeres 60 or more

Post yolk-sac larvae:

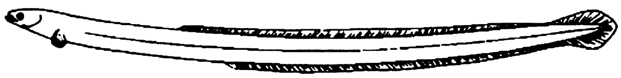
- Round, robust head
- Gular plate
- Long dorsal fin, origin above pectoral fins





ANGUILLIDAE — freshwater eels

Larvae are absent from the Ohio River drainage, but elvers with adult characteristics occur.



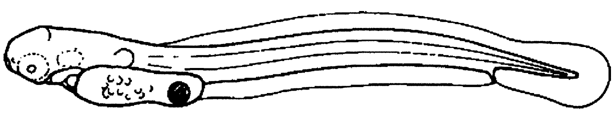
CLUPEIDAE — herrings

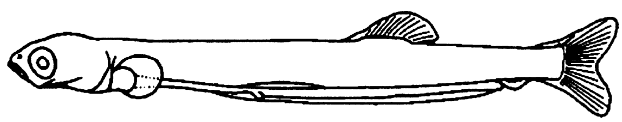
Yolk-sac larvae:

- Slender, little pigment, transparent
- Oil may or may not be visible
- Large oil globule, if present, will be located posteriorly
- Posterior vent
- Fewer than ten postanal myomeres
- Dorsal finfold origin anterior, at mid-yolk sac early and just behind head later

Post yolk-sac larvae:

- Slender, little pigment
- Posterior vent
- Anal fin posterior to dorsal fin





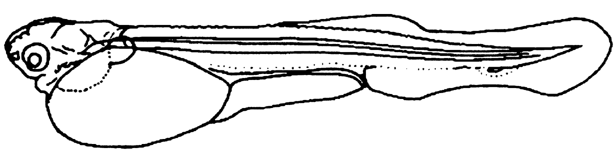
HIODONTIDAE — mooneyes

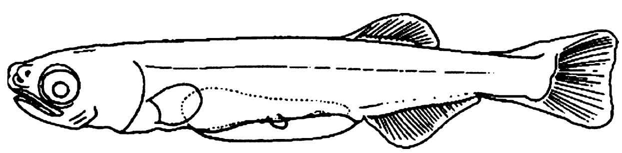
Yolk-sac larvae:

- Hatch at about 7 mm TL
- Large yolk sac
- Anterior oil globule
- Dorsal finfold origin near midbody

Post yolk-sac larvae:

- Robust
- Large eye
- 17 or more postanal myomeres
- Dorsal fin insertion over anal fin



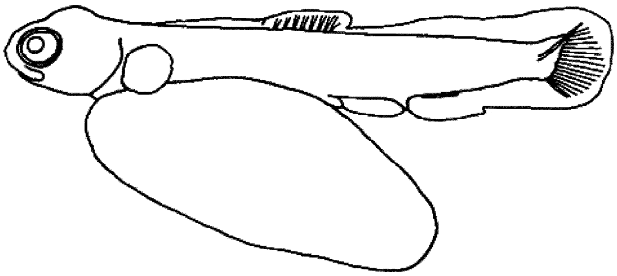


YOLK-SAC LARVAE | POST YOLK-SAC LARVAE

SALMONIDAE — trouts

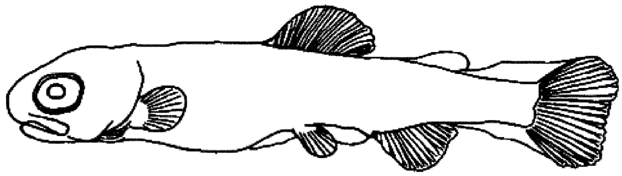
Yolk-sac larvae

- Large, greater than 11 mm TL at hatching
- Large yolk, initially pendulus
- Advanced fin development prior to complete yolk absorption
- Vent about two thirds back on body



Post yolk-sac larvae

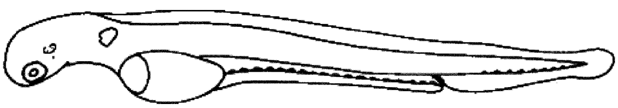
- Robust
- Large, rounded head
- Adipose fin



OSMERIDAE — smelts

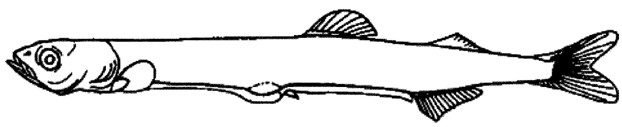
Yolk-sac larvae

- Long, slender, herring-like
- Small head
- Yolk positioned well posterior to pectoral fins
- Single, anterior oil globule
- Vent about three quarters back on body



Post yolk-sac larvae

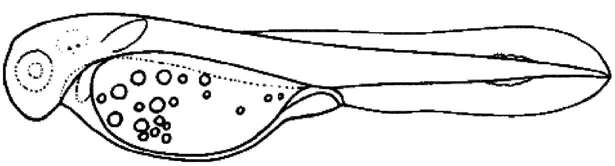
- Elongate, slender, herring-like
- Adipose fin
- Anal fin posterior to dorsal fin



UMBRIDAE — mudminnows

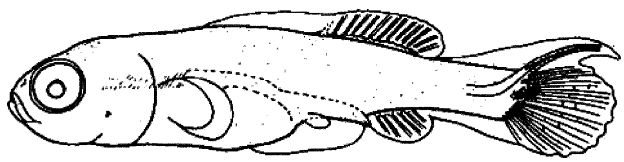
Yolk-sac larvae

- Yolk with many oil globules
- Vent slightly posterior to midbody
- Urostyle extends to posterior margin of caudal finfold



Post yolk-sac larvae

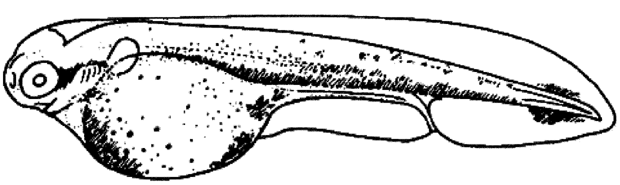
- Robust
- Darkly pigmented
- Urostyle extends beyond margin of developing caudal fin



ESOCIDAE — pikes

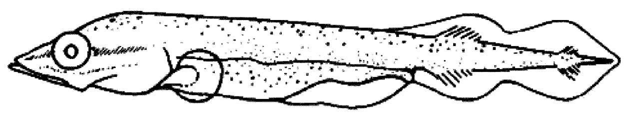
Yolk-sac larvae

- Darkly pigmented
- Vent about two thirds back on body



Post yolk-sac larvae

- Elongate
- Extended, depressed, duck-like snout
- Posterior dorsal fin



YOLK-SAC LARVAE	POST YOLK-SAC LARVAE

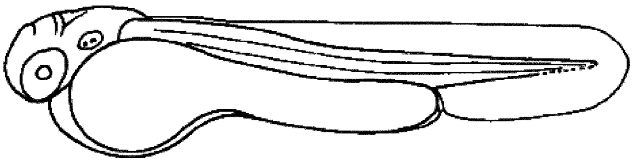
CYPRINIDAE — carps and minnows

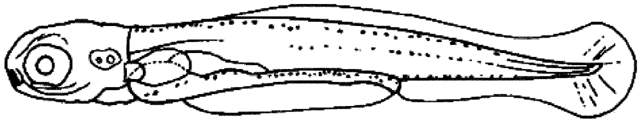
Yolk-sac larvae:

- Yolk long, cylindrical, initially bulbous anteriorly
- Pigmentation varies from light to heavy
- Vent usually slightly beyond midbody

Post yolk-sac larvae:

- 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





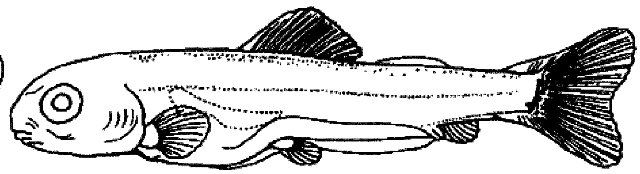
CATOSTOMIDAE — suckers

Yolk-sac larvae:

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

Post yolk-sac larvae:

- Mouth shape and position varies from inferior (later in development) to terminal and oblique
- Pigment variable but often in three rows, dorsally, ventrally, and midlaterally, dorsal pigment may also be in one to three rows
- Air bladder obvious
- Single dorsal fin



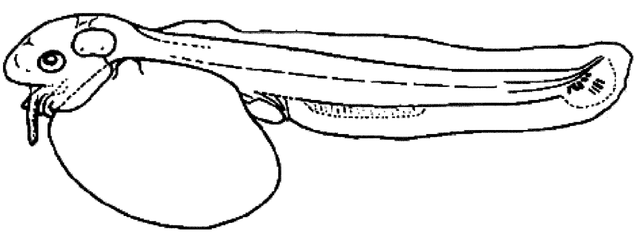
ICTALURIDAE — catfishes

Yolk-sac larvae:

- Large bulbous yolk
- Barbels evident at hatching
- Advanced fin development before complete yolk absorption

Post yolk-sac larvae:

- No post yolk-sac larval phase



YOLK-SAC LARVAE / POST YOLK-SAC LARVAE

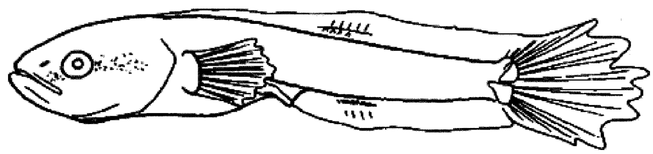
AMBLYOPSIDAE — cavefishes

Yolk-sac larvae

- No information

Post yolk-sac larvae

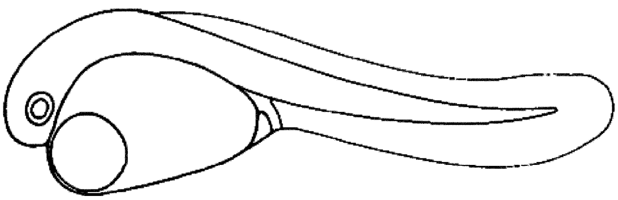
- Caudal fin rounded
- Pelvic fins lacking in all but one species (*Amblyopsis spelaeu*)
- Eyes and pigment may be reduced or lacking in all genera except *Chologaster*



APHREDODERIDAE — pirate perches

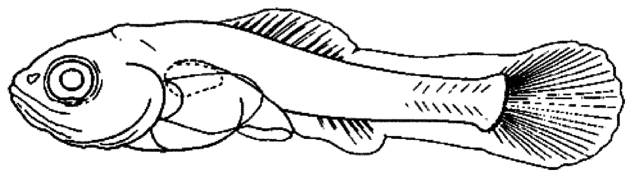
Yolk-sac larvae

- Small, about 3 mm TL at hatching, yolk absorbed between 4–5 mm TL
- Usually fewer than 30 total myomeres
- Anterior oil globule



Post yolk-sac larvae

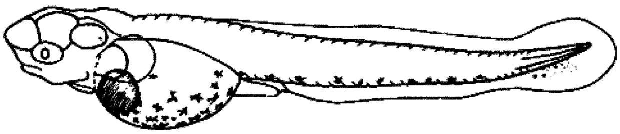
- Head and body robust
- Usually fewer than 30 total myomeres
- Anus begins to migrate toward gular region at about 9 mm TL



