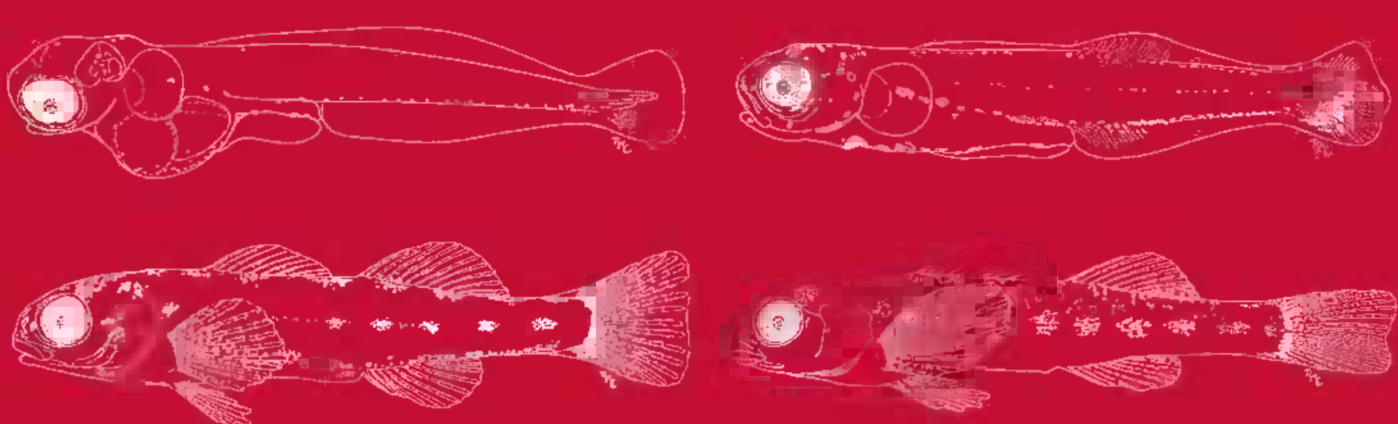
REPRODUCTIVE BIOLOGY AND EARLY LIFE HISTORY OF FISHES IN THE OHIO RIVER DRAINAGE

Percidae—Perch, Pikeperch, and Darters

VOLUME 4



Thomas P. Simon
Robert Wallus

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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

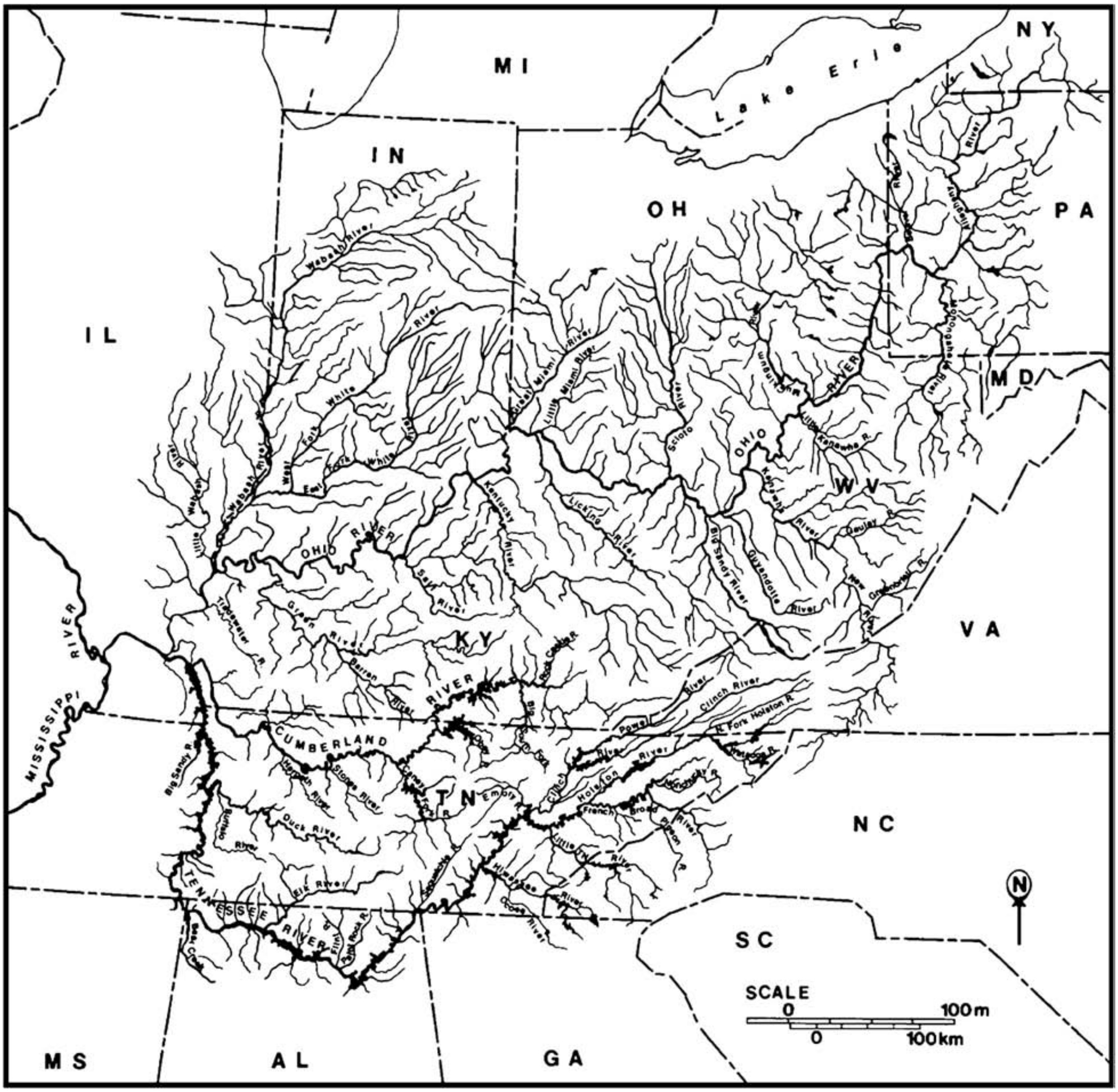

Figure 1 Map of Ohio River system.

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

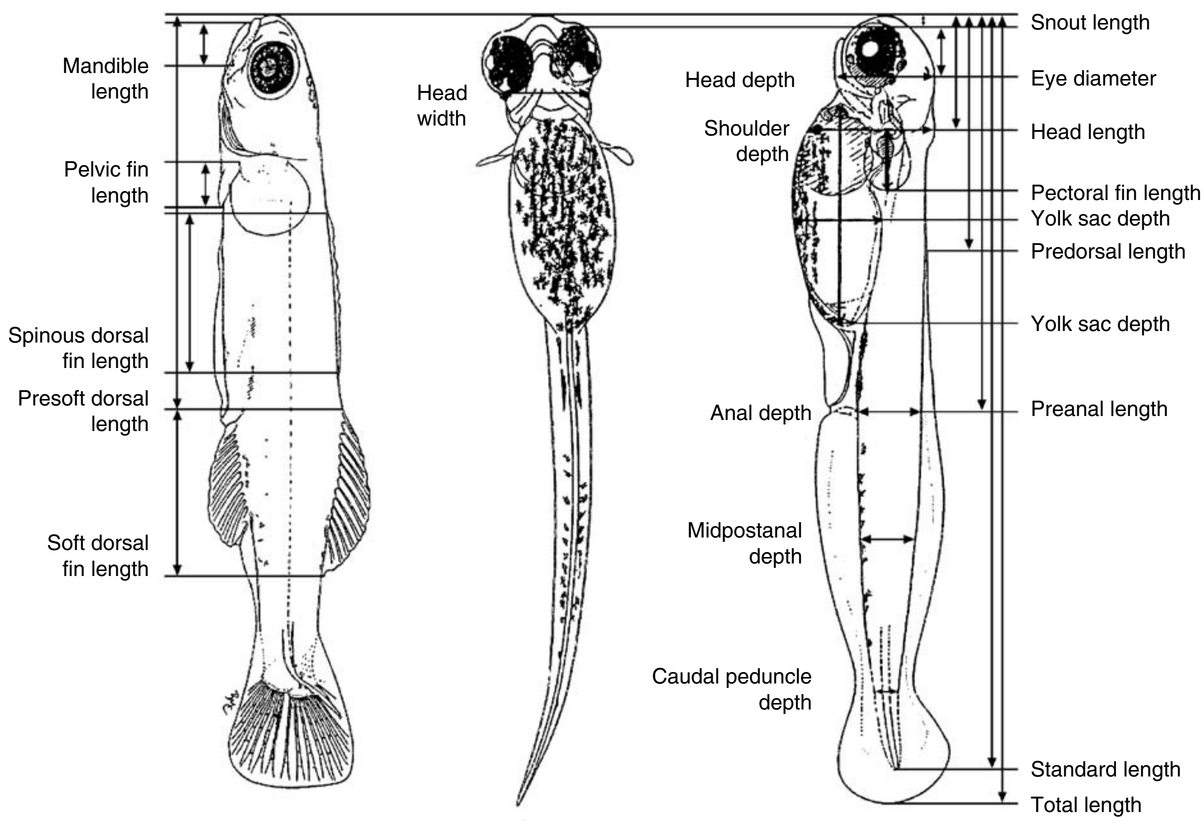

Figure 2 Diagrammatic representation of typical yolk sac and post yolk sac larval percid (Simon 1994).

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.

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Distinguishing Characteristics

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

Robert Wallus and Thomas P. Simon

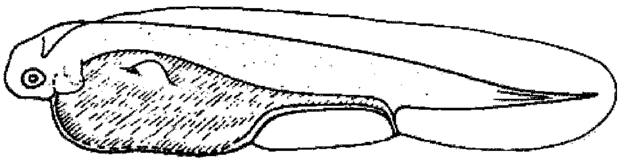
In all, 27 families of fishes occur in the Ohio River drainage. The following pictorial guide is based on distinguishing characteristics that are diagnostic to separate each of the families. Diagnostic characters for yolk-sac and post yolk-sac stages of development are highlighted for each family.

YOLK-SAC LARVAE | POST YOLK-SAC LARVAE

ACIPENSERIDAE — sturgeons

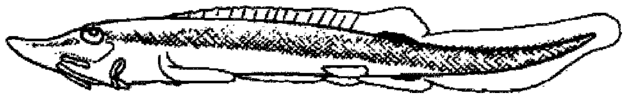
Yolk-sac larvae

- 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

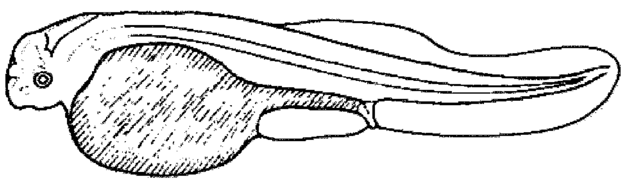
- Extended snout with four ventral barbels
- Ventral mouth
- Heterocercal tail



POLYODONTIDAE — paddlefishes

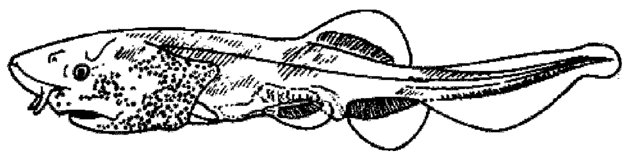
Yolk-sac larvae

- 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

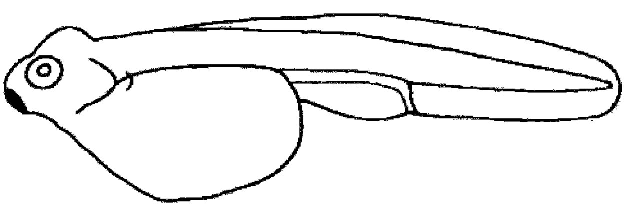
- Rostrum develops with two ventral barbels
- Numerous sensory patches present on head and operculum
- Heterocercal tail



LEPISOSTEIDAE — gars

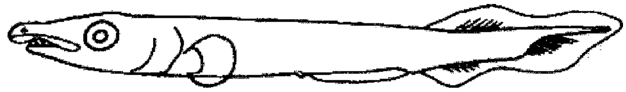
Yolk-sac larvae

- 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

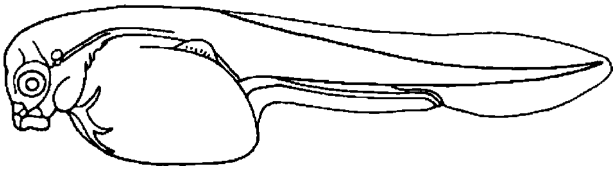


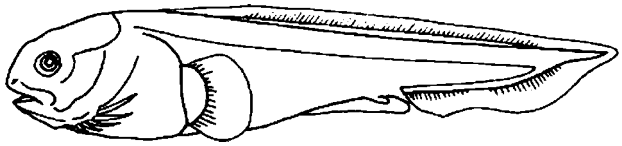
YOLK-SAC LARVAE	POST YOLK-SAC LARVAE

AMIIDAE — bowfins

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

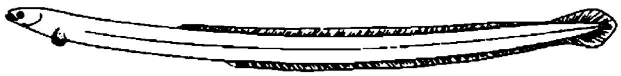
Post yolk-sac larvae:
- Round, robust head
- Gular plate
- Long dorsal fin, origin above pectoral fins





ANGUILLIDAE — freshwater eels

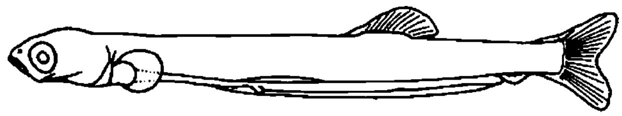
Larvae are absent from the Ohio River drainage, but elvers with adult characteristics occur.



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

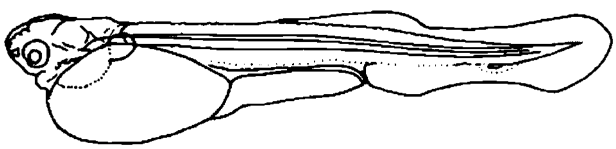
Post yolk-sac larvae:
- Slender, little pigment
- Posterior vent
- Anal fin posterior to dorsal fin

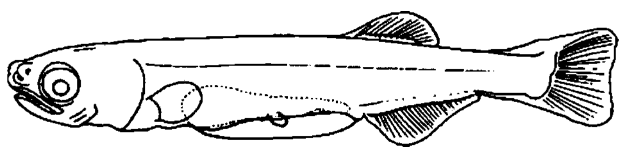


HIODONTIDAE — mooneyes

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



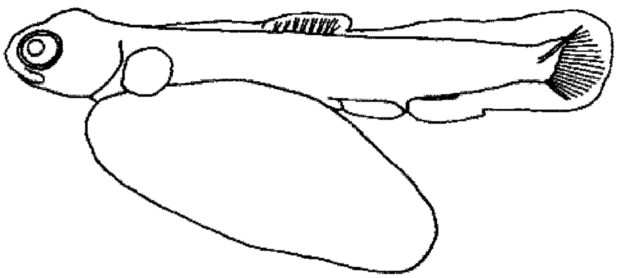


YOLK-SAC LARVAE / POST YOLK-SAC LARVAE

SALMONIDAE — trouts

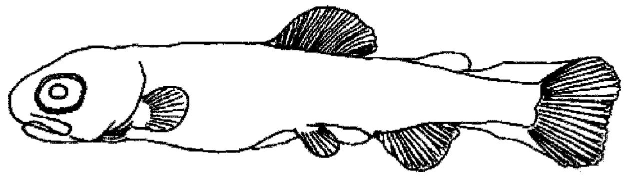
Yolk-sac larvae

- 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

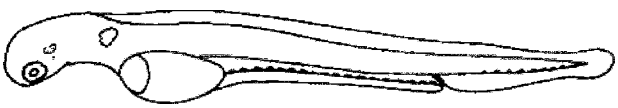
- Robust
- Large, rounded head
- Adipose fin



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



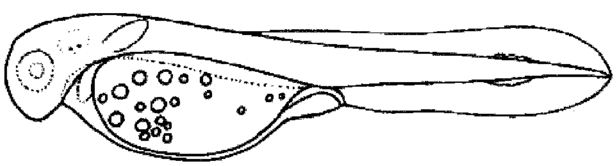
Post yolk-sac larvae

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

UMBRIDAE — mudminnows

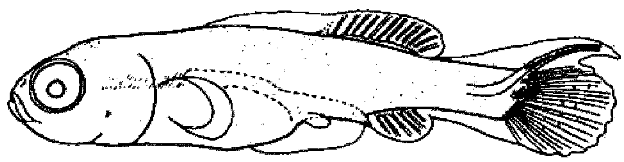
Yolk-sac larvae

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



Post yolk-sac larvae

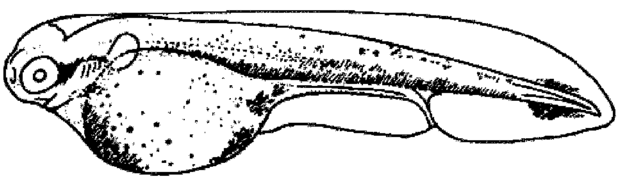
- Robust
- Darkly pigmented
- Urostyle extends beyond margin of developing caudal fin



ESOCIDAE — pikes

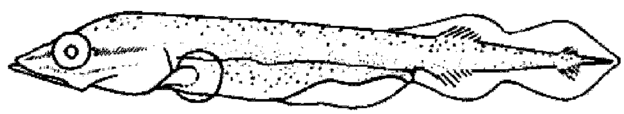
Yolk-sac larvae

- 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

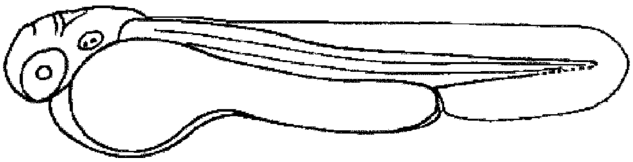
CYPRINIDAE — carps and minnows

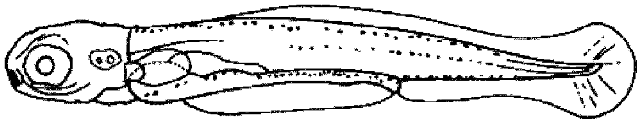
Yolk-sac larvae

- 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





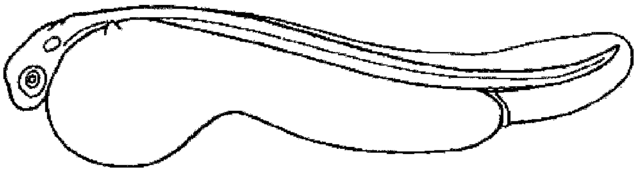
CATOSTOMIDAE — suckers

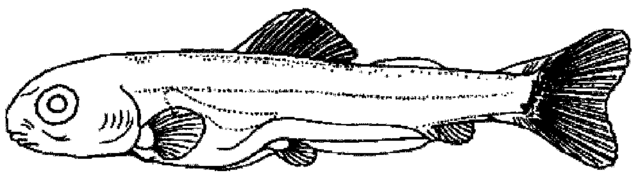
Yolk-sac larvae

- 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





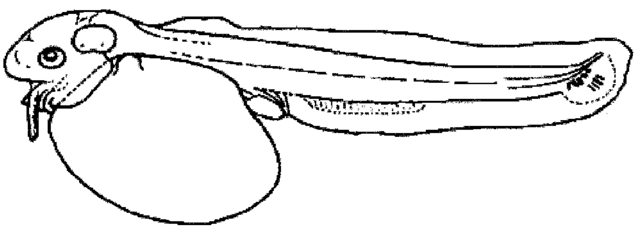
ICTALURIDAE — catfishes

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

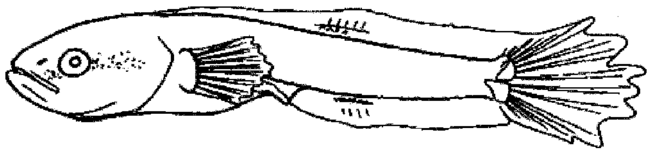


YOLK-SAC LARVAE	POST YOLK-SAC LARVAE

AMBLYOPSIDAE — cavefishes

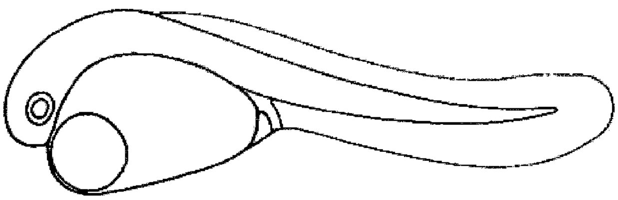
Yolk-sac larvae
- No information

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*

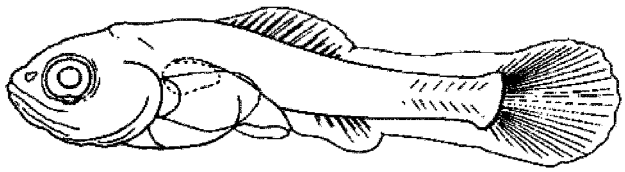


APHREDODERIDAE — pirate perches

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

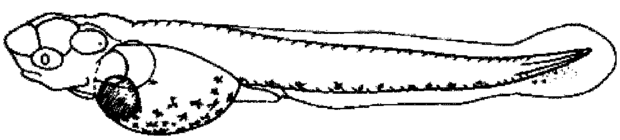


Post yolk-sac larvae
- Head and body robust
- Usually fewer than 30 total myomeres
- Anus begins to migrate toward gular region at about 9 mm TL

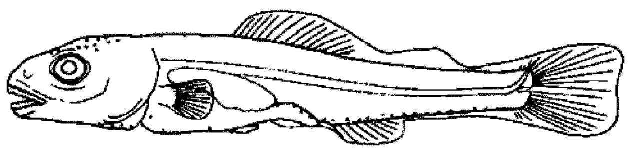


PERCOPSIDAE — trout-perches

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

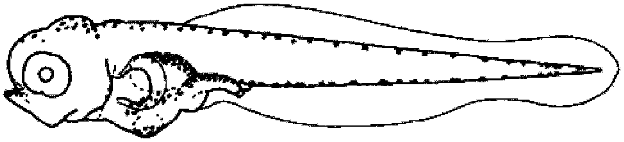


Post yolk-sac larvae
- Large head
- Adipose fin
- Long snout
- Air bladder obvious

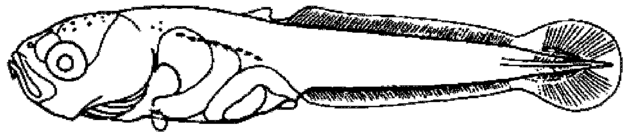


GADIDAE — codfishes

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

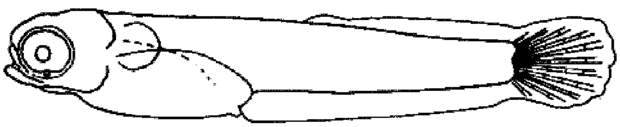


YOLK-SAC LARVAE / POST YOLK-SAC LARVAE

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

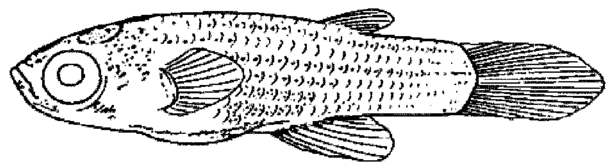
POECILIIDAE — livebearers

Yolk-sac larvae

- Inside female

Post yolk-sac larvae

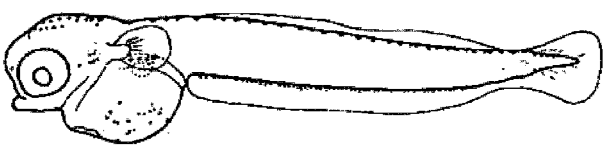
- Scales present at birth
- Rays in all fins at birth
- Superior mouth
- Dorsal fin short, seven to eight rays



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



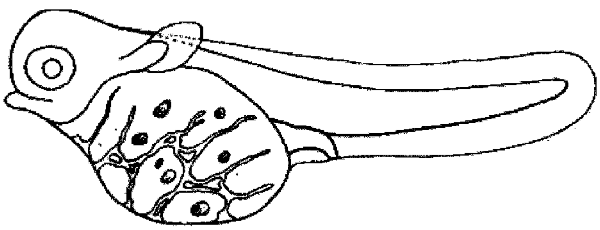
Post yolk-sac larvae

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

GASTEROSTEIDAE — sticklebacks

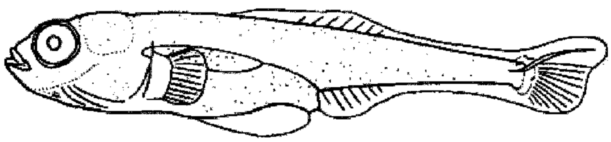
Yolk-sac larvae

- 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

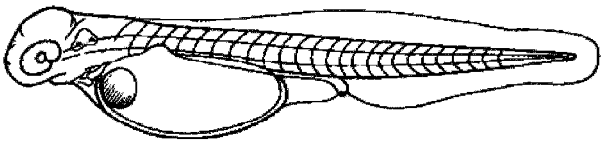


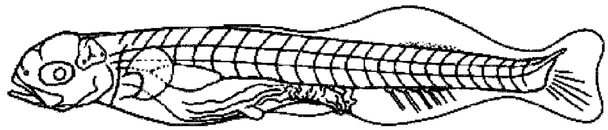
YOLK-SAC LARVAE	POST YOLK-SAC LARVAE

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

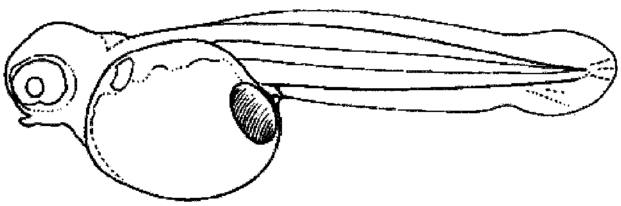


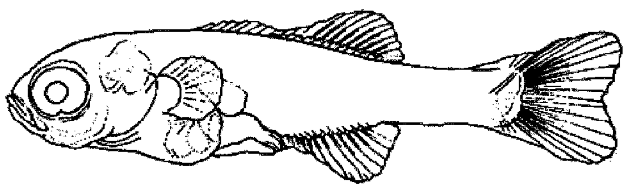


CENTRARCHIDAE — sunfishes

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

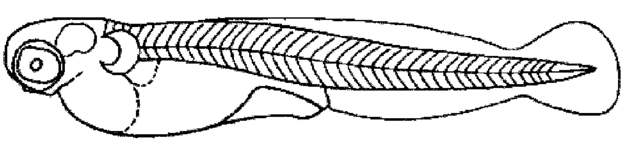


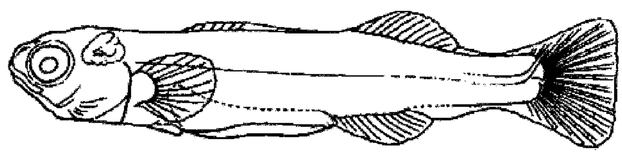


PERCIDAE — perches

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

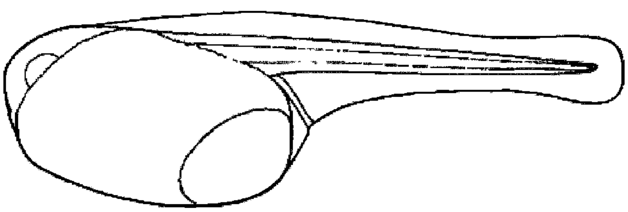


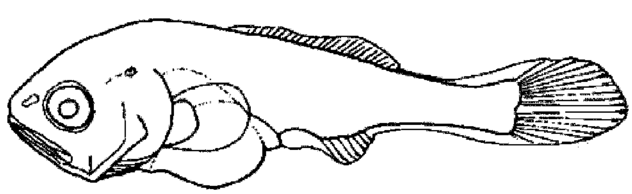


SCIAENIDAE — drums

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

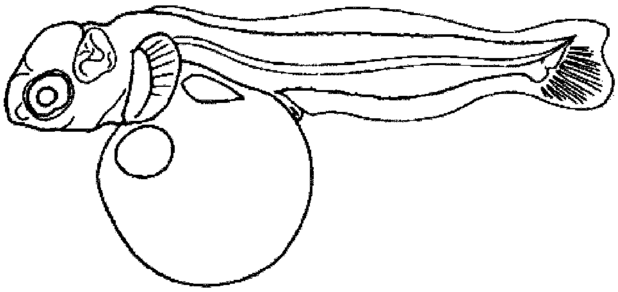




YOLK-SAC LARVAE

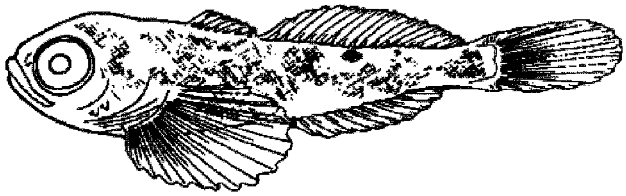
COTTIDAE — sculpins

- 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

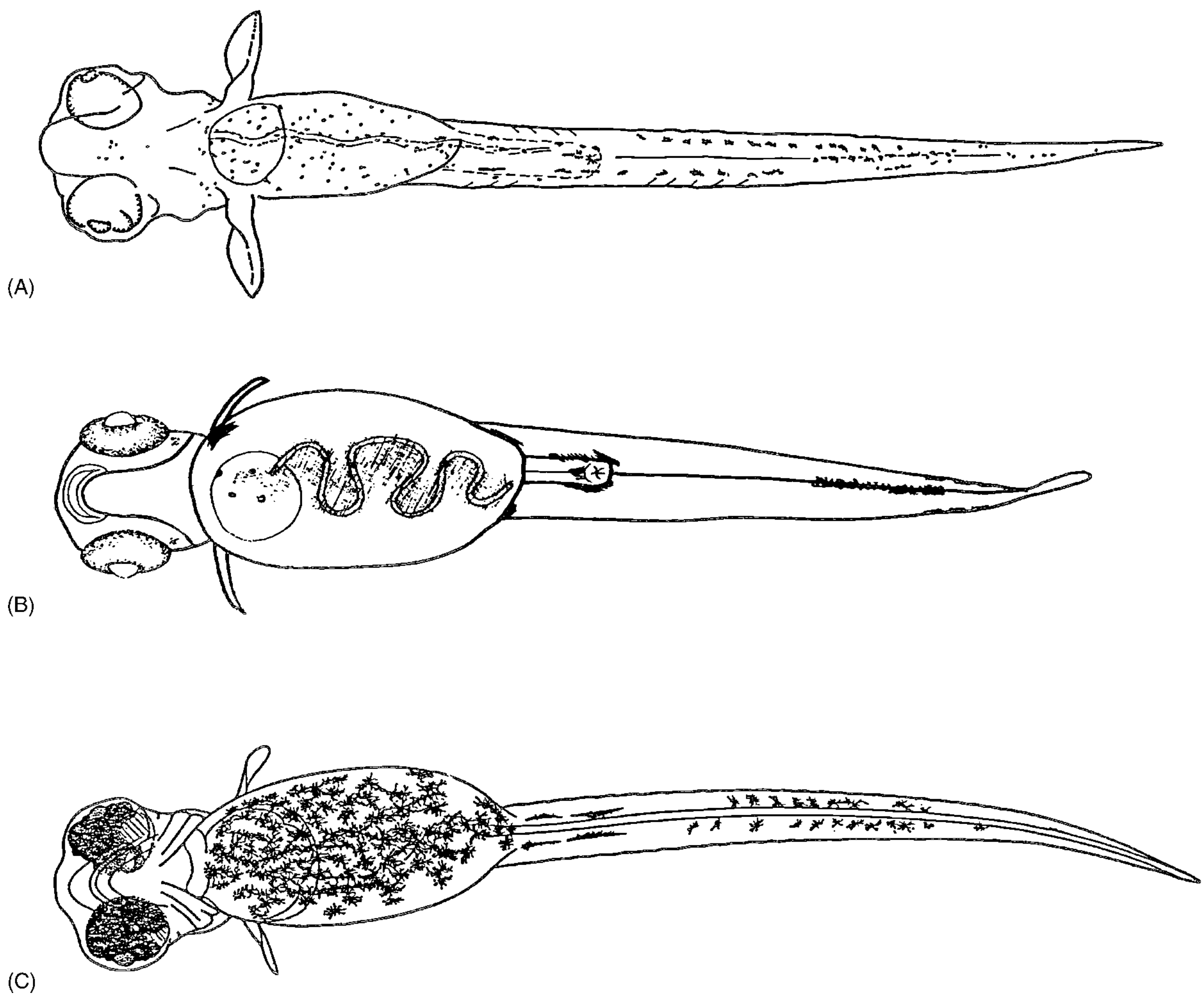


Figure 3 Vitelline vein structure of yolk-sac larval percids: (A) single, mid-ventral; (B) serpentine, single mid-ventral; and (C) complex network plexus. (From Simon, T. P. 1994. Doctoral dissertation, University of Illinois, Chicago, U.S.A. with permission.)