PERCOPSIDAE — trout-perches

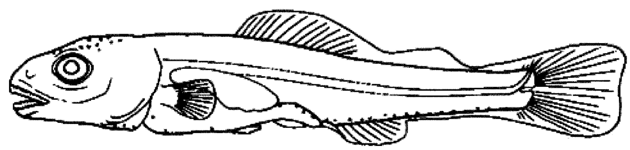
Yolk-sac larvae

- More than 30 total myomeres
- Hatching size 5.3–6 mm TL
- Large head
- Pointed snout with inferior mouth
- Vent slightly anterior



Post yolk-sac larvae

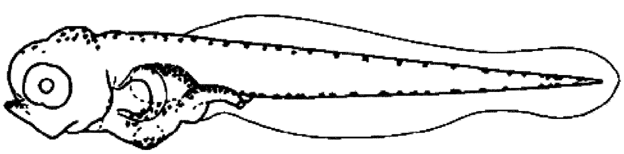
- Large head
- Adipose fin
- Long snout
- Air bladder obvious



GADIDAE — codfishes

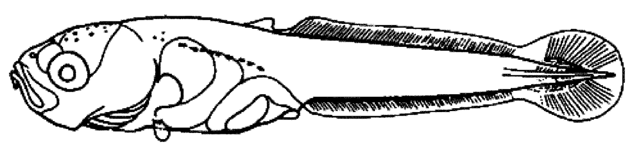
Yolk-sac larvae

- More than 50 total myomeres
- Large head
- Short gut
- Anterior vent opens laterally on finfold



Post yolk-sac larvae

- Single barbel on chin
- Second dorsal fin and anal fin long
- Isocercal tail
- Pelvic fins positioned under pectoral fins

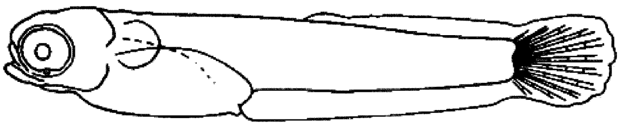


YOLK-SAC LARVAE	POST YOLK-SAC LARVAE

FUNDULIDAE — killifishes

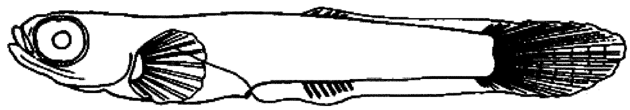
Yolk-sac larvae

- Stubby, robust
- Caudal fin with rays at hatching
- Vent anterior, near posterior margin of yolk



Post yolk-sac larvae

- Large head
- Superior mouth
- Rounded caudal fin
- Stocky caudal peduncle
- Ten or more dorsal rays



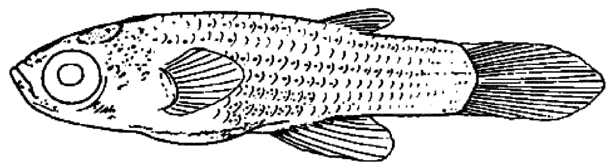
POECILIIDAE — livebearers

Yolk-sac larvae

- Inside female

Post yolk-sac larvae

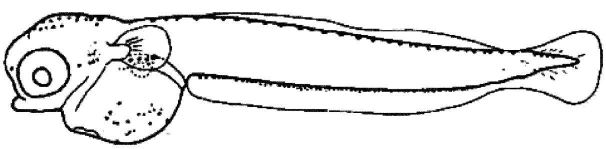
- Scales present at birth
- Rays in all fins at birth
- Superior mouth
- Dorsal fin short, seven to eight rays



ATHERINIDAE — silversides

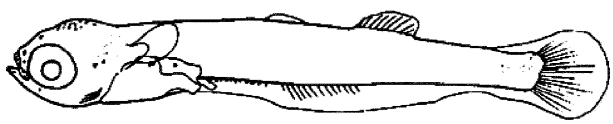
Yolk-sac larvae

- Elongate, slender
- Anterior vent (about one quarter back on body), immediately behind yolk sac
- Preanal myomeres, six to nine
- Preanal finfold absent or vestigal



Post yolk-sac larvae

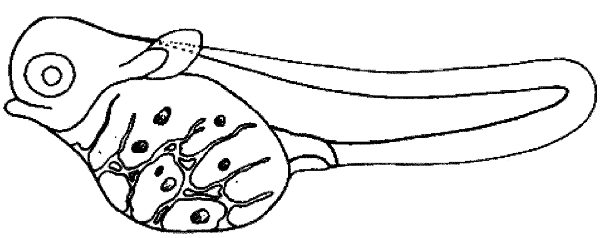
- Elongate, slender
- Mouth small, terminal
- Two dorsal fins
- Anterior vent



GASTEROSTEIDAE — sticklebacks

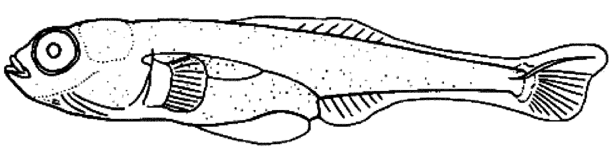
Yolk-sac larvae

- Short (5–6 mm TL), stubby
- Vent at midbody or slightly posterior
- Vitelline vessel over yolk
- Small oil globules present



Post yolk-sac larvae

- Sloping head, superior mouth
- Narrow caudal peduncle

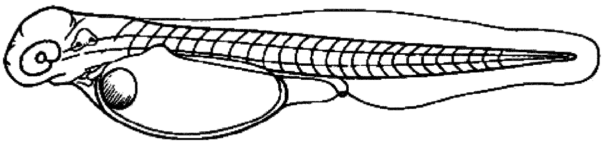


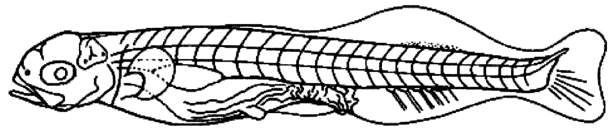
YOLK-SAC LARVAE	POST YOLK-SAC LARVAE

MORONIDAE — temperate basses

Yolk-sac larvae:
- Vent slightly posterior to midbody
- Single, large, anterior oil globule
- Low total myomere count, 25–26 or fewer

Post yolk-sac larvae:
- "S" shaped gut
- Low myomere count
- Late larvae with well-developed mouth with teeth
- Spinous dorsal fin develops secondarily

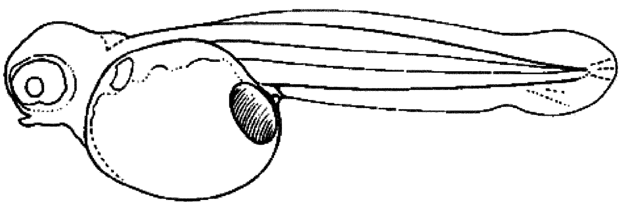


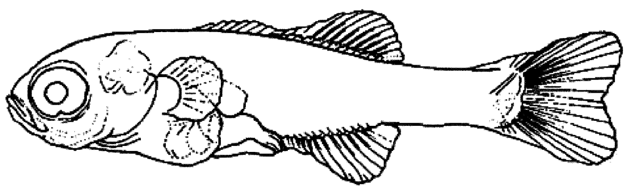


CENTRARCHIDAE — sunfishes

Yolk-sac larvae:
- Large, oval yolk sac at hatching
- Position of oil globule variable, but usually posterior
- Vent anterior to midbody

Post yolk-sac larvae:
- Usually robust with large head
- Air bladder distinct
- Gut short, coils with growth
- Spinous and soft dorsal fins continuous

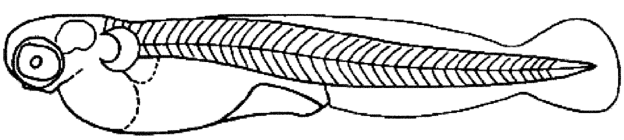


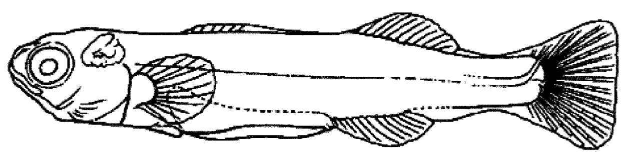


PERCIDAE — perches

Yolk-sac larvae:
- Vent near midbody
- Large anterior oil globule
- Pectoral fins usually well developed at hatching
- Total myomere counts higher than in moronids or centrarchids

Post yolk-sac larvae:
- large pectoral fins
- Spinous dorsal separate from soft dorsal fin

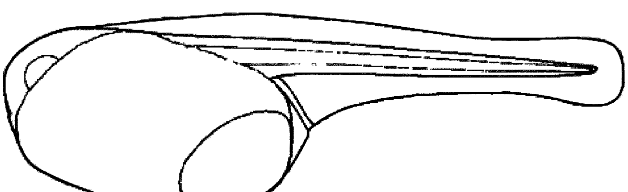


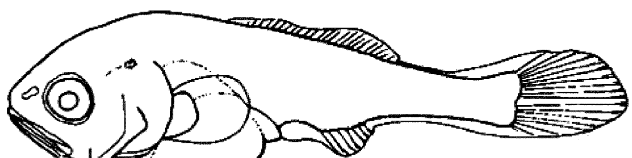


SCIAENIDAE — drums

Yolk-sac larvae:
- Small, 3–5 mm TL
- Large posterior oil globule
- About 25 total myomeres

Post yolk-sac larvae:
- Heavy, truncate body
- Large, deep head
- Spinous and soft dorsal fins continuous
- Soft dorsal fin long, 24+ rays

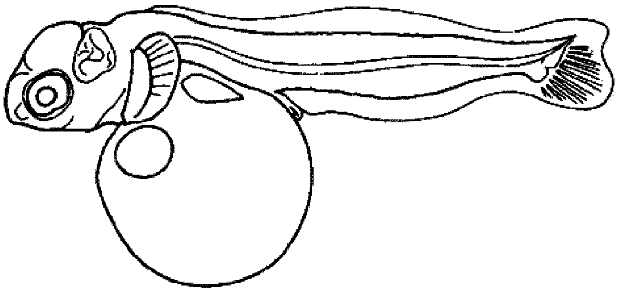




YOLK-SAC LARVAE

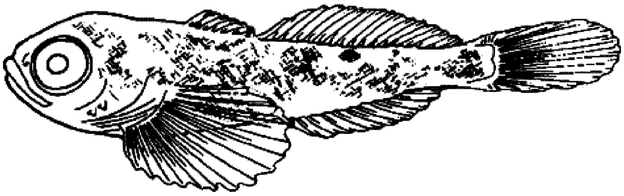
COTTIDAE — sculpins

- Robust with large head and large round yolk sac
- Fins well developed before yolk absorption is complete
- Anterior vent



POST YOLK-SAC LARVAE

- Large pectoral fins
- Two dorsal fins
- Second dorsal fin and anal fin long
- Caudal fin spatulate



Taxonomic Diagnosis of Young Perch, Pikeperch, and Darters in the Ohio River Drainage

Thomas P. Simon

The state of the art for identification of the family Percidae has not yet reached the level where diagnostic keys can be developed. Incomplete and missing species descriptions would result in an incomplete record for darters occurring in the Ohio River drainage. The purpose of this volume is to compile all available published and original information on the family Percidae and take our knowledge of this group, based on reproductive biology and early life history, a giant step forward. In addition, we identify areas that require additional research so that others can fill these gaps in our knowledge.

Despite our increased knowledge, we are still unable to identify with certainty all members of the family Percidae. The current state of the art may be aided by patterns observed in generic, subgeneric, and species groups, that can be used to identify species via a combination of approaches. When using this volume, the practitioner should first determine the genus to which the specimen belongs. This can be done by evaluating the generic information that is included at the beginning of each section. We include diagnostic characters that can be used to separate yolk sac and larval specimens using ontogenetic characters, while juveniles can be identified using adult characters. Second, based on the shape and size of the specimen, the individual fish can be compared to subgeneric information provided in this chapter to determine the group membership. By comparing known information for described species within the subgenus, many choices can be eliminated, which can also aid in the identification of species outside the Ohio River drainage. Once the subgenus is known and if the specimen does not resemble any of the described species, then the next step is to rely on distribution information contained within each species account to narrow the range of choices. Many darters are localized in their distribution, so a "probable" or tentative species selection can be made in most situations.

Distinguishing characteristics of the family Percidae are a vent near the midbody (usually ranging from 45 to 55% of the TL); a large anterior oil globule; pectoral fins that are usually well developed at hatching, with the exception of members of *Percina*; and total myomere counts that are higher than those of Moronidae and Centrarchidae, usually >15 preanal (range: 15–26) and 18–26 postanal myomeres. Juvenile percids usually have large pectoral fins and always possess two dorsal fins with spines in the first and rays in the second (see the diagnostic section in *Perca* to separate darters, *Sander*, and *Perca*).

The use of ontogenetic data sets to resolve relationships with the tribe Etheostomatini provides solutions to several issues surrounding the problematic relationships of darters. Page and Burr (1991) classified *Ammocrypta* as a subgenus of *Etheostoma* based on the study by Simons (1988); however, this classification is not supported by ontogenetic data. The *Ammocrypta* are not recognized as a subgenus of *Etheostoma* (see generic account for *Ammocrypta* for additional information) and therefore four genera of darter are recognized in this classification. The recognized genera include *Crystallaria*, *Percina*, *Ammocrypta*, and *Etheostoma*.

Simon et al. (1992) showed that *Crystallaria* was considered the most plesiomorphic of the darter genera, using a hypothetical proto-percid ancestor and an outgroup of *Percina* (*P. caprodes*, *P. macrolepida*, and *P. shumardi*) and *Etheostoma* (e.g., *E. longimanum*, *E. perlongum*, and *E. vitreum*). This ancestral proto-percid was based on the following traits: simple burying mode of reproduction; small egg diameters; pelagic drift; large size at hatching; simple stomodeum; deflected head over the yolk sac; larger size at development of ontogenetic markers, i.e., notochord flexion, formation of fin rays, development of functional gills; high meristic counts, i.e., including myomeres and fin rays; and elongate, slender body with limited yolk platelets. The only synapomorphy of *Crystallaria* from the ancestral proto-percid was the size of the pectoral fins from the proto-percid ancestor. Simon et al. (1992) support the elevation of the species to generic status as defined by Simons (1991).

Simon et al. (1992) also showed that *Etheostoma* evolved from *Ammocrypta* and that *Percina* is a sister group to *Ammocrypta*. Williams (1975) recognized two species groups within *Ammocrypta* comprised of the plesiomorphic *pellucida* group (*A. vivax*, *A. meridiana*, and *A. pellucida*) and the divergent *beani* group (*A. clara*, *A. bifasciata*, and *A. beani*). Recognition of the two species groups was confirmed by the ontogenetic data; however, the species groups were paraphyletic as a result of the exclusion of the most recent common immediate ancestors from the analysis. This was a similar disjunction observed in the study by Simons (1992), where the *Etheostoma* species chosen for the cladistic analysis were species of the subgenera *Boleosoma* and *Ioa*. The apparent sister taxa relationship between *Ammocrypta* and *Etheostoma* was a result of the relationship between the most derived species of *Ammocrypta*, i.e., *A. clara*, and the most plesiomorphic taxa of *Etheostoma.* In the study by Simons (1992), this formed the basis for the phenetic relationship between *Ammocrypta* and *Ioa*; while the ontogenetic study showed that the relationship between *Ammocrypta* and *Etheostoma* was between the most derived *A. clara* and the least derived *E. longimanum*, which bridged a large evolutionary gap between the two groups. Based on the ontogenetic analysis, no member of *Ammocrypta* ever formed a sister taxa relationship with *E. vitreum*. The suspected sister taxa relationship between adults of *Ammocrypta* and *Ioa* was probably a result of convergent evolution as a result of similar feeding and burying characteristics adapted in the osteological features studied by Simons (1992), resulting in a phenetic similarity rather than shared derived states. We refute the classification of *Ammocrypta* as a subgenus of *Etheostoma* and resurrect it to full generic status.

PRELIMINARY INTRODUCTION TO SUBGENERA OF THE DARTER GENUS *ETHEOSTOMA*

Page (1981) and Bailey and Etnier (1988) diagnosed darter phylogenetic relationships among subgenera of *Etheostoma*. The modifications made by Page (1981) increased the number of darter subgenera by 21% (six subgenera added) by recognizing *Odontopholis*, *Nanostoma*, *Psychromaster*, *Fuscatelum*, *Boleichthys*, and *Belophlox*. Page combined several subgenera including *Ulocentra* to form *Nanostoma*, and members of the subgenera *Microperca*, *Hololepis*, *Villora*, and *Etheostoma exile* to form *Boleichthys*. Page also removed previous members of *Oligocephalus* and *Villora* to form *Belophlox* and *Fuscatelum*. Perhaps Page's most controversial action was the formation of *Nanostoma*. This action has not been widely accepted by many southeastern systematists and has resulted in the recognition of two classifications for the snubnose darters. Bailey and Etnier (1988) recognized *Ulocentra* as a monophyletic sister group of subgenus *Etheostoma* and suggested that several of the characters used to define *Nanostoma* are convergent with *Etheostoma*. The additional study of genetic, osteological, and ontogenetic data sets will resolve the differences between these two classifications.

Ontogenetic evaluation of darter subgenera began in the Mississippi River drainage (Simon, 1985); however, darter systematic relationships could not be completely determined due to a lack of data for other drainages and species. Simon (1983, 1985, 1987, 1994, 1997) developed a phylogenetic classification for *Etheostoma.* Diagnostic ontogenetic character traits for the genus *Etheostoma* include the possession of well-developed pectoral fins; a functional maxillary and mandible; greatest body depth >14% TL; preanal myomeres <18, with the exception of subgenera *Etheostoma* and *Poecilichthys*; vitelline vein morphology either single serpentine mid-ventral or complex, network, plexus (Figure 3); body depth at anus <8% TL; and caudal peduncle depth >3.8% TL.

The following subgeneric classification for *Etheostoma* is based on Page (1981), Bailey and Etnier (1988), Simon (1983, 1985, 1987a, 1987b, 1994, 1997), and original data used to describe adult and ontogenetic classification based on cladistic analysis (see Simon et al. [1992] and Simon [1994] for information on the phylogenetic methods and character set). For many *Etheostoma* subgenera, there are no discrepancies between Page (1981) and Bailey and Etnier

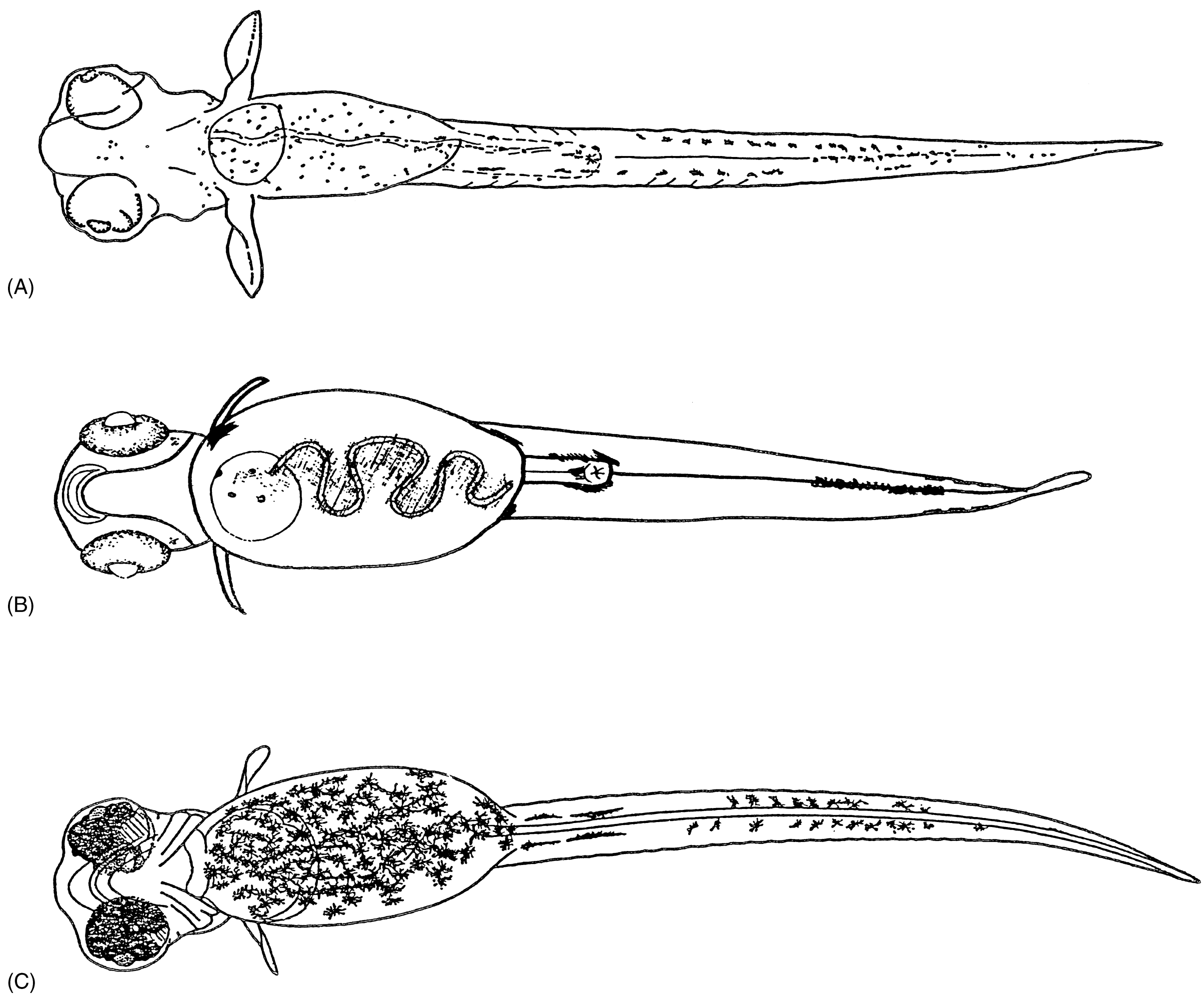


Figure 3 Vitelline vein structure of yolk-sac larval percids: (A) single, mid-ventral; (B) serpentine, single mid-ventral; and (C) complex network plexus. (From Simon, T. P. 1994. Doctoral dissertation, University of Illinois, Chicago, U.S.A. with permission.)