(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).

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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.

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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]

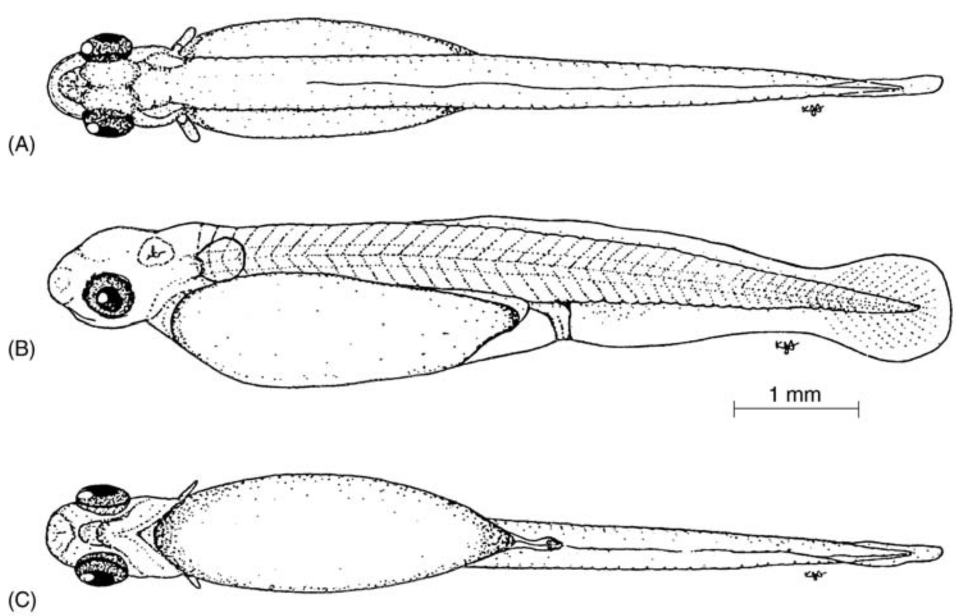

Figure 4 Development of young *Ammocrypta clara,* western sand darter, 4.1 mm. (A–C) yolk-sac larvae. (Redrawn from reference 9, with authors' permission.)

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.*

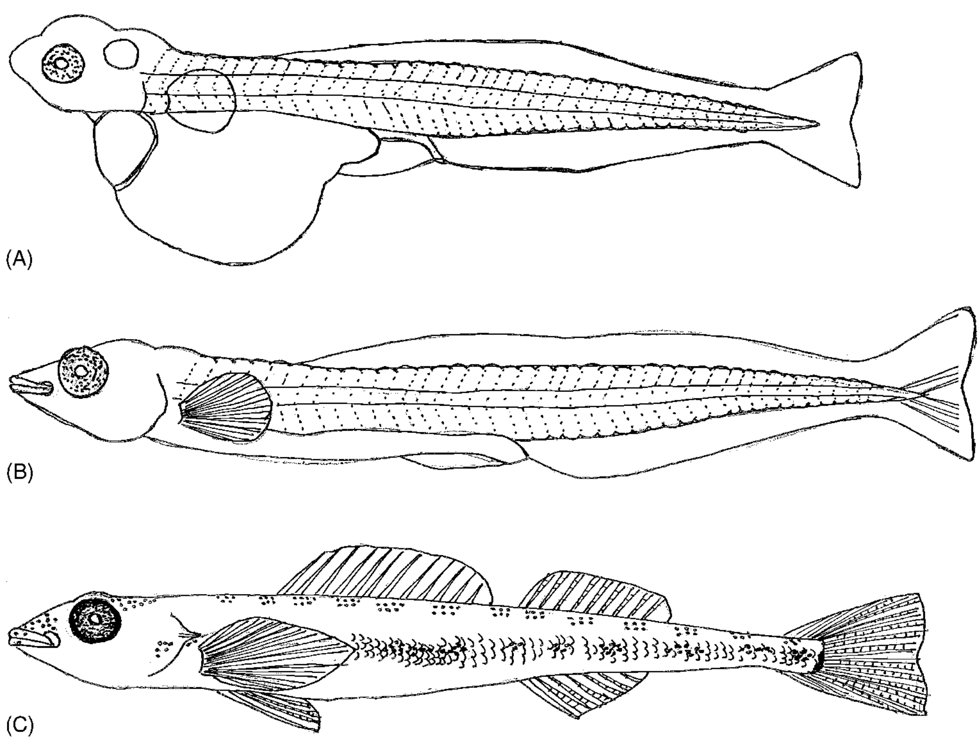

Figure 5 *Ammocrypta clara,* western sand darter, Mississippi River, Alma, WI. (A) yolk-sac larva, 5.2 mm, lateral view. (B) post yolk-sac larva, 7.0 mm, lateral view, and (C) juvenile, 17.2 mm, lateral view (original drawings).

Larger juveniles. Spinous dorsal IX–XIII; soft dorsal 9–13; pectoral rays 12–15; anal rays I 8–11; pelvic rays I 5.[2,3,8] Caudal fin truncate.

Morphology
Lateral scales 63–81; posterior 3–5 scales deflected ventrally; scale rows above lateral line 0–2; below lateral line 1–5. Palatine and prevomerine teeth absent; narrow premaxillary frenum; branchiostegal membranes separate, rays 6, 6. The cheeks and opercles are partially scaled; nape and dorsum along the base of the dorsal fins are unscaled or with a few scattered scales; the breast and belly are partially scaled; the caudal peduncle is mostly scaled.[3] Cephalic sensory canals complete, lateral canal pores 5, supratemporal canal pores 3, supraorbital canal pores 4, coronal pore present; infraorbital canal pores 8; preoperculomandibular canal pores 8.[7] Vertebrae 38–42.[7,8]

Morphometry
See Table 7.

Pigmentation
17.0 mm TL. Dorsum of cranium with a dusky area over cerebellum; 12 dorsal blotches occur along the mid-dorsum evenly spaced from anterior pectoral fin base to origin of caudal fin base. Mid-lateral blotches conspicuous, however, distributed as discrete melanophores.*

Larger juveniles. Lower portion of the head is unpigmented, with the exception of a few melanophores along the rami of the jaw. Scales of the cheek and opercles have melanophores along the exposed margins and central portion. A solid band of pigment extends dorsally around the tip of the snout to just below the level of the nostrils. Brown blotches, 12–16, occur along the mid-dorsum, usually evenly spaced. Laterally, a narrow stripe extends the length of the body; 9–13 horizontal blotches exist along the stripe, usually centered on the lateral stripe. A row of melanophores present from the base of the last anal ray posterior to the caudal base. Median fin pigment restricted to margins of spines and rays; pelvic fins are unpigmented.[7]

TAXONOMIC DIAGNOSIS OF YOUNG WESTERN SAND DARTER

Similar species: other sand darters.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 6)
Eggs. Laid in shallow habitats buried in coarse sand and gravel substrates without silt in slight current.[9] No parental guarding is provided.[5] Embryos

Figure 6 General distribution of western sand darter *Ammocrypta clara,* in the Ohio River system (shaded areas).

develop in the darkness of interstitial spaces of clean sand and coarse gravel.*

Yolk-sac larvae. Yolk-sac larvae remain in the interstitial spaces of gravel riffles until capable of feeding. Specimens were then collected in surface drift collections along the main channel border of the Mississippi River downstream of the island area. Larvae 4.1–6.8 mm TL are photophobic and drift between dusk and night remaining in the rock interstices during the day. Higher numbers of larvae were collected during dusk diel periods than during the day. Present during June to early July in drift collections. Density of yolk-sac larvae was $0.12/100\ m^3$ after a 3–4 day incubation and absorption of yolk period.*

Post yolk-sac larvae. Individuals are pelagic drifters occurring in the water column during dusk and night diel periods.* Larvae are active swimmers remaining in the water column until 7.8 mm TL, becoming demersal at lengths >8.0 mm TL.*

Juveniles. *Ammocrypta clara* occurs over silt margins and sand substrates adjacent to the main-channel border of large rivers. Specimens 28–40 mm TL were commonly collected in the main channel border areas of the Mississippi River especially on island shorelines. In the White River, IN, young-of-the-year western sand darters were collected from long expanses of clean sand and gravel formed on the inside of river bends that possessed slight to moderate current velocities. Densities were low, typically $<0.01/100\ m^3$ or less than 1 individual/10,000 m^2.*

Table 8

Average calculated total length (mm TL) of young western sand darters from Wisconsin and Tennessee.

State	Age 1	2	3
Wisconsin[10,11,*]	42–63	51–66	58–65
Tennessee[13]	44	56	61

Early Growth

Western sand darters are 28–44 mm TL by early October in WI.* Young-of-year reach 71% of total growth during first year of life and 91% by the second year of life.[11] Specimens collected from WI ranged between 39 and 60 mm during August and September.[8] Young-of-the-year collected during September 1992 were 37 mm TL.* The length–weight relationships for western sand darters are $\log W = -12.5174 + 3.0949 \log L$, where weight is in g and total length is in mm.[8,10]

Feeding Habits

Juveniles and young adults feed primarily on the immature stages of aquatic insects, such as mayflies, midge larvae, and *Hyallela*.[4,12] Specimens from the Powell River, TN, feed exclusively on midge larvae.[13] Five specimens from the Mississippi River consumed heptageniid mayfly nymphs (10%), midge larvae (72%), and nematodes (5%).

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* Original reproductive, early distribution, and growth information was obtained from ichthyoplankton data collected by Large Rivers Research Station in the Mississippi River during 1981–1983. Original fecundity information is from specimens curated at the Northeast Louisiana University Museum of Zoology, Monroe, and Indiana Biological Survey. Developmental data are from a series obtained from the Mississippi and Black Rivers, WI (LRRC larval fish reference collection, Bloomington, IN).

EASTERN SAND DARTER

Ammocrypta pellucida (Putnam)

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

RANGE

Ammocrypta pellucida occurs from VT and southern QB; west to eastern IL; and south to KY; it is found only in the Ohio and St. Lawrence drainages.[1,2,3] The species is thought to have entered the Great Lakes system post glacial retreat through the Maumee–Wabash connection and spread to local drainages of Lake Erie, Lake St. Clair, and southern Lake Huron.[2] Occurs in upper Wabash, White, and Maumee Rivers, IN,[*,4] Cumberland River, KY, and Powell River, TN.[5,6]

HABITAT AND MOVEMENT

Ammocrypta pellucida inhabits creeks and large rivers with moderate current over clean sand,[2] avoiding the swiftest portions of riffles and heavily silted substrates.[2,3,8,14] It prefers clear to slightly turbid waters.[*,4] Remains buried in the sand during daylight emerging at dusk and night to forage.[9–11] Substrate reported to be primarily sand, with some small gravel and cobble.[4,7] It is known to conceal itself in the substrate;[5,6,10,14] however, it 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.* Burying behavior is probably an energy-conservation mechanism providing safety while resting.[5,6,10] Seasonal migrations occur with adults migrating from riffles and runs to pools during late fall to winter, returning to shallows during the spring to spawn.* Startle responses of captive eastern sand darters suggest that escape mechanisms may involve leaving the water to confuse predators.[6] Eastern sand darters prefer shallow water (0.3–0.5 m) during the day.* Most collected at depths < 0.5 m with moderate water velocities and stream widths of about 15 m.* The species from the Tippecanoe River, IN, was reported to prefer water depths of 0.3 m, which was typically the deepest, swiftest runs over substrates of sand (80%) and gravel (20%).[16]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

The eastern sand darter is known to occur in the Wabash, Tippecanoe, and White Rivers, IN,* from the mouth of the Cumberland River east to the Allegheny and Monongahela Rivers, excluding their upland tributaries.[1–3] The Kanawha and Big Sandy Rivers have never yielded the species except in their lowermost reaches.[2] Reported from the upper Tennessee River drainage and from the Powell and Cumberland Rivers; however, Powell River specimens were actually *A. clara*.[13,18] The species is widely distributed but rare in IN;* considered endangered in KY;[13] locally abundant in Middle Island Creek and Little Kanawha River, WV;[15] extirpated from many of the inland streams of OH and possibly the Ohio River, where the last specimen was collected from Galia Co. in 1977.[8] Rare due to heavy siltation and turbidity of former habitats and to the construction of dams that limit mobility and recolonization.[6]

SPAWNING

Location

Spawning occurs over sand-gravel substrates in slight to moderate current in shallow riffles.[*,16] Spawning was observed on April 7, 1988 at 2100 h in laboratory aquaria over sand and gravel substrates.[16]

Season

Spawning occurred from early April to mid-June in the Tippecanoe River, IN;[16] mid-May to August over the species entire range.[10] Spawning occurred in June and July in the Ohio River drainage and 2–3 weeks later in the St. Lawrence River drainage population;[2,10] occurred during May until August in Salt Creek, OH.[14] Peak breeding season, estimated by the presence of male breeding tubercles, was between June and July.[10] Males began developing breeding tubercles in late November, with peak development occurring in late February and March, suggesting an early summer spawning period.* Spawning is considered to take place between late May through late August.[17] Female ovaries show differential stages of ova development during mid-June and mid-July. Females were spent by mid-July, with no ripe ova found after the first week of August.[10] Spawning adults were observed in the Tippecanoe River, IN, during late May.* Spawning in laboratory aquaria occurred from early April to mid-June.[16]

Temperature
Spawning occurred at 20–23°C in laboratory aquaria; at 17–26°C in field observations from the Tippecanoe River, Fulton Co., IN;[7,16,*] and ranged from 14.4 to 24.4°C in Salt Creek, Vinton Co., OH.[14]

Fecundity (see Table 9)
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 averaged 343.1 ova and ranged from 22 to 829 ova in OH.[14] Females having more ova or attaining larger sizes also bore more mature ova. Females between 37.9 and 50.1 mm SL contained between 22 and 829 undeveloped ova averaging 0.99 mm diameter.[14,*] Mature females represented 40% of the total female population in OH.[14]

Sexual Maturity
Adults may live to reach age 2[14] or 3,* however, maturity is at age 2 for males and age 1 for females.[*,14] Adult males from OH had reduced testes between October and May. Testes of mature males became greatly enlarged and had a fine granular appearance. Testes were much broadened, clavate, and thickened anteriorly.[14] Testes of a 58.7 mm TL male, 12 mm in length,* were 0.032% of the body weight on June 12. Male tuberculation was absent from September to January.* Male tuberculation developed between January and April, with maximum development by late June or early July.[*,14] Tubercles developed on the ventral inner surface of the pelvic fins, and not on the anal or caudal fin rays as in other *Ammocrypta.*[10,14] Females <36 mm SL by May were not sexually mature, 25% of females between 31 and 36 mm TL were mature, while 37–50.1 mm SL females were mature.[*,14] Males <34 mm SL were all immature,[14] while 72% of 45–57 mm TL males were mature, and all males >58 mm TL were mature. Males were larger than females with a mean TL of 42.5 mm compared to 42.0 mm TL for females. This length difference was not considered sexually dimorphic. Males exhibited sexually dimorphic traits during the reproductive season with the development of nuptial tubercles between the pelvic fins, enlargement and dark pigmentation of the anal fin, and the shorter and broadly conical shape of the genital papillae, while females had distended abdomens, a shorter anal fin, and a digitiform, more elongate and flaccid, and some what flattened tube touching the base of the anal fin.[14,16,*]

Spawning Act
Ammocrypta pellucida is an egg burier. Reproductive guild is the nonguarding, open substrate spawning psammophil guild. Spawning occurred day and night; the eastern sand darter is an intermittent spawner, with females spawning many times during the season and depositing eggs every 4–5 days. Laboratory observation of reproductive behavior was based on specimens from the Tippecanoe River,

Table 9

Ovarian and fecundity data for eastern sand darters from the Tippecanoe River, IN,* and Salt Creek, OH.[14]

		Percent Occurrence of Ova			
Date	Fecundity Range	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
December	361.8[14]	100	—	—	0.2
February	281[14]	100	—	—	0.22
March	383[14]	100	—	—	0.28
May	331[14]	—	88.2	11.8	0.99
June	401[14]	—	83	17	1.05
July	321[14,*]	—	80	20	0.97
August	336[14,*]	—	91.8	8.2	1.03

Fulton Co., IN.[16] A single female was pursued by four males, with the males often resting their pelvic fins and chins on her back. When ready to spawn, the female swam into a sand and gravel area. During 75% of the spawning episodes the female was mounted by a single male who positioned himself directly on top of her. Egg deposition occurred as the pair buried their tails and caudal peduncles into the substrate and vibrated. Eggs were deposited singly in the substrate. The other 25% of the spawning episodes involved a trio that included a second male. This male positioned himself alongside the female and vibrated with the pair. The males and female remained in close contact while the female was partially buried. The male developed dark pigmentation on the first three to four outer rays of the pelvic fins and small nuptial tubercles on the ventral surface of the first few outer pelvic rays. It was apparent that the tubercles were used to hold or stimulate the female during spawning.[16] Courtship behavior was nonaggressive, with the male rubbing his snout and head against the female's operculum and the side of her cranium. This behavior seemed to cause her to initiate spawning.* The sex ratio was 1:1 based on specimens examined during the reproductive period in Salt Creek, Vinton Co., OH.[14] Adult sex ratios were constant throughout the year, suggesting little or no migration between feeding and spawning habitat.[14]

EGGS

Description
Spherical, demersal, 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.* Fertilized eggs were translucent, spherical, and slightly adhesive, averaging 1.4 mm diameter (range: 1.1–1.7 mm).[16] Latent ova were 0.2–0.22 mm diameter, early maturing and 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 OH. The smallest or immature ova were usually faceted and translucent to clear with no yolk development and a visible nucleus, mature ova were smaller and opaque white or light yellow, and ripe ova were orange to translucent orange and averaged 1.0 mm.[14]

Incubation
Hatching occurred in 96–120 h at 20.5–23°C.[*,7]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 7.

Size Range
5.5–5.7 mm TL[7] at hatching, yolk absorption complete by 7.4 mm TL.[*,7]

Myomeres
Predorsal myomeres 6–10; preanal 23–26; postanal 18–19; and total myomeres 41–44.[7]

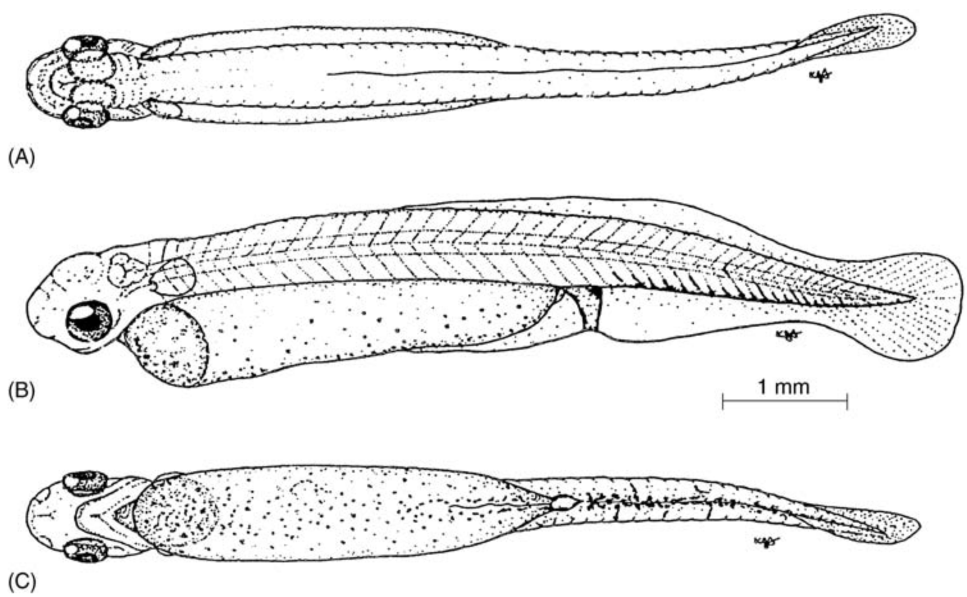

Figure 7 Development of young *Ammocrypta pellucida*, eastern sand darter, Tippecanoe River, Pulaski Co., IN. (A–C) 5.4 mm TL, yolk-sac larva, dorsal, lateral, and ventral view. (From reference 7, with authors' permission.)

Morphology
5.5–5.7 mm TL. Body terete in cross-section; stomodeum present with no functional mouth parts; head not deflected over the yolk sac; pale yellow yolk; yolk sac large (40.1% TL), elongated oval, tapering posteriorly; a single mid-ventral serpentine vitelline vein is present with a single loop.[7]

6.8–7.4 mm TL. Digestive system and gills functional before complete yolk absorption; complete yolk absorption occurred by 7.4 mm.[7]

Morphometry
See Table 10.

Fin Development
5.5–7.4 mm TL. Dorsal and anal finfolds complete, pectoral fins small, but present; incipient rays absent in all median and paired fins.[7]

Pigmentation
5.5–6.2 mm TL. Eyes pigmented with melanophores; heavily pigmented mid-ventral yolk sac; melanophores adjacent to the anus; and an expanded double row of melanophores at every postanal myosepta from the anus to caudal peduncle base.[7]

6.3–7.4 mm TL. Melanophores present on the cranium, near the otic capsule, distributed dorsally over the gut, form an anterior cresent on the breast and outline the vitelline vein to the anus.[7]

POST YOLK-SAC LARVAE

Size Range
>7.4 mm TL* to 18 mm TL.*

Myomeres
Predorsal myomeres 6–10; preanal 23–26; postanal 18–19; and total myomeres 41–44.*[,7]

Morphology
>7.4–8.9 mm TL. Notochord flexion.[7]

12.8–18 mm TL. Snout pointed; body elongate; dorsal fin insertion 27% TL, anterior of anus.*

Morphometrics
See Table 10.

Fin Development
>7.4–8.9 mm TL. Fin rays formed in caudal fin; finfold complete, dorsal and anal finfolds differentiated.*

12.8–16.2 mm TL. Median fins with development of rays in each of the fins; finfolds completely differentiated. Pelvic fin bud present at 12.8 mm TL.*

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

Pigmentation
>7.4–8.9 mm TL. Several postanal stellate melanophores formed along the mid-ventral myosepta.*

12.8–18.0 mm TL. Melanophores dorsally on cranium, concentrated on the optic lobe, cerebellum, and snout. Melanophores occur on dorsum from nape posterior to caudal peduncle; 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.[7]

JUVENILES

Size Range
18* to 36 mm TL.[8]

Fin Development
18–20 mm TL. All median and paired fin rays distinct and with full complement of fin spines and rays. Finfolds completely differentiated, caudal fin truncate.*

Larger juveniles. Spinous dorsal VII–XII; soft dorsal 8–12; pectoral rays 12–16; anal rays I 7–11; pelvic rays I 5.[2,3,8] Caudal fin truncate.

Morphology
Lateral scales 65–84, complete; lateral line slightly or not deflected downward posteriorly; scale rows below lateral line 4–7. Gill membrane slightly joined. Palatine and prevomerine teeth absent; narrow premaxillary frenum; branchiostegal rays 5, 5. The cheeks and opercles are scaled; nape varies from unscaled to partially scaled; the breast and belly are unscaled, with the exception of embedded scales near the prepectoral area.[10,12,23] Cephalic sensory canals complete, lateral canal

Table 10

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

	Total Length Groupings			
TL Range (mm)	5.5–6.8	7.4–8.9	12.8–16.2	18.0–20.0
N	24	8	5	5
Ratios	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)
As Percent HL				
SnL	15.6 ± 1.4	18.5 ± 3.1	22.9 ± 2.2	25.0 ± 2.8
	(13.2–19.2)	(17.3–22.5)	(17.9–22.9)	(18.7–28.1)
ED	32.2 ± 4.1	32.4 ± 2.2	28.1 ± 1.7	27.5 ± 1.7
	(23.9–45.0)	(30.4–35.6)	(27.5–33.2)	(23.8–32.2)
As Percent TL				
HL	15.6 ± 1.4	16.9 ± 1.1	17.9 ± 1.2	18.2 ± 1.0
	(13.2–19.2)	(16.4–20.4)	(14.3–18.1)	(16.4–19.8)
HW	8.5 ± 1.7	11.8 ± 1.2	12.6 ± 2.3	12.9 ± 1.8
	(7.2–12.5)	(10.9–13.6)	(11.4–15.6)	(9.8–13.9)
PreDFL	33.2 ± 3.9	33.5 ± .3.6	32.2 ± 2.9	32.3 ± 3.2
	(25.1–38.1)	(29.8–34.9)	(27.1–34.6)	(26.5–33.6)
PreAFO	62.1 ± 1.2	54.1 ± 1.6	54.8 ± 2.7	54.5 ± 2.2
	(59.6–63.3)	(52.8–56.4)	(49.3–56.2)	(50.8–55.5)
PreAL	62.1 ± 1.2	54.1 ± 1.6	54.8 ± 2.7	54.5 ± 2.2
	(59.6–63.3)	(52.8–56.4)	(49.3–56.2)	(50.8–55.5)
PosAL	37.9 ± 1.1	45.9 ± 2.9	45.2 ± 2.9	45.5 ± 2.0
	(36.7–40.4)	(43.6–47.2)	(44.8–50.7)	(44.5–49.2)
SL	96.6+0.6	90.4 ± 1.2	87.4 ± 1.7	86.4 ± 2.3
	(93.5–97.9)	(88.6–92.5)	(86.5–92.8)	(83.4–89.7)
YSL	40.1 ± 9.9			
	(32.4–52.8)			
P1L	5.5 ± 1.4	11.2 ± 3.1	12.8 ± 3.6	15.9 ± 2.9
	(3.4–7.7)	(9.8–12.8)	(9.5–15.5)	(9.3–16.7)
D1FL	66.8 ± 1.4	64.5 ± 6.7	20.1 ± 4.5	20.5 ± 2.9
	(64.5–79.6)	(63.1–77.2)	(17.9–23.9)	(17.4–23.9)
D2FL			14.9 ± 4.8	15.9 ± 1.6
			(11.4–18.8)	(12.6–19.0)
CFL	3.4 ± 1.4	9.6 ± 2.2	12.6 ± 2.0	12.5 ± 2.4
	(2.1–6.5)	(7.5–12.4)	(7.2–13.5)	(8.8–13.4)
BDE	11.3 ± 1.3	9.7 ± 1.0	7.7 ± 0.7	7.5 ± 0.9
	(9.4–13.9)	(8.3–10.2)	(6.8–8.4)	(6.2–7.9)
BDP1	12.4 ± 1.5	11.3 ± 1.3	10.8 ± 2.1	10.9 ± 1.8
	(9.8–15.2)	(9.2–13.0)	(8.6–14.1)	(8.3–11.6)
BDA	7.4 ± 0.6	8.2 ± 0.9	8.9 ± 0.5	9.5 ± 0.3
	(6.0–8.7)	(7.6–8.4)	(8.6–9.2)	(8.9–9.7)
MPosAD	5.3 ± 1.1	5.6 ± 0.5	6.0 ± 0.1	6.6 ± 0.4
	(4.5–6.2)	(5.0–6.1)	(5.8–6.1)	(6.0–7.0)
CPD	2.7 ± 0.2	3.0 ± 1.0	4.6 ± 0.4	4.8 ± 0.2
	(2.4–3.2)	(2.2–3.5)	(4.1–4.8)	(4.7–5.1)
YSD	6.7 ± 2.0			
	(1.3–10.1)			

pores 5, supratemporal canal pores 3, supraorbital canal pores 4, coronal pore present; infraorbital canal pores 8; preoperculomandibular canal pores usually 10, range between 9 and 11.[7] Vertebrae 42–45.[3,4,10]

Morphometry
See Table 10.

Pigmentation
18.0–44.9 mm TL. Dorsum of the head and body pellucid white with a silvery cast. Ventrum of the head and body white or silvery. A series of 12–16 small, olive spots along the dorsal ridge, becoming rows of paired spots along the base of the dorsal fins, with a single row on each side of the fin. A series of 9–14 oblong, dusky-olive spots along the lateral line becoming posteriorly confluent. Some specimens possess a suffused band of yellow present along the lateral line, median and paired fins transparent.*

Larger juveniles. Lower portion of the head is unpigmented, the back is slightly yellowish, becoming silvery white along the sides and ventral surface. A row of 10–14 small, round, green spots occur along the mid-lateral, and 12–16 spots along the mid-dorsum of the back, becoming paired at the bases of the dorsal fins. Median fin and paired fins unpigmented, with the exception of males who at maturation develop dusky pigmentation in the first 3–4 ray membranes.[8,10,23]

TAXONOMIC DIAGNOSIS OF YOUNG EASTERN SAND DARTER

Similar species: other sand darters.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 8)
Eggs. Laid in shallow habitats and buried in coarse sand and gravel substrates.[7] No parental guarding

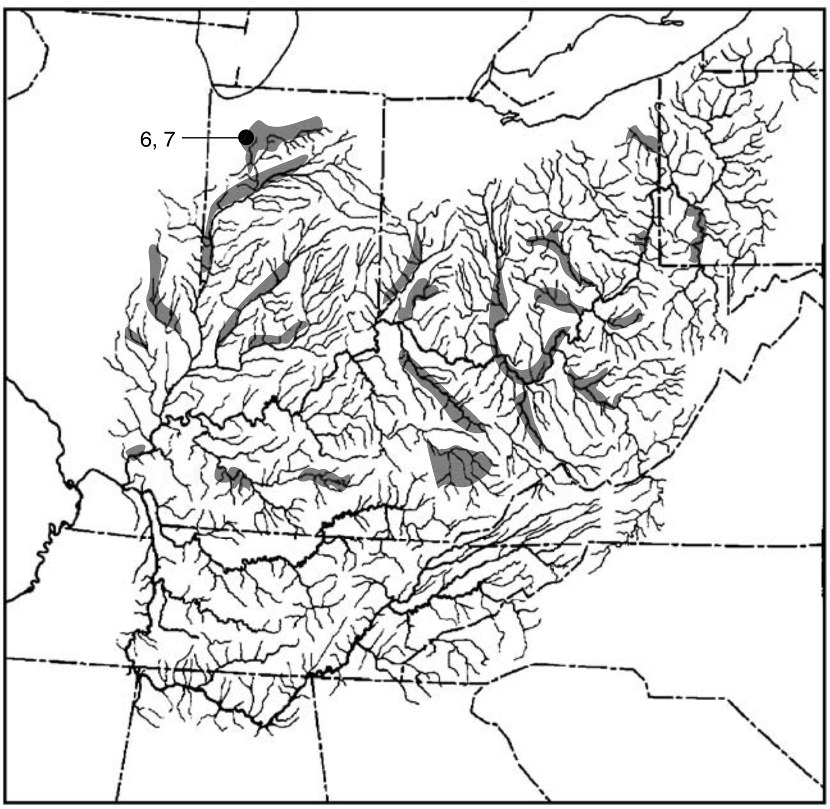

Figure 8 General distribution of eastern sand darter in the Ohio River system (shaded areas) and areas where early life history information has been collected (circles). Numbers indicate appropriate references.

is provided.[7,16] Embryos develop in the darkness of interstitial spaces of clean sand.* A total of 66 ova were collected from mixed sand and gravel in an area 10 × 16 cm.[16]

Yolk-sac larvae. Yolk-sac larvae remain in the interstitial spaces of gravel riffles until capable of feeding. Specimens were collected in surface drift collections along the stream border of the Tippecanoe River, Fulton Co., IN. Larvae 5.5–6.8 mm TL are photophobic and drift between dusk and night, remaining in the rock interstices during the day collections. Higher numbers of larvae were collected during dusk diel periods than during day collections. Present during late June to mid-July in drift collections. Maximum density of yolk-sac larvae was 0.002/100 m^3 during late June in the Tippecanoe River, IN.*

Post yolk-sac larvae. Individuals are pelagic drifters, occurring in the water column during dusk and night diel periods.* Larvae are active swimmers, remaining in the water column from 5.5 to 6.8 mm TL, becoming benthic at lengths >7.4 mm TL. Larvae were collected from nearshore margins from sluggish water immediately downstream of riffle habitats.*

Juveniles. Early juveniles are more tolerant of silt margins than adults, occurring in areas adjacent to coarse sand–gravel riffles of large rivers. In the Tippecanoe River, IN, young-of-the-year eastern sand darters were collected from along the sand margins on the inside of river bends with silt covering that possessed slight to moderate current velocities. Densities were <1 individual/m^2.*

Early Growth (see Table 11)

Eastern sand darters were 34–41 mm SL by late April or May in OH.* Young-of-the-year reach 65.4% of total growth during the first year of life and 87.5% by the second year of life (see Figure 9).[14,*] Specimens collected from OH ranged between 28 and 53 mm during October.[8] Young-of–the-year collected during September 1992 were 35 mm TL in the White and Tippecanoe Rivers, IN.* The length–weight relationship of eastern sand darters was $\log W = -13.1674 + 3.0949 \log L$, where weight is in g and total length is in mm.*

Table 11

Average calculated TL (mm) of young eastern sand darters in Ohio and Indiana.