(1988). Several subgenera do not occur in the Ohio River drainage, including subgenera *Ioa*, *Belophlox*, and *Villora.* Accordingly, no comments are made about these subgenera although this classification did not recognize either *Ioa* or *Villora*. Information contained below each subgenus includes species found within the Ohio River drainage, summaries of adult and ontogenetic characters that diagnostically differentiate these subgenera, and additional notes based on closely related species groups.

Litocara Bailey

Included species: *Etheostoma sagitta.*

Diagnosis. Adults. Adults are large, cylindrical inhabitants of pool and riffle areas of small- to moderate-sized streams. Snout long and pointed, lateral line complete or nearly so, nuptial tubercles present on scales of male in area above anal fin base. A pair of black basicaudal spots present. Males with bright blue and red breeding colors (Page, 1981; Bailey and Etnier, 1988).

Ontogenetic. *Litocara* is a plesiomorphic subgenus (Simon, 1994). Synplesiomorphic characters shared with genus *Percina* include slender body depths; elevated numbers of meristic characters; limited pigmentation; and small, laterally compressed, rectangular yolk sacs. Apomorphies of *Litocara* include melanophores on the snout; melanophores distributed on the mid-ventral yolk sac, dorsally over the gut, and at every postanal myosepta; 17–18 preanal and 22–23 postanal myomeres; and elevated ray element numbers in the soft dorsal, pectoral, and caudal fins; a burier reproductive mode; a moderate hatching length (4.6 mm TL); pointed snout; small head length/TL (0.177); equal preanal length/TL (0.505); moderate–large predorsal length/TL (0.266); small spinous dorsal fin length/TL (0.128); small soft dorsal fin length/TL (0.136); small head depth (0.143); small shoulder depth (0.173); small anal depth (0.083); laterally compressed, elongate yolk sac; 14 dorsal spines; 12 anal rays; 6 predorsal myomeres; 18 presoft dorsal myomeres; modally, 52 lateral line scales; naked cheek and opercle; presence of mid-lateral pigmentation; no parental care, adult males guard spawning territory; and precocious soft dorsal and anal fin ray development (Simon, 1994).

Etheostoma Rafinesque

Included species: *Etheostoma blennioides* complex including *E. b. blennioides*, *E. b. pholidotum*, and *E. b. newmanii; Etheostoma blennius* are the only taxa retained in the subgenus *Etheostoma.*

Diagnosis. Adults. Relatively large, cylindrical species with greatly expanded pectoral fins; broad heads; complete lateral lines; high scale and ray counts; swift riffle inhabitants in medium to large streams and rivers; predominantly green and dark red in nuptial males; little sexual dimorphism; four to seven regular dorsal saddles; anterior saddle well separated from occiput; complete cephalic canals; and broadly connected gill membranes. Breeding tubercles on ventral scales of males (Bailey and Etnier, 1988; Simon, 1994).

Ontogenetic. Synapomorphic traits include a plexus vitelline vein, egg attachers depositing eggs in algal mats; and hatching between 5.3 and 6.5 mm TL (Simon, 1994). The subgenus has an egg-attaching reproductive mode; large, spherical propagules (range: 1.7–2.1 mm); moderate hatching lengths (range typically 5.3–5.7 mm TL); large spinous dorsal fin length/TL (range 0.121–0.231); large soft dorsal fin length/TL (range: 0.196–0.219); small pectoral fin length/TL (range: 0.063–0.075); moderate pelvic fin length/TL (range: 0.146–0.170); moderate mid-postanal depth/TL (range: 0.053–0.058); moderate caudal peduncle depth/TL (range: 0.029–0.031); narrow head width/HL (range: 0.731–0.759); 13–16 pectoral rays; 2 anal spines; modally, 4–5 predorsal myomeres; 6 branchiostegal rays; network vitelline vein; functional jaw structure; and sexually dichromatic males during spawning period (Simon, 1994).

Vaillantia Jordan

Included species: *Etheostoma chlorosoma.*

Diagnosis. Adult. The subgenus has a black bridle forming around the anterior fusion of the preorbital bars around the snout; an incomplete lateral line; presence of palatine and prevomerine teeth; absence of premaxillary frenum; modally six branchiostegal rays; branchiostegal membranes that are moderately joined across the isthmus; females lack a bilobed urogenital papilla; possesses densely covered cheeks and opercles with exposed scales (Page, 1981; Bailey and Etnier, 1988; Simon, 1994).

Ontogenetic. The subgenus is monophyletic possessing limited pigmentation, which is distributed primarily on the ventral yolk sac and at each postanal myosepta (Simon, 1994). The subgenus has elevated preanal myomere and fin ray element counts. Ray elements develop late, a typical plesiomorphic trait, and the body is slender and laterally compressed. The subgenus is diagnosed by small egg diameters (0.8 mm); small hatching lengths (4.3 mm TL); small head length/TL (0.165); large preanal length/TL (0.533); small predorsal length/TL (0.237); moderate pelvic fin length (0.134); narrow midpostanal depth/TL (0.047); small head width/TL (0.790); modally, 9 dorsal spines; modally, 11 soft dorsal rays; modally, 13 pectoral rays; a single anal spine; reduced principal and secondary caudal fin rays; modally, 20 preanal myomeres; interrupted infraorbital canal with 2–4 pores;

interrupted supratemporal pores; pelagic drift behavior; and no sexually dimorphic males, except for darkening of fin membranes or head.

Allohistium Bailey

Included species: *Etheostoma cinereum.*

Diagnosis. Adult. This monophyletic species group includes only *E. cinereum*, which is a large, laterally compressed inhabitant of boulder pool areas of medium-sized rivers. The subgenus has complete lateral line; gill membranes separate; snout long and pointed; soft dorsal fin of nuptial males greatly enlarged; upper sides are marked with a series of wavy, reddish-brown horizontal lines; gill rakers vestigial (Page, 1981; Bailey and Etnier, 1988).

Ontogenetic. No information is currently available for this group.

Psychromaster Jordan and Evermann

Included species: *Etheostoma tuscumbia.*

Diagnosis. Adult. This monotypic species subgenus includes *E. tuscumbia*, which is a small, laterally compressed inhabitant of springs and spring runs. Diagnostic characters include: single anal spine; incomplete lateral line; no chromatic breeding colors; scaled branchiostegal membranes. Supratemporal and interorbital area of head scaled (Page, 1981; Bailey and Etnier, 1988).

Ontogenetic. Limited information exists for this species and a diagnosis cannot be included.

Poecilichthys Agassiz

Included species: *Etheostoma variatum*, *E. histrio*, *E. rupestre*, and *E. swannanoa.*

Diagnosis. Adults. Breeding tubercles not occurring on ventral scales of males or females. The subgenus is diagnosed by the presence of eyes set high on the head with a short, rounded snout, heavy lips, usually well-developed frenum; gill membranes broadly joined; large, rounded pectoral fins; supratemporal and infraorbital sensory canals complete; first anal fin spine thick and stiff; genital papilla of females with a long, rounded tube and that of males with a short, flattened tube (Simon, 1994).

Ontogenetic. The resurrected subgenus *Poecilichthys*, herein recognized, includes the *variatum* species group, *E. histrio*, and *E. rupestre* (Simon, 1994). The *variatum* species group consists of *E. variatum*, *E. kanawhae*, *E. osburni*, *E. euzonum* (two subspecies), and *E. tetrazonum.* All of the species occur in the Ohio River basin or the Ozark region of MO and AR (McKeown et al., 1984). All of the species possess relatively plesiomorphic character traits, possessing high meristic counts; postanal myomeres radiating mid-laterally; tapering yolk sacs; usually spherical eyes (with the exception of *E. histrio*); and most species are either egg buriers or egg attachers. Three species groups can be recognized based on ontogenetic development.

The subgenus *Poecilichthys* contains previously recognized members of the saddleback darters of *Etheostoma*: *E. variatum* and *E. tetrazonum* (Simon, 1994). The subgenus has larger preanal lengths/TL (range: 0.518–0.540); moderate predorsal lengths (range: 0.254–0.291); small pectoral fin length/TL (range: 0.054–0.099); small head depth/TL (range: 0.113–0.146); small anal depth/TL (range: 0.073–0.090); broad caudal peduncle depths (range: 0.028–0.031); 12–14 dorsal soft rays; 18–20 preanal myomeres; typically 4–5 predorsal myomeres, with the exception of *E. tetrazonum* that has 8 predorsal myomeres; 19–22 presoft dorsal myomeres; 7–8 infraorbital pores; and no parental care is provided by adults with the exception of some territorial guarding.

The *Etheostoma swannanoa* species group includes *E. swannanoa* and possibly *E. thalassinum* (Simon, 1994). *Etheostoma swannanoa* possesses 23 postanal myomeres and hatches between 6.2 and 6.6 mm. It possesses more dorsal and mid-lateral melanophores than any other member of the subgenus. Ontogenetic development of fin ray elements is intermediate between *E. blennioides* and *E. variatum*.

The *E. variatum* species group includes the saddleback darters (Simon, 1994). These species are egg buriers; possess a characteristic melanophore cluster near the anal fin, a single mid-ventral vitelline vein, and spherical eyes.

The *E. histrio* species group includes *E. histrio* and *E. rupestre* (Simon, 1994). These species possess the most advanced character state within the subgenus. Diagnostic character traits include the lowest preanal myomere counts, spherical eye diameters, tapering yolk sacs, and the presence of a few mid-ventral stellate melanophores.

Doration Jordan

Included species: *Etheostoma jessiae* and *E. stigmaeum.*

Diagnosis. Adult. Small- to moderate-sized cylindrical species with predominately red and blue nuptial colors, two anal spines, complete or incomplete lateral line, six dorsal saddles, and narrowly joined gill membranes; absence of palatine teeth, presence of prevomerine teeth; branchiostegal membranes narrowly joined across the isthmus, a long and tubular genital papilla in breeding females. Etnier and Starnes (1993) recognize only *E. stigmaeum* and recognize *E. jessiae* as a subspecies. The *stigmaeum* complex is poorly understood, with perhaps two additional forms either becoming subspecies or species (Howell, 1968; Simon, 1994), or four additional species being recognized (Layman, 1993).

Ontogenetic. *Doration* is considered monophyletic and includes two species (Simon, 1994, 1997). Characteristics of the subgenus include egg-burying mode of reproduction; a single, mid-ventral vitelline vein; elevated (18) preanal myomere counts; and absence of pigmentation from the dorsal and lateral body. *Doration* possesses a small egg diameter (range: 1.3–1.7 mm); pointed snout; oval–spherical eyes; small head length/TL (range: 0.162–0.185); moderate predorsal length/TL (range: 0.278–0.280); small pectoral fin length/TL (range: 0.062–0.092); narrow shoulder depth/TL (0.128); narrow midpostanal depth/TL (range: 0.053–0.058); laterally compressed, rectangular yolk sac; 5 predorsal myomeres; 18 presoft dorsal myomeres; 10 preoperculomandibular pores; presence of mid-lateral pigmentation; and precocious notochord flexion.

The subgenus is poorly understood, but Simon (1997) considered *E. jessiae* and *E. stigmaeum* to be separate and distinct species. Studies of populations from TN, AL, and AR show two distinct species that are primarily separated by postanal pigmentation. *Etheostoma jessiae* has several distinct postanal clusters, while *E. stigmaeum* has melanophores distributed at almost every postanal myoseptum.