State	Age 1	Age 2	Age 3
Ohio[14]	34–53	45–53	
Indiana*	31–42	37–46	45–53

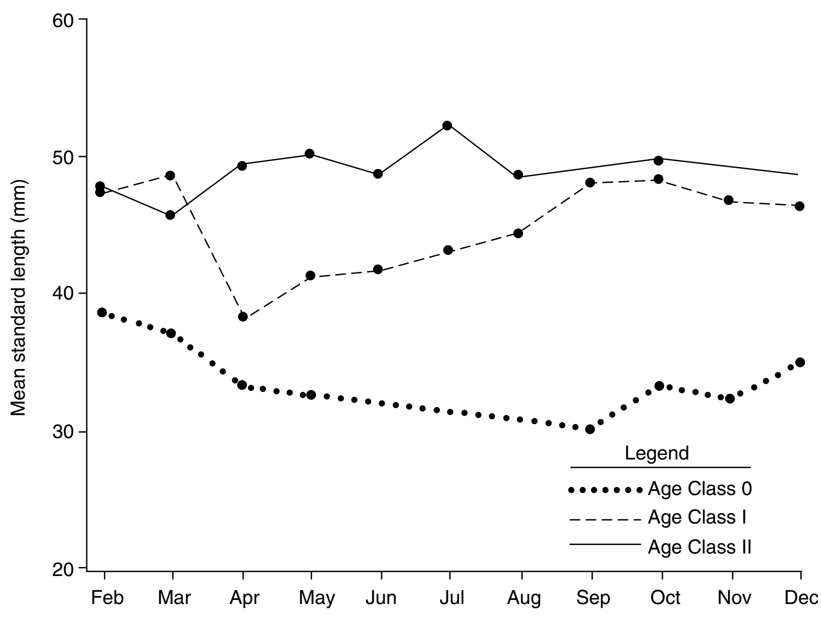

Figure 9 Growth trends for age classes of *Ammocrypta pellucida* based on monthly mean standard lengths for populations from Salt Creek, Vinton Co., OH. (From reference 14.)

Feeding Habits

Juveniles and young adults feed primarily on the immature stages of aquatic insects such as mayflies, midge larvae, and *Hyallela*.[4,12] Four specimens from IL fed on midge larvae (81%), other dipterans (12%), and mayfly larvae (7%);[20] or *Chironomus* and mayfly larvae;[21] and those from the Embarras River, IL, consumed midge and black fly larvae.[22] Lake Erie populations collected from near the Bass Islands consumed 90% midge larvae, while specimens from West Branch Mahoning River (Beaver River) and Beaver Creek (Wabash River) consumed 100% midge larvae.[19] Salt Creek, OH, specimens consumed chironomids primarily during February through April, and was never less than 80% of the diet the remainder of the year. The remaining 10–20% of the diet was composed of mayflies, caddisflies, stoneflies, zooplankton, arachnids, and oligochaeta.[19]

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* Original reproductive, early distribution, and growth information was obtained from adult and ichthyoplankton data collected by Large Rivers Research Station in the Tippecanoe River during 1989–1992. Developmental data are from a series obtained from the Tippecanoe River, IN (LRRC larval fish reference collection).

SCALY SAND DARTER

Ammocrypta vivax Hay

Ammocrypta: sand concealed; *vivax*: vivious, meaning vigorous.

RANGE

Ammocrypta vivax occurs along the Mississippi Embayment and Coastal Plain portions of the Gulf of Mexico drainage, from as far west as the San Jacinto River, TX and east to the streams entering Pascagoula Bay, MS. Found in southeastern OK, through the Red and Arkansas Rivers; north to the St. Francis and Little River drainage of southeastern MO.[1–3,8]

HABITAT AND MOVEMENT

The scaly sand darter inhabits large creeks and large rivers with moderate current.[3] Substrates reported to be primarily sand or silty sand.[1–3] In MO and AR, it has been collected from sloughs and drainage ditches, where silt, gravel, and hard clay predominate.[2] It is known to conceal itself in the substrate; however, the mechanics of burial is unknown but assumed to be similar to that of other sand darters.[*,7] Reported to prefer fast velocities and coarse substrates clear of debris and cover.[6]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Ammocrypta vivax formerly was present in the Tennessee River Plain from Jonathan Creek, Marshall Co., during pre-impoundment study of Kentucky Lake.[5] Probably extirpated from the Ohio River drainage.[5] Known only from a single specimen from the Buffalo River, TN.[4]

SPAWNING

Location
Spawning occurs over sand substrates in moderate current in shallow water.[7]

Season
Spawning occurs during mid-summer throughout the range,[3,9] late May[5] or June and July in AR;[7] ripe individuals were found in east TX in early April.[10] Males began developing breeding tubercles from mid-April until mid-August, suggesting a summer spawning period.[9]

Temperature
Unknown.

Fecundity
AR females contain 60–70 undeveloped ova.[5]

Sexual Maturity
Unknown. Mature males exhibited sexually dimorphic traits during the reproductive season, with the development of nuptial tubercles on the ventral surface of the pelvic spine, pelvic rays, dorsal surface of pelvic rays, anal spine, and anal rays. Females had distended abdomens and exhibited differences in genital papillae.[5]

Spawning Act
Unknown. Suspected to be egg buriers, which is similar to other sand darters. Females spawn either with single or multiple males by remaining in close contact with them while the female is partially buried. Reproductive guild is the non-guarding, open substrate spawning psammophil guild.*

EGGS

Description
Spherical, demersal, non-adhesive.*

Incubation
Unknown.

Development
Unknown.

YOLK-SAC AND POST YOL-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown to 47.9 mm TL.[5]

Fin Development
Larger juveniles. Spinous dorsal XIII–XIV; soft dorsal 9–12; pectoral rays 13–17; anal rays I 7–10; pelvic rays I 5.[2,3] Caudal fin emarginate (notched) to slightly forked.

Morphology
Lateral scales 58–79, complete; body almost completely scaled. Scale rows 1–7 above lateral line and 6–12 rows below lateral line. Palatine and prevomerine teeth absent; narrow premaxillary frenum; branchiostegal membranes separate, rays 6, 16. The nape is usually partially scaled; the breast and pectoral fin base have embedded scales, and the cheek and opercle are fully scaled.[3,9] Sensory canal system complete; lateral canal pores 5; supratemporal pores 3; supraorbital pores 4; coronal pore present; infraorbital pores 3; preoperculomandibular canal pores 9–11.[9] Vertebrae 41–43.[2,3,9]

Morphometry
Juveniles can be identified using typical adult characters.[5]

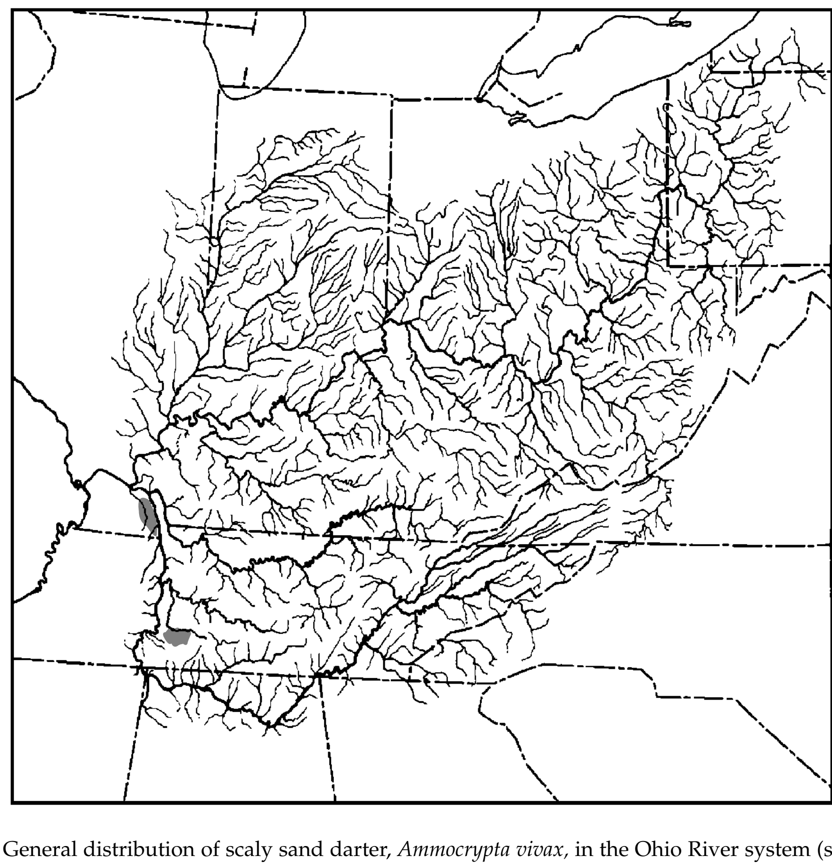

Figure 10 General distribution of scaly sand darter, *Ammocrypta vivax,* in the Ohio River system (shaded areas).

Pigmentation
Larger juveniles. Dorsum and dorsolateral surface of the head are yellowish-orange; laterally cheeks and opercles iridescent yellow-green. Varying size, shape, intensity, and position includes 9–16 lateral brown blotches. Usually circular to oval with the long axis positioned vertically. Midline of dorsum with 10–15 blotches occasionally merges with the lateral or dorsal blotches, resulting in a reticulate pattern. The venter is unpigmented, except for a line of melanophores extending from the base of the last anal ray posteriorly to the caudal fin. Spinous dorsal fin pigment is variable with a narrow marginal band and a wider basal band. The anal fin has melanophores present along the margins of the basal margin 0.66–0.75 of fin rays and occasionally on membranes of fins. Pectoral fins have pigment on the dorsal half to two thirds of the fin. Pelvic fins with pigment on rays and membranes usually concentrated around rays.[9]

TAXONOMIC DIAGNOSIS OF YOUNG SCALY SAND DARTERS

Similar species: other sand darters.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 10)
Eggs. Probably deposited in sand substrates as other *Ammocrypta*. No parental guarding is provided. Embryos develop in the darkness of interstitial spaces of clean sand and coarse gravel.*

Yolk-sac larvae. Unknown.

Post yolk-sac larvae. Unknown.

Juveniles. Occur in creeks and rivers of various sizes, usually over substrates of sand in moderate current.[2,3,5,7]

Early Growth
Unknown.

Feeding Habits
Juveniles and young adults feed on the immature stages of aquatic insects.[8] AR specimens feed exclusively on midge larvae.[5]

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GENUS
Crystallaria (Jordan)

Thomas P. Simon

This monotypic genus was previously considered a part of the genus *Ammocrypta* (Williams, 1975). The crystal darter, *Crystallaria asprella*,was considered a sister species to *Ammocrypta* based on the shared traits of a 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 *Ammocrypta,* while Simons combined the latter genus with *Etheostoma*. Simon et al. (1992) considered ontogenetic characteristics between the derived *E. vitreum*, *Ammocrypta*, and *Crystallaria* and recognized the separation of *Crystallaria* from *Ammocrypta* based on early life history traits. However, the sister taxa relationships between *Ammocrypta* and *Etheostoma* were considered to be based on shared functional feeding relationships, which refuted the synonymy of *Ammocrypta* with *Etheostoma* based on early life history attributes. The traits used by Simons to combine *Ammocrypta* with *Etheostoma* were not based on homologous structures and violated the assumptions of cladistic analysis.

Crystallaria is considered a pleisiomorphic genus among the darters, and apomorphies include the presence of prevomerine teeth and a premaxillary frenum (Page, 1983). The crystal darter has experienced severe range reduction in the northern portions of its range and has been eliminated from the Ohio River drainage. In addition, the crystal darter may actually represent two species based on a northern and southern distribution.

CRYSTAL DARTER

Crystallaria asprella (Jordan)

Crystallaria: Crystal like, referring to the clear, translucent body; *asprella*: diminutive of "aspro," meaning rough in reference to scalation and resembling the Eurasian percid (Zingel).

RANGE

Crystallaria asprella occurs in mainstream tributaries of the upper Mississippi River from central WI to southern LA. In OK, it occurs in the Red River drainage as far as the Little River; Gasconade River, MO, the only tributary of the Missouri River with verified records; in the Mobile Bay drainage and Perdido River from the lower Coosa westward, and most commonly, in the Tombigbee River.[1–3]

HABITAT AND MOVEMENT

The crystal darter inhabits moderate to large streams with moderate current over clean sand and gravel.[4,5] Substrate reported to be primarily gravel, with some small cobble and patches of sand.[16] It is known to conceal itself in the substrate,[6] however, it differs in the mechanics of burial from other sand darters.* Observations of aquarium-held individuals indicated a reverse burial, with individuals covering themselves with gravel using their large pectoral fins.* Seasonal migrations occur, with adults migrating from riffles to pools during late fall to winter (E. J. Tyberghein, Alabama power, personal communication).The crystal darter prefers deeper water (2–5 m) during the day and moves into shallows at night or on heavily overcast days.[10] Most collected at depths between 114 and 148 cm with water velocities 46–90 cm/s. Shallower water with similar velocities yielded fewer specimens.[16]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Crystallaria asprella has been extirpated from the mainstream Ohio River and adjacent tributaries. It has not been collected in the lower Ohio River since 1929.[7] Former range included the Cumberland, Green, and Ohio Rivers, KY; Wabash and Whitewater Rivers, IN; and the Ohio River, WV.[1] It is considered extirpated in KY,[7] IN,* IL,[8] and OH,[5] but was recently collected in WV.[7] It is rare due to heavy siltation and turbidity of former rivers, and due to the construction of dams, which limit mobility and recolonization. Last collected in TN in 1939 from the Cumberland River, Clay Co., and Roaring River, Jackson Co.; considered extirpated, although may still persist in the larger deeper chutes of large rivers.[14]

SPAWNING

Location
Crystallaria asprella spawns over gravel substrate in moderate current in shallow water. Adults vacate deeper riffle areas and are believed to spawn in a meandering side channel riffle. Water depths range from 60 to 90 cm with moderate to swift flow.[9]

Season
Spawning occurs from late February or early March until late April in Tallapoosa River, AL;[9,12] equivalent to early April in study area. Males begin developing breeding tubercles in late November with peak development in late January. The development of breeding tubercles on males in January and February in MS and LA suggests an early spring spawning period.[14,15] A decrease in ova size during April suggests spawning was completed in the Saline River, AR.[16]

Temperature
Spawning began at 12–13°C.[9]

Fecundity (see Table 12)
A female (123 mm TL) had ovaries that were 0.23% of the body weight, containing 6885 undeveloped ova averaging 0.2 mm diameter.[11]

Sexual Maturity
Adults may live to reach age 7,[11] however, maturity is suspected to be at age 3. An adult male (134 mm TL) from WI had testes that were 0.04% of the body weight on July 28 and 27 mm in length. Male tuberculation was absent from May to August.[16] Male

Table 12

Fecundity data for crystal darters from the Saline River, AR.[16]

Date	Mean GSI	Percent Occurrence of Ova: Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
May–July	0.19–0.28	100	—	—	0.10–0.11
August	0.45	62	38	—	0.11
September	0.24	12	88	—	0.14
October	1.00	0	100	—	0.36–0.47
November	2.18	0	100	—	0.36–0.47
January	10.2	0	100	—	0.85
February	17.1	0	100	—	0.98
March	13.5	0	76	24	1.2
April	15.17	0	76	24	1.06

tuberculation at maximum development occurred between January and April. Females of 50–65 mm SL were all sexually mature, 50% of 47–49 mm SL females were mature, while 33% of females <46 mm SL were sexually mature. Males <55 mm SL were all immature, while 55.6% of males 56–57 mm SL, 75% of all males 59–60 mm SL, and all males >61 mm SL were mature. Males were considerably larger than females with a mean SL of 75.3 mm compared to 65.3 mm SL for females. Males exhibited sexually dimorphic traits during the reproductive season, such as the enlargement of the anal and soft dorsal fins and the shorter and more triangular shape of the genital papillae, while females had distended abdomens, more rounded, shorter anal and soft dorsal fins, and a tapered, flattened tube.[16]

Spawning Act

Crystallaria asprella is an egg burier. Suspected to be similar to other sand darters in that males and a female remain in close contact while the female lies partially buried. Aquarium observations found that a male maintains a serpentine clasp and head-to-head orientation and that the pair moves forward in the substrate. Reproductive guild is the non-guarding, open substrate spawning psammophil guild. Aquarium observations showed that courtship behavior is very aggressive, with the male pecking on the female's cranium to cause her to initiate spawning. When the female did not follow the males, they quivered and led her to the spawning substrate. Further pecking continued by the males, which caused the female to develop a brain hemorrhage.[9,*] The sex ratio was 1:1 based on specimens examined during the reproductive period in the Saline River, AR.[16]

EGGS

Description

Spherical, demersal, nonadhesive*; 1.2–1.4 mm in diameter; yolk pale yellow in color, with a translucent smooth egg chorion.* Latent ova were 0.1–0.14 mm in diameter, early maturing ova were 0.36–0.47 mm, and mean ripe ova were 1.2 mm in diameter.[16]

Incubation

Incubation in 7–10 days at unspecified temperatures between 12 and 15°C.*

Development

Unknown.

YOLK-SAC LARVAE

See Figure 11

Size Range

7.4–8.2 mm TL at hatching, yolk absorption complete by 10.2–10.8 mm TL.[*,9]

Myomeres

Predorsal myomeres 6–10; preanal 23–25; postanal 19–24; and total myomeres 43–49.[9]

Morphology

7.4–8.9 mm TL. Body laterally compressed; jaws well developed; head not deflected over the yolk

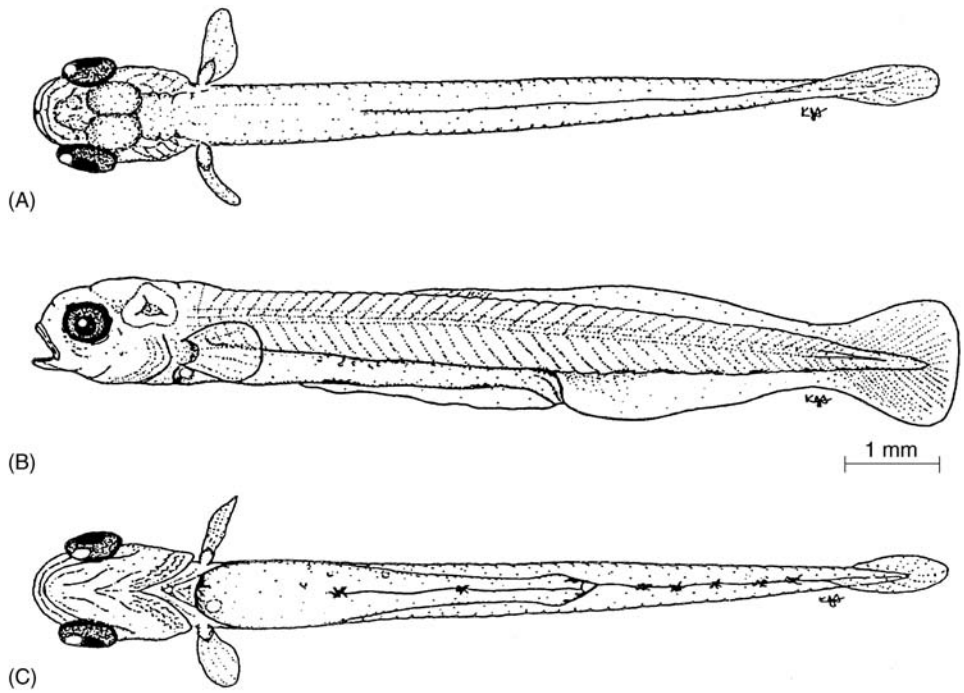

Figure 11 Development of young crystal darter, *Crystallaria asprella*. (A–C) Yolk-sac larva, 10.2 mm TL, dorsal, lateral, and ventral views. (From reference 9, with authors' permission.)

sac; yolk sac small (23.6%), tapering posteriorly; a single mid-ventral serpentine vitelline vein is present with a single loop.[9]

9.2 mm TL. Gills and digestive system functional.

10.2–10.8 mm TL. Yolk absorption complete.

Morphometry
See Table 13.

Fin Development
7.4–9.9 mm TL. Dorsal and anal finfolds complete, pectoral fins well developed; incipient rays absent from all median and paired fins.[9]

10.2–10.8 mm TL. Incipient rays begin to develop in the caudal and spinous dorsal fins. First ray formed in the caudal fin at 10.8 mm TL.

Pigmentation
7.4–9.1 mm TL. Eyes pigmented with melanophores; entire body unpigmented.[9]

9.2–10.9 mm TL. Pigmentation develops ventrally on the breast, several stellate melanophores mid-ventrally from the anterior preanal finfold to the anus; five stellate melanophores on the mid-ventral postanal trunk.[9]

POST YOLK-SAC LARVAE

Size Range
10.9–22 mm TL.*

Myomeres
Predorsal myomeres 6–10; preanal 22–24; postanal 24; and total myomeres 46–48.*[,9]

Morphology
10.9 mm TL. Notochord flexion.[9]

22 mm TL. Body translucent with yellowish cast dorsally and white ventrally. Four distinct dorsal brown saddles present with oblong blotches along the mid-lateral. Snout bridle apparent with brown pigment connection along the outline of the lips.*

Morphometry
See Table 13.

Fin Development
10.9 mm TL. Fin rays formed in caudal fin; finfold complete, not differentiated.*

Table 13

Morphometric data expressed as percent of HL and TL for young crystal darters from the Tallapoosa River, AL.*

TL range (mm) *N* Ratios	Total Length Groupings 7.0-8.8 13 Mean ± SD (Range)	 10.2-10.8 3 Mean ± SD (Range)	 22.0 1 Mean ± SD (Range)
As Percent HL			
SnL	16.2 ± 6.1 (0.7–22.1)	17.4 ± 3.2 (17.3–22.4)	23.9
ED	29.7 ± 3.0 (23.8–32.2)	29.4 ± 2.2 (24.4–32.6)	23.9
As Percent TL			
HL	17.4 ± 1.4 (15.7–20.6)	18.8 ± 1.1 (16.2–20.4)	19.2
HW	11.5 ± 0.8 (10.7–13.0)	12.8 ± 1.2 (10.9–13.6)	14.1
PreDFL	28.7 ± 4.6 (20.5–36.7)	27.5 ± 5.6 (18.8–35.9)	26.0
PreAFO	56.2 ± 1.2 (53.6–57.6)	53.8 ± 1.5 (52.8–57.4)	47.5
PreAL	56.2 ± 1.2 (53.6–57.6)	53.8 ± 1.5 (52.8–57.4)	47.5
PosAL	43.8 ± 2.1 (43.4–46.4)	46.2 ± 2.9 (42.6–47.2)	52.5
SL	97.3+1.0 (96.3–98.6)	93.4 ± 1.2 (91.6–94.5)	90.6
YSL	23.6 ± 1.6 (22.4–26.0)	20.9[a]	
P1L	8.8 ± 1.9 (4.9–10.9)	10.2 ± 3.1 (9.8–12.8)	13.1
D1FL	71.3 ± 3.2 (63.5–79.5)	72.5 ± 4.4 (64.1–80.2)	20.2
D2FL	19.4		
CFL	2.7 ± 1.4 (1.4–3.7)	5.6 ± 2.2 (5.5–8.4)	8.8
BDE	12.3 ± 0.8 (11.6–13.4)	10.7 ± 1.0 (9.3–11.2)	7.3
BDP1	11.7 ± 1.1 (10.1–13.3)	11.3 ± 1.3 (10.2–13.0)	10.4
BDA	7.7 ± 0.1 (7.4–7.8)	8.2 ± 0.9 (7.8–8.4)	10.4
MPosAD	5.6 ± 0.4 (5.0–6.3)	5.6 ± 0.5 (5.0–6.6)	6.0
CPD	2.4 ± 0.5 (1.6–3.3)	2.7 ± 1.0 (1.8–3.5)	4.5
YSD	5.4 ± 2.8 (3.4–6.7)	0.9[a]	

[a] Only a single specimen in this length range possessed a yolk sac.

Pigmentation
10.9 mm TL. Identical to the 10.2–10.8 mm TL length interval.

JUVENILES

Size Range
>22–81 mm[10] or 144 mm TL.[11]

Fin Development
22 mm TL. All median and paired fin rays distinct and with full complement of fin spines and rays. Finfolds completely differentiated, caudal fin truncate to notched but not yet distinctly forked.*

Larger juveniles. Spinous dorsal XII–XV; soft dorsal 12–15; pectoral rays 15–17; anal rays I 12–15; pelvic rays I 5.[2,3] Caudal fin deeply forked.

Morphology
Lateral scales 81–93; pored scales on caudal fin 0–4; palatine and prevomerine teeth present; narrow premaxillary frenum; branchiostegal membranes separate, rays 6,6. The nape is scaled, the breast and belly are unscaled, the cheek and opercle are partially scaled.[3] Vertebrae 45–48.[3]

Morphometry
Unknown.

Pigmentation
81 to 144 mm TL. Body translucent with yellowish cast dorsally and silver ventrally. Often four wide brown saddles on the dorsum that extends anteroventrally to the lateral line and connects to a midlateral series of oblong dark brown blotches. Dark brown mottling covers the area between the saddles or, if the saddles are absent, covers the entire upper half of the body. Around the snout and extending from eye to eye onto the upper lip is a wide dark-brown stripe. Fins are clear but the soft dorsal and pectoral fins may have concentric rows of light brown spots.[3]

TAXONOMIC DIAGNOSIS OF YOUNG CRYSTAL DARTERS

Similar species: sand darters of genus *Ammocrypta*.[9]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 12)

Eggs. Eggs are laid in riffle habitats over coarse sand and gravel substrates in moderate current. No parental guarding is provided. Embryos develop in the darkness of interstitial spaces of clean sand and coarse gravel.*

Yolk-sac larvae. Yolk-sac larvae remain in the interstitial spaces of gravel riffles until capable of feeding. Specimens were then collected in a backwater pool adjacent to a riffle area. Larvae 7.4–10.9 mm TL are photophobic and drift between dusk and night, remaining in the rock interstices during the day. Present during March after a 3–4 week incubation and absorption of yolk period.*

Post yolk-sac larvae. Individuals are pelagic drifters occurring in the water column during dusk and night diel periods.*

Juveniles. A young-of-the-year crystal darter was collected from brown stained water 0.6–1.1 m in depth, over a sand substrate in moderate to strong current.[10]

Early Growth (see Table 14)

Crystal darters were 30–38 mm SL by early May in AR.[13] A mid-September series of 13 specimens from Tennessee averaged 50 mm SL, while an age 1 individual collected in May was 70 mm SL.[14] Specimens collected from Saline River, AR, ranged between 35 and 50 mm during June, 40 and 58 mm SL during July, 41 and 52 mm SL during August, 31 and 56 mm SL during September, and 45 and 67 mm SL during October.[16] An age 0 specimen collected in WI was 81 mm TL on September 29, while an age 3 crystal darter 166 mm TL that weighed 25.8 g was collected in July.[4] Young-of-the-year collected during November 1983 and 1992 ranged between 57 and 66 mm SL.[16] The length–weight relationship of crystal darters was $\log W = -13.4213 + 3.2708 \log L$, where weight is in g and total length is in mm.[4]

Feeding Habits

Juvenile and young adults feed on the immature stages of aquatic insects. In WI, they feed on larvae including mayflies, crane flies, black

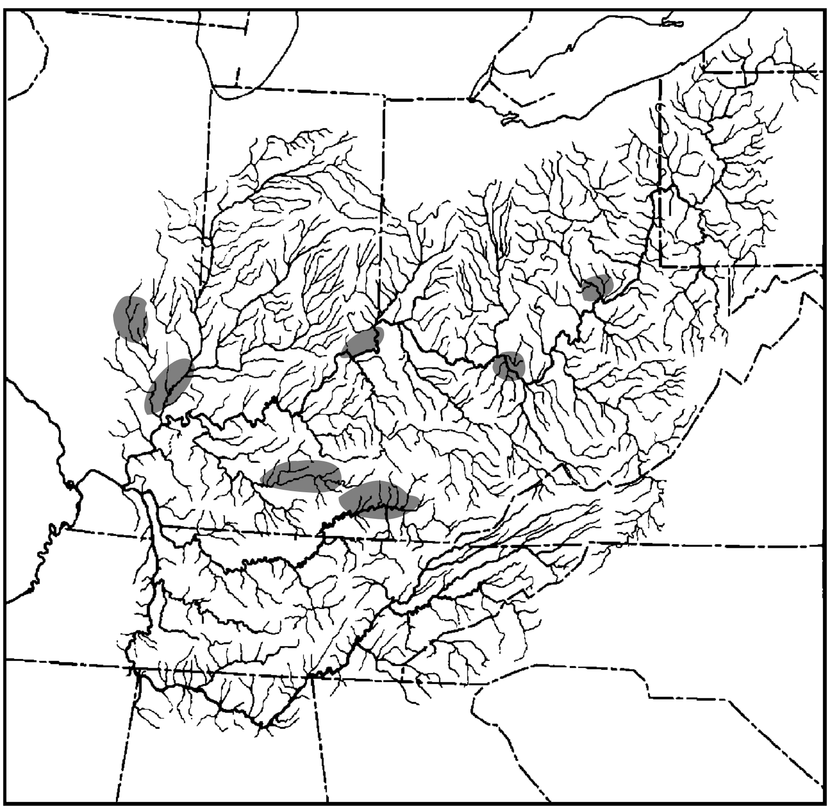

Figure 12 General distribution of crystal darter in the Ohio River system (shaded areas).

flies, caddisflies, and midges.[11] Specimens from the Tombigbee River contained only heptageniid mayfly nymphs.[14]

Table 14

Average calculated TL of young crystal darters in several states.

State	Age 1	Age 2	Age 3
Wisconsin[10,11]	97–142	144–157	166
Tennessee[14]	70 (SL)		
Arkansas (June)[16]	62–77 (SL)	84–94 (SL)	

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* Original reproductive, early distribution, and growth information was obtained from ichthyoplankton data collected by Alabama Power and Large Rivers Research Station in the Tallapoosa River during the spring of 1989. Developmental data are from a series obtained from Alabama Power, AL (LRRC larval fish reference collection).

GENUS
Etheostoma Rafinesque

The genus *Etheostoma* contains about 120 species and is the most biologically diverse genus of North American freshwater fishes. Most members are diminutive and spectacularly colored, creating heightened sexual dimorphism between males and females during the spawning period. The genus is morphologically and behaviorally the most derived of the darters and is considered monophyletic (Bailey and Etnier, 1988). The genus is defined by the absence of large scales that occur on the breast between the bases of the pelvic fins and a mid-ventral row as in *Percina*. The lateral line is either complete or incomplete with moderate to reduced scale counts. It also has a complete to incomplete cephalic sensory canal system, with many subgenera showing the development of a complete head canal that becomes interrupted during juvenile development; gill membranes that are either separate or connected; 5–6 branchiostegal rays; and the swim bladder is either vestigial or absent (Page, 1981, 1983). Ontogenetic traits that diagnose the genus include the possession of well-developed pectoral fins (often with incipient rays at hatching); a functional maxillary and mandible; maximum body depth >14% TL; preanal myomere counts <18, with the exception of subgenera *Etheostoma* and *Poecilichthys*; body depth at anus <8% TL; and caudal peduncle depth >3.8%; yolk sac robust; and vitelline vein either single serpentine or complex network plexus (Simon, 1985b, 1994).