Nanostoma Putnam

Included species: *Etheostoma zonale.*

Diagnosis. Adult. The subgenus *Nanostoma* was originally used as a generic name for *Poecilichthys zonalis* (Jordan, 1877). The name was thought to be preoccupied by *Nannostomus Gunther* 1872, but instead was determined to be a synonym of *Etheostoma* and was resurrected as a valid subgenus by Page (1981) and Page and Burr (1982). Page (1981) combined the subgenus *Ulocentra* with *E. zonale* to form subgenus *Nanostoma*.

Ontogenetic. The subgenus *Nanostoma* includes members of the *E. zonale* species group, i.e., *E. zonale* and *E. lynceum*, newly elevated *E. vinctipes* (Mississippi drainage form in IN), and *E. inscriptum*; also recognized is a monophyletic *Ulocentra* from Page's classification (Simon, 1994). Diagnostically, the subgenus *Nanostoma* is an attaching reproductive mode in algal beds; large hatching length (range: 5.9–6.4 mm TL); nearly equal preanal to postanal length; eye shape varies between species, either spherical or oval; large predorsal length/TL (range: 0.273–0.345); moderate head depth/TL (range: 0.134–0.161); large anal depth/TL (range: 0.087–0.106); moderate to large caudal peduncle depth/TL (range: 0.028–0.046); reduced 8–10 dorsal spines; 13–15 pectoral fin rays; 17–19 presoft dorsal fin myomeres; single, mid-ventral to complex plexus vitelline vein shape; and territorial guarding of spawning area by male.

Ulocentra Jordan

Included species: *Etheostoma atripinne*, *E. baileyi*, *E. barrenense*, *E. duryi*, *E. etnieri*, *E. flavum*, *E. rafinesquei*, *E. simoterum*, and *E. zonistium.*

Diagnosis. Adult. Adult phylogenies determined by Page (1981) and Bailey and Etnier (1988) are both correct when viewed in light of ontogenetic cladistic analysis (Simon, 1994). The *Ulocentra* are small, slightly laterally compressed species with complete lateral lines; broadly connected gill membranes; habitats in slack water areas or gentle riffles in small- to moderate-sized streams; moderate scale and fin ray counts; eight or more dorsal saddles, anterior saddle touching occiput; striking sexual dimorphism; and red, yellow, green, and blue nuptial colors. Breeding tubercles are absent.

Ontogenetic. The *Ulocentra* consists of 14–15 species; however, 10 species occur in the Ohio River drainage. The species in this subgenus are very closely related (Simon, 1994), exhibiting an egg-attaching mode of reproduction of the vertical sides and crevices of rocks; small egg diameters; hatching at small sizes; precocious fin element development; clustered melanophores dorsally on the cranium; branchial musculature reflects light when viewed under cross-polarized light; single, mid-ventral serpentine vitelline vein; and a low number of preanal and postanal myomeres (Simon, 1994). Synapomorphies differentiating *Ulocentra* from *Nanostoma* include oval eye shape; moderate spinous dorsal fin length/TL (range: 0.115–0.198); moderate soft dorsal fin length/TL (range: 0.142–0.200), with the exception of *E. atripinne* (range: typically between 0.180 and 0.200); moderate head depth/TL (range: 0.120–0.180); and pectoral fin depth/TL moderate (range: 0.142–0.219).

The two species groups diagnosed by Bailey and Etnier (1988) can be recognized by pigmentation differences (Simon, 1994). The *simoterum* species group includes denser melanophores on the midlateral body, ventrally on the yolk sac, and on each postanal myoseptum, while the *duryi* species group has a greater frequency of dorsal melanophores.

Boleosoma Dekay

Included species: *Etheostoma nigrum*, *E. susanae*, and an undescribed form from IN (T. P. Simon and B. E. Fisher, unpublished data).

Diagnosis. Adult. Small, cylindrical species often with a single anal spine and an incomplete lateral line. Gill membranes broadly joined, nuptial males darkened on body and fins, nuptial females with bilobed urogenital papilla. Eggs deposited beneath rocks or similar objects.

Ontogenetic. The *Boleosoma* subgenus includes three species groups with six species and two taxa possessing multiple subspecies, including *E. longima-*

num, *E. podostemone*, *E. perlongum*, *E. olmstedi*, *E. nigrum*, and *E. susanae* (Simon, 1994). *Boleosoma* is an egg-clusterer; hatching sizes diminutive; reduced preanal myomere counts are typically 15–16, while postanal myomeres are 21; all groups have a plexus vitelline vein, tapering to spherically shaped yolk sacs, and typically spherical eyes (Simon, 1994). Synapomorphies for *Boleosoma* include pointed snouts; short to equal preanal length/TL (range: 0.489–0.538); large pectoral fin length/TL (range: 0.088–0.135); broad caudal peduncle depth/TL (range: 0.030–0.040); modally, 12–13 pectoral rays; modally either 1–2 anal spines; reduced principal caudal fin rays; modally, 15–16 preanal myomeres; modally, 20–21 postanal myomeres; modally, 14–16 presoft dorsal myomeres; demersal drift behavior; pigmented midventral postanal myosepta clustered into 4–6 blotches, with the exception of *E. longimanum* and *E. o. maculaticeps*, which are pigmented at virtually every postanal mid-ventral myosepta; parental care, consisting of guarding, rubbing, and fanning eggs by adult male; and precocious spinous dorsal spines (Simon, 1994).

***Nothonotus* Putnam**

Included species: *Etheostoma acuticeps*, *E. aquali*, *E. bellum*, *E. camurum*, *E. chlorobranchium*, *E. maculatum*, *E. microlepidum*, *E. rufilineatum*, *E. sanguifluum*, *E. tippecanoe*, *E. vulneratum*, and *E. wapiti*.

Diagnosis. Adult. Small- to moderate-sized, laterally flattened inhabitants of swift riffles in medium to large streams and rivers. Lateral line complete; head canals complete; scale and fin ray counts high; gill membranes separate; six branchiostegal rays; dorsal saddles nine or more or not apparent; and frenum well developed. Sexual dimorphism striking, eggs attached beneath rocks or buried in gravel. Most species with dark horizontal lines laterally. Twelve species belong to *Nothonotus* in the Ohio River drainage, and another three species occur outside the drainage (Zorach 1968, 1969, 1970, 1972; Zorach and Raney, 1967; Etnier and Williams, 1989).

Ontogenetic. *Nothonotus* possess well-developed stomodeum and pectoral fins; nondeflected head over the yolk sac; spherical and pigmented eyes, except in *E. maculatum* and *E. vulneratum*; precocious fin ray development; a single serpentine mid-ventral vitelline vein originates at the single anterior oil globule and proceeds through yolk sac; and possessing mid-ventrally clustered melanophores originating at the eighth postanal myomere and dispersed posteriorly along the next eight myomeres (Simon et al., 1987).

Taxa in the subgenus can be divided into egg-burier and egg-clumping species groups (Simon et al., 1987). The egg clumpers usually have >19 preanal myomeres, large (>32.0% SL) spherical yolk sacs at hatching, dorsal pigmentation, and mid-lateral caudal peduncle dashes of melanophores. Egg-burying species usually have a small (<32.0% SL) oval to ovoid yolk sac, <19 preanal myomeres, and no dorsal or caudal peduncle pigmentation (Simon et al., 1987).

***Oligocephalus* Girard**

Included species: *Etheostoma asprigene*, *E. caeruleum*, *E. luteovinctum*, *E. spectabile*, and *E. swaini*.

Diagnosis. Adult. The *Oligocephalus* includes five species and at least one undescribed species in the Ohio River drainage. Simon and Fisher (unpublished data) describe a large river form of *E. asprigene* from IN. *Oligocephalus* are small, laterally compressed inhabitants of quiet waters to gentle riffles or large rivers to small streams and springs. Males are brilliantly colored in reds, blues, and greens on the body and dorsal fin. Lateral line incomplete, scale counts low to moderate, gill membranes never broadly joined; dorsal saddles 8 or more or inconspicuous (Page, 1981; Bailey and Etnier, 1988).

Ontogenetic. Provisional diagnostic characters for *Oligocephalus* include hatching at moderate lengths (5.0–6.7 mm TL); reduced number of preanal myomeres 15–16; moderate number of postanal myomeres 19–21; body robust, moderate-sized greatest body depth/TL (range: 0.165–0.229); jaws developed at hatching; precocious fin ray development in paired and median fins; possessing a tapering yolk sac with a vitelline vein plexus.

***Ozarka* Williams and Robison**

Included species: *Etheostoma boschungi*.

Diagnosis. Adult. *Ozarka* are small, nearly cylindrical inhabitants of slackwater areas of small rivers, streams, and springs. The subgenus differs from *Oligocephalus* in lacking chromatic colors in soft dorsal fin, sharing similar nuptial tubercle patterns, and unique breeding behavior (Williams and Robison, 1980).

Ontogenetic. Preliminary characterization of the subgenus *Ozarka (*Simon and Garcia, 1990) shows that larvae possess precocious fin ray development, tapered yolk sacs; preanal myomere counts similar to *Oligocephalus* (15–16); high preanal length/TL (>52%); few postanal myomeres (17–18); cephalic sensory canal development and squamation at lengths >15 mm; heavily pigmented larva; and demersal larva with plant-spawning reproductive mode (Simon and Garcia, 1990).

***Fuscatelum* Page**

Included species: *Etheostoma parvipinne*.

Diagnosis. Adult. This monotypic species group was formerly part of *Oligocephalus*. It differs from that subgenus in lacking chromatic breeding colors; possessing broadly joined gill membranes; and having 1–2 anal spines; complete lateral line (Page, 1981).

Ontogenetic. No information is available for early life stages.

Catonotus Agassiz

Included species: *Etheostoma barbouri*, *E. corona*, *E. crossopterum*, *E. flabellare*, *E. forbesi*, *E. kennicotti*, *E. neopterum*, *E. nigripinne*, *E. obeyense*, *E. olivaceum*, *E. oophylax*, *E. percnurum*, *E. psuedovulatum*, *E. smithi*, *E. squamiceps*, *E. striatulum*, and *E. virgatum*.

Diagnosis. Adult. A large group of small, laterally flattened species that typically occurs in small streams. Lateral line incomplete; infraorbital and supratemporal canals typically interrupted; spinous dorsal fin with ten or fewer spines; dorsal fin of nuptial male with soft, fleshy knobs on spines or soft rays extending well past membranes (Page, 1975b, Page, 1981; Braasch and Mayden, 1985; Bailey and Etnier, 1988; Page et al., 1992). Chromatic breeding colors, when present, are reds and yellows (Bailey and Etnier, 1988). All species (17), with the exception of *E. chienense*, occur in TN, including another undescribed species related to *E. flabellare*.

Ontogenetic. *Catonotus* possess a large, spherical yolk sac, yolk-sac length/TL (range: 0.32–0.42); well-developed pectoral fins; precocious fin ray development; and yolk sac absorbed after initial fin ray development; 15–16 preanal myomeres; a complex vitelline vein network on ventral yolk sac; and complete supraorbital canal retrogressing to adult interrupted condition during juvenile development (Simon, 1987, 1988; Simon and Layman, 1995).

Boleichthys Girard

Species included: *Etheostoma gracile*, *E. microperca*, and *E. proeliare*.