The genus *Etheostoma* includes 62 species divided among 15 subgenera in the Ohio River drainage (Table 15; Page, 1981). Forty-six species are endemic to the drainage. Of the eighteen subgenera of *Etheostoma*, 15 occur in the Ohio River drainage. Significant research contributing to our understanding of *Etheostoma* phylogenetic relationships includes Bailey and Gosline (1955), Collette (1965), Page (1981), and Bailey and Etnier (1988). There are several theories on the evolutionary relationships of the genus *Etheostoma,* which suggest opposing viewpoints and controversial placements of several groups. The most controversial group placement has involved the *Nannostoma-Ulocentra* controversy (Page, 1981; Bailey and Etnier, 1988), and the *Boleichthys-Microperca, Hololepis, and Villora* subgenera (Hubbs and Cannon, 1935; Collette and Yeager, 1962; Page, 1981; Bailey and Etnier, 1988). Simon (1994) proposed an alternative classification to resolve the genus *Etheostoma* based on ontogenetic information. This third classification is used here since it resolves many of the contentious issues remaining among the genus.

The reproductive biology of many *Etheostoma* species is known and two approaches have been developed for classifying reproduction. Balon (1975, 1981) modified the reproductive guild concept to classify fishes into groups based on spawning behavior, spawning placement, early life history drift, and vitelline vein structure. Simon (1999) revised the classification of North American freshwater fishes, including the darters, since new information exists on early life history traits. Page (1985) developed the concept of reproductive modes principally as a way to categorize the spawning behavior of darters. The genus *Etheostoma* exhibits a wide variety of reproductive modes. Behaviors include burying, clumping, attaching, and clustering. These behaviors form a continuum of derived reproductive acts. Our own efforts have resulted in the spawning and rearing of 120 species of darters. Many species were observed in aquaria spawning. We have also documented the incubation, egg development, and fecundity of many species for which we previously did not have any information.

Ontogenetic information is available for many subgenera in this group; however, several of the subgenera with few members still require additional study (see diagnostic chapter, p. 19). Limiting factors that restricted the culture of several species are their rarity and inclusion on the Federal Endangered Species list. As a result, it may be impossible to develop information for many of these species until they are removed from the list, despite our success in breeding and culturing species, as for example in the case of fountain darter *E. fonticola* (Brandt et al., 1993).

Table 15

Common and scientific names of darters in the genus *Etheostoma* occurring in the Ohio River drainage with subgeneric membership (Simon, 1994).

Common Name	Scientific Name	Subgenus
Sharphead darter	*E. acuticeps* Bailey	*Nothonotus*
Coppercheek darter	*E. aquali* Williams and Etnier	*Nothonotus*
Mud darter	*E. asprigene* (Forbes)	*Oligocephalus*
Cumberland snubnose darter	*E. atripinne* Jordan	*Ulocentra*
Emerald darter	*E. baileyi* Page and Burr	*Ulocentra*
Teardrop darter	*E. barbouri* Kuehne and Small	*Catonotus*
Splendid darter	*E. barrenense* Burr and Page	*Ulocentra*
Orangefin darter	*E. bellum* Zorach	*Nothonotus*
Greenside darter complex	*E. blennioides.* Rafinesque	*Etheostoma*
Blenny darter	*E. blennius* Gilbert and Swain	*Etheostoma*
Slackwater darter	*E. boschungi* Wall and Williams	*Ozarka*
Rainbow darter	*E. caeruleum* Storer	*Oligocephalus*
Bluebreast darter	*E. camurum* (Cope)	*Nothonotus*
Greenfin darter	*E. chlorobranchium* Zorach	*Nothonotus*
Bluntnose darter	*E. chlorosoma* (Hay)	*Vaillantia*
Ashy darter	*E. cinereum* Storer	*Allohistium*
Crown darter	*E. corona* Page and Ceas	*Catonotus*
Fringed darter	*E. crossopterum* Braasch and Mayden	*Catonotus*
Blackside snubnose (Black) darter	*E. duryi* Henshall	*Ulocentra*
Cherry darter	*E. etnieri* Bouchard	*Ulocentra*
Fantail darter complex	*E. flabellare* Rafinesque	*Catonotus*
Saffron darter	*E. flavum* Etnier and Bailey	*Ulocentra*
Barrens darter	*E. forbesi* Page and Ceas	*Catonotus*
Slough darter	*E. gracile* (Girard)	*Boleichthys*
Harlequin darter	*E. histrio* Jordan and Gilbert	*Poecilichthys*
Blueside darter	*E. jessiae* (Jordan and Brayton)	*Doration*
Stripetail darter	*E. kennicotti* (Putnam)	*Catonotus*
Redband darter	*E. luteovinctum* Gilbert and Swain	*Oligocephalus*
Spotted darter	*E. maculatum* Kirtland	*Nothonotus*
Smallscale darter	*E. microlepidum* Raney and Zorach	*Nothonotus*
Least darter	*E. microperca* Jordan and Gilbert	*Boleichthys*
Lollypop darter	*E. neopterum* Howell and Dingerkus	*Catonotus*
Blackfin darter	*E. nigripinne* Braasch and Mayden	*Catonotus*
Johnny darter complex	*E. nigrum* Rafinesque	*Boleosoma*
Barcheek darter	*E. obeyense* Kirsch	*Catonotus*
Dirty darter	*E. olivaceum* Braasch and Page	*Catonotus*
Guardian darter	*E. oophylax* Ceas and Page	*Catonotus*
Goldstripe darter	*E. parvipinne* Gilbert and Swain	*Fuscatelum*
Duskytail darter	*E. percnurum* Jenkins	*Catonotus*
Cypress darter	*E. proeliare* (Hay)	*Boleichthys*
Egg-mimic darter	*E. psuedovulatum* Page and Ceas	*Catonotus*
Kentucky snubnose darter	*E. rafinesquei* Burr and Page	*Ulocentra*
Redline darter	*E. rufilineatum* (Cope)	*Nothonotus*
Arrow darter	*E. sagitta* (Jordan and Swain)	*Litocara*
Bloodfin darter	*E. sanguifluum* (Cope)	*Nothonotus*
Tennessee snubnose darter	*E. simoterum* (Cope)	*Ulocentra*
Slabrock darter	*E. smithi* Page and Braasch	*Catonotus*
Orangethroat darter	*E. spectabile* (Agassiz)	*Oligocephalus*
Spottail darter	*E. squamiceps* Jordan	*Catonotus*
Speckled darter	*E. stigmaeum* (Jordan)	*Doration*
Striated darter	*E. striatulum* Page and Braasch	*Catonotus*
Gulf darter	*E. swaini* (Jordan)	*Oligocephalus*
Swannanoa darter	*E. swannanoa* Jordan and Evermann	*Poecilichthys*
Tippecanoe darter	*E. tippecanoe* Jordan and Evermann	*Nothonotus*
Tuscumbia darter	*E. tuscumbia* Gilbert and Swain	*Psychromaster*
Variegate darter	*E. variatum* (Kirtland)	*Poecilichthys*
Striped darter	*E. virgatum* Jordan	*Catonotus*
Wounded darter	*E. vulneratum* (Cope)	*Nothonotus*
Boulder darter	*E. wapiti* Etnier and Williams	*Nothonotus*
Banded darter	*E. zonale* (Cope)	*Nannostoma*
Bandfin darter	*E. zonistium* Bailey and Etnier	*Ulocentra*

A range of drift behaviors may be observed among members of *Etheostoma.* Several of the plesiomorphic subgenera exhibit either a pelagic or epi-benthic drift behavior, which carries them distances downstream from their spawning grounds to their nursery habitats. Other species are benthic, and this is correlated with yolk reserves, parental investment, and a reduction in egg production. Simon (1994) suggested that several subgenera exhibit a truncation of larval stages so that subgenera such as *Catonotus* skip a larval period and develop from yolk-sac larvae immediately into juveniles. The large yolk reserves provided by females yield fewer eggs, which are guarded by a male, thereby ensuring fitness and guaranting the successful recruitment of their genetic code into future generations.

Many yolk-sac larvae of the *Etheostoma* species are photophobic and cannot tolerate light. In some extreme examples, exposure to light can cause the mortality of the eggs or newly hatched larvae. For example, *E. tippecanoe is* a cryptic species that buries into cobble substrates and lays eggs in the interstitial pore spaces. Eggs that were retrieved from aquaria spawning and cultured following methods identified in Simon (1987b), revealed high mortality in egg and yolk-sac survivorship. By covering the egg-hatching containers and keeping them in the dark, we greatly improved our hatching success. Future research efforts must include the field quantification of resource utilization by larval and juvenile stages, and limiting factors in recruitment.

SHARPHEAD DARTER

Etheostoma (*Nothonotus*) *acuticeps* Bailey

Etheostoma: various mouths; *acuticeps*: sharp or pointed head

RANGE

Etheostoma acuticeps is found only in the Holston and Nolichucky Rivers in eastern TN, western VA, and western NC.[3]

HABITAT AND MOVEMENT

The sharphead darter inhabits the swiftest portions of riffles, with a surface velocity of 2 m/s. The preferred substrate is rubble and small boulders 5–20 cm in diameter, usually well covered with *P. ceratophyllum*, at a depth of 15–30 cm. Occurs at an altitude of 645 m in the Cane River and 536 m in the South Fork Holston River.[3]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma acuticeps is sporadic and rare, and occurs in the lower 6 km of the Cane River, NC; the lower 51 km of the Nolichucky River between Davy Crockett and Douglas Reservoirs,[1,2] and possibly the lower kilometer or two of the South Fork Holston River above the South Holston Reservoir in VA.[3] Extinct at the type locality, South Fork Holston River, 11 km southeast Bristol, due to construction of the South Fork Holston Reservoir, and at all previously known South Fork locations due to impoundment and tailwaters of reservoirs.[4]

SPAWNING

Location
Eggs are apparently buried in sand substrates next to rocks, similar to *E. camurum* and *E. rufilineatum*.[3] Eggs are deposited in swift current, near midchannel, and buried in sand substrates next to rocks.[6]

Season
In TN, breeding occurs from late June until mid-August.[3,4]

Temperature
Spawning occurs from 18 to 20° C[6]; eggs were collected from the Nolichucky River at 25°C.[3]

Fecundity
Number of eggs increases with female length: a 39 mm female had 100 ova, while a 55 mm female had 300 ova.[3] A 57 mm TL female had 273 ova, while a 62 mm TL female had 363 ova.

Sexual Maturity
Males and females were sexually mature at age 1.[3]

Spawning Act
Information on reproduction is lacking; however, males are very aggressive during the breeding season. Breeding males display territoriality by intense color changes and the biting of other males.[3] Observations of breeding behavior are unknown, but suspected to be similar to *E. camurum*.*

EGGS

Description
Mature ova are demersal, adhesive, spherical, with a single oil globule, a narrow perivitelline space, and a sculptured, unpigmented chorion.[6] Yolks are amber-brown and opaque, and egg diameters range from 1.8 to 2.1 mm.[6]

Incubation
Eggs hatched in 220 h at 23°C.[3]

Development
Embryonic development details from fertilization to 272 h.[3]

YOLK-SAC LARVAE

See Figure 13

Size Range
Newly hatched at 6.2 mm SL–6.4 mm TL[6]; yolk absorbed by 7.8 mm SL or 8.1 mm TL.[6]

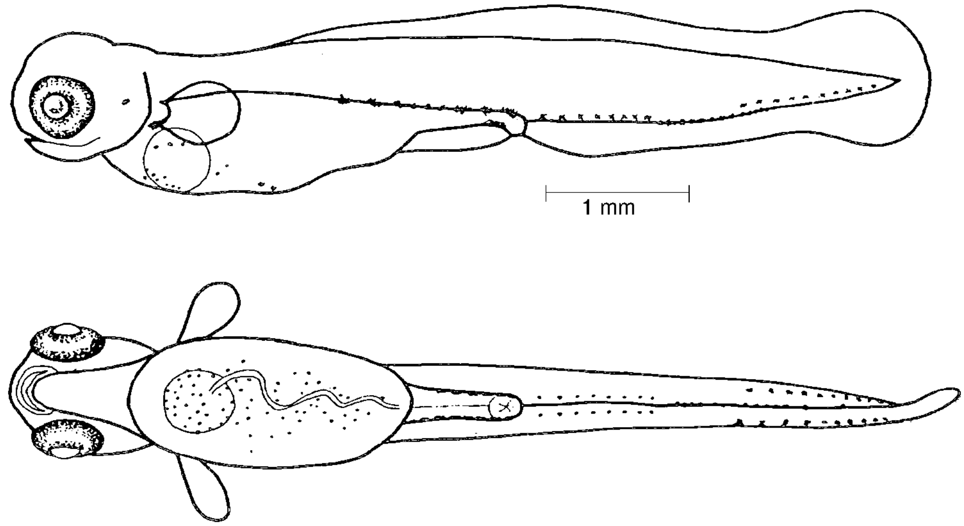

Figure 13 Sharphead darter *Etheostoma acuticeps* (newly hatched larva), 6.4 mm TL, lateral and ventral views, Nolichucky River, TN. (From reference 6, with authors' permission).

Myomeres
Preanal myomeres 19–21; postanal 19–21; 39–41 total.[6]

Morphology
6.4–8.1 mm TL. Body laterally compressed, yolk sac tapered, possesses a well-developed stomodeum and pectoral fins, a non deflected head over the yolk sac, and spherical unpigmented eyes. A single serpentine vitelline vein originates at the anterior portion of the oil globule and proceeds mid-ventrally along the yolk sac. Yolk sac elongate, 30.9% SL, oval with pale yellow translucent yolk. Soft dorsal fin origin initiates even with the anus.[6]

Morphometry
See Table 16.

Fin Development
6.4–8.1 mm TL. Well-developed pectoral fins at hatching; continuous dorsal and anal finfolds.[6]

Pigmentation
See Figure 13

6.4–8.1 mm TL. Melanophores densely distributed on the oil globule and scattered mid-ventrally, heavily outlining the vitelline vein, posterior otic capsule, prepectoral shoulder, dorsal yolk sac and gut, ventral anus, and most hypaxial postanal myosepta.[2] Possess a concentrated cluster of melanophores mid-ventrally near postanal myomere 8, and are evenly distributed postero-ventrally over the next eight myomeres.[6]

POST YOLK-SAC LARVAE

Size Range
Yolk absorbed 8.1 mm to lengths about 20.0 mm.[6]

Myomeres
Preanal myomeres 19–21; postanal 19–21; 38–42 total myomeres.*

Morphology
8.1 mm TL. Yolk sac absorbed; gut straight; body elongate and laterally compressed; notochord flexion has not occurred.[6]

Morphometry
See Table 16.

Fin Development
8.1 mm TL. First rays formed in anal fin, no additional fin ray analgen formed.[6]

Pigmentation
8.1 mm TL. Pigmentation same as during previous yolk sac stage.[6]

JUVENILES

Size Range
Greater than 20.0[6] to 32–35 mm TL.[3]

Table 16

Morphometric data expressed as percentage SL for young *E. acuticeps* larvae from Tennessee.[6]

	TL Groupings	
Length Range (mm)	6.2–7.8	
N	13	
	Mean ± SD	(Range)
As Percent SL		
SnL	2.0±0.4	(1.5–2.7)
PEL	8.9±0.3	(8.4–9.9)
OP1L	17.1±1.7	(13.4–20.2)
ODL	28.1±3.6	(23.3–35.0)
PVL	56.6±2.1	(52.2–59.1)
PCL	103.7±0.9	(102.2–106.2)
MAXL-Y	30.9±0.2	(30.6–31.3)
P1L	6.4±0.3	(5.8–7.2)
HD	13.6±0.9	(11.5–14.6)
OP1D	16.5±2.3	(13.0–21.8)
OD1D	16.7±2.9	(12.8–20.5)
OD2D	10.7±1.2	(8.1–12.4)
BPVD	10.7±1.2	(8.1–12.4)
MPMD	8.2±0.7	(7.0–9.3)
AMPMD	3.5±0.1	(2.9–4.6)
MAX-YD	12.1±2.2	(8.2–17.6)
BPEW	11.6±1.2	(9.8–12.9)
OP1W	10.9±2.0	(8.3–16.3)
OD1W	11.5±1.9	(9.4–16.0)
OD2W	6.6±0.9	(4.5–8.2)
BPVW	6.6±0.9	(4.5–8.2)
AMPMW	2.8±0.3	(2.4–3.3)
MAXW-Y	11.9±1.9	(7.9–16.0)

Fins
Spinous dorsal XI–XIII; soft dorsal rays 11–13; pectoral rays 12–14; pelvic spines/rays I/5; anal spines/rays II/7–9; primary caudal rays 8 + 9.[1,2]

Morphology
Total lateral line scales 54–65; total vertebrae 38–39.[1,2] Gill membranes separate to slightly connected; compressed laterally, with a deep caudal peduncle.[1,2] Cheek, opercle, and breast are unscaled.[2]

Pigmentation
32 mm TL. Body yellow-brown, with a slight yellow venter and dark yellow fins. Laterally are 12–15 dusky vertical bars and thin dark horizontal stripes; orbital bars are poorly developed or absent.[1] An additional broad terminal band encircles caudal peduncle. At caudal fin base is a large dark spot with very pale areas above and below. Horizontal dark stripes are most distinct on caudal peduncle, but extend forward almost to origin of spinous dorsal fin. Usually a diffuse humeral spot.[2]

TAXONOMIC DIAGNOSIS OF YOUNG SHARPHEAD DARTER

Similar species: other *Nothonotus* species.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 14)
Eggs. Eggs are buried in sand substrates in swift current next to rocks in mid-channel habitats.[6]

Yolk-sac larvae. Yolk-sac larvae remain on the bottom and swim at sporadic intervals.[3] They remain in gravel substrates, probably until yolk sac is nearly exhausted, similar to other *Nothonotus*.*

Post yolk-sac larvae. At 245 h actively swimming, mouth and gills functional and clearly distinguishable.[3]

Juveniles. Juveniles were collected on the upstream side of main channel islands, occurring over gravel substrates in shallow waters <0.1 m, usually found in association with cobble and *Podestemum* in moderate currents.*

Early Growth
Fall juveniles were about 24 mm and did not grow much during the winter, appearing in the January, April, and May collections at nearly the same size.[3]

Feeding Habits
The diet includes simulids, baetids, and hydropsychids, which comprised 72% of prey organisms eaten.[3]

Figure 14 Distribution of sharphead darter, *E. acuticeps,* in the Ohio River system (shaded area) and areas where early life history information has been collected (circle). Number indicates appropriate reference.

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COPPERCHEEK DARTER

Etheostoma (*Nothonotus*) *aquali* Williams and Etnier

Etheostoma: various mouths; *aquali*: derived from the Cherokee "agaquali," which means cheek, referring to the diagnostic copper-colored markings on the cheek.

RANGE

Etheostoma aquali is endemic to the Duck and Buffalo Rivers and their large tributaries in TN.[1–5]

HABITAT AND MOVEMENT

Etheostoma aquali inhabits moderate to swift current over boulder, cobble, and gravel riffles at depths of 0.3–1.0 m in large streams to small rivers.[1–5] It prefers deep riffles, runs, and flowing pools,[4] and shoal areas with substrates of large gravel, cobble, or unconsolidated rock.[4,5] *E. aquali* uses habitats with fast current and is commonly associated with large rock.[5]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma aquali occurs in the Duck River only in the main channel and lower portions of a few large tributaries in Bedford, Maury, Hickman, and Humphrey Counties. In the Buffalo River, it has only been collected from the main channel in Lewis, Wayne, and Perry Counties.[5]

SPAWNING

Location

Nests are prepared by a male beneath slab rock or flattened boulders. Females were observed ovipositing the eggs, which often results in a wedge-shaped, multilayered egg mass rather than a single layer as observed in *Boleosoma* and *Catonotus.*[4]

Season

Spawning occurs during early May until mid-June.[4–6]

Temperature

Spawning occurs at temperatures <22°C[4,6] and continues at temperatures of 24°C.[6] Spawning in the Duck River, Marshall County, TN, occurs at temperatures between 16 and 18°C.[7]

Fecundity

Unknown. Page et al.[6] reported that a nest stone discovered from the Buffalo River possessed 551 eggs that were in various stages of development,[6] which suggests multiple spawnings with several females.[4,6]

Sexual Maturity

The length at which sexual maturity is attained is unknown; however, specimens that are age 2 were sexually mature.[6] Specimens 50–65 mm SL are sexually mature.[6]

Spawning Act

Etheostoma aquali is an egg clumper.[6,7] Large territorial males guard areas around the nest stone, which are located in swift, shallow water. Females were observed to swim beneath the nest stone and tightly wedge themselves (more or less right-side up) in the interface between the stone and gravel substrate. Although the male ignored them, it appears that eggs are laid with the female wedged between the rock and substrate. Males spawned over females, wedged between the nest stones.[6,7] One of two males guarded a smaller stone that possessed three small clumps of eggs. The eggs were separated by distances of 2 cm, located in the interface between the nest stone and gravel substrate. Each nest stone contained eggs in various stages of development, which was obviously the result of multiple spawns.[6]

EGGS

Description

Ovarian examination showed that large mature ova averaged 1.2–1.3 mm.* Mean diameter of spawned eggs from the Buffalo River, Lewis County, TN, was 1.8 mm;[6] Duck River eggs were

2.0 mm in diameter.[7] Eggs of *E. aquali* are demersal, adhesive, and spherical, possessing a single oil globule, a narrow perivitelline space, and a sculptured and unpigmented chorion.[7]

Incubation
Eggs incubated at 24–28°C hatched in 3–4 days (72–96 h)[6]; these probably are underestimates of incubation periods.

Development
Unknown.

YOLK-SAC LARVAE

See Figure 15

Size Range
6.5 mm TL[6] or 7.2–7.7 mm SL.[7]

Myomeres
Preanal myomeres 19–(20)–21; postanal 18–(19)–20; total myomeres 38–40.[7]

Morphology
7.2 mm SL. Newly hatched yolk-sac larvae possess a large (33.7% SL) pale yellow translucent, spherical to oval yolk sac. Yolk-sac larvae have a pigmented spherical eye without an anterior cranium extension, and a developed jaw. Mid-ventral yolk sac with a single serpentine vitelline vein.[7]

Morphometry
See Table 17.[7]

Fin Development
7.2 mm SL. Newly hatched yolk-sac larvae possess developed pectoral fin without incipient fin rays; soft dorsal fin origin even with the anus.[7]

Pigmentation
7.2–7.7 mm SL. Dorsal pigmentation present forming several clusters outlining the otic capsule, forming a series of lateral dashes from the middle yolk sac to the anus, and a single line from the dorsal origin to the caudal peduncle base. Lateral melanophores are present on the midopercle and at the edge of the mouth. A large melanophore cluster dorsally over the single oil globule. Ventrally, a series of melanophores scattered at the anterior edge of the serpentine mid-ventral vitelline vein, edging

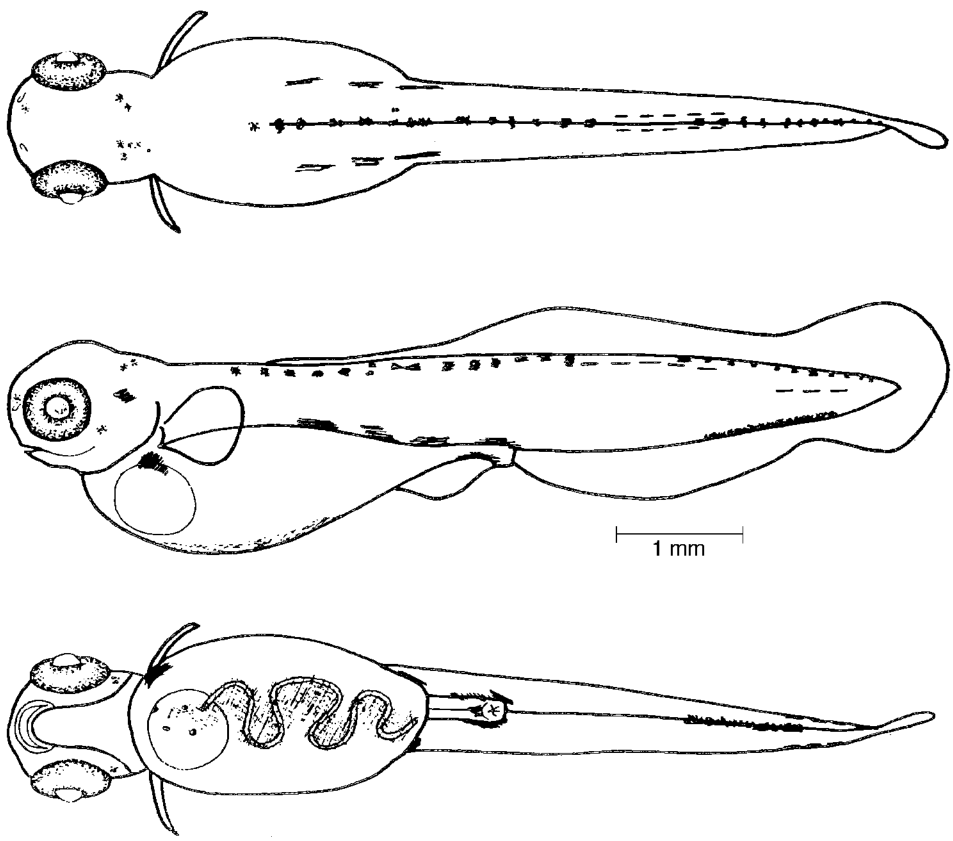

Figure 15 Coppercheek darter, *E. aquali*, Duck River, Marshall County, TN, 7.2 mm SL Yolk-sac larva, dorsal, lateral, and ventral aspects. (From reference 7, with authors' permission.)

Table 17

Morphometric data expressed as percentage of standard length (SL) for young coppercheek darter from Duck River, TN.[7]

TL Range (mm)	Total Length Groupings 7.2–7.7	7.8–8.4
N	5	4
Ratios	Mean ± SD (Range)	Mean ± SD (Range)
As Percent SL		
SnL	2.0 ± 0.2 (1.8–2.4)	2.3 ± 0.5 (2.0–2.8)
ED	10.8 ± 1.2 (9.7–13.1)	12.9 ± 0.3 (12.5–13.8)
HL	18.1 ± 1.7 (15.9–20.7)	21.2 ± 0.6 (19.3–22.0)
HW	13.1 ± 0.6 (11.9–13.5)	13.8 ± 0.4 (11.9–14.6)
PreDFL	32.1 ± 3.0 (27.8–36.1)	33.6 ± 3.6 (30.3–35.1)
PreAL	55.3 ± 1.5 (53.2–57.4)	54.3 ± 1.6 (52.6–55.3)
PosAL	44.7 ± 1.0 (43.6–46.8)	45.7 ± 2.9 (44.7–47.4)
PC	103.8+0.8 (102.6–104.0)	102.7 ± 0.5 (101.2–103.3)
YSL	33.7 ± 0.5 (33.2–34.3)	
P1L	10.7 ± 0.9 (8.9–11.7)	11.3 ± 3.1 (9.9–13.2)
CFL	3.8 ± 1.3 (2.6–4.0)	3.2 ± 2.2 (2.8–4.3)
BDE	15.0 ± 0.6 (13.9–15.6)	16.2 ± 1.2 (14.8–17.6)
BDP1	17.5 ± 1.7 (15.7–19.7)	16.4 ± 1.3 (15.6–18.3)
BDA	11.2 ± 0.3 (10.7–11.6)	13.3 ± 0.9 (12.4–15.4)
MPosAD	8.2 ± 0.8 (7.3–9.3)	8.8 ± 0.9 (7.9–8.5)
CPD	3.7 ± 0.5 (2.9–4.3)	3.9 ± 1.0 (3.4–4.9)
YSD	10.4 ± 2.0 (8.4–13.5)	

the outside distal edge of the yolk sac, outside gut near the anus, and a mid-lateral dash occurs near the caudal peduncle. Cross-hatched or brushed melanophores are present mid-ventrally over the vitelline vein.[7]

POST YOLK-SAC LARVAE

Size Range
7.7 mm SL to unknown lengths.[7]

Myomeres
Preanal myomeres 19–(20)–21; postanal 18–(19)–20; total myomeres 38–40.[7]

Morphology
7.7 mm SL. Yolk sac absorbed.[7]

Morphometry
See Table 17.[7]

Fin Development
7.7 mm SL. Fin rays form in the anal fins.[7]

Pigmentation
7.7 mm SL. Dorsal pigmentation present and forming several clusters outlining the otic capsule, a series of lateral dashes from the middle yolk sac to the anus, and a single line from the dorsal origin to the caudal peduncle base. Lateral melanophores are present on the midopercle, and at the edge of the mouth. Oil globule with a large melanophore cluster dorsally over the single oil globule. Ventrally, a series of melanophores is scattered at the anterior edge of the serpentine mid-ventral vitelline vein, edging the outside distal edge of the yolk sac and the outside gut near the anus; a mid-lateral dash occurs near the caudal peduncle.

JUVENILES

Size Range
Unknown.

Fin Development
Larger Juveniles. Spinous dorsal fin XII–XIV; soft dorsal rays 11–14; pectoral rays 12–(13–4)–16; anal fin spines/rays II/8–(9–10); pelvic fin rays I/5; caudal fin rays 16–19.[2–5]

Morphology
Total vertebrae count 38–40 including one urostylar element. Scales in the lateral series complete with 57–67 (59–67) pored scales in the lateral range.[2–5] Gill membranes separate to narrowly join; frenum present. Scales absent from nape, breast, prepectoral area, and occasionally anterior belly; opercles

scaled and cheeks with a few scales underlying postorbital spot.[4,5] Infraorbital and supratemporal canals complete.[2–5]

Morphometry
Unknown.

Pigmentation
Juveniles. Background body color brown, with pale yellow background color on median fins and ventral areas; all fins covered with brown spots.[4]

TAXONOMIC DIAGNOSIS OF YOUNG COPPERCHEEK DARTER

Similar species: Simon et al.[7] placed *E. aquali* in the egg-clumper group along with *E. maculatum, E. camurum,* and *E. vulneratum.* These species possess more than 19 preanal myomeres, large (>32.0% SL) spherical yolk sacs, dorsal pigmentation in either a single or double row, and a series of mid-lateral dashes near the caudal peduncle. Within this group, *E. vulneratum* exhibits the largest egg diameter and size at hatching, while *E. maculatum* is most similar to *E. vulneratum* but hatches at 5.0 mm SL. Larvae of *E. aquali* can be distinguished from the other species based on the cross-hatched or brushed melanophores that cover the vitelline vein.[7]

Variation
Our study populations of *E. aquali* exhibited little intraspecific variation.[7]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 16)
Eggs. Eggs are clumped in the interface spaces between stones along the channel border.[6,7]

Yolk-sac larvae. Yolk-sac larvae were collected from beneath interstitial spaces between stones.11 Yolk-sac larvae are epibenthic and drift in the water column shortly after hatching.7

Post yolk-sac larvae. Larvae remain in shallow downstream pools and along the nearshore edge.7

Figure 16 Distribution of coppercheek darter, *E. aquali* in the Ohio River system (shaded area) and area where early life history information has been collected (circle). Number indicates appropriate reference. (From reference 7, with authors' permission.)

Juveniles. Occur on the downstream edges of shallow riffles by mid-September.*

Early Growth (see Table 18)
Males grew more rapidly than females; lengths of late fall and early spring specimens suggest that age 1 specimens attain lengths of 30 mm SL.[4]

Feeding Habits
Diet was primarily hydropsychid caddisflies, midge larvae, mayfly nymphs, blackfly larvae, and a variety of other immature insects and snails.[4]

Table 18

Average calculated total length (mm TL) of young coppercheek darters in Tennessee.[4]

	Age		
State	1	2	3
Tennessee[4]	30	45	60

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Materials Examined: TN: Marshall Co.: Duck River, TVA uncatalogued (5).

MUD DARTER

Etheostoma (*Oligocephalus*) *asprigene* (Forbes)

Etheostoma: various mouths; *asprigene*: rough cheek, in reference to the well-scaled cheeks.

RANGE

Etheostoma asprigene occurs in the Mississippi Valley from southern MN southward, on the Coastal Plain, and from a few eastern tributaries to the Mississippi River westward to the Neches River, TX. The mud darter occurs throughout the Wabash and White Rivers, IN, and the lower Tennessee and Cumberland Rivers, TN and KY.[1–4]

HABITAT AND MOVEMENT

The preferred habitat of the mud darter includes both small clay bottom riffles and the margins of large rivers along tree roots and root wads.* Mud darters occur in overflow swamps, oxbows, and reservoirs, in sluggish current, and over a variety of substrates including sand, detritus, and silty gravel.[1–4] In streams, they occur in riffles during the day and migrate to pools at night.[5] The species often occurs with detritus or near undercut or brushy banks.[5] It is often associated with vegetation, brush, or rocks that provide protection.[5]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma asprigene is found in the lower Tennessee and Cumberland Rivers, TN and KY.[1–3] The species occurs in tributaries of the middle to lower Wabash River and East Fork White River, IN[4] from the Sugar Creek and Driftwood River Forks downstream, IN.*

SPAWNING

Location
Spawning occurred over vegetation along the margins of sluggish streams and root wads over silty gravel substrates at depths <0.5 m in moderate flow.[4–6,*]

Season
Spawning season occurs from March to May.[4,6]

Temperature
Spawning occurs at temperatures of about 17–20°C.[5,*]

Fecundity (see Table 19)
Females (48–60 mm TL) collected in early April from the Mississippi River, WI, had ovaries that were 9.14% of the body weight, containing 1085.8 total ova averaging 0.85 mm in diameter.* Cummings et al.[5] reported that females from IL had 50–94 mature eggs.

Sexual Maturity
Adults live to reach age 3[5,7]; however, maturity is suspected to be at age 1 for females.[5] An adult male (56 mm TL) from IN had testes that were 0.94% of the body weight on April 2.* Male tuberculation was absent, and females had a circular pad that may elongate into a short tube.[*,2] Females 40 mm TL were all sexually mature.[4,5] Males <40 mm TL were all immature, while all males >40–45 mm TL were mature.[*,4,5] Males exhibited sexually dimorphic traits during the reproductive season with the increase in brightly colored pigmentation and extension of a broad flap that supported a smaller terminal section.[*,2,5,6]

Spawning Act
The reproductive mode of *E. asprigene* is an attacher.[5,6] Males did not defend territories but were generally aggressive toward other males. Males courted females by circling and erecting their fins. Females selected spawning sites on elevated surfaces or released eggs over vegetation. Fertilization occurred after the male mounted her in an S-shaped configuration; 1–3 eggs per spawning event were deposited directly on submerged plants or 5–10 were released above vegetation.[4–6] We speculated that sticks and other woody debris are used for spawning.[4–6] Our observations suggest that spawning takes place in root wads that occur along the bank.*

Table 19

Fecundity data for mud darter from the Mississippi River, WI.*

			Number of Ova			
Date	TL	GSI	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
April 1	60	7.2	624	311	281	0.83
	58	11.9	668	429	301	0.90
	58	9.9	649	423	398	0.77
	58	7.6	608	361	330	0.77
	56	12.6	688	331	203	0.90
	55	7.4	436	264	241	0.83
	53	8.3	413	294	225	0.83
	51	8.8	332	224	195	0.90
	50	8.0	394	256	212	0.90
	48	9.7	341	228	198	0.83

EGGS

Description

Egg diameters from Lake Creek, IL, were 1.1–1.5 mm in diameter.[5] Eggs from Cypress Creek, Morehouse Parish, LA, were spherical, mean = 1.0 mm diameter (range = 0.8–1.1 mm); translucent, demersal, and nonadhesive. Eggs possessed translucent, pale amber yolk (mean = 0.95 mm diameter; range = 0.75–1.0 mm), a single oil globule (mean = 0.23 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.*

Incubation

Hatching occurs after 125–144 h at an incubation temperature of 22°C.[5]

Development

Unknown.

YOLK-SAC LARVAE

See Figure 17

Size Range

Populations from Lake Creek, IL, hatch between 4.2 and 5.6 mm TL[5]; yolk absorbed by 6.9 mm TL.*

Myomeres

Preanal myomeres 13 (2), 14 (1), or 15 (4) (N = 7, mean = 14.3); postanal 18 (3), 19 (3), 20 (1) (N = 7, mean = 18.7); with total 33 (4), 34 (2), or 35 (1) (N = 7, mean = 33.6).* Specimens from Lake Creek had 13–15 preanal myomeres and 18–20 postanal myomeres.[5]

Morphology

4.2–5.6 mm TL. Newly hatched: body terete; snout blunt; with functional jaws, upper jaw even with lower jaw; well-developed pectoral fins without incipient rays; yolk sac small (18.6% TL), oval to tapered posteriorly; yolk translucent clear to pale yellow, with a single oil globule; complex plexus of vitelline veins mid-ventrally on yolk sac; head not deflected over the yolk sac; and eyes oval.*[,5]

5.0–6.9 mm TL. Digestive system functions before complete yolk absorption.*

Morphometry

See Table 20.*

Fin Development

4.2–5.6 mm TL. Well-developed pectoral fins without incipient rays.[6]

Pigmentation

4.2–5.6 mm TL. Newly hatched: eyes pigmented; no melanophores dorsally over either the anterior or posterior cerebellum and nape; no melanophores distributed laterally or dorsally over the gut posterior to the yolk sac; ventral pigmentation consists of a midventral stripe of stellate melanophores surrounding the vitelline vein on the yolk sac; punctate melanophores along every midventral postanal myosepta.*[,5]

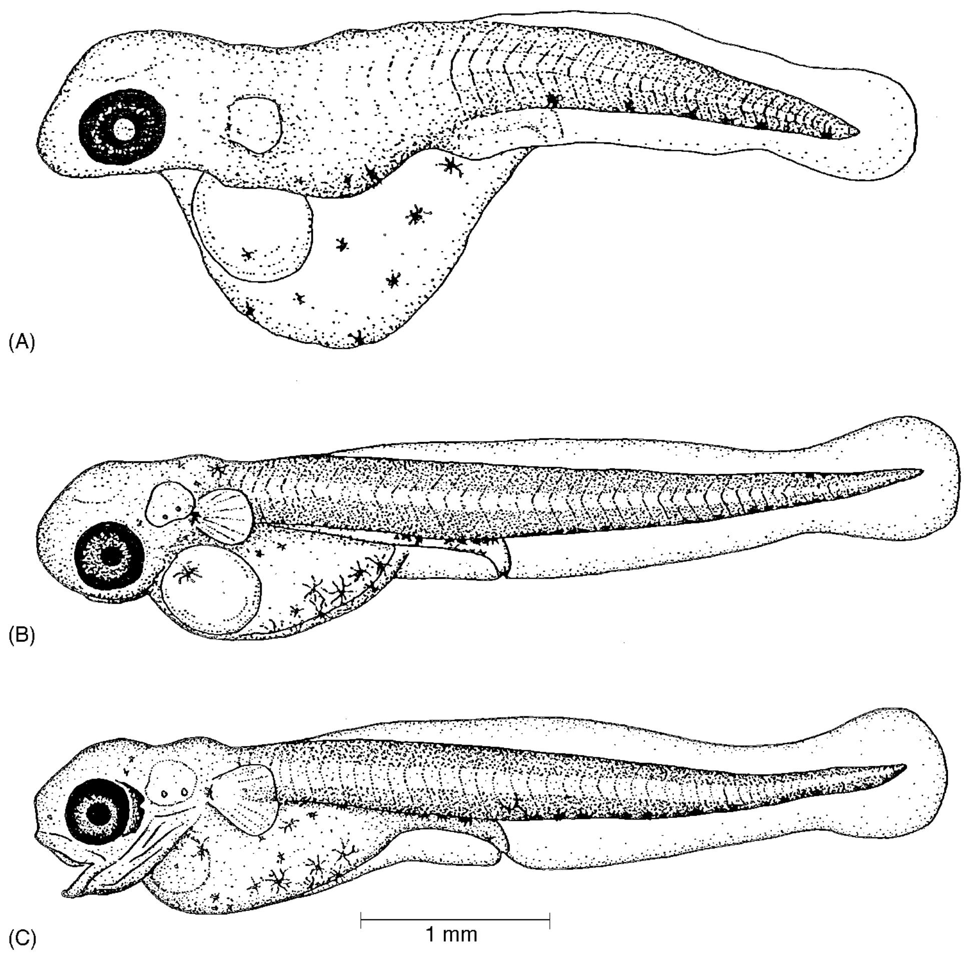

Figure 17 *Etheostoma asprigene*, mud darter, Lake Creek, IL: (A) yolk-sac larva, 3.6 mm TL, lateral; (B) yolk-sac larva, 4.2 mm TL, lateral views; (C) yolk-sac larva, 4.9 mm TL, lateral view. (A–C from reference 5, with authors' permission).

5.7–6.9 mm TL. No dorsal pigmentation over the optic lobe. Ventral pigmentation consists of single midventral melanophores from the breast to the anus; staggered, paired melanophores from the anus to the caudal peduncle.[5,*]

LARVAE

Size Range
>7.0 to 14.0 mm TL.*

Myomeres
Preanal myomeres 13 (14), 14 (2), or 15 (7) (*N* = 23, mean = 14.3), postanal myomeres 22 (3), 23 (7), 24(1), 25 (3), 26 (3), 27 (3) or 28 (3) (*N* = 23, mean = 26.3), with total myomeres 35 (2), 36 (6), 37 (1), 38 (4), 39 (3), 42 (3) or 43 (3) (*N* = 23, mean = 38.1).*

Morphology
>7.0 mm TL. Yolk absorbed.[6]

14.0 mm TL. Operculum and gill arches function and premaxilla and mandible formed; neuromast development occurs mid-laterally from the anterior trunk posteriad. No swim bladder forms; gut straight, without striations; portion of gut posterior stomach normal in length, between 7.4 and 10.0 mm.*

Morphometry
See Table 20.*

Fin Development
>7.0 mm TL. First rays form in caudal fin; soft dorsal fin rays and branchiostegal rays form; pelvic fin buds form anterior to dorsal fin origin after complete yolk absorption; notochord flexion precedes caudal fin ray development, and anal fin rays form; pectoral fin rays form.*

14.0 mm TL. Dorsal and anal finfold partially differentiate; spinous dorsal forms between; pelvic fin buds present without incipient rays; complete adult fin ray counts in median fins. Spinous dorsal fin

Table 20

Morphometry of Young mud darter, *E. asprigene*, larvae grouped by selected intervals of total length.*

	Total Length Size Interval							
	5.2–6.9 mm		14.0–16.0 mm		18.0–22.9 mm		23.0–30.5 mm	
Character	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
Length (% of TL)								
Upper jaw (HL)	22.9 ± 5.86	(0.60–0.96)	22.9 ± 5.86	(0.60–0.96)	36.4 ± 8.84	(1.08–1.68)	31.2 ± 8.86	(1.27–2.50)
Snout (HL)	22.9 ± 5.86	(0.60–0.96)	23.5 ± 2.38	(0.64–0.90)	31.3 ± 8.26	(0.81–1.60)	24.3 ± 5.94	(1.04–2.00)
Eye diameter (HL)	22.9 ± 5.86	(0.60–0.96)	27.9 ± 4.13	(0.84–0.98)	33.3 ± 7.60	(1.00–1.62)	27.2 ± 6.65	(1.25–2.00)
Head	22.9 ± 5.86	(0.60–0.96)	22.3 ± 2.69	(3.00–3.60)	19.2 ± 4.31	(2.56–5.88)	23.2 ± 3.94	(3.25–7.50)
Predorsal	22.9 ± 5.86	(0.60–0.96)	29.3 ± 2.55	(3.90–5.12)	30.5 ± 1.66	(5.40–7.25)	28.8 ± 3.23	(3.49–9.00)
Dorsal insertion	22.9 ± 5.86	(0.60–0.96)	42.8 ± 8.59	(4.50–7.68)	50.4 ± 2.42	(8.64–11.8)	50.1 ± 3.80	(8.11–15.5)
D2 origin	22.9 ± 5.86	(0.60–0.96)	45.8 ± 10.8	(4.50–8.64)	53.3 ± 3.18	(9.18–12.8)	51.9 ± 3.80	(8.60–16.0)
D2 insertion	22.9 ± 5.86	(0.60–0.96)	59.0 ± 19.4	(4.50–8.64)	73.2 ± 3.29	(9.18–12.8)	73.3 ± 4.49	(8.60–16.0)
Preanal	22.9 ± 5.86	(0.60–0.96)	51.7 ± 2.00	(7.50–8.00)	54.0 ± 7.04	(9.25–18.0)	52.3 ±1.20	(11.8–16.0)
Postanal	22.9 ± 5.86	(0.60–0.96)	48.3 ± 1.96	(6.50–8.00)	48.1 ± 3.78	(8.50–13.1)	47.6 ± 1.31	(10.3–14.6)
Standard	22.9 ± 5.86	(0.60–0.96)	85.4 ± 2.55	(12.3–13.8)	86.2 ± 1.42	(15.5–19.3)	85.9 ± 1.30	(19.5–26.4)
Yolk sac	22.9 ± 5.86	(0.60–0.96)						
Fin Length (% of TL)								
Pectoral	22.9 ± 5.86	(0.60–0.96)	15.8 ± 1.93	(2.00–2.70)	14.9 ± 2.95	(1.60–4.62)	18.6 ± 1.72	(3.68–6.12)
Spinous dorsal	22.9 ± 5.86	(0.60–0.96)	18.0 ± 2.00	(2.52–3.00)	19.9 ± 1.71	(3.24–5.08)	21.2 ± 1.56	(4.14–6.50)
Soft dorsal	22.9 ± 5.86	(0.60–0.96)	17.7 ± 4.04	(2.08–3.00)	19.8 ± 0.81	(3.24–4.62)	21.4 ± 1.75	(4.04–6.50)
Caudal	22.9 ± 5.86	(0.60–0.96)	14.6 ± 2.55	(1.75–2.75)	13.8 ± 1.42	(2.25–3.70)	14.1 ± 1.30	(2.45–4.50)
Body Depth (% of TL)								
Head at Eyes	22.9 ± 5.86	(0.60–0.96)	17.0 ± 4.76	(2.10–3.60)	16.4 ± 3.40	(2.52–5.88)	16.3 ± 2.77	(3.46–6.46)
Head at P1	22.9 ± 5.86	(0.60–0.96)	18.3 ± 1.11	(2.66–3.96)	18.3 ± 1.15	(3.92–4.38)	18.4 ± 1.08	(4.27–5.42)
Preanal	22.9 ± 5.86	(0.60–0.96)	13.9 ± 1.47	(1.68–2.33)	15.0 ± 0.71	(2.50–3.46)	16.1 ± 1.20	(3.22–5.00)
Caudal peduncle	22.9 ± 5.86	(0.60–0.96)	8.00 ± 0.00	(1.12–1.28)	8.18 ± 0.44	(1.46–2.11)	8.67 ± 0.96	(1.84–3.00)
Yolk sac	22.9 ± 5.86	(0.60–0.96)						
Body Width (% of HL)								
Head	22.9 ± 5.86	(0.60–0.96)	53.6 ± 4.27	(1.50–2.10)	81.1 ± 25.3	(1.50–2.10)	67.4 ± 22.4	(3.00–5.53)
Myomere Number								
Preanal	22.9 ± 5.86	(0.60–0.96)	13.5 ± 0.58	(13.0–14.0)	13.5 ± 0.89	(13.0–15.0)	15.0 ± 0.00	(15.0–15.0)
Postanal	22.9 ± 5.86	(0.60–0.96)	22.8 ± 0.55	(22.0–23.0)	24.6 ± 1.78	(22.0–27.0)	28.0 ± 0.00	(28.0–28.0)
Total	22.9 ± 5.86	(0.60–0.96)	36.3 ± 0.55	(36.0–37.0)	38.1 ± 2.33	(35.0–42.0)	43.0 ± 0.00	(43.0–43.0)

Note: Data presented as percent head length (HL) or total length (TL), with a single standard deviation.

origin situated over preanal myomere 3, soft dorsal origin over preanal myomere 15. Both finfolds completely differentiate.*

Pigmentation

>7.0 mm TL. Dorsum of cranium with several large melanophore clusters on cerebellum; laterally, a single series of subdermal melanophores from gut to anus, no other melanophores laterally along the midline. Ventral pigmentation includes a series of melanophores mid-ventrally from the breast to the anus: two clusters of mid-ventral postanal melanophores beginning at postanal myomere, and stellate melanophores at each mid-ventral postanal myosepta.*

14.0 mm TL. Melanophores on cranium and from soft dorsal fin origin to midfin. Lateral melanophores over the otic capsule and midline of operculum; laterally 11 blotches over the gut extending posteriorly from midanal fin to the caudal peduncle. The distinguishing three spots formed at the base of the caudal peduncle. Rectangular blocks of pigment present from head to middle of soft dorsal. Dorsal pigmentation consists of seven circular blotches starting at the front tip of soft dorsal. Ventral pigmentation consists of a single series of melanophores from the anal fin to the caudal peduncle.*

JUVENILES

Size Range

>14.0 to 40–45 mm TL.[*,3]

Fin Development

14.8–16.0 mm TL. Complete adult fin ray counts in median fins; first pelvic fin ray forms by 14.8 mm; caudal fin truncate, rays with segmentation.* Dorsal and anal finfolds completely differentiated.[6]

18.0–22.9 mm TL. Average predorsal length 30.5% TL.*

Larger Juveniles. Spinous dorsal fin IX–XII; soft dorsal rays 10–14; pectoral rays 11–15; anal fin rays II 6–8; pelvic fin rays I 5; caudal fin rays 14–18[1–4] (see Table 21).*

Morphology

15.0–18.0 mm TL. Lateral line forming. Squamation intiated at 15.0 mm TL.*

18.5 to 21.1 mm TL. Squamation complete; cheek scales, usually embedded; cheek, opercle, and nape are completely scaled; breast naked; belly variable either fully scaled or naked anteriorly.*

Total vertebrae count 35–37 including one urostylar element. Scales in the lateral series incomplete with 28–46 pored scales and 35–53 total scales in the lateral range from TN.[2–4] Gill membranes separate, frenum present. Supraorbital and infraorbital canals complete.*

Morphometry

Unknown.

Pigmentation

15.0–16.0 mm TL. Outline of cerebellum and optic lobe covered with melanophores; seven dorsal saddles becoming apparent, on nape, anterior spinous dorsal fin origin, midspinous dorsal fin, anterior spinous dorsal fin insertion, immediately posterior soft dorsal fin origin, soft dorsal fin insertion, and over the caudal peduncle. Lateral pigmentation includes the beginning of the preorbital bar formation; pigment in the hypaxial portion of the operculum; and beginning of four elliptical mid-lateral clusters of melanophores. Ventral pigmentation forming a series of melanophores between the pelvic fins, extending to anus; there are two clusters of postanal pigmentation at midanal fin and at the mid-caudal peduncle. Scattered melanophores outline the caudal fin rays; a single stripe is present on the spinous dorsal and anal fins; and a few melanophores are present in the epaxial portion of the pectoral fin.*

18.0–30.5 mm TL. Preorbital bar, cerebellum, and optic lobe pigmentation dense; nine dorsal saddles from the nape to the caudal peduncle. Five vertical stripes forming posterior soft dorsal fin origin. Ventral pigmentation includes a series of melanophores from the anal fin insertion to the caudal fin base. Three distinct blotches of pigment form on caudal peduncle. Spinous dorsal fin with a distal and midfin stripe; soft dorsal fin with a midfin stripe; pectoral fin with several scattered melanophores in the epaxial half of the fin; and caudal fin with melanophores outlining the caudal fin base. No pigmentation present in the pelvic or anal fins.*

TAXONOMIC DIAGNOSIS OF YOUNG MUD DARTER

Similar species: members of subgenus *Oligocephalus*.[5]

Adult. Etheostoma asprigene is similar to *E. swaini* and *E. caeruleum.* The species differs from *E. swaini* in

Table 21

Meristic counts and size (mm TL) at the apparent onset of development for *E. asprigene.**

Attribute/event	*Etheostoma asprigene**	Literature
Branchiostegal Rays	6,6	6,6[2–4]
Dorsal Fin Spines/Rays	X–XI/11–13	IX–XII/10–14[2–4]
First spines formed	>7.0	
Adult complement formed	14.0	
First soft rays formed	>7.0	
Adult complement formed	14.0	
Pectoral Fin Rays	13–14	11–15[2,3]
First rays formed	>7.0	
Adult complement formed	>7.0	
Pelvic Fin Spines/Rays	I/5	I/5[2,3]
First rays formed	14.8	
Adult complement formed	15.0	
Anal Fin Spines/Rays	II/6–8	II/6–8[2–4]
First rays formed	>7.0	
Adult complement formed	< 14.0	
Caudal Fin Rays	vii–xi, 8–11 + 7–11, viii–xi	14–18[4]
First rays formed	>7.0	
Adult complement formed	<14.0	
Lateral Line Scales	48–55	35–53[2–4]
Myomeres/Vertebrae	36–43/35–37	Unknown/35–37[2,4]
Preanal myomeres	13–15	
Postanal myomeres	18–28	

having a depigmented nape, with scales absent or embedded, and lacking a dark blotch at the posterior base of the spinous dorsal fin. *E. asprigene* is allopatric with *E. caeruleum* but differs in possessing an orange breast and separate connected gill membranes.

Larva. The early life history of *E. asprigene* is similar to *E. swaini.* The two species can be differentiated by their pigmentation. *Etheostoma asprigene* can be separated from *E. caeruleum* since it has 16 preanal myomeres, while *E. asprigene* has <15 preanal myomeres.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 18)

Eggs. Eggs are attached to vegetation, woody debris, or broadcast over vegetation in slow, sluggish pools of streams or backwaters of large river habitats.*[,5]

Yolk-sac larvae. Yolk-sac larvae remain in vegetation mats, root wads, or root mat pore spaces; the species is benthic and is rarely collected from the pelagic drift.*

Post yolk-sac larvae. Larvae stay in close association with the substrate. The precocious development of fin rays in the paired and median fins enables the species to be able to inhabit the slower flowing margins of natal habitats in large rivers and the edges of flowing pools in stream habitats.*

Juveniles. Early juveniles utilize the downstream pools and margins of backwater areas adjacent to spawning areas as nursery habitats.*

Early Growth

Apparently, individuals do not exceed 3 years of age.[5,7] During their first year of life, young darters attained 40–45 mm TL in TN,[4] and 41.5 mm TL in

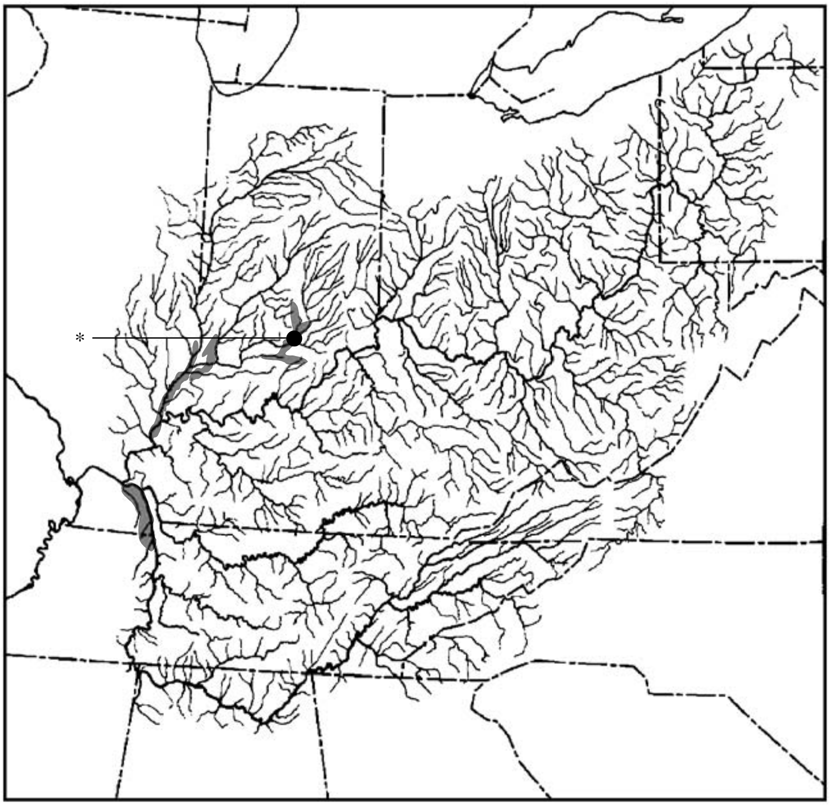

Figure 18 Distribution of mud darter, *E. asprigene* in the Ohio River system (shaded area) and areas where early life history information has been collected (circle). Asterisk indicates original information.

WI.[7] Mud darters from the East Fork White River, IN, attained 37–42 mm TL during their first year of life* (see Table 22).

Feeding Habits
The main components of the diet in IL include midge and caddisfly larvae, mayfly nymphs, and isopods.[5] A juvenile specimen (15.8 mm TL) from the upper Mississippi River, Pool 5, WI, had eaten a larval gizzard shad that was 10 mm TL. Larval and juvenile specimens from the East Fork White River ate copepods, daphnids, midge larvae, and oligochaetes.*

Table 22

Average calculated total length (mm TL) of young mud darters from Indiana, Illinois, and Wisconsin.

	Age		
State	**1**	**2**	**3**
Wisconsin (mean)[7]	41.5	52	
Illinois[5]	40–45	50–55	60+
Indiana*	37–42	50–54	62–65

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* Original fecundity data for mud darter from the Mississippi River, WI. Descriptive and life history information from the East Fork White River, IN, curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

CUMBERLAND SNUBNOSE DARTER

Etheostoma (*Ulocentra*) *atripinne* (Jordan)

Etheostoma: various mouths; *atripinne*: black fin, in reference to the dark pigmentation pattern that persists in the dorsal fins of preserved males.

RANGE

Etheostoma atripinne occurs throughout the middle Cumberland River basin, KY and TN.[1–3] The species occurs from Wolf River, TN, and Fishing Creek, KY, westward to the Harpeth River, TN, and the Red River, KY and TN. The species is absent from most of Caney Fork and above Cumberland Falls.[2]

HABITAT AND MOVEMENT

The Cumberland snubnose darter inhabits moderate-gradient, clear to slightly turbid small streams to moderate-sized rivers. Adults prefer unsilted gravel substrates or bedrock strewn with rubble in moderate current.[*,1–4,6,8]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma atripinne is narrowly confined to the Cumberland River drainage. Its range closely follows that of *E. simoterum*.[4]

SPAWNING

Location

Spawning occurs in a vertical position. Breeding males and ripe females were caught along a steep bank against a stump and its roots, which broke the force of the adjacent turbulent riffle. It was reported that spawning occurred along the vertical bank, along the tree roots themselves, or on the sides of rocks in rocky or bedrock pools.[2,5]

Season

Males collected in spawning color in mid-February from moderate current in Brush Creek, Smith County, TN.[5] The peak spawning of the Cumberland snubnose darter occurs from April through early May in TN.[4,5] Spawning throughout its range occurs from mid-April until early June (R. Wallus, personal communication).[6]

Temperature

Spawning activity initiated in Brush Creek, TN, when temperatures reached 25–27°C[5] and 15–16°C in Dry Creek, TN (R. Wallus, personal communication).[6]

Fecundity (see Table 23)

Females (42–52 mm TL) collected in early to mid-April from Dry Creek, TN, had ovaries that were 12.6% of the body weight, containing 198.6 total ova averaging 0.57 mm diameter.* Females had 56–124 mature eggs[5].

Sexual Maturity

Adults live to reach age 2,[2,3] however; maturity is suspected to be at age 1.[7] An adult male (56.3 mm TL) from TN had testes that were 1.23% of the body weight on April 12.* Male tuberculation was absent and females had a long tubular genital papilla.* Females 50–62 mm TL were all sexually mature, 32% of 45–50 mm TL females were mature, while none of the females <45 mm TL were sexually mature. Males <48 mm TL were all immature, while all males >52 mm TL and 35% of all males 50–56 mm TL were mature.* Males exhibited sexually dimorphic traits during the reproductive season with an increase in brightly colored pigmentation and extension of the genital papillae from the cloacal pad, while females had distended abdomens and a long tubular genital papilla.[*,2,3,6]

Spawning Act

The reproductive mode of *E. atripinne* is an attacher.[6] In aquarium observations, breeding males are not observed defending stationary territories but are combative when other males come in close proximity. The male courts the female by exhibiting his erect

Table 23

Fecundity data for Cumberland snubnose darter from Dry Creek, TN.*

			% Occurrence of Ova			
Date	TL	GSI	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
April 5	56	11.3	144	89	34	1.2
	55	10.5	124	47	62	1.2
	54	12.6	132	20	48	1.2
April 12	54	13.5	83	73	18	1.3
	52	12.2	91	23	38	1.3
	51	14.6	94	12	49	1.4
	50	13.4	91	59	59	1.2

spinous dorsal fin in a lateral body display. Receptive females lead a single male to the egg deposition site. The male mounts the female and the pair vibrates as 1 to 2 eggs are released and concurrently fertilized. The pair is observed to deposit eggs at multiple sites and the species is promiscuous, spawning with multiple partners during the course of the observations.[5,6]

EGGS

Description
Eggs from Brush Creek, Smith Co., TN[5] are similar to eggs from Dry Creek, Dekalb Co., TN, and are spherical (mean = 1.2 mm diameter, range= 1.0–1.4 mm); translucent; demersal; and adhesive. Eggs possess translucent, pale yellow yolk (mean = 1.1 mm diameter; range= 0.9–1.3 mm); a single oil globule (mean = 0.26 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[6]

Incubation
Hatching occurs after 240–264 h at an incubation temperature of 19.4–20°C.[6]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 19

Size Range
TN populations from Dry Creek hatch between 4.6–4.9 and 5.6 mm TL.[6]

Myomeres
Preanal myomeres 15 (1), 16 (61), 17 (3), or 18 (1) (*N* = 66, mean = 16.1); postanal 22 (64) or 23 (2) (*N* = 66, mean = 22.0); with total 38 (60), 39 (5), or 40 (1) (*N* = 66, mean = 38.1).[6]

Morphology
4.6–4.9 mm TL. Newly hatched: body terete; snout blunt; with functional jaws, upper jaw even, to slightly extending past lower jaw; well-developed pectoral fins without incipient rays; yolk sac small (16.6% TL), oval to tapered posteriorly; yolk translucent clear to pale yellow, with a single oil globule; single serpentine vitelline vein mid-ventrally on yolk sac; head not deflected over the yolk sac; and eyes oval.[6]

5.0–5.3 mm TL. Digestive system functions before complete yolk absorption.[6]

Morphometry
See Table 24.[6]

Fin Development
4.6–5.8 mm TL. Well-developed pectoral fins without incipient rays.[6]

Pigmentation
4.3–4.7 mm TL. Newly hatched: eyes pigmented; melanophores dorsally over anterior and posterior cerebellum and nape; melanophores distributed laterally, dorsally over the gut posterior the yolk sac; ventral pigmentation consists of a mid-ventral stripe of stellate melanophores surrounding the vitelline vein on the yolk sac, and punctate melanophores along every mid-ventral postanal myosepta.[6]

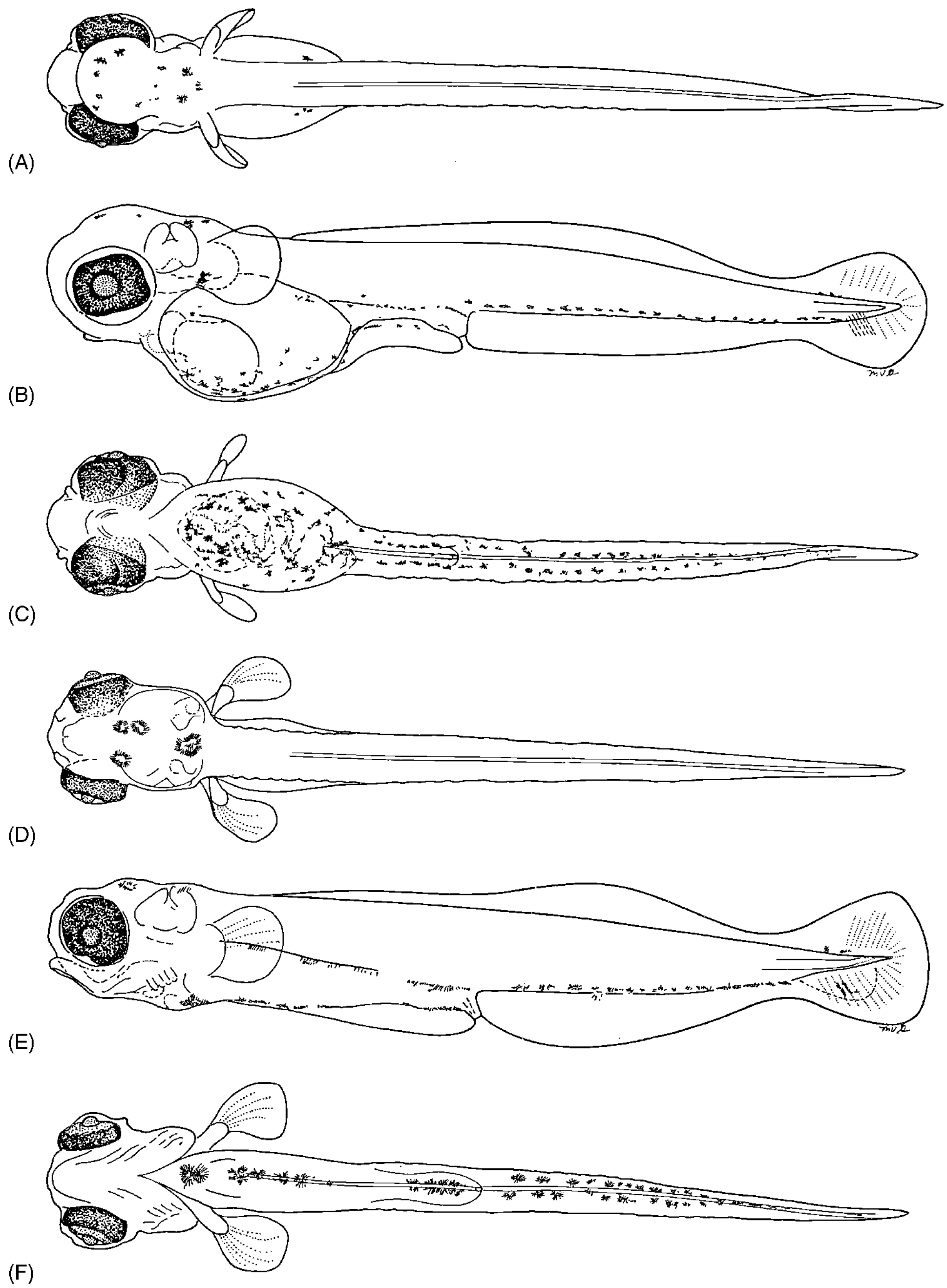

Figure 19 *Etheostoma atripinne*, Cumberland snubnose darter, Dry Creek, Dekalb County, TN. Yolk- sac larva, 4.7 mm TL: (A) dorsal, (B) lateral, (C) ventral views. Post yolk-sac larva, 6.8 mm TL: (D) dorsal, (E) lateral, (F) ventral views. (From reference 6, with author's permisssion.)