Diagnosis. Adult. The *Boleichthys* are considered the most derived members of the genus *Etheostoma* because of the reduced number of pored lateral line scales, interrupted infraorbital pore conditions in the head canal, reduction in spine and ray number, and reduced size. Our analysis confirms Page's (1981) combination of the groups *Hololepis*, *Villora*, and *Microperca* with *Etheostoma exile*.

Ontogenetic. Synapomorphies for *Boleichthys* include small hatching lengths (3.0–3.5 mm TL); reduced 15 preanal myomeres; reduced 19 postanal myomeres; reduction in morphometric characters including body depth/TL, yolk-sac length/TL, and greatest body depth/TL; possessing indented egg envelopes; spawning among aquatic vegetation along stream banks; and small yolk-sac length/TL (0.23–0.28) (Simon, 1983, 1985; Simon and Faber, 1987; Simon et al., 1995).

PRELIMINARY INTRODUCTION TO SUBGENERA OF THE DARTER GENUS *PERCINA*

The following subgeneric classification for *Percina* is based on Bailey and Gosline (1955), Collette (1965), Page (1974a, 1976a, 1977, 1983) and Page and Whitt (1973a, 1973b), Simon (1985), Simon and Kaskey (1991), and original data used to describe adult and ontogenetic classification based on cladistic analysis. The following subgeneric treatment is primarily from Page (1974a). All nine subgenera of *Percina* are recognized in the Ohio River drainage.

Alvordius Girard

Included species: *Percina macrocephala*, *P. maculata*, and *P. roanoka*.

Diagnosis. Adult. The subgenus *Alvordius* is the most diverse subgenus, containing 8 described and another 1–2 undescribed species (Etnier and Starnes, 1993). *Alvordius* has a naked breast, a nonserrate preoperculum; separate gill membranes; highly modified midventral scales in males; a broad frenum; absence of bright colors, with the exception of *P. roanoka*; tuberculate ridges occur on rays of the anal and pelvic fins. All species have a prominent mid-lateral stripe or a row of dark blotches (Raney and Hubbs, 1948; Page, 1974a; Mayden and Page, 1979; Beckham, 1980).

Ontogenetic. Preliminary characterization of *Alvordius* includes moderate preanal myomere counts (18–23); high postanal myomere counts (20–28); small to large yolk sac, tapering posteriorly (0.254–0.389); and oval eyes.

Cottogaster Putnam

Included species: *Percina copelandi.*

Diagnosis. Adult. *Cottogaster* contains the smallest members of *Percina*. *Cottogaster* possesses small maximum size; low meristic values; absence of a frenum; presence of breeding tubercles and a complete row of modified mid-ventral scales in males; chromatic breeding colors absent; preoperculum with a smooth edge; gill membranes separate.

Ontogenetic. *Cottogaster* looks similar to members of subgenus *Boleosoma*. *Cottogaster* has small egg sizes (1.4 mm diameter); short preanal length/TL (0.426); well-developed jaws at hatching; reduced preanal myomeres (14); high postanal myomeres (24); robust greatest body depth/TL (0.164); robust anal depth/TL (0.180); body unpigmented.

***Ericosma* Jordan**
Included species: *Percina evides.*

Diagnosis. Adult. *Ericosma* males are brightly colored; well-developed breeding tubercles or tuberculate ridges and well-developed modified belly scales present; frenum present; preoperculum with smooth margins; gill membranes separate (Page, 1974a).

Ontogenetic. *Ericosma* can be diagnosed by moderate spherical egg diameters (1.8–2.1 mm); moderate preanal myomere counts (18–19); high postanal myomere counts (24–26); and yolk sac triangular, large, and deepest in center of the membrane; moderate preanal length/TL (0.487–0.495).

***Hadropterus* Agassiz**
Included species: *Percina sciera.*

Diagnosis. Adult. *Hadropterus* consists of four species, of which only one occurs in the Ohio River drainage. Diagnostic characters include the presence of serrations on the margins of the preoperculum; well-developed row of modified mid-ventral scales; broad frenum; moderately connected gill membranes; vertical row of three blotches at base of caudal fin; absence of chromatic breeding colors, with the exception of a yellow marginal band on the dorsal fin (Richards and Knapp, 1964).

Ontogenetic. Preliminary characterization of *Hadropterus* includes small to moderate spherical eggs (1.1–1.5 mm); moderate preanal myomere counts (19–21); moderate postanal myomere counts (21–22); pigmentation forming a ventral band from anterior yolk sac to anus; and high preanal length/TL (0.530–0.548).

***Hypohomus* Cope**
Included species: *Percina aurantiaca.*

Diagnosis. Adult. The monotypic species group possesses brightly colored males with yellow and orange sides; row of discrete dark spots on the sides; gill membranes separate; preoperculum with smooth border; frenum well developed; tuberculate ridges present on anal and pelvic fin rays; modified mid-ventral scales weakly developed; high caudal fin rays 17 (Page, 1974a).

Ontogenetic. No information exists for this species.

***Imostoma* Jordan**
Included species: *Percina shumardi*, *P. tanasi*, and *P. vigil*.

Diagnosis. Adult. *Imostoma* possesses excessive elongation of the anal fin in males (base over 70% of the length of spinous dorsal fin base); modified mid-ventral scales are poorly developed; frenum narrow to absent; gill membranes separate; chromatic breeding colors absent; nuptial tubercles well developed; eyes dorsally placed and close together; and four widely spaced dorsal saddles that angle down and forward (Page, 1974a).

Ontogenetic. *Imostoma* is characterized by large egg diameters (2.0 mm); an intermediate preanal myomere number (18); high postanal myomere number (22–26); yolk sac moderate, oval; body slender with greatest body depth/TL (0.12–0.14); greater head depth/TL; distinct pigmentation of obliquely rising melanophores from anus to caudal fin (Simon, 1985).

***Odontopholis* Page**
Included species: *Percina strictogaster.*

Diagnosis. Adult. Two species of *Odontopholis* are recognized that possess a keel-like extension of the ventral caudal fin base in breeding males and an increase of scales with extremely long cteni on the ventral portion of the body, including the breast, belly, and lower caudal peduncle; modified mid-ventral scales restricted to the area between pelvic fin bases; frenum well developed; gill membranes separate; nuptial tubercles and chromatic breeding colors absent; preoperculum with smooth border.

Ontogenetic. No information exists for *Odontopholis.*

***Percina* Haldeman**
Included species: *Percina burtoni* and *P. caprodes*.

Diagnosis. Adult. *Percina* are considered the most derived of the genus and are characterized by a large conical snout and tiger stripe patterns of dark, vertical bars on a straw-colored background; frenum very broad; gill membranes separate; border of preoperculum smooth; modified mid-ventral scales well developed; males develop orange submarginal bands on spinous dorsal fin; nuptial tubercles present as tuberculate ridge on anal and pelvic fin rays and as hardened swellings on ventral scales (Page, 1974a).

Ontogenetic. All members of the subgenus possess high preanal myomere counts (19–24); high postanal myomere counts (18–24); slender greatest body depth/TL (0.10–0.12); narrow caudal peduncle depth/TL; sparse pigmentation limited principally to yolk sac postanal myomeres (Simon, 1985; Simon and Kaskey, 1991).

***Swainia* Jordan and Evermann**
Included species: *Percina oxyrhyncha*, *P. phoxocephala*, and *P. squamata*.

Diagnosis. Adult. Three of the five species of *Swainia* occur in the Ohio River drainage. They are characterized by very long snouts; presence of a submarginal orange band in spinous dorsal fin;

frenum well developed; 17 primary caudal fin rays; gill membranes moderately connected; branchiostegal rays occasionally 7; preoperculum with smooth border; modified mid-ventral scales well developed; discrete nuptial tubercles absent but tuberculate ridges present on anal and pelvic fin rays.

Ontogenetic. Preliminary diagnosis of *Swainia* includes moderate egg sizes (1.3–1.8 mm); moderate preanal myomere number (22); moderate postanal myomere number (21); and moderate yolk sac/TL, oval to rectangular and tapering posteriorly (0.338).

LITERATURE CITED

Bailey, R.M. and D.A. Etnier. 1988.
Bailey, R.M. and W.A Gosline. 1955.
Beckham, E.C. 1980.
Braasch, M.E. and R.L. Mayden. 1985.
Collette, B.B. 1965.
Etnier, D.A. and J.D Williams. 1989.
Howell, J.F. 1968.
Layman, S.R. 1993.
Mayden, R.L. and L.M. Page. 1979.
McKeown, P.E. et al. 1984.
Page, L.M. 1974a.
Page, L.M. 1975b.
Page, L.M. 1976a.
Page, L.M. 1977.
Page, L.M. 1981.
Page, L.M. 1983.
Page, L.M. and B.M. Burr. 1991.
Page, L.M. et al. 1992.
Page, L.M. and G. S. Whitt. 1973a.
Page, L.M. and G.S. Whitt. 1973b.
Raney, E.C. and C.L. Hubbs. 1948.
Richards, W.J. and L.W. Knapp. 1964.
Simon, T.P. 1983.
Simon, T.P. 1985.
Simon, T.P. 1987a.
Simon, T.P. 1987b.
Simon, T.P. 1988.
Simon, T.P. 1994.
Simon, T.P. 1997.
Simon, T.P. and D.J. Faber. 1987.
Simon, T.P. and N.J. Garcia. 1990.
Simon, T.P. and S.R. Layman. 1995.
Simon, T.P. and J.B. Kaskey. 1991.
Simon, T.P. et al. 1995.
Simons, A.M. 1988.
Simons, A.M. 1991.
Simons, A.M. 1992.
Williams, J.D.1975.
Williams, J.D. and H.W. Robison. 1980.
Zorach, T. 1968.
Zorach, T. 1969.
Zorach, T. 1970.
Zorach, T. 1972.
Zorach, T. and E.C. Raney. 1967.

Reproductive Biology and Life History Accounts for Percids in the Ohio River Drainage

Thomas P. Simon

The current volume is the fourth in this series and focuses on the family Percidae (pikeperch, perch, and darters). This volume contains accounts of the reproductive biology and early life history of 85 species of percids that occur in the Ohio River drainage. It provides a compilation of previously published illustrations and information, and a large amount of original unpublished descriptive data and early life ecology information. A short discussion of similar species is included at the end of each species account.

Available information on darter early life stage taxonomy has primarily been the result of life history studies and research conducted in the Ohio and Mississippi River drainages. Much of this current volume is based on original research conducted over the last 20 years. Early life history information was obtained from the extensive life history studies conducted by Lawrence M. Page and Brooks M. Burr, the aquarium spawning of captive adults, original data compilation, and from field and laboratory work conducted by the Tennessee Valley Authority.

Current theory on the systematics of the percids is based on adult morphology (Bailey and Gosline, 1955; Collette, 1963, 1965, 1967; Collette and Banarescu, 1977; Page, 1974a, 1981, 1983; Kuehne and Barbour, 1983; and Bailey and Etnier, 1988). Within the tribe Etheostomatini, two opposing viewpoints exist on darter systematics (Page, 1981; Bailey and Etnier, 1988). A few studies have evaluated the systematics of darters based on ontogenetic relationships (Simon, 1985, 1987, 1994, 1997). The diagnostic chapter advances an ontogenetic-based systematic hypothesis that resolves many of the outstanding issues between *Ammocrypta* and *Etheostoma* and relationships of *Etheostoma* subgenera.

LITERATURE CITED

Bailey, R.M. and D.A. Etnier. 1988.
Bailey, R.M. and Gosline. 1955.
Collette, B.B. 1963.
Collette, B.B. 1965.
Collette, B.B. 1967.
Collette, B.B. and P. Banarescu. 1977.
Kuehne, R.A. and R. Barbour. 1983.
Page, L.M. 1974a
Page, L.M. 1981.
Page, L.M. 1983.
Simon, T.P. 1985.
Simon, T.P. 1987.
Simon, T.P. 1994.
Simon, T.P. 1997.

GENUS
Ammocrypta Jordan

Thomas P. Simon

Based on the ontogenetic character analysis and description of *Etheostoma vitreum* (Simon, 1994), we recognize and elevate the subgenus *Ammocrypta* back to full generic status. The genus *Ammocrypta* is composed of six species and is considered a pleisomorphic darter genus by Williams (1975); however, it was reduced to a subgenus of *Etheostoma* by Simons (1991). Simons combined the sand darters with the darter subgenus *Ioa* based on an analysis of cranial morphology. Comparisons between adult members of the subgenera *Boleosoma, Ioa, Vaillantia,* and *Ammocrypta* were made using cladistic analysis. Change in cranium morphology is not a derived trait shared between the four subgenera; rather, it is an adaptation toward feeding in sand habitats. Simon et al. (1992) considered ontogenetic characteristics between the derived *Etheostoma vitreum*, *Ammocrypta*, and *Crystallaria* and recognized the separation of *Crystallaria* from *Ammocrypta* based on early life history traits. However, Simon et al. (1992) and Simon (1994) recognized the sister taxa relationships between *Ammocrypta* and *Etheostoma* as an example of convergent evolution based on similar functional feeding relationship and burying characteristics. Simon (1994) and this study refute the sister taxa relationship between *Ammocrypta* and *Etheostoma vitreum* based on ontogenetic characters.

The sand darters are considered a sister group to the crystal darter *Crystallaria asprella* based on the shared single anal spine, the arrangement of breeding tubercles, reduced frontal bones, narrow interorbital areas, narrowly conjoined branchiostegal membranes, and elongate median fin rays. Moore (1968), Simons (1991), and Wiley (1992) separated the genus from *Crystallaria*. Williams (1975) split the subgenus into two distinct species groups, each containing three species. *Ammocrypta* is considered a pleisiomorphic genus among the darters, and apomorphies include the absence of prevomerine teeth and a premaxillary frenum (Page, 1983). Simon et al. (1992) indicated that apomorphies of the early life stages of the *Ammocrypta* include the presence of a stomodeum, head not deflected over the yolk sac, spherical and pigmented eyes, a long oval yolk sac, and a single mid-ventral vitelline vein.

Three species of *Ammocrypta* are found in the Ohio River drainage (Table 4). *Ammocrypta pellucida* is wide ranging and perhaps the most stable of the three species. *Ammocrypta clara* has a limited range, but does not seem to have diminished. *Ammocrypta vivax* is considered extirpated from the Ohio River drainage. The sand darters have experienced range reduction as a result of the loss of clean sand substrates in large rivers. Dredging, channelization, erosion, and increased siltation have reduced the amount of available habitat.

Table 4

Common and scientific names of darters in the genus *Ammocryta* occurring in the Ohio River drainage following Williams (1975).

Western sand darter	*Ammocrypta clara* Jordan and Meek
Eastern sand darter	*Ammocrypta pellucida* Putnam
Scaly sand darter	*Ammocrypta vivax* Hay

WESTERN SAND DARTER

Ammocrypta clara Jordan and Meek

Ammocrypta: sand concealed, in reference to lying buried in the sand; *clara*: clear, referring to the clear to transparent flesh.

RANGE

Ammocrypta clara occurs in mainstream tributaries of the upper Mississippi River drainage from southeastern MN and central WI; collected from a tributary of Green Bay, WI; occurs in upper Wabash, White, and Maumee Rivers, IN,[*,2] Cumberland and Green Rivers, KY; and south to the Neches, Sabine, and lower Red River drainages of TX and OK.[3,4]

HABITAT AND MOVEMENT

The western sand darter inhabits moderate to large streams with slight to moderate current over clean sand, although it is known to inhabit areas with gravel and silt.[3,4,8] It prefers clear to slightly turbid waters.[10] Considered to be primarily nocturnal, and presumed to be buried in the sand during daylight emerging at dusk and night to forage.[5] Preferred substrate is primarily sand, with some small gravel and cobble.[7] It is known to conceal itself in the substrate,[7,11,14–16] but differs in the mechanics of burial from the crystal darters.* Observations of aquarium-held individuals indicated a head-first burial, with individuals arching their backs and plunging into the substrate using their large pectoral fins for acceleration.* Seasonal migrations occur with adults migrating from riffles and runs to pools during late fall to winter and entering shallows during the spring to spawn.* Western sand darters prefer shallow water (0.2–0.9 m) during the day.[10] Most collected at depths <15 cm with moderate water velocities and stream widths about 18 m;[10] occurring from slight depressions in bedrock that contained deposits of silty sand and depths of 1 m.[13]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Ammocrypta clara is known from the Wabash and White Rivers, IN;* Green and Cumberland Rivers and Wolf Creek, KY;[6] and the Clinch and Powell Rivers, TN.[13] The species is widespread in IN, but is considered extirpated from KY, with the last collections in 1925 and 1938, when the species was recorded from the Cumberland River in the now impounded Lake Cumberland and Wolf Creek, respectively.[7] Populations occur only in the Powell and Clinch Rivers, TN, where it is considered very rare.[13] The species rarity is due to heavy siltation and turbidity of former rivers, and to the construction of dams that limit mobility and recolonization.[5]

SPAWNING

Location

Spawning occurs over sand substrate in slow current in shallow water. A spawning congregation of adults was observed on the downstream side of an island in the Mississippi River, Pool 7, in shallow water.* Water depths ranged from 50 to 60 cm with slow to moderate flow.[5,9]

Season

July and early August were considered peak breeding seasons due to the presence of male breeding tubercles.[7,8] Males began developing breeding tubercles in late November with peak development in late February and March, suggesting an early summer spawning period.* Spawning occurs between late June through July in WI[8,10] and throughout the southern portions of its range.[3,18] A decrease in the ova size during August suggests that spawning was completed in late July.[7] Spawning was observed in the Black and Mississippi Rivers, WI, during late May.[5,9] Increased activity was reported, with spawning in mid-summer in IA[16] and during summer in IL.[17]

Temperature

Spawning begins at 22°C.[5,9]

Fecundity (see Tables 5 and 6)

A female collected in late June had ovaries that were 8.1% of the body weight, while in early and mid-July they averaged 7.9%, and in early August 2.0%.[7,10] Fecundity of 61–324 ova in TN.[13] A female (62 mm TL) collected in late April contained 234 undeveloped ova averaging 0.75 mm diameter.*

Table 5

Comparison of the number of ova per female western sand darter over range.

Location	Age	N	TL	No. of Ova
Wisconsin*, Wisconsin River	2	5	54–62	535.6
Missouri*, Big River	2	5	52–55	464.2
Indiana*, White River	2	3	53–57	485.7
	3	2	64–66	544.2

Table 6

Ovarian and fecundity data for western sand darters from the Mississippi River, WI.*

			Percent Occurrence of Ova			
Date	Mean GSI	Fecundity Range	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
September–November	0.19–0.28		100	—	—	0.11–0.14
Feburary	0.4		85	15	—	0.24
March	1.0		0	100	—	0.65
April	2.3		0	100	—	0.75
May	4.6	158*	0	64	36	0.8
June	8.1	61–311[10,*]	0	33	67	0.85
July	5.9	142–342[10,*]	0	45	55	0.78
August	2.0	50–88[10,*]	0	75	25	0.7

Sexual Maturity

Adults may live to reach age 3,[8,10] however, maturity is at age 2 for males and age 1 for females.* An adult male (55 mm TL) from WI had testes 12 mm in length that were 0.035% of the body weight on June 28.* Male tuberculation was absent from September to January.* Male tuberculation developed between January and April with maximum development by late June or early July.[7,15,*] Tubercles first developed on the anal and pelvic fins, then on the caudal fin rays. Females >58 mm TL were all sexually mature, and 53% of females between 46–54 mm TL were mature, while 30% of 43–46 mm TL females were mature.* Males <55 mm TL were all immature, while 56–57 mm TL were 60% mature, and 75% of all males 59–60 mm TL and all males >61 mm TL were also mature. Females were consistently larger than males, with a mean TL of 56.3 mm compared with 53.5 mm TL for males. Males exhibited sexually dimorphic traits during the reproductive season, with the enlargement of the anal fin and the shorter and more triangular shape of the genital papillae, while females had distended abdomens, a shorter soft dorsal fin, and a tapered, somewhat flattened tube.*

Spawning Act

Ammocrypta clara is an egg burier. Reproductive guild is the nonguarding, open substrate spawning psammophil guild. A spawning congregation of 50 or more adults was observed in the downstream side of an island in the Mississippi River, WI. Females remained on the periphery of the spawning cluster until ready to spawn. The female, when ready to spawn, swam into the group of males and was subsequently pursued. Courtship behavior was nonaggressive, with the male rubbing his snout and head against the female's operculum and the side of her cranium as they swam away from the main group of males. This behavior seemed to cause her to initiate spawning. Males that approached females not ready to spawn were avoided, the female often retreating to another area along the edge of the spawning cluster.[5,9,*] The sex ratio was 1:1.2 males to females, based on specimens examined during the reproductive period in the Mississippi River, WI.* The spawning cluster of adults was in dynamic motion, moving continuously along the shoreline. Adults were so preoccupied with spawning that they were netted using a Surber sampler.* The female was joined by several males as she swam away from the cluster to shallow areas with coarse sand in slow to moderate velocities. The males and females remained in close contact while the female was partially buried. The males maintained a serpentine clasp or lay parallel to the female, with a head-to-head orientation, and the spawning pair or trio vibrated as they swam forward in the substrate. Although it could not be confirmed, the female seemed to be laying more than a few eggs during a single spawning attempt; however, after each attempt she left the males to return to the outside of the spawning cluster.*

EGGS

Description
Spherical, demersal, and non-adhesive;* 0.9–1.0 mm in diameter; yolk pale yellow in color, with a single oil globule, a narrow perivitelline space, and translucent smooth egg chorion.* Latent ova were 0.1–0.14 mm in diameter, early maturing ova were 0.47–0.5 mm, late maturing ova were 0.7–0.82 mm, and mean ripe ova were 1.0 mm in diameter.* Three size classes of ova were reported in WI: yellow eggs, 0.5 mm diameter; orange ova, 0.75 mm; and orange eggs, 1.0 mm.[8,10]

Incubation
Hatching occurred in 161 h at 22°C.*

Development
Unknown.

YOLK-SAC LARVAE

See Figure 4.

Size Range
4.1–4.5 mm TL[5] to 5.0 mm TL[5,9] at hatching, yolk absorption complete by 6.8 mm TL.*

Myomeres
Predorsal myomeres 5–6; preanal 18–21; postanal 18–19; and total myomeres 37–40.[9]

Morphology
4.1–4.5 mm TL. Body terrate in cross-section; functional mouth parts with jaws well developed; head not deflected over the yolk sac; pale yellow yolk; yolk sac moderate (30.6% TL), elongated oval, tapering posteriorly; a single mid-ventral serpentine vitelline vein is present with a single loop.[9]

5.0—6.8 mm TL. Digestive system and gills functional before complete yolk absorption; complete yolk absorption occurred by 6.8 mm.[9]

Morphometry
See Table 7.