5.0–5.7 mm. Dorsal pigmentation consists of expanded melanophores over the optic lobe. Lateral pigmentation present dorsally over the stomach and gut. Ventral pigmentation consists of single midventral melanophores from the breast to the anus; and staggered, paired melanophores from the anus to the caudal peduncle.[6]

POST YOLK-SAC LARVAE

See Figures 19 and 20

Size Range

5.3–5.6 mm, phase completed by 9.6 mm TL.[6]

Myomeres

Preanal 15 (1), 16 (61), 17 (3), or 18 (1) (N = 66, mean = 16.1); postanal 22 (64) or 23 (2) (N = 66, mean = 22.0); with total 38 (60), 39 (5), or 40 (1) (N = 66, mean = 38.1).[6]

Morphology

5.3–5.6 mm TL. Yolk absorbed.[6]

Table 24

Morphometry of Young *E. atripinne* grouped by selected intervals of total length (N = sample size).[6]

	Total Length (TL) Intervals (mm)											
	4.60–5.94 (N = 23)		6.08–7.71 (N = 17)		8.12–9.98 (N = 20)		10.1–12.8 (N = 17)		13.4 (N = 1)		21.1 (N = 1)	
Characters	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean**	**Range**	**Mean**	**Range**
Length (% of TL)												
Upper Jaw[a]	24.2 ± 4.50	(0.16–0.40)	24.6 ± 4.26	(0.23–0.37)	24.1 ± 5.14	(0.22–0.66)	26.0 ± 3.84	(0.42–0.83)	33.1	(0.94)	29.6	(1.50)
Snout[a]	13.8 ± 2.75	(0.08–0.21)	15.0 ± 1.79	(0.12–0.26)	17.0 ± 1.68	(0.22–0.39)	18.7 ± 1.34	(0.31–0.56)	19.0	(0.54)	17.8	(0.90)
Eye Diameter[a]	45.0 ± 3.28	(0.40–0.48)	41.0 ± 3.86	(0.42–0.58)	37.2 ± 2.38	(0.59–0.76)	34.9 ± 1.81	(0.62–1.00)	33.8	(0.96)	29.6	(1.50)
Head	18.2 ± 0.73	(0.84–1.14)	18.5 ± 1.44	(0.92–1.50)	19.9 ± 1.07	(1.48–2.29)	21.1 ± 1.08	(2.00–2.68)	21.3	(2.84)	23.9	(5.06)
Predorsal	27.4 ± 1.53	(1.29–1.82)	27.3 ± 1.41	(1.53–2.14)	27.5 ± 1.12	(2.17–3.00)	27.9 ± 1.25	(2.46–3.60)	27.5	(3.68)	27.0	(5.70)
Dorsal insertion					29.3 ± 6.19	(2.17–4.90)	39.4 ± 10.7	(2.46–6.00)	46.3	(6.18)	48.5	(10.2)
D2 origin					29.7 ± 7.37	(2.17–5.30)	41.9 ± 12.9	(2.46–6.42)	49.9	(6.66)	49.7	(10.5)
D2 insertion					37.8 ± 14.7	(2.17–5.30)	57.0 ± 19.8	(2.46–6.42)	68.6	(6.66)	68.3	(10.5)
Preanal	48.3 ± 1.00	(2.24–2.83)	49.8 ± 1.02	(3.00–3.78)	51.2 ± 0.78	(4.13–5.26)	50.6 ± 0.77	(5.18–6.34)	47.8	(6.38)	47.3	(10.0)
Postanal	51.7 ± 1.01	(2.36–3.12)	50.2 ± 1.02	(3.08–3.96)	49.0 ± 0.95	(3.98–5.07)	49.4 ± 0.77	(4.86–6.46)	52.2	(6.98)	52.7	(11.1)
Standard	96.0 ± 1.50	(4.45–5.70)	95.7 ± 0.73	(5.86–7.37)	91.3 ± 2.33	(7.59–8.94)	86.9 ± 3.47	(8.82–11.1)	85.2	(11.4)	83.8	(17.7)
Yolk Sac	16.6 ± 7.37	(0.20–1.20)										
Fin Length (% of TL)												
Pectoral	8.72 ± 1.86	(0.28–0.72)	11.3 ± 1.50	(0.50–0.94)	13.4 ± 2.80	(0.80–1.86)	16.1 ± 2.40	(1.22–2.34)	16.7	(2.23)	18.9	(4.00)
Pelvic			1.88	(0.14–0.14)	4.42 ± 2.67	(0.10–1.29)	9.59 ± 4.59	(0.26–1.94)	13.0	(1.74)	15.5	(3.28)
Spinous Dorsal					17.9 ± 1.56	(1.52–1.90)	19.5 ± 1.01	(2.06–2.42)	18.7	(2.50)	21.5	(4.54)
Soft dorsal					20.1 ± 1.51	(1.72–2.20)	19.7 ± 1.30	(1.91–2.70)	18.7	(2.50)	18.6	(3.94)
Caudal	3.98 ± 1.50	(0.04–0.43)	4.29 ± 0.73	(0.21–0.39)	8.66 ± 2.33	(0.39–1.34)	13.1 ± 3.47	(0.86–2.49)	14.8	(1.98)	16.2	(3.43)
Body Depth (% of TL)												
Head at Eyes	14.7 ± 1.21	(0.66–0.97)	14.1 ± 0.86	(0.79–1.08)	14.7 ± 0.48	(1.18–1.46)	14.7 ± 0.55	(1.33–1.93)	15.1	(2.02)	14.0	(2.95)
Head at P1	14.2 ± 2.04	(0.56–0.98)	13.9 ± 0.96	(0.76–1.10)	14.7 ± 0.40	(1.17–1.52)	16.5 ± 3.11	(1.40–3.60)	17.2	(2.30)	17.9	(3.78)
Preanal	7.92 ± 0.72	(0.34–0.54)	9.85 ± 0.82	(0.52–0.81)	12.4 ± 0.61	(0.90–1.34)	13.3 ± 0.66	(1.20–1.81)	14.1	(1.89)	14.7	(3.10)
Mid-Postanal	5.80 ± 0.62	(0.24–0.41)	7.00 ± 0.76	(0.36–0.62)	8.46 ± 0.52	(0.65–0.88)	8.68 ± 0.40	(0.80–1.16)	9.36	(1.25)	9.28	(1.96)
Caudal Peduncle	2.77 ± 0.30	(0.12–0.20)	3.51 ± 0.72	(0.15–0.34)	6.47 ± 0.63	(0.40–0.72)	7.10 ± 0.43	(0.64–0.92)	7.49	(1.00)	8.14	(1.72)
Yolk sac	7.60 ± 2.32	(0.24–0.54)										
Body Width (% of HL)												
Head	71.7 ± 6.12	(0.60–0.84)	72.5 ± 5.59	(0.80–1.10)	66.6 ± 5.47	(0.94–1.34)	63.3 ± 3.22	(1.22–1.71)	53.5	(1.52)	48.6	(2.46)
Myomere Number												
Predorsal	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)	4.00	(4.00)		
Soft dorsal	17.0	(17.0–17.0)	17.0 ± 0.00	(17.0–17.0)	17.0 ± 0.00	(17.0–17.0)	17.0 ± 0.00	(17.0–17.0)	17.0	(17.0)		
Preanal	16.0 ± 0.21	(15.0–16.0)	16.1 ± 0.25	(16.0–17.0)	16.1 ± 0.45	(16.0–18.0)	16.1 ± 0.34	(16.0–17.0)	16.0	(16.0)		
Postanal	22.1 ± 0.29	(22.0–23.0)	22.0 ± 0.00	(22.0–22.0)	22.0 ± 0.00	(22.0–22.0)	22.0 ± 0.00	(22.0–22.0)	22.0	(22.0)		
Total	38.0 ± 0.21	(38.0–39.0)	38.1 ± 0.25	(38.0–39.0)	38.1 ± 0.45	(38.0–40.0)	38.1 ± 0.34	(38.0–39.0)	38.0	(38.0)		

[a] Proportion expressed as % HL.

Note: Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

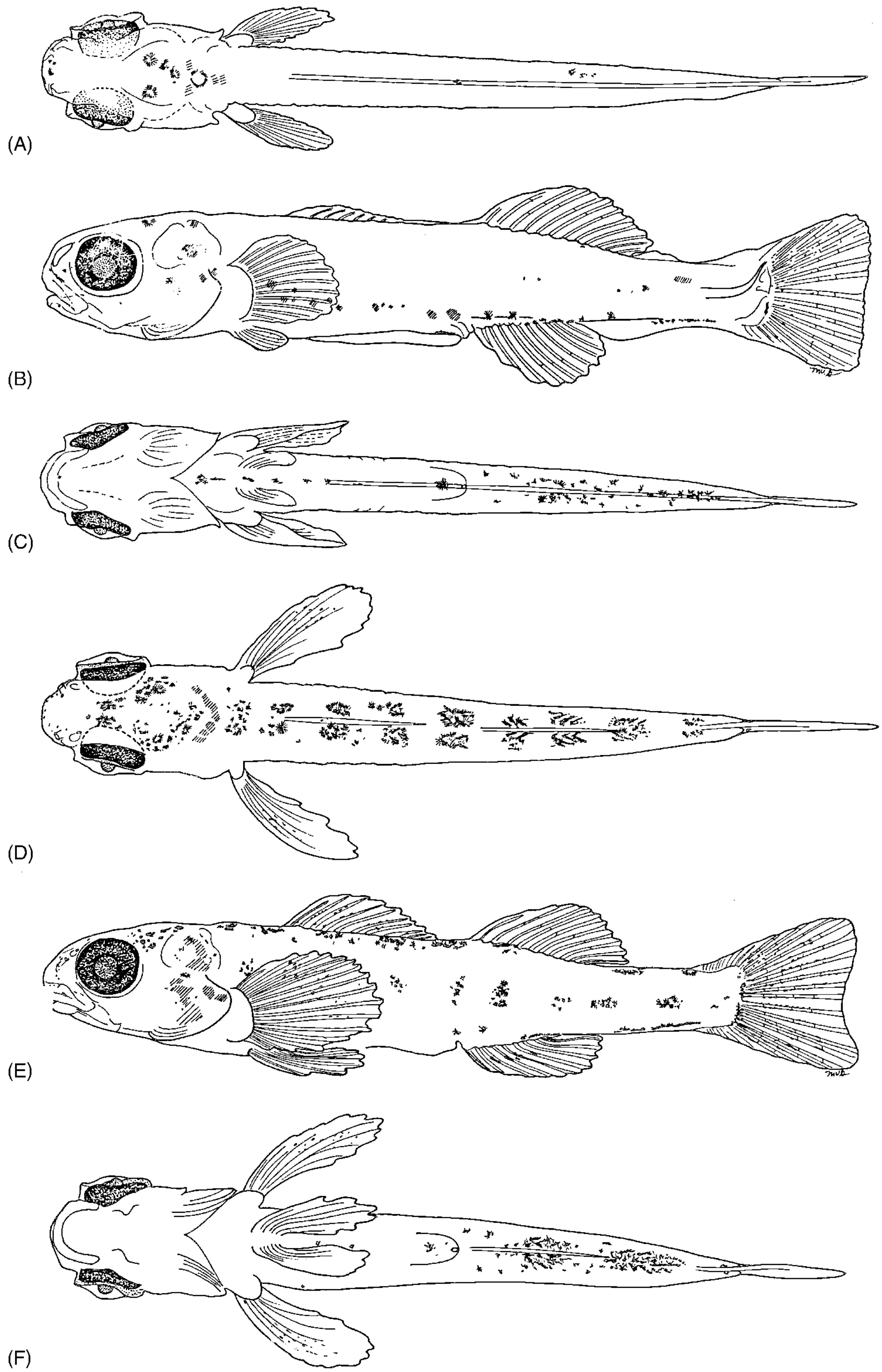

Figure 20 *Etheostoma atripinne*, Cumberland snubnose darter, Dry Creek, Dekalb County, TN. Post yolk-sac larva, 9.6 mm TL: (A) dorsal, (B) lateral, (C) ventral views. Early juvenile, 13.1 mm TL: (D) dorsal, (E) lateral, (F) ventral views. (From reference 6, with author's permission.)

5.9–6.1 mm TL. Operculum and gill arches function and premaxilla and mandible form.[6]

7.0–8.1 mm TL. Neuromast development occurs mid-laterally from the anterior trunk posteriad. No swim bladder forms; gut straight, without striations, portion of gut posterior stomach normal in length, between 7.4 and 10.0 mm.[6]

Morphometry
See Table 24.[6]

Fin Development
6.4–7.2 mm TL. First rays form in caudal fin; soft dorsal fin rays and branchiostegal rays form between 6.6 and 7.2 mm.[6]

7.4 mm TL. Pelvic fin buds form anterior to dorsal fin origin after complete yolk absorption.[6]

7.7–8.4 mm TL. Notochord flexion preceding caudal fin ray development by 7.7 mm and anal fin ray form between 7.7 and 8.4 mm.[6]

8.4 mm TL. Pectoral fin rays form.[6]

8.4–9.6 mm TL. Dorsal and anal finfold partially differentiate between 8.4 and 8.5 mm; spinous dorsal forms between 8.4 and 9.0 mm; first pelvic fin rays form between 8.5 and 9.6 mm; complete adult fin ray counts in median fins 8.6–9.0 mm. Spinous dorsal fin origin situated over preanal myomere 4, soft dorsal origin over preanal myomere 17.[6]

9.0–10.8 mm TL. Both finfolds completely differentiate.[6]

Pigmentation
6.0–6.7 mm TL. Dorsal pigmentation consists of expanded melanophores over the optic lobe. Lateral pigmentation present dorsally over the stomach and gut. Ventral pigmentation consists of single mid-ventral melanophores from the breast to the anus; and staggered, paired melanophores from the anus to the caudal peduncle.[6]

6.8–8.8 mm TL. It Dorsum of cranium with several large melanophore clusters on cerebellum; laterally, a single series of subdermal melanophores from gut to anus, no other melanophores laterally along the midline. Ventral pigmentation includes a series of melanophores mid-ventrally from the breast to the anus; two clusters of mid-ventral postanal melanophores beginning at postanal myomere 4 forming paired, stellate melanophores at each mid-ventral postanal myosepta.[6]

8.9–10.7 mm TL. Several melanophores on cranium and from soft dorsal fin originate to midfin. Lateral melanophores are present over the otic capsule and operculum and laterally, over the gut, extending posteriorly from midanal fin to the caudal peduncle. Ventral pigmentation consists of a single series of melanophores from the breast to the anus, becoming scattered from the anal fin to the caudal pedule.[6]

JUVENILES

See Figures 20 and 21

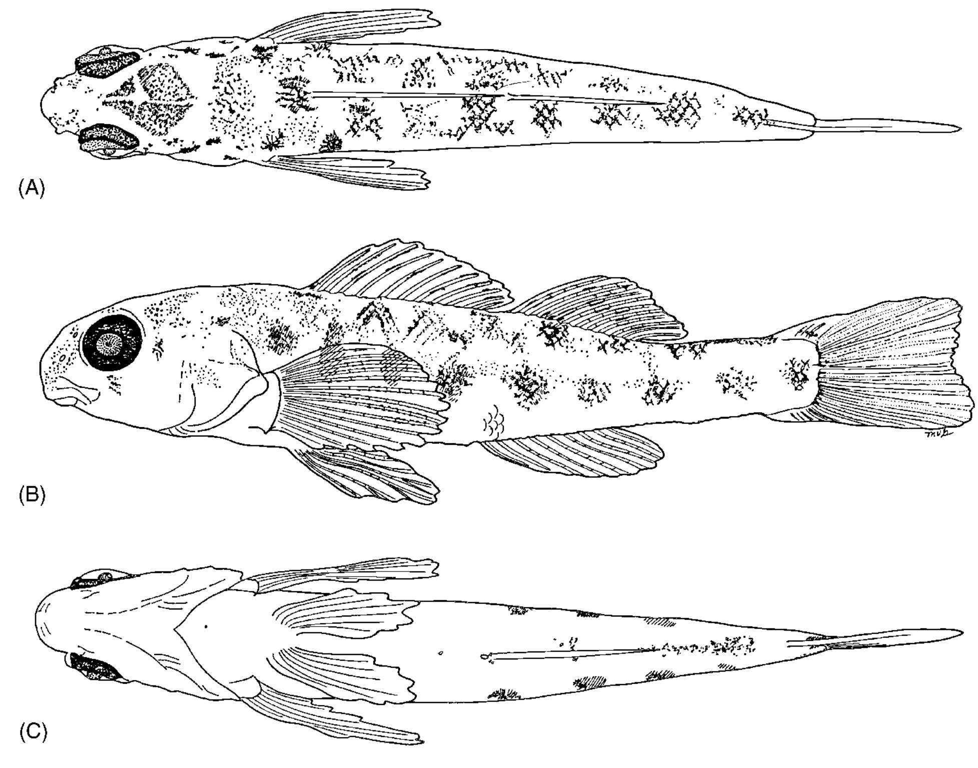

Figure 21 *Etheostoma atripinne*, Cumberland snubnose darter, Dry Creek, Dekalb County, TN. Juvenile, 21.1 mm TL: (A) dorsal (B) lateral, (C) ventral views. (From reference 6, with permission.)

Size Range
9.8[6] to 40 mm TL.*

Fin Development
12.7–14.8 mm TL. Complete adult fin ray counts in median fins; caudal fin rays with segmentation, truncate to slightly emarginate.[6]

14.8 mm TL. Average predorsal length 25.7% SL (range= 23.8–26.5% SL), and 28.7% TL (range= 26.6–30.7% TL). First pelvic fin ray forms by 14.8 mm. Dorsal and anal finfolds completely differentiated.[6]

Morphology
Total vertebrae count 38–39 (N = 3, mean = 38.3), including one urostylar element. Scales in the lateral series from Dry Creek range from 47 to 61, which is the range for the entire species distribution.[2,3,6] Fin ray meristics and length at appearance are included in Table 25.[6]

10.3–12.0 mm TL. Average predorsal length 29.7% SL (range= 27.2–30.4% TL), and 27.5% TL (range= 25.2–28.1% TL). Upper jaw equal with lower jaw, becoming subterminal between 10.3 and 12.0 mm. Infraorbital and supraorbital canals form by 11.7 mm.[6]

12.0–12.3 mm TL. Initiation of squamation.[6]

12.6–13.0 mm TL. Lateral, subtemporal and preoperculomandibular head canals form (12.6 mm); caudal fin slightly emarginate (13.0 mm).[6]

14.0 mm TL. Infraorbital, lateral, and supratemporal head canals complete, preoperculomandibular canal complete with 8–10 pores, infraorbital pores 7 to 9.[3,5,6]

18.0 mm TL. Lateral line began forming.[6]

Table 25

Meristic counts and size (mm TL) at the apparent onset of development for *E. atripinne*.

Attribute/event	*Etheostoma atripinne*	Literature
Branchiostegal Rays	5,5	5,5[2–4]
Dorsal Fin Spines/Rays	X–XII/10–13	IX–XIII/9–12[1–3]
First spines formed	8.4–9.0	
Adult complement formed	9.3–9.8	
First soft rays formed	6.7–7.2	
Adult complement formed	8.5–9.0	
Pectoral Fin Rays	15	14[2–4]
First rays formed	8.4	
Adult complement formed	8.4	
Pelvic Fin Spines/Rays	I/5	I/5[2–4]
First rays formed	8.5–9.6	
Adult complement formed	8.5–9.6	
Anal Fin Spines/Rays	II/7–9	II/6–8[2–4]
First rays formed	7.7–8.4	
Adult complement formed	8.4–9.0	
Caudal Fin Rays	vii–xi, 8 + 7, viii–xi	
First rays formed	6.4–7.2	
Adult complement formed	8.4–9.0	
Lateral Line Scales	47–61	50–60[1–3]
Myomeres/Vertebrae	38–40/38–39	Unknown/38–40[2–4, 12]
Preanal myomeres	15–18	
Postanal myomeres	22–23	

21.1–25.0 mm TL. Squamation complete; cheek scales, usually embedded; cheek, opercle, and nape are completely scaled; breast naked; belly variable either fully scaled or naked anteriorly.[2,3,6]

Morphometry
See Table 24.[6]

Pigmentation
11.0–13.4 mm TL. Outline of cerebellum and optic lobe covered with melanophores; 9 to 10 dorsal saddles becoming apparent, on nape, anterior spinous dorsal fin origin, mid-spinous dorsal fin, anterior spinous dorsal fin insertion, between the dorsal fin gap, immediately posterior soft dorsal fin origin, midsoft dorsal fin, soft dorsal fin insertion, and over the caudal peduncle. Lateral pigmentation includes the beginning of the preorbital bar formation; pigment in the hypaxial portion of the operculum; and beginning of nine, elliptical mid-lateral clusters of melanophores. Ventral pigmentation forming a series of melanophores between the pelvic fins, extending to anus; two clusters of postanal pigmentation at mid-anal fin and at the mid-caudal peduncle. Scattered melanophores outline the caudal fin rays; a single stripe on the spinous dorsal and anal fins; and a few melanophores in the epaxial portion of the pectoral fin.[6]

21.1 mm TL. Preorbital bar, cerebellum, and optic lobe pigmentation dense; nine dorsal saddles from the nape to the caudal peduncle. Nine lateral rectangular to oval blotches from the shoulder to the caudal fin base; with a zig-zag connection of pigmentation anteriorly connecting the lateral blotches to the dorsal saddles. Ventral pigmentation iludes a series of melanophores from the anal fin insertion to the caudal fin base. Spinous dorsal fin with a distal and midfin stripe; soft dorsal fin with a midfin stripe; pectoral fin with several scattered melanophores in the epaxial half of the fin; and caudal fin with melanophores outlining the caudal fin base. No pigmentation present in the pelvic or anal fins.[6]

TAXONOMIC DIAGNOSIS OF YOUNG CUMBERLAND SNUBNOSE DARTER

Similar species: members of subgenus *Ulocentra.*[6] The single population of *E. atripinne* studied exhibits significant interspecific variation with *E. simoterum* in myomere counts, ontogenetic events, and body proportions. *Etheostoma atripinne* is the diminutive of *E. simoterum*, attaining equivalent levels of development at smaller length intervals.[6]

Adult. The *E. simoterum* complex may consist of the nominal form as well as *E. atripinne,* as a subspecies from the Cumberland River drainage. Burr and Warren [7] suggested that Etnier[8] combined the two forms with recommendation of subspecies recognition. Etnier[8] recommended further study of the taxonomy of these two forms. Bailey and Etnier[9] indicated *E. s. atripinne* was a part of the *simoterum* group. For the current study, each is recognized as a distinct species for the purposes of description and phylogenetic analysis.

Etheostoma atripinne can be differentiated from *E. simoterum* based on 47–61 lateral line scales and nine dorsal saddles. *Etheostoma atripinne* has modes of 50–58 lateral line scales and 18–24 scales around the caudal peduncle. *Etheostoma atripinne* occurs throughout the middle Cumberland River from downstream of Big South Fork, KY and TN, and from the Duck River and nearby tributaries from west-central TN. In a study of *E. etnieri,* Bouchard[10] indicated that the Duck River population of *E. atripinne* was intermediate between *E. atripinne* of the Cumberland drainage and *E. simoterum* of the middle and upper Tennessee River system. This has led to speculation that the two forms are conspecifics.

Larva. *Etheostoma atripinne* is virtually identical to species *E. simoterum* in pigmentation and myomere counts. Both species have overlapping, low preanal (15 to 17) myomere counts, while *E. atripinne* has a slightly lower average for postanal (22.0, mode 22) myomeres. The species differ in eye shape, with *E. atripinne* having oval eyes and *E. simoterum* possessing spherical eyes. The species differ in virtually every ontogenetic event, with *E. atripinne* being the diminutive of *E. simoterum.*[6]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (see Figure 22)
Eggs. Egg sites include the vertical sides and horizontal tops of rocks in riffle and flowing pool habitats, in slight to moderate current.[6]

Yolk-sac larvae. Aquarium observations indicate that Cumberland snubnose darter larvae were epi-benthic immediately after hatching, becoming demersal only at lengths >13 mm, at which they remain benthic and in close association with the substrate.[6]

Post yolk-sac larvae. Cumberland snubnose darter larvae from Dry Creek are collected in water from

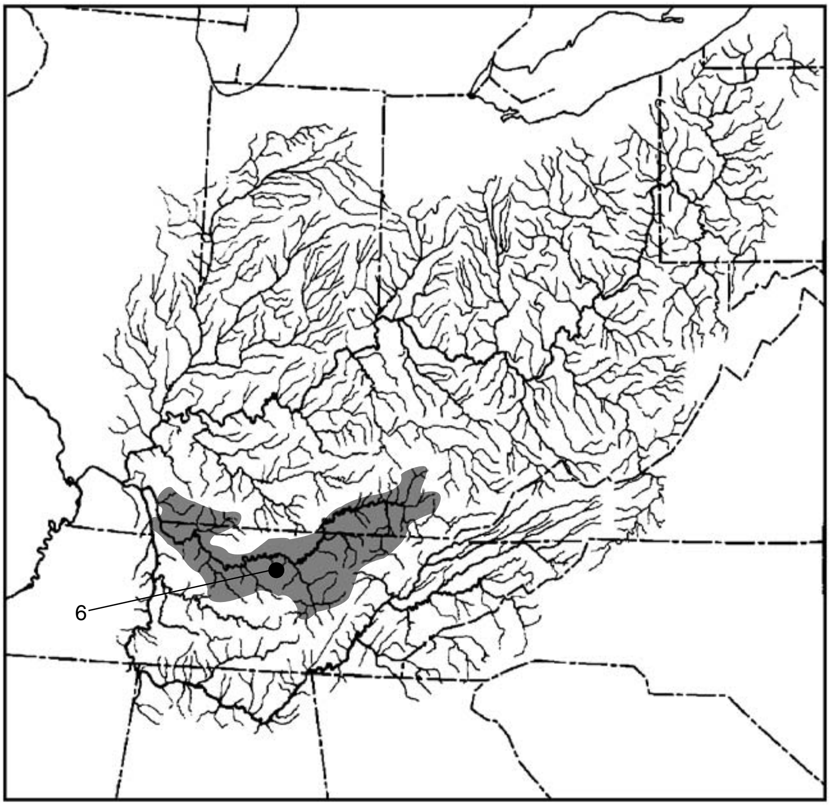

Figure 22 Distribution of Cumberland snubnose darter, *E. atripinne* in the Ohio River system (shaded area) and areas where early life history information has been collected (circle). Number indicates appropriate reference.

0.3 to 0.5 m depth during low flow, near banks, eddy areas over sand and gravel habitats and behind tree roots. These and other structures act as obstructions in flowing habitat from early May and in slack water habitat 0.25–0.3 m in depth during mid-May until late June (R. Wallus, personal communication). All length intervals <13 mm are collected in epibenthic dipnet samples from the nearshore habitats usually associated with tree roots or rubble.[6]

Juveniles. Larvae and early juveniles utilize the downstream slackwater pools and backwater areas adjacent to spawning riffles and pools as nursery habitats. Juveniles >21 mm TL are the smallest individuals found on the margins of the riffle and flowing pool habitat in Dry Creek.[6]

Early Growth (see Table 26)
Page and Mayden[5] and Etnier and Starnes[4] reported Cumberland snubnose darter surviving only a single year (18 months), with age 1 fish averaging 44–49 mm at first reproduction. The truncation of larval and juvenile stages of development is necessary in order to increase the fitness of an annual spawning species.

Feeding Habits
The diet of Cumberland snubnose darters includes a large percentage of mayfly nymphs, blackfly, and midge larvae, and lesser numbers of caddisfly, stonefly, and beetle larvae. Juveniles feed on microcrustaceans and dipteran larvae.*

Table 26

Average calculated length (mm TL) of young Cumberland snubnose darters in Kentucky.

State	Age 1	2	3
Kentucky*	37–42	40–52	52+

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* Original fecundity and life history information from TN: Dekalb Co.: Dry Creek, tributary to North Prong Barren Fork River, Collins River drainage, 1.5 miles upstream from Dowelltown, at US Hwy 70 bridge, LRRC 824 (8); LRRC 825 (13); TV 3077 (13); TV uncatalogued (141). Fecundity information curated at Northeast Louisiana University Museum of Zoology, Monroe, LA.

EMERALD DARTER

Etheostoma (*Ulocentra*) *baileyi* Page and Burr

Etheostoma: various mouths; *baileyi*: named in honor of Reeve M. Bailey, Curator Emeritus of Fishes, University of Michigan ichthyologist who studied darters and published numerous papers on the systematics and taxonomy of percids.

RANGE

Etheostoma baileyi inhabits the upper Cumberland and upper Kentucky River systems.[1–3] Below Cumberland Falls, the species is restricted to the Rockcastle River and Big South Fork. Above Cumberland Falls, *E. baileyi* occurs in Jellico Creek, Clear Fork, and the Cumberland River.[2]

HABITAT AND MOVEMENT

The emerald darter inhabits moderate-gradient, clear, small streams to medium-sized rivers. Adults prefer pools over rock rubble and over unsilted gravel substrates in riffles and runs with moderate current.[3–6] During the winter months, adults move to deeper, calmer waters.[2,6]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma baileyi is closely associated with the Cumberland Plateau. This is one of the few darters to occur above Cumberland Falls and is found below them in the Laurel and Rockcastle Rivers as well as in a few tributaries of the Big South Fork, TN. It occurs in the upper Kentucky River basin as far downstream as Red River. Endemic species restricted to the upper Cumberland and Kentucky Rivers.[5]

SPAWNING

Location
Spawning occurs on the vertical sides and horizontal tops of almost any inclined surface in riffle and run habitats, in slight to moderate current.[6] In aquarium observations, a single male displays lateral and erect spinous dorsal fins to potential female mates. Clayton[6] suggested that spawning behavior was probably similar to other *Ulocentra*.

Season
Ripe males and females were collected in mid- to late March in moderate current along run and riffle margins.[6,7] Spawning occurs from early April to early June in central KY,[6] and from late March to early June over the species range in TN and KY.[2,8] May is considered the period of peak reproduction.[3]

Temperature
In Middle Fork Red River, Powell Co., KY, spawning activity initiated when temperatures reached 15–19°C and ceased when temperatures were over 25°C [6] or about 18–20°C.[2]

Fecundity
Gravid females had 110–240 ova with an average of 35 mature eggs.[2,6]

Sexual Maturity
Adults live to reach age 3,[2,6] however, maturity is suspected to be at age 1.[6] An adult male (54.7 mm TL) from KY had testes that were 1.24% of the body weight on April 24.* Male tuberculation was absent and females have a long tubular genital papilla.*[,6] Males exhibited sexually dimorphic traits during the reproductive season with an increase in brightly colored pigmentation and extension of the genital papillae from the cloacal pad, while females had distended abdomens and a long tubular genital papilla.*[,6]

Spawning Act
The reproductive mode of *E. baileyi* is an attacher.[6] In aquarium observations, the male follows an interested female to the egg site, usually a small protective nook or crack, and with the male mounted on the back of the female and their vents juxtaposed, the female presses against the vertical sides of the substrate and the male fertilizes the egg.[6,7] Adults maintain a head-to-head orientation with vents juxtaposed and pressed against the vertical surface. Eggs are laid individually on the vertical surface of the rock. The pair is observed to switch positions on the rock, depositing eggs on different sections of the same and different rocks. Each adult was promiscuous, spawning with multiple partners on

different rocks as noted by Page and Mayden[12] in their observations of *E. atripinne*. No cleaning of the rock surface or parental care was provided before or after the eggs were laid.

EGGS

Description
Eggs from Middle Fork Red River, Clay Co., KY, are spherical (mean = 1.6 mm diameter; range = 1.5–1.8 mm); translucent; demersal; and adhesive. Eggs possess translucent, pale yellow yolk (mean = 1.5 mm diameter; range = 1.4–1.6 mm); a single oil globule (mean = 0.5 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[6,7]

Incubation
Hatching occurs after 360–384 h at 16–18°C; 297.6–312 h at 17.5–19.5°C; and 173–192 h at an incubation temperature of 20–22°C.[6,7]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 23

Size Range
Populations from Middle Fork Red River, Clay Co., KY hatch between 4.5–4.8 mm and KY, yolk is absorbed by 6.4 mm TL.[6,7]

Myomeres
Preanal 15 (N = 22), postanal 22 (N = 22), with total 37.[7]

Morphology
4.5–4.8 mm TL. Newly hatched: body terete; snout blunt; with functional jaws, upper jaw even, to slightly extending past lower jaw; well-developed pectoral fins without incipient rays; yolk sac moderate (27.4% TL), oval to tapered posteriorly; yolk translucent pale yellow, with a single oil globule; single serpentine vitelline vein mid-ventrally on yolk sac; head not deflected over the yolk sac; eyes oval.[7]

5.0–5.3 mm TL. Digestive system functions before complete yolk absorption.[7]

6.2–6.4 mm TL. Digestive system function; yolk mostly absorbed; operculum and gill arches function; premaxilla and mandible form.[7]

Morphometry
See Table 27.[7]

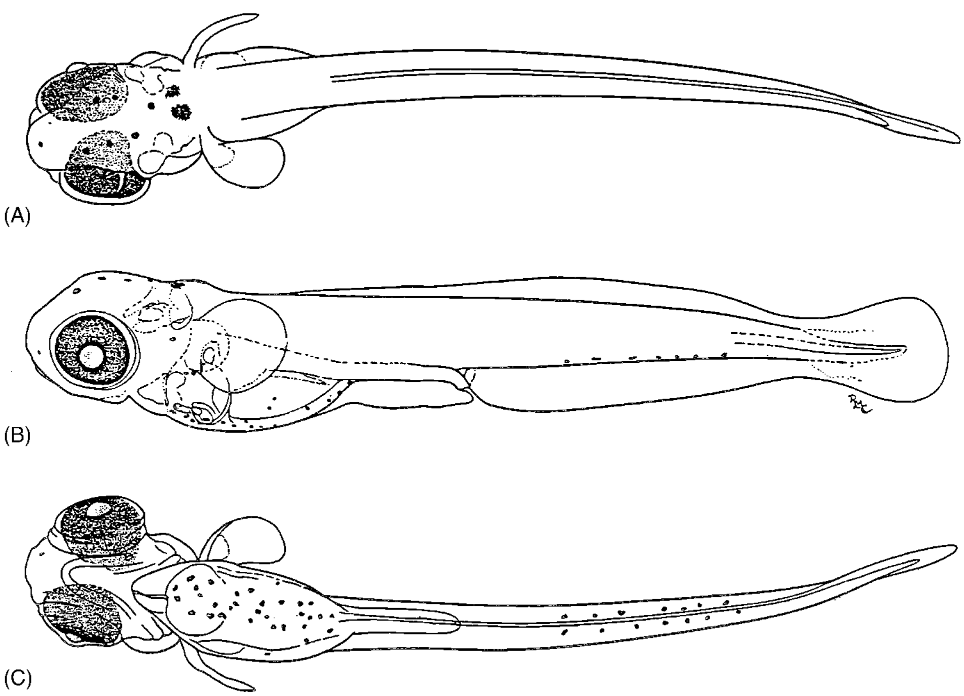
(A)
(B)
(C)

Figure 23 *Etheostoma baileyi*, emerald darter, Middle Fork Red River, Powell County, KY. Yolk-sac larva, 4.7 mm TL: (A) dorsal, (B) lateral, (C) ventral views. (A–C from reference 7, with author's permission.)

Table 27

Morphometry of *E. baileyi* larvae (*N* = sample size).[7]

Characters	Total Length (TL) 4.5–6.23 mm Mean	(*N* = 22) Range
Length (% of TL)		
Upper jaw[a]	12.9	(0.15)
Snout[a]	7.76	(0.09)
Eye diameter[a]	49.1	(0.57)
Head	18.6	(1.16)
Predorsal	25.0	(1.56)
Dorsal insertion	25.0	(1.56)
D2 origin	25.0	(1.56)
D2 insertion	25.0	(1.56)
Preanal	50.6	(3.15)
Postanal	49.4	(3.08)
Standard	95.8	(5.97)
Yolk sac	27.4	(1.71)
Fin Length (% of TL)		
Pectoral	10.3	(0.64)
Pelvic		
Spinous dorsal		
Soft dorsal		
Caudal	4.17	(0.26)
Body Depth (% of TL)		
Head at eyes	12.0	(0.75)
Head at P1	16.7	(1.04)
Preanal	8.83	(0.55)
Mid-postanal	7.38	(0.46)
Caudal peduncle	2.89	(0.18)
Yolk sac	10.6	(0.66)
Body Width (% of HL)		
Head	60.3	(0.70)
Myomere Number		
Predorsal	4.00	(4.00)
Soft dorsal		
Preanal	16.0	(16.0)
Postanal	23.0	(23.0)
Total	39.0	(39.0)

[a] Proportion expressed as percent head length.

Note: Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation.

Fin Development
See Table 28.[7]

6.2–6.4 mm TL. Well-developed pectoral fins with rays evident.[7]

Pigmentation
4.5–4.8 mm TL. Newly hatched: eye pigmented; melanophores absent dorsally over posterior cerebellum or nape; melanophores distributed laterally absent; ventral pigmentation consists of mid-ventral paired series of punctate melanophores forming a band near the vitelline vein on the yolk sac and punctate melanophores along every mid-ventral postanal myosepta.[7]

6.2–6.4 mm TL. Similar to previous length interval with the exception of melanophores on yolk sac becoming more concentrated.[7]

POST YOLK-SAC LARVAE

Size Range
No specimens are available between 6.4 mm[6,7] and <13.9 mm

Myomeres
No information.

Morphology
No information.

Morphometry
No information.

Fin Development
No information.

Pigmentation
No information.

JUVENILE

Size Range
13.9[7] to 36 mm TL.*

Fin Development
13.9 mm TL. Complete adult fin ray counts in median fins; caudal fin rays with segmentation,

Table 28

Meristic counts and size (mm TL) at the apparent onset of development for *E. baileyi*.[6,7]

Attribute/event	*E. baileyi*	Literature
Branchiostegal Rays	5,5	5,5[1–3,8,11]
Dorsal fin spines/rays	X–XII/10–13	IX–XIII/10–13[1,2,3,8,11]
First spines formed	>6.4	>6.4[6,7]
Adult complement formed	13.9	13.9[6,7]
First soft rays formed	>6.4	>6.4[6,7]
Adult complement formed	13.9	13.9[6,7]
Pectoral Fin Rays	15	13–16[1,2,3,8]
First rays formed	>6.4	>6.4[6,7]
Adult complement formed	13.9	13.9[6,7]
Pelvic Fin Spines/Rays	I/5	I/5[1,2,3,8]
First rays formed	13.9	>6.4[6,7]
Adult complement formed	13.9	13.9[6,7]
Anal Fin Spines/Rays	II/7–8	II/6–8[1,2,3,8,11]
First rays formed	>6.4	>6.4[6,7]
Adult complement formed	13.9	13.9[6,7]
Caudal Fin Rays	vii, 8 + 7, vi	11–18[1,8]
First rays formed	>6.4	>6.4[6,7]
Adult complement formed	13.9	13.9[6,7]
Lateral Line Scales	45–56	43–56[1,2,3,8,11]
Myomeres/Vertebrae	37/38–41	37/38–41[1,2,3,8,11]
Preanal myomeres	15	15[6,7]
Postanal myomeres	22	22[6,7]

slightly emarginate.[7] Pelvic fin rays form.[7] Spinous dorsal fin origin situated over preanal myomere 4, soft dorsal origin over preanal myomere 16.

19.6 mm TL. Average predorsal length 26.1% SL and 25.0% TL.[7]

Larger juveniles. Spinous dorsal XI (IX–XIII), soft dorsal 11 (10–13); pectoral rays 13–16; anal rays II 6–8; pelvic rays I 5; caudal rays 13–18.[2,3,7]

Morphology

Total vertebrae count ranged between 38 (7), 39 (39), 40 (13), and 41 (4) (N = 63, mean = 39.2).[2,3,7] Scales in the lateral series 45–56 (usually 46–53).[2,3,7] Fin ray meristics and length at appearance are included in Table 28.[7]

13.9 mm TL. Average predorsal length 29.7% SL (range= 27.2–30.4% TL), and 27.5% TL (range= 25.2–28.1% TL). Upper jaw equal with lower jaw, subterminal. Caudal fin slighltly emarginate.[7]

19.6 mm TL. Lateral line complete; infraorbital, supraorbital, lateral, subtemporal, and preoperculo-mandibular head canals not formed.[7] Branchiostegal rays 5.[7]

25.1 mm TL. Infraorbital, lateral, and supratemporal head canals not interrupted, preoperculomandibular canal complete with 8–10 pores, infraorbital pores 7–9.[7]

25.1–36.0 mm TL. Squamation complete; cheek and opercle are completely scaled, posterior part of nape is scaled but may be embedded or absent near head. Prepectoral area scaled but breast naked.[2,3,7]

Morphometry
No information.

Pigmentation
13.9 mm TL. Cranial pigmentation with diffuse preorbital and suborbital bars formed; 8–9 dorsal saddles forming at nape, just posterior spinous dorsal origin, mid-spinous dorsal fin, between gap of dorsal fins, immediately posterior soft dorsal origin, midsoft dorsal fin, soft dorsal fin insertion, and at caudal peduncle base; 9–10 lateral blotches along mid-lateral from pectoral fin origin to caudal peduncle base; dorsum and mid-lateral blotches consist of scattered melanophores; ventral pigmentation distributed over anal fin and at each mid-ventral myosepta.[7]

19.6–25.1 mm TL. Preorbital bar extends onto upper lip; postorbital bar reduced to a black spot behind eye and on upper opercle.[7]

TAXONOMIC DIAGNOSIS OF YOUNG EMERALD DARTER

Similar species: members of subgenus *Ulocentra*.[7] The single population of *E. baileyi* studied exhibits significant interspecific variation with *E. simoterum* and *E. atripinne* in myomere counts, ontogenetic events, and body proportions. *Etheostoma atripinne* is the diminutive of *E. simoterum,* attaining equivalent levels of development at smaller length intervals.[6]

Adult. *Etheostoma baileyi* is endemic to the Cumberland Plateau. Bailey and Etnier [9] indicated that *Etheostoma baileyi* was a part of the *Ulocentra* group, which was validated by Simon[7] through phylogenetic analysis. *Etheostoma baileyi* can be differentiated from *E. simoterum* based on coloration. *Etheostoma baileyi* is primarily green while *E. simoterum* and *E. atrippine* are orange or reddish. *Etheostoma atripinne* has modes of 50–60 lateral line scales compared to 46–53 for *E. baileyi.*

Larva. No intraspecific variation of *E. baileyi* could be studied due to the limited availability of material from the Middle Fork Red River, KY. The species differs from the *E. simoterum* species group in myomere count modes and pigmentation. All other members of the *E. simoterum* species group have dorsal pigmentation on the cranium; higher preanal (mode, 16) myomere counts than *E. baileyi*, while the mode for postanal myomeres overlaps with other taxa (22). The shape and absorption of the

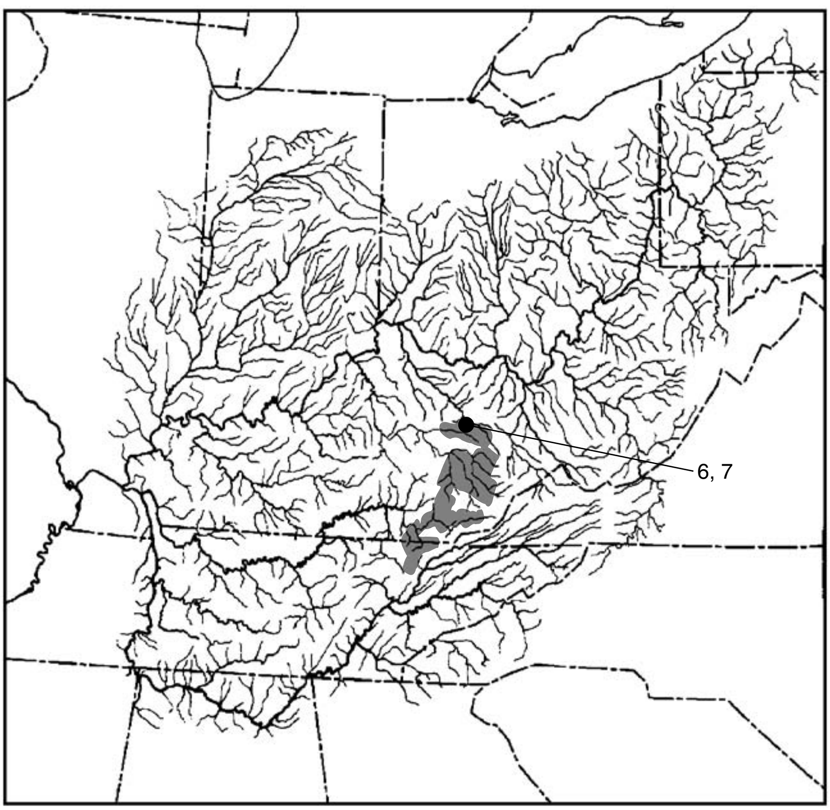

Figure 24 Distribution of emerald darter, *E. baileyi* in the Ohio River system (shaded area) and areas where early life history information has been collected (circle). Number indicates appropriate reference.

yolk sac is similar to other *Ulocentra*. Pigmentation is consistent with other *Ulocentra* exhibiting typical ventral pigmentation.[7]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 24)
Eggs. Egg sites include the vertical sides and horizontal tops of almost any inclined surfacein riffle and run habitats, in slight to moderate current.[6,7]

Yolk-sac larvae. Aquarium observations indicate emerald darter yolk-sac larvae are epibenthic immediately after hatching, capable of rising 100 mm into the water column.[7]

Post yolk-sac larvae. Aquarium observations indicate emerald darter larvae are epibenthic immediately after hatching, capable of rising 100 mm into the water column.[6]

Juveniles. Emerald darters become demersal only at lengths >13.9 mm, at which time they remain in close association with the substrate. Juvenile emerald darters are collected from run habitats and flowing pools, usually over gravel substrates, during mid-June.[6]

Early Growth
Clayton[6] and Etnier and Starnes[2] reported emerald darters surviving 3 years, with age 1 fish averaging 38 mm at first reproduction (see Table 29).

Feeding Habits
Clayton reported juveniles having a large niche breadth. The diet of emerald darters included a large percentage of mayfly nymphs, blackfly, and midge larvae, and lesser numbers of caddisfly, stonefly, and beetle larvae. Juveniles fed on microcrustaceans and dipteran larvae.[6,7] Midge larvae and pupae were dominant food items, with some use of caddisfly and mayfly immatures.[2]

Table 29

Average calculated length (mm TL) of young emerald darters in Kentucky.

State	Age 1	Age 2	Age 3
Kentucky[2]	38	45	53

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5. Burr, B.M. and M.L. Warren, Jr. 1986.
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8. Page, L.M. and B.M. Burr. 1982.
9. Bailey, R.M. and D.A. Etnier. 1988.
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11. Bailey, R.M. and W.A. Gosline. 1955.
12. Page, L.M. and R.L. Mayden. 1981.

* Simon, T.P., unpublished data.

TEARDROP DARTER

Etheostoma (*Catonotus*) *barbouri* Kuehne and Small

Etheostoma: various mouths; *barbouri*: named for Roger W. Barbour, vertebrate zoologist and wildlife photographer at the University of Kentucky.

RANGE

Etheostoma barbouri is confined to the Barren River system and the upper portion of the Green River system, KY and TN.[1–4]

HABITAT AND MOVEMENT

The preferred habitat of the teardrop darter is sandy pool areas in small-to medium-sized streams with abundant small flat stones. It is locally common near the margins of streams where slab rocks along the edges of pools or margins of run habitat occur. Depths in these areas are $<$0.5 m with slow-moderate currents.[4–6,*]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma barbouri is endemic to the Green River and Barren River, KY and TN.[1–6]

SPAWNING

Location
Underside of slabrocks along the margins of pools.[7]

Season
Spawning occurs in late May[7]; April through May.[3]

Temperature
Unknown.

Fecundity
Unknown. Two nests contained monolayers of 42 and 70 eggs attached to the underside of a slabrock. It was presumed that the eggs on the under side of the rock were contributed by several females.[7] Flynn and Hoyt[8] reported annual egg production of 17–48 eggs per female.

Sexual Maturity
Males were sexually mature at age 1 but did not spawn until age 2, while both age 1 and 2 females spawned.*

Spawning Act
The reproductive mode of the teardrop darter is a clusterer.[2] Adults deposit their eggs on the underside of slabrocks, where they are guarded by a male.[1–3,5–8] The general description of reproduction follows that of other *Catonotus*.[7]

EGGS

Description
Unknown.

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Larger Juveniles. Spinous dorsal fin VIII–X; soft dorsal rays 11–15; pectoral rays 10–13; anal fin rays II 7–10; pelvic fin rays I 5; caudal fin rays 14–17.[1–3,5,6]

Morphology
Scales in the lateral series incomplete, with 0–7 pored scales and 40–49 scales in the lateral series from TN.[1–3]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG TEARDROP DARTERS

Similar species: similar to other members of the *Catonous* subgenus.[3] In the study area it is sympatric with *E. flabellare, E. squamiceps*, and *E. kennicotti.*[3]

Adult. *Etheostoma barbouri* is similar to *E. flabellare, E. squamiceps*, and *E. kennicotti* but can be separated from all of these *Catonotus* species by its 12 or fewer pored lateral line scales.

Larva. Aspects of the early life history and reproductive biology of *E. barbouri* are unknown.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (See Figure 25)
Eggs. Eggs are laid on the underside of slab rocks.[1–6]

Yolk-sac larvae. Unknown.

Post yolk-sac larvae. Unknown.

Juveniles. Unknown.

Early Growth
Largest specimen reaches 72 mm TL.[1]

Feeding Habits
The diet includes midge and blackfly larvae, copepods, cladocerans, and immature mayflies and caddisflies.[3]

Figure 25 Distribution of teardrop darter, *E. barbouri* in the Ohio River system (shaded area).

LITERATURE CITED

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6. Page, L.M. and D.W. Schemske. 1978.
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8. Flynn, R.B. and R.D. Hoyt. 1979.

* Simon, T.P., unpublished data.

SPLENDID DARTER

Etheostoma (*Ulocentra*) *barrenense* Burr and Page

Etheostoma: various mouths; *barrenense*: "of the Barren," in reference to the Barren River.

RANGE

Etheostoma barrenense is a Barren River endemic occurring in the upper Barren River, KY and TN, a part of the upper Green River system.[2–5]

HABITAT AND MOVEMENT

The splendid darter inhabits moderate-gradient, clear, small- to moderate-sized streams. Adults prefer unsilted gravel and large rocks, over limestone bedrock substrates in flowing pools, and the margins of riffle and run habitats.[2,6,11]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma barrenense is common in tributaries of the Barren River including Drakes, Trammel, Beaver, Peter, Long Fork, and Fallen Timber Creeks, Bays Fork, and East Fork Barren River.[2,11]

SPAWNING

Location

Spawning occurs on the vertical sides and horizontal tops of rock in riffle and flowing pool habitats, in slight to moderate current.[7–9,11]

Season

Winn[7,8] found males in spawning color in Trace Creek, TN, in April in moderate current in runs and deep pools. Splendid darter spawning occurs during mid-March until mid-June in KY,[10] and from late March or early April until mid-May in TN[8] (R. Wallus, personal communication). Peak spawning throughout its range occurs during April and May.[10,11]

Temperature

Spawning activity initiated in laboratory aquaria when temperatures reached 21–22°C.[7]

Fecundity

Etheostoma barrenense has clutch size correlated with increasing female age and total length.[8] Females that were 2 years old produced about 800 ova, while 3-year-old females produced fewer ova.[3]

Sexual Maturity

Adults live to reach age 3;[3] however, maturity is suspected to be at age 1.[3,7] An adult male (56.3 mm TL) from TN had testes that were 1.23% of the body weight on April 12.* Male tuberculation was absent and females had a long tubular genital papilla.* Males exhibited sexually dimorphic traits during the reproductive season with an increase in brightly colored pigmentation and extension of the genital papillae from the cloacal pad, while females had distended abdomens and a long tubular genital papilla.[*,3,4,7,8,11]

Spawning Act

The reproductive mode of *E. barrenense* is an attacher.[11] In field and laboratory observations, males establish dominance hierarchies and maintain floating territories in deep pools and runs over limestone bedrock. A single male follows a single female to the egg site and mounts the female as their bodies press against the vertical sides of large inclined stones. Spawning position was reported to be between 45° and an obtuse angle.[7,8] Adults maintain a head-to-head orientation with vents juxtaposed. The body of the male is S-shaped, with his pelvic fins resting on the depressed spinous dorsal fin of the female and the caudal and anal fins curve to one side of her caudal peduncle. Eggs are laid individually on the vertical surface of the rock. Generally, several eggs are laid during a single spawning event as the pair ascends steep rocks as much as 30 cm off the bottom.[7–8] The pair is observed to switch positions on the rock depositing eggs on different sections of the same and different rocks.[7,8] Eggs were also observed attached to a pore on an individual piece of gravel, but were not buried in the gravel.[8] Adults maintained in the aquarium switch spawning partners as noted by Page and Mayden with observations of *E. atripinne* and *E. etnieri* (R. Wallus, personal communication). *Etheostoma barrenense* is a fractional spawner reproducing over extended periods.[11] No cleaning of the rock surface or parental care is provided before or after the eggs are laid.[11]

EGGS

Description
Eggs from Little Hurricane Creek, Clay Co., TN[11] are spherical (mean = 1.4 mm diameter, range = 1.3–1.6 mm); translucent; demersal; and adhesive. Eggs possess translucent, pale yellow yolk (mean = 1.3 mm diameter; range = 1.3–1.4 mm); a single oil globule (mean = 0.5 mm); a moderate perivitelline space (mean = 0.15 mm); and an unsculptured and unpigmented chorion.[11]

Incubation
Hatching occurs after 264–288 h at an incubation temperature of 16–17ºC[7] and after 216–264 h at 18.9–19.4ºC (R. Wallus, personal communication).

Development
Unknown.

YOLK-SAC LARVAE

See Figure 26

Size Range
TN populations from Hurricane Creek hatch between 4.2–4.8 mm and yolk is absorbed by 6.3 mm TL.[11]

Myomeres
Preanal myomeres 15 (1), 16 (61), 17 (3), or 18 (1) (*N* = 66, mean = 16.1); postanal myomeres 22 (64) or 23 (2) (*N* = 66, mean = 22.0); with total myomeres 38 (60), 39 (5), or 40 (1) (*N* = 66, mean = 38.1).[11]

Morphology
4.2–4.8 mm TL. Newly hatched: body terete; snout blunt; with functional jaws; mouth terminal; upper jaw even, to slightly extending past lower jaw; well-developed pectoral fins without incipient rays; yolk sac small (15.7% TL), oval to tapered posteriorly; yolk translucent pale yellow, with a single oil globule; single serpentine vitelline vein mid-ventrally on yolk sac; head not deflected over the yolk sac; and eyes oval.[11]

4.9 mm TL. Digestive system functions prior to complete yolk absorption.[11]

4.3–5.5 mm TL. Operculum and gill arches function (5.1 mm) and premaxilla and mandible form.[11]

Morphometry
See Table 30.[11]

Fin Development
4.6–5.8 mm TL. Well-developed pectoral fins without incipient rays.[11]

Pigmentation
4.2–4.8 mm TL. Newly hatched: eye pigmented; melanophores dorsally over posterior cerebellum or nape; laterally, several single melanophores along mid-lateral, posterior orbit, immediately anterior anus, and two near future anal fin; melanophores distributed dorsally over the gut posterior the yolk sac. Ventral pigmentation consists of a mid-ventral band of stellate melanophores surrounding the vitelline vein on the yolk sac, and punctate melanophores along every mid-ventral postanal myosepta forming a continuous stripe.[11]

4.8–6.3 mm TL. Laterally, a series of two melanophore clusters forming a single line of pigmentation over the stomach and posterior gut; a continuous mid-ventral stripe of melanophores from the nearly absorbed oil globule to the end of the stomach but not extending onto the anus. Lateral melanophore series from the anterior anus to the end of future anal fin.[11]

POST YOLK-SAC LARVAE

See Figures 26 and 27

Size Range
6.0–9.6 mm TL.[11]

Myomeres
Preanal 15 (1), 16 (61), 17 (3), or 18 (1) (*N* = 66, mean = 16.1); postanal 22 (64) or 23 (2) (*N* = 66, mean = 22.0); with total; 38 (60), 39 (5), or 40 (1) (*N* = 66, mean = 38.1).[11]

Morphology
7.0–8.0 mm TL. Neuromast development occurs mid-laterally from the anterior trunk posteriad (7.0–7.8 mm TL); notochord flexion simultaneously or shortly after caudal fin ray development (7.1–7.6 mm).[11]

Morphometry
See Table 30.[11]

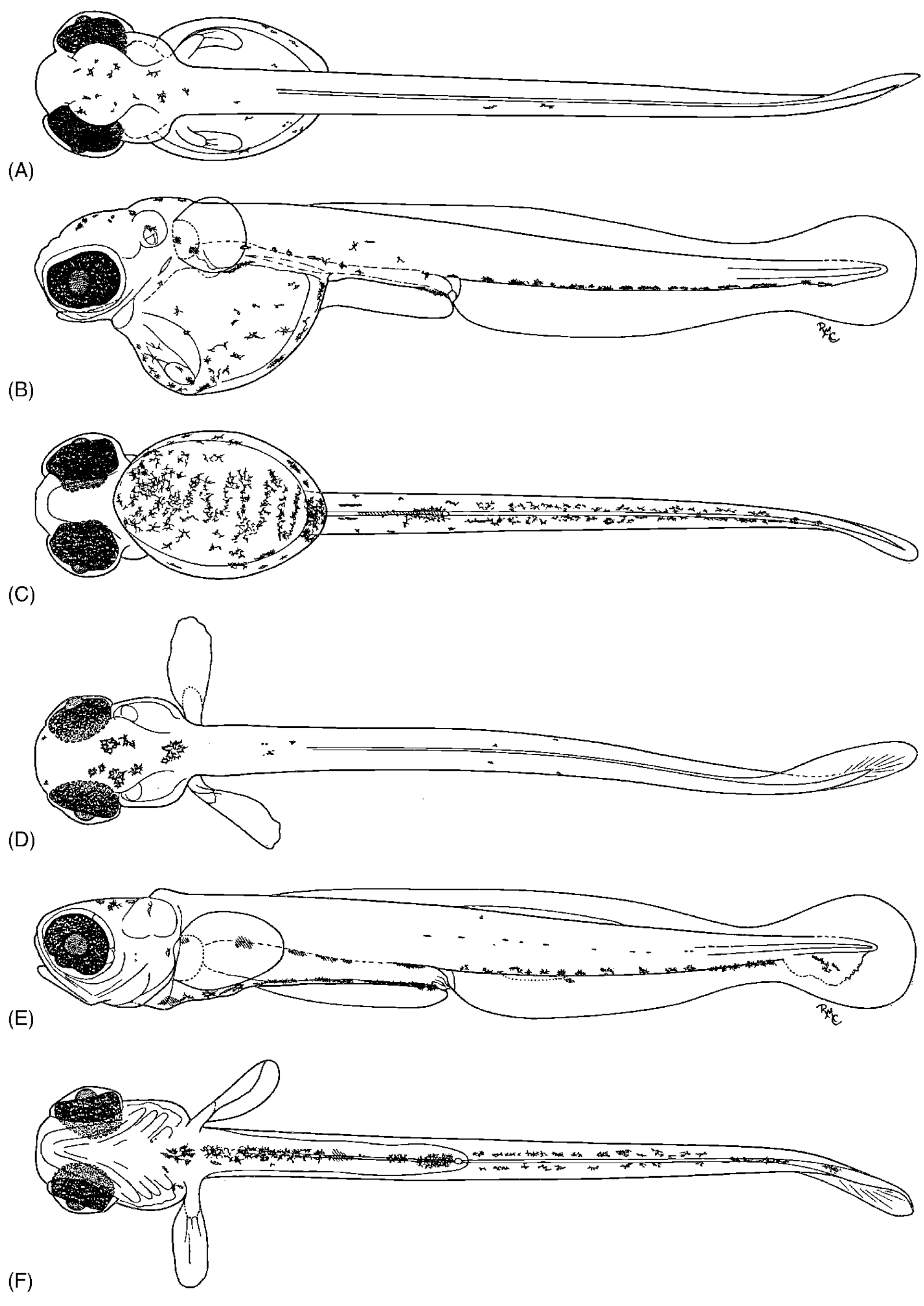

Figure 26 *Etheostoma barrenense*, splendid darter, Little Hurricane Creek, Clay County, TN. Yolk-sac larva, 4.2 mm TL: (A) dorsal, (B) lateral, (C) ventral views. Post yolk-sac larva, 6.2 mm TL: (D) dorsal, (E) lateral, (F) ventral views. (A–F from reference 11, with author's permission.)