Fin Development
4.1–6.8 mm TL. Dorsal and anal finfolds complete, pectoral fins small, but present; incipient rays absent in all median and paired fins.[9]

Pigmentation
4.1–6.8 mm TL. Eyes pigmented with melanophores; entire body unpigmented.[9]

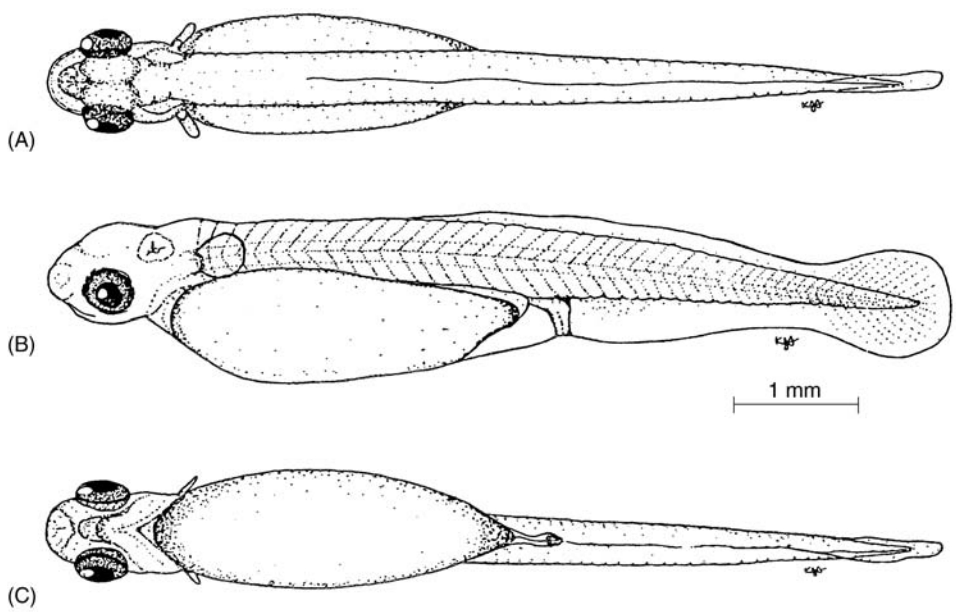


Figure 4 Development of young *Ammocrypta clara,* western sand darter, 4.1 mm. (A–C) yolk-sac larvae. (Redrawn from reference 9, with authors' permission.)

Table 7

Morphometric data expressed as percent of HL and TL for young western sand darters from the Mississippi River.*,[9]

	Total Length Groupings			
TL range (mm)	**4.1–6.8**	**7.0–8.9**	**10.0–16.8**	**17.0–26.0**
N	**4**	**3**	**4**	**5**
Ratios	**Mean ± SD (Range)**	**Mean ± SD (Range)**	**Mean ± SD (Range)**	**Mean ± SD (Range)**
As Percent HL				
SnL	17.4 ± 3.4	17.5 ± 3.1	18.9 ± 2.2	9.4 ± 2.8
	(15.8–20.8)	(17.3–22.4)	(16.9–22.9)	(17.7–23.1)
ED	41.3 ± 1.4	39.4 ± 2.2	37.9 ± 1.9	36.5 ± 1.8
	(38.0–44.4)	(34.4–42.6)	(33.5–40.1)	(33.8–39.2)
As Percent TL				
HL	17.4 ± 1.1	17.1 ± 1.1	16.2 ± 1.2	15.3 ± 1.0
	(15.6–20.2)	(16.4–20.4)	(14.3–18.1)	(13.4–16.8)
HW	12.0 ± 1.5	12.8 ± 1.2	12.1 ± 2.3	12.9 ± 1.9
	(9.8–13.6)	(10.9–13.6)	(11.4–15.6)	(9.3–14.2)
PreDFL	22.6 ± 2.6	23.5 ± .3.6	26.2 ± 2.9	27.3 ± 3.9
	(20.4–35.5)	(19.8–34.9)	(20.1–31.6)	(19.5–33.3)
PreAFO	52.4 ± 1.5	52.1 ± 1.5	49.8 ± 3.0	49.1 ± 2.2
	(50.0–54.1)	(51.8–53.4)	(48.3–53.2)	(47.9–52.4)
PreAL	52.4 ± 1.5	52.1 ± 1.5	49.8 ± 3.0	49.1 ± 2.2
	(50.0–54.1)	(51.8–53.4)	(49.8–53.2)	(47.9–52.4)
PosAL	47.6 ± 1.1	47.9 ± 2.9	51.2 ± 2.9	50.9 ± 2.0
	(45.9–50.0)	(46.6–48.2)	(46.8–50.2)	(47.6–52.1)
SL	96.3+0.9	93.4 ± 1.2	90.6 ± 1.7	90.3 ± 2.6
	(86.4–97.6)	(91.6–94.5)	(87.5–93.8)	(86.4–94.3)
YSL	30.6 ± 2.0			
	(27.5–33.6)			
P1L	7.5 ± 1.4	10.2 ± 3.1	14.8 ± 5.2	15.2 ± 2.8
	(6.1–8.6)	(9.8–12.8)	(9.1–17.2)	(9.9–16.4)
D1FL	87.4 ± 3.4	74.8 ± 6.7	24.6 ± 4.5	24.2 ± 2.9
	(64.5–79.6)	(63.1–77.2)	(17.9–26.7)	(18.7–26.5)
D2FL			14.4 ± 4.4	15.2 ± 1.7
			(11.9–18.8)	(13.4–19.1)
CFL	3.7 ± 1.4	4.6 ± 2.2	8.9 ± 2.0	9.1 ± 3.4
	(2.4–13.6)	(4.1–8.4)	(5.9–12.8)	(5.7–13.7)
BDE	13.9 ± 0.5	10.7 ± 1.0	7.3 ± 0.7	6.7 ± 0.9
	(13.2–14.4)	(9.3–11.2)	(5.6–9.9)	(6.2–7.3)
BDP1	19.6 ± 1.4	10.3 ± 1.3	10.4 ± 2.1	9.4 ± 1.1
	(17.4–21.8)	(9.2–13.0)	(8.6–14.1)	(8.3–9.6)
BDA	7.7 ± 0.2	8.0 ± 0.9	8.1 ± 0.5	8.2 ± 0.6
	(7.3–7.8)	(7.8–8.4)	(7.6–8.5)	(7.7–9.0)
MPosAD	7.5 ± 0.2	6.6 ± 0.5	6.0 ± 0.1	5.5 ± 0.3
	(7.2–7.6)	(5.0–6.9)	(5.7–6.1)	(5.2–5.7)
CPD	3.0 ± 0.2	3.1 ± 1.0	4.5 ± 0.4	4.5 ± 0.2
	(2.9–3.2)	(1.9–3.5)	(4.1–4.6)	(4.2–4.7)
YSD	5.5 ± 2.2			
	(3.1–15.6)			

POST YOLK-SAC LARVAE

See Figure 5.

Size Range
7.0 mm TL* to 16.8 mm TL.*

Myomeres
Predorsal 5–6; preanal 18–21; postanal 18–19; and total myomeres 37–40.*[,9]

Morphology
7.0–8.9 mm TL. Snout pointed; body elongate; dorsal fin insertion 27% TL, anterior of anus. Notochord flexion.[9]

Morphometrics
See Table 7.

Fin Development
8.0 mm TL. Fin rays formed in caudal and pectoral fins; finfold complete, dorsal and anal finfolds differentiated.*

10.0–12.0 mm TL. Median fins with development of rays in each of the fins; finfolds completely differentiated. Pelvic fin bud present at 10.9 mm TL.*

16.8 mm TL. Adult complement of fin rays present in all median fins, paired fins with adult counts in pectoral fins.*

Pigmentation
6.0–7.0 mm TL. Several postanal stellate melanophores formed along the mid-ventral myosepta.*

8.0–12.0 mm TL. Melanophores dorsally on cranium, concentrated on the optic lobe, cerebellum, and snout. Melanophores occurring on dorsum from nape posterior at every third myomere; a continuous line of melanophores occurs along the mid-lateral and base of the caudal peduncle; ventrally, a single melanophore occurs at the base of each postanal myosepta.[5]

JUVENILES

See Figure 5.

Size Range
17*–42 mm TL.[11]

Fin Development
26 mm TL. All median and paired fin rays distinct and with full complement of fin spines and rays. Finfolds completely differentiated, caudal fin truncate.*

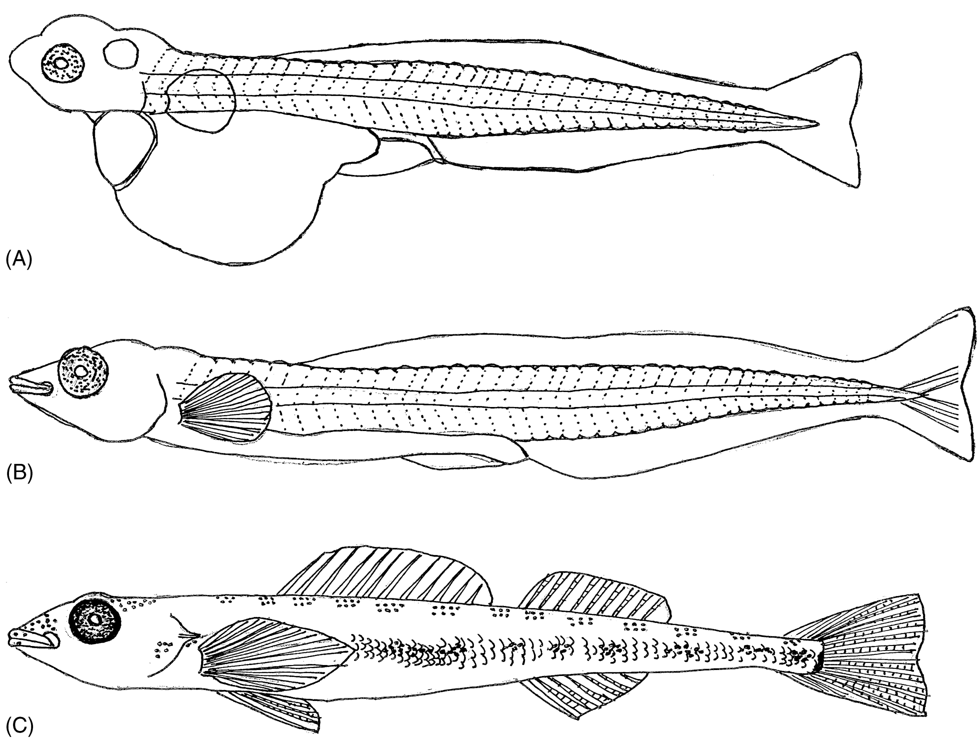


Figure 5 *Ammocrypta clara,* western sand darter, Mississippi River, Alma, WI. (A) yolk-sac larva, 5.2 mm, lateral view. (B) post yolk-sac larva, 7.0 mm, lateral view, and (C) juvenile, 17.2 mm, lateral view (original drawings).