Fin Development

See Table 31.[11]

6.3–6.6 mm TL. First rays form in caudal fin between 6.3 and 6.6 mm; soft dorsal fin rays and branchiostegal rays form between 6.6 and 7.2 mm.[11]

7.1–7.8 mm TL. Soft dorsal fin rays and branchiostegal rays form (7.1–7.8 mm); anal fin ray forms (7.8 mm).[11]

7.8–9.3 mm TL. Pelvic fin buds form anterior to dorsal fin origin after complete yolk absorption (7.8–8.3 mm); spinous dorsal (7.1–8.5 mm); dorsal and anal finfold partially differentiated (7.8–9.1 mm). First rays form in pectoral fin (8.3–9.1 mm).[11]

8.9–9.7 mm TL. First pelvic fin ray forms (9.1–9.7 mm); complete adult fin ray counts in median fins (7.1–9.4 mm).[11]

Table 30

Morphometry of Young *E. barrenense* grouped by selected intervals of total length (N = sample size).

	Total Length (TL) Intervals (mm)									
	4.24–5.97 (N = 13)		6.00–7.81 (N = 13)		8.20–9.80 (N = 33)		10.0–11.9 (N = 15)		12.5 (N = 1)	
Characters	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean	Range
Length (% of TL)										
Upper jaw[a]	16.2 ± 4.40	(0.10–0.24)	17.4 ± 4.03	(0.16–0.33)	19.2 ± 4.12	(0.23–0.50)	23.0 ± 2.28	(0.36–0.60)	22.2	(0.55)
Snout[a]	13.8 ± 2.21	(0.10–0.16)	13.2 ± 2.76	(0.10–0.22)	15.5 ± 2.27	(0.14–0.40)	17.4 ± 1.70	(0.32–0.46)	16.9	(0.42)
Eye diameter[a]	45.7 ± 2.42	(0.37–0.44)	42.3 ± 2.73	(0.48–0.63)	39.4 ± 1.98	(0.60–0.83)	36.6 ± 2.18	(0.72–0.89)	33.9	(0.84)
Head	19.2 ± 1.84	(0.77–1.06)	19.6 ± 1.31	(1.18–1.61)	19.9 ± 0.92	(1.50–2.08)	20.2 ± 0.60	(2.00–2.40)	19.8	(2.48)
Predorsal	28.8 ± 3.35	(1.15–1.55)	27.5 ± 3.43	(1.37–2.34)	27.5 ± 0.92	(2.22–2.77)	28.0v0.74	(2.74–3.48)	28.7	(3.60)
Dorsal insertion					32.0 ± 10.7	(0.00–4.77)	47.5 ± 1.51	(4.65–5.72)	46.6	(5.84)
D2 origin					33.1 ± 12.3	(0.00–5.16)	52.0 ± 1.16	(5.17–6.12)	50.6	(6.34)
D2 insertion					38.4 ± 20.6	(0.00–5.16)	71.5 ± 1.03	(5.17–6.12)	70.7	(6.34)
Preanal	49.1 ± 2.19	(2.11–2.57)	49.8 ± 0.72	(2.97–3.90)	50.3 ± 1.05	(4.00–5.07)	50.3 ± 0.66	(5.00–5.94)	48.1	(6.03)
Postanal	50.9 ± 2.20	(2.13–3.42)	50.3 ± 0.85	(3.00–4.05)	49.7 ± 1.05	(4.16–5.00)	49.7 ± 0.66	(4.92–5.94)	51.9	(6.51)
Standard	94.9 ± 4.87	(4.16–4.89)	95.6 ± 0.87	(5.82–7.42)	89.6 ± 1.57	(7.44–8.80)	86.3 ± 2.92	(8.10–10.3)	86.4	(10.8)
Yolk sac	15.7 ± 9.19	(0.20–1.06)								
Fin Length (% of TL)										
Pectoral	6.89 ± 1.49	(0.23–0.44)	11.4 ± 3.53	(0.46–1.34)	13.9 ± 1.95	(0.90–1.68)	15.1 ± 1.74	(1.22–2.12)	12.9	(1.62)
Pelvic			4.19 ± 1.43	(0.20–0.40)	5.54 ± 1.71	(0.13–0.90)	8.44 ± 1.59	(0.58–1.24)	13.2	(1.65)
Spinous dorsal					19.7 ± 1.70	(1.33–2.02)	19.5 ± 1.58	(1.82–2.32)	17.9	(2.24)
Soft dorsal					19.3 ± 1.25	(1.52–2.00)	19.4 ± 1.01	(1.68–2.29)	20.1	(2.52)
Caudal	5.14 ± 4.87	(0.08–1.25)	4.37 ± 0.87	(0.18–0.48)	10.4 ± 1.57	(0.56–1.21)	13.7 ± 2.92	(1.14–2.39)	13.6	(1.71)
Body Depth (% of TL)										
Head at eyes	16.0 ± 1.01	(0.64–0.88)	15.6 ± 1.37	(0.91–1.28)	14.7 ± 0.80	(1.12–1.63)	14.6 ± 0.54	(1.43–1.76)	14.1	(1.77)
Head at P1	16.9 ± 3.76	(0.63–1.03)	14.8 ± 4.84	(0.66–2.00)	13.7 ± 1.20	(0.88–1.48)	15.1 ± 0.67	(1.40–1.86)	15.9	(2.00)
Preanal	8.28 ± 0.84	(0.30–0.47)	10.8 ± 2.42	(0.46–1.02)	11.6 ± 1.34	(0.74–1.32)	13.2 ± 1.08	(1.18–1.67)	14.1	(1.77)
Mid-postanal	5.80 ± 0.76	(0.20–0.34)	7.67 ± 1.56	(0.32–0.68)	8.09 ± 0.87	(0.54–0.88)	8.75 ± 0.54	(0.82–1.08)	9.09	(1.14)
Caudal peduncle	2.93 ± 0.40	(0.11–0.16)	4.38±1.45	(0.16–0.50)	4.87 ± 1.80	(0.36–0.73)	7.04 ± 0.40	(0.66–0.90)	6.86	(0.86)
Yolk sac	10.5 ± 5.12	(0.22–0.80)								
Body Width (% of HL)										
Head	72.2 ± 3.54	(0.60–0.84)	72.0 ± 7.37	(0.80–1.18)	67.6 ± 3.89	(1.04–1.44)	64.7 ± 3.86	(1.18–1.52)	65.3	(1.62)
Myomere Number										
Predorsal	3.23 ± 0.44	(3.00–4.00)	3.00 ± 0.00	(3.00–3.00)	3.12 ± 0.33	(3.00–4.00)	3.27 ± 0.46	(3.00–4.00)	3.00	(3.00)
Soft dorsal			16.5 ± 0.71	(16.0–17.0)	17.0 ± 0.22	(16.0–17.0)	16.2 ± 0.43	(16.0–17.0)	16.0	(16.0)
Preanal	16.3 ± 0.48	(16.0–17.0)	16.4 ± 0.51	(16.0–17.0)	16.2 ± 0.42	(16.0–17.0)	16.6 ± 0.63	(16.0–18.0)	16.0	(16.0)
Postanal	22.0 ± 0.00	(22.0–22.0)	22.0 ± 0.00	(22.0–22.0)	22.1 ± 0.33	(22.0–23.0)	22.0 ± 0.00	(22.0–22.0)	22.0	(22.0)
Total	38.3 ± 0.48	(38.0–39.0)	38.4 ± 0.51	(38.0–39.0)	38.3 ± 0.54	(38.0–40.0)	38.6 ± 0.63	(38.0–40.0)	38.0	(38.0)

[a] Proportion expressed as percent head length.

Note: Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

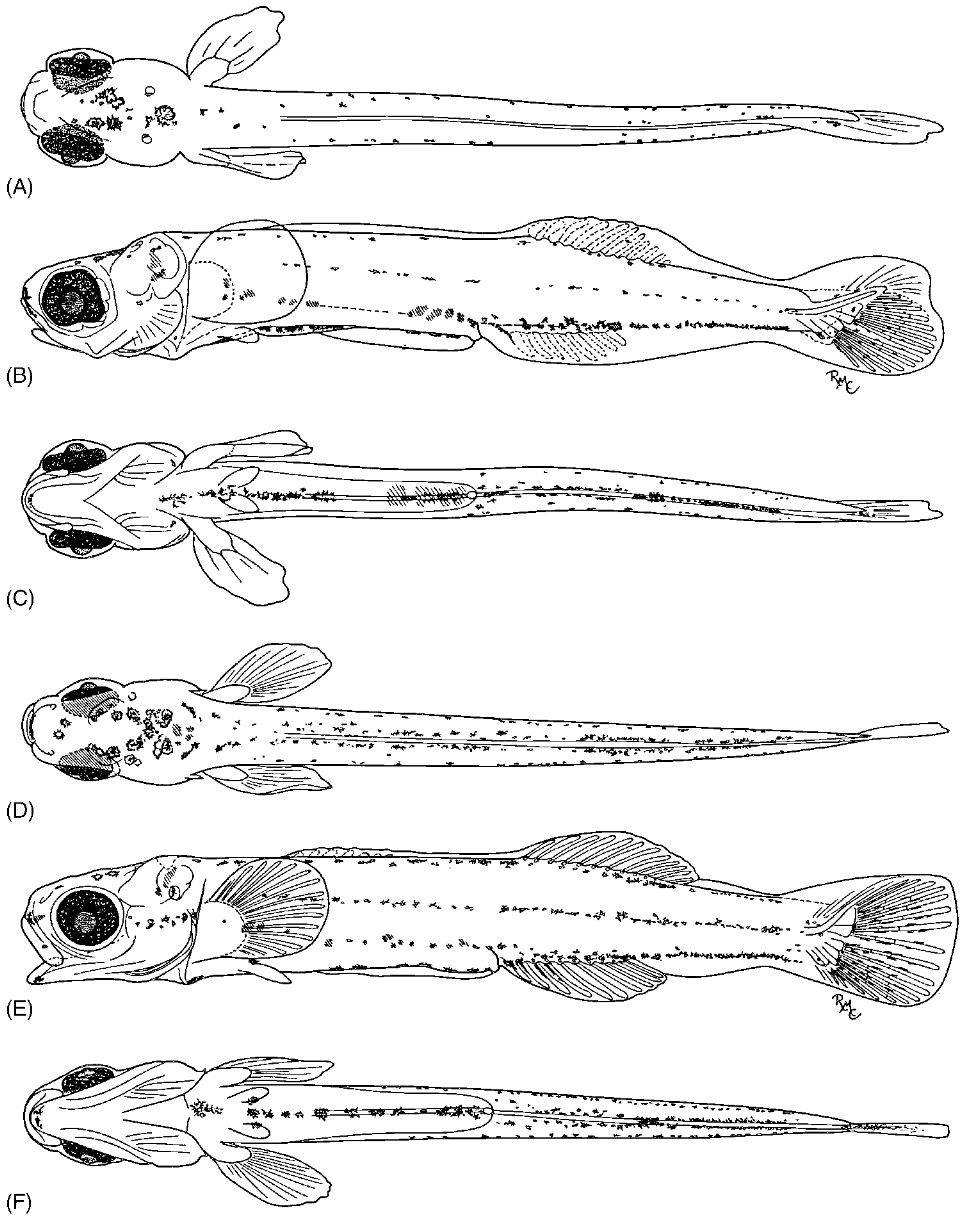

Figure 27 *Etheostoma barrenense*, splendid darter, Little Hurricane Creek, Clay County, TN. Post yolk-sac larva, 7.9 mm TL: (A) dorsal (B) lateral, (C) ventral views. Post yolk-sac larva, 10.3 mm TL, (D) dorsal, (E) lateral, (F) ventral views. (A–F from reference 11, with author's permission.)

Pigmentation

6.8–8.8 mm TL. Dorsum of cranium has several large melanophore clusters on cerebellum, forming preorbital and postorbital bars; dorsum of body with patches of melanophores at dorsal fin gap and at caudal peduncle. Laterally, a series of midlateral melanophores from the midstomach to the caudal peduncle; ventrally, a mid-ventral stripe of single melanophores from the breast to the caudal peduncle base.[11]

8.9–9.7 mm TL. Cranial clusters of melanophores on tip of snout and chin, posterior eye on cheek, and dorsum of cerebellum; second cluster of ventral melanophores forming over the developing anal fin.[11]

JUVENILES

See Figure 28

Size Range

>10.3[11]–35 mm TL.*

Table 31

Meristic counts and size (mm TL) at the apparent onset of development for *E. barrenense*.[11]

Attribute/event	*Etheostoma barrenense*	Literature
Branchiostegal Rays	5,5	5,5[3,10,14]
Dorsal Fin Spines/Rays	X–XII/10–13	X–XII/10–13[3,10,14]
First spines formed	7.1–8.5	
Adult complement formed	7.1–8.5	
First soft rays formed	7.1–7.8	
Adult complement formed	7.8	
Pectoral Fin Rays	15	13–15[3,10]
First rays formed	8.3–9.1	
Adult complement formed	8.3	
Pelvic Fin Spines/Rays	I/5	I/5[3,10]
First rays formed	9.1–9.7	
Adult complement formed	9.1–9.7	
Anal Fin Spines/Rays	II/7–9	II/6–8[3,10,14]
First rays formed	7.7–8.4	
Adult complement formed	7.8	
Caudal Fin Rays	viii–x, 8-9 + 7–8, viii–ix	12–15[10]
First rays formed	6.3–6.6	
Adult complement formed	7.1–10.1	
Lateral Line Scales	42–49	42–49[3,10,14]
Myomeres/Vertebrae	38–40/38–39	Unknown/38–40[3,10,15]
Preanal myomeres	16–18	
Postanal myomeres	22–23	

Fin Development

12.5 mm TL. Caudal fin slightly emarginate.[11]

12.7–14.8 mm TL. Complete adult fin ray counts in median fins; caudal fin rays with segmentation, truncate to slightly emarginate.[11]

Morphology

Total vertebrae count 38–39 (N = 3, mean = 38.3), including one urostylar element. Scales in the lateral series range from 42 to 49 from Hurricane Creek,[11] which is the range for the entire species distribution.[3,4,6] Fin ray meristics and length at appearance are included in Table 31.[11]

8.9–10.0 mm TL. Both finfolds completely differentiated (8.9–10.0 mm). No swim bladder forms; gut straight, without striations, portion of gut posterior stomach normal in length between 7.0 and 10.0 mm.[11]

11.4–12.5 mm TL. Upper jaw equal with lower jaw, mouth becoming subterminal.[11]

>12.5 mm TL. Infraorbital and supraorbital canals formed; lateral, subtemporal and preoperculomandibular head canals form. Initiation of squamation and lateral line begins to form.[11]

Early Juvenile. Infraorbital, lateral, and supratemporal head canals not interrupted, preoperculomandibular canal complete with 8–10 (usually 9) pores, infraorbital 7–9 (usually 8) pores.[11] Cheek scales variable, usually embedded, naked to completely scaled; opercle, nape, and belly are completely scaled; breast naked (97%) to partially scaled.[3,4]

Morphometry

See Table 30.[11]

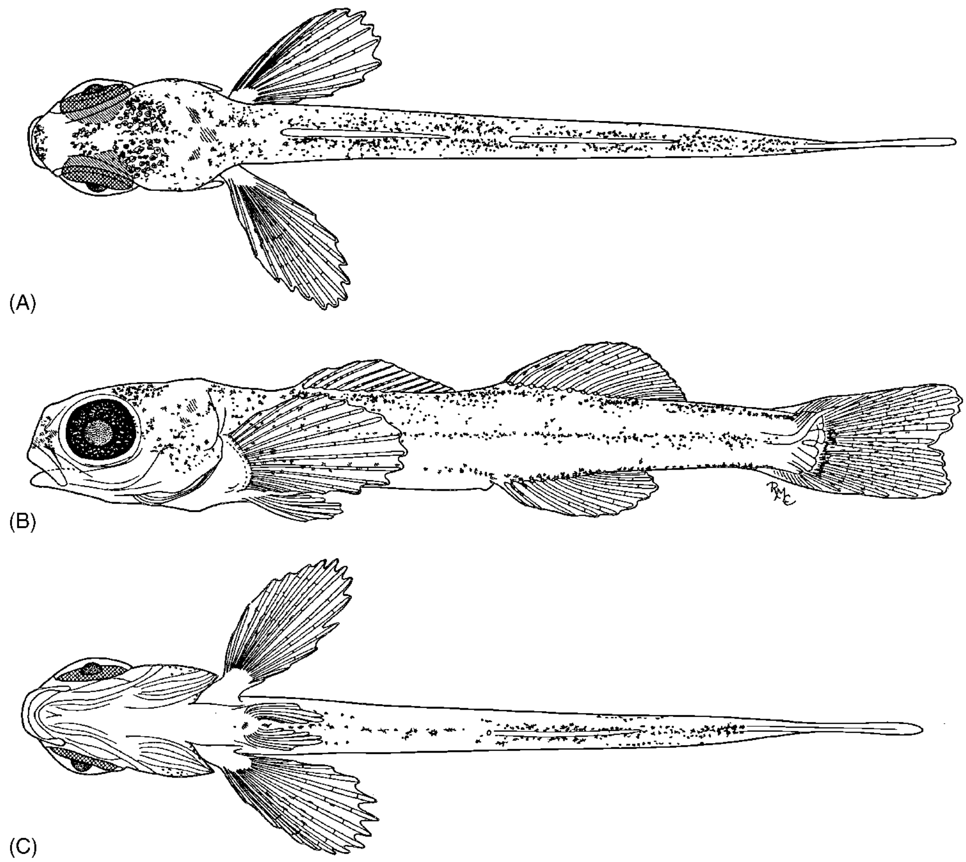

Figure 28 *Etheostoma barrenense*, splendid darter, Little Hurricane Creek, Clay County, TN. Juvenile, 11.2 mm TL, (A) dorsal, (B) lateral, and (C) ventral views. (A–C from reference 11, with author's permission.)

Pigmentation

9.8–10.8 mm TL. Distinct preorbital and postorbital bar, and chin pigmentation outlines mandible and maxillae; melanophores scattered dorsally on cerebellum and optic lobe; dorsum with a series of melanophores forming a continuous melanophore series from the nape to the caudal peduncle. A series of melanophores extend along the mid-lateral from the shoulder to the hypural plate; a series of large clustered melanophores forming a series of cutaneous and subdermal stripe over the gut; several large clustered melanophores present over the anus. Ventral melanophores form a single mid-ventral row from the breast to the anus; mid-ventral melanophores densely distributed over the entire anal fin forming two rows; and densely distributed along mid-ventral myosepta from anal fin insertion to the caudal fin base.[11]

11.2–12.5 mm TL. Cranium with distinct melanophores outlining the maxillae, anterior cerebellum, and covering the optic lobe; scattered middorsal melanophore stripe from the nape to the caudal fin forming eight distinct dorsal saddles. The lateral melanophore series extends from the shoulder to the base of the caudal peduncle; and dorsally over the gut. Ventral melanophore series consists of a single line from the interpelvic area to the anus, and outlining in a double row the anal fin lepidiotrichia interdigitation with the pterigiophores, then forming scattered accumulation from the anal fin insertion to the caudal fin base. Proximal stripe of melanophores exists in the spinous dorsal fin, distally in the soft dorsal fin; melanophores scattered on the pectoral fin; vertical stripe of melanophores along the caudal fin base and scattered on the fin. No pigmentation apparent in the anal or pelvic fins.[11]

TAXONOMIC DIAGNOSIS OF YOUNG SPLENDID DARTER

Similar species: members of subgenus *Ulocentra*.[6] The single population of *E. barrenense* studied exhibits significant interspecific variation with *E. simoterum* in myomere counts, ontogenetic events, and body proportions. *Etheostoma barrenense* is the diminutive of *E. simoterum,* attaining equivalent levels of development at smaller length intervals.[6]

Adult. *Etheostoma barrenense* is a member of the *simoterum* species group of the darter subgenus *Ulocentra*. *Etheostoma barrenense* can be differentiated from other members of the *E. simoterum* species group based on higher lateral line and traverse scale counts. *Etheostoma barrenense* has 42–49 lateral line scales and 12–14 traverse scales; 7–10 dark bars confluent with a mid-lateral dark stripe; and a dorsum with 7–9 (usually 8 or more) saddles. *Etheostoma barrenense* occurs throughout the upper Barren River and its tributaries, KY and TN.[2–4,6]

Larva: *Etheostoma barrenense* is very similar to species *E. rafinesquei*, but differs in subtle pigmentation and myomere counts. Both species have overlapping, moderate preanal (16–17) myomere counts, while *E. barrenense* has lower postanal (mode, 22) myomere counts.[11]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (See Figure 29)
Eggs. Egg sites include the vertical sides and horizontal tops of rocks in riffle and flowing pool habitats, in slight to moderate current.[7,9]

Yolk-sac larvae. Aquarium observations indicate splendid darter larvae were epibenthic immediately after hatching. Newly hatched larvae were first collected early to mid-April.[11]

Post Yolk-sac larvae. Aquarium observations indicate splendid darter larvae becoming demersal at lengths >13 mm; they remain benthic and in close association with the substrate.[11] Splendid darter larvae from Middle Fork Drakes Creek are collected in equal numbers from gravel and algal covered rock areas, from areas adjacent to riffles, and from behind tree roots and other structures that act as obstructions in flowing pool habitat from mid-April to late May.[13] In Little Hurricane Creek, specimens are collected from adjacent riparian bank vegetation, along slack water flow regimes, from water 0.3 m in depth over mud substrates. In Middle Fork Drakes Creek, specimens attain a maximum density of 40/10 m^3 in mid-May. Larvae appear from late April until late May. All length intervals are collected in lighttraps from the rock nearshore habitats usually associated with tree roots or rubble.[11]

Juveniles. Early juveniles utilize rock near shore habitats usually associated with tree roots or rubble.[11] Juveniles were collected from early June to early July.[11]

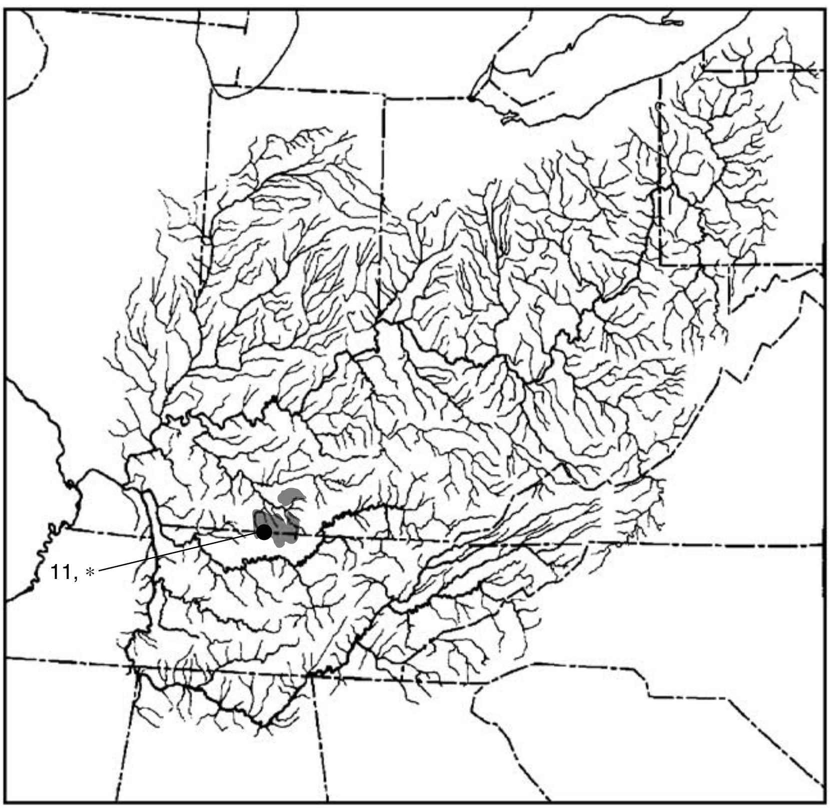

Figure 29 Distribution of splendid darter, *E. barrenense* in the Ohio River system (shaded area) and areas where early life history information has been collected (circle). Number indicates appropriate reference.

Early Growth (See Table 32)
Splendid darter survives 2 years (24 months), with age 1 fish averaging 44–49 mm at first reproduction.[5]

Feeding Habits
The diet of splendid snubnose darters includes a large percentage of mayfly nymphs, blackfly and midge larvae, and lesser numbers of caddisfly, stonefly, and beetle larvae. Juveniles fed on microcrustaceans and dipteran larvae.[*,3]

Table 32

Average calculated length (mm TL) of young splendid darters in Kentucky.

State	Age 1	Age 2	Age 3
Kentucky*	37–42	40–52	52+

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* Original data from TN: Clay Co.: Little Hurricane Creek, 0.5 miles N Tennessee Hwy 52 near Oak Grove, TV 3080 (6); TV 3066 (6); TV 2989 (38); TV uncatalogued (10). Little Hurricane Creek, at Church of Christ, Clementsville, TV 2987 (15). Specimens curated at Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

ORANGEFIN DARTER

Etheostoma (*Nothonotus*) *bellum* Zorach

Etheostoma: various mouths; *bellum*: beautiful.

RANGE

Endemic to the Barren and Green River systems above their confluence, KY, and TN.[1–5]

HABITAT AND MOVEMENT

Etheostoma bellum inhabits swift gravel riffles in creeks and small rivers.[1–5] It prefers shallow riffles ranging from 0.1 to 0.15 m over small gravel.[1–4] *Etheostoma bellum* uses habitats with fast current in shallow areas and is associated with small substrate sizes and smooth substrates.[9] Females occupy areas with slower current velocities, smaller substrate sizes, and smoother substrates.[9] *Etheostoma bellum* exhibits a wide range of habitat orientations and is most frequently observed nestled between pebbles or holding onto the side of a large pebble or cobble.[9]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma bellum is endemic and generally distributed in the upper Green and Barren Rivers. The bluebreast darter reported from the Green and Barren Rivers is actually an orangefin darter.[4,6]

SPAWNING

Location
Eggs are buried in fast-flowing gravel riffles and laid in clusters.[8]

Season
Spawning occurs during late June or early July;[4,5,8] or from late April to late June.[8]

Temperature
Spawning occurs from 20 to 25°C.[8]

Fecundity (see Table 33)
Average number of ova is 41 and probably represents average clutch size rather than fecundity.[8] Female *E. bellum* showed statistically significant increasing fecundity (ANOVA, F=63.077, p>0.0001) with increasing length. Females between 48 and 58 mm, collected on April 1, 1983, had 43–131 large mature ova, while females between 54–66 mm had 228–378 large mature ova.

Sexual Maturity
Sexual maturity was typically attained at age 2; however, some early hatched 1-year olds were sexually mature.[8]

Table 33

Fecundity data for orangefin darter from the Green River drainage, unnamed creek, Metcalfe Co., KY.

		Number of Ova			
Length (TL)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
48	41.8	269	149	43	0.90
54	45.6	401	378	—	1.11
58	63.7	349	216	131	0.76
66	266	437	300	228	1.11

Spawning Act
Etheostoma bellum is an eggburier.[7,8,10] Large territorial males spawn over females buried in the gravel.[8] Females are mounted by males as pairs burrow into the substrate. Females attach eggs beneath the substrate to buried objects. Fertilization of the eggs occurs as the female is partially buried.[7,8]

EGGS

Description
Ovarian examination showed that ovoid latent ova range from 0.2 to 0.4 mm, early maturing, small spherical cream-colored ova range from 0.5 to 0.83 mm, and large mature ova range between 0.76 and 1.11 mm (T.P. Simon, unpublished data).[7] The mean diameter of mature ova from Kentucky was 1.58 mm.[8] Eggs of *E. bellum* are demersal, adhesive, and spherical, possessing a single oil globule, a narrow perivitelline space, and a sculptured and unpigmented chorion.[7,8]

Incubation
Eggs incubated at 23°C hatched in 7–9 days (168–216 h).[8]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 30

Size Range
5.9–8.0 mm SL.[8]

Myomeres
Preanal 18–19; postanal 19–20; total 37–39.[7] Fisher reported myomere counts of 16 preanal, 19 postanal, and 35 total.[8] He described a 7.15 mm mesolarval specimen that is clearly a cyprinid, with 27 preanal and 11 postanal myomeres.[8] Our opinion is that Fisher's preanal myomere counts may be incorrect and possibly incomplete since the count may not include the partial myomeres just posterior to the operculum. Our experience does not show that significant a preanal myomere range.

Morphology
5.9 mm SL. Yolk-sac larvae possess a small (24.5% SL) pale yellow, translucent, ovoid yolk sac, a pigmented spherical eye without an anterior cranium extension, and a developed jaw. Mid-ventral yolk sac with a single serpentine vitelline vein.[7]

Morphometry
See Table 34.

Fin Development
5.9 mm SL. Newly hatched yolk-sac larvae possess a developed pectoral fin without incipient fin rays.[7]

8.0 mm SL. Larvae develope incipient anal fin rays and several caudal fin rays.[7]

Pigmentation
5.9–8.0 mm SL. No dorsal pigmentation is present; melanophores are present on the midopercle, oil

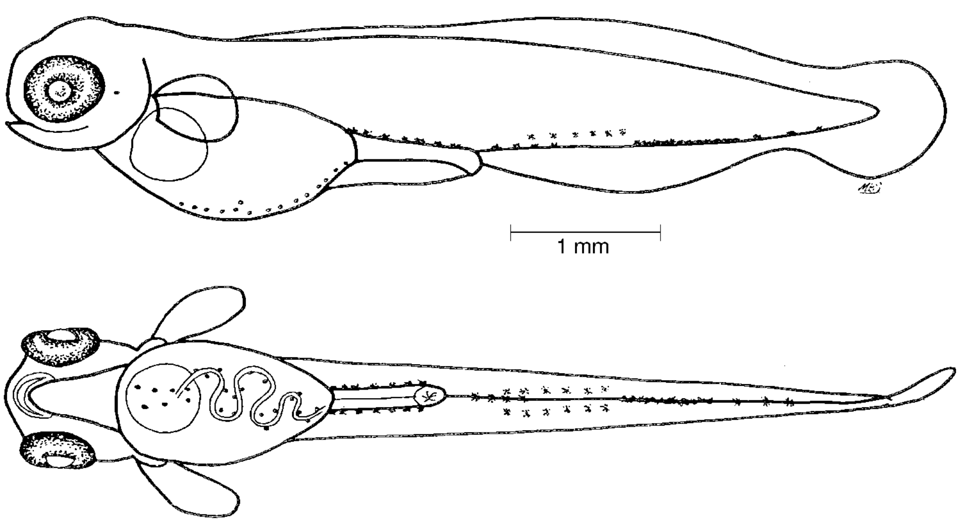

Figure 30 *Etheostoma bellum*, orangefin darter, Middle Fork Drakes Creek, Warren County, KY, yolk-sac larva 5.9 mm SL, lateral, and ventral aspects. (From reference 7, with authors' permission.)

Table 34

Morphometric data expressed as percentage of standard length (SL) for young orangefin darter from Middle Fork Drakes Creek, KY.[7]

	Total Length Groupings	
TL Range (mm)	6.3–7.9	8.0–8.3
N	12	3
Ratios	Mean ± SD (Range)	Mean ± SD (Range)
As Percent SL		
SnL	2.9 ± 0.6	3.4 ± 0.4
	(1.8–3.7)	(3.0−3.9)
ED	9.9 ± 1.3	12.3 ± 0.2
	(7.8–11.8)	(12.2−12.5)
HL	18.4±1.4	19.9 ± 0.3
	(17.8−19.6)	(19.6−20.2)
HW	10.5 ± 1.3	12.8 ± 0.4
	(7.3–11.6)	(11.9−13.6)
PreDFL	26.9 ± 1.5	33.5 ± 3.6
	(23.7−28.3)	(29.8−34.9)
PreAL	55.3 ± 1.0	54.1 ± 1.6
	(53.7−56.7)	(52.8−56.4)
PosAL	44.7 ± 1.0	45.9 ± 2.9
	(43.3−46.3)	(43.6−48.2)
PC	103.9 ± 1.3	101.7 ± 0.5
	(102.2−106.7)	(101.2−102.5)
YSL	24.5 ± 0.4	
	(24.0−25.1)	
P1L	7.8 ± 0.9	11.2 ± 3.1
	(5.7−9.2)	(9.8−12.8)
CFL	3.9 ± 1.3	7.7 ± 2.2
	(2.1−6.5)	(7.5−12.4)
BDE	13.6 ± 1.3	15.4 ± 1.0
	(10.9−14.8)	(14.3−16.4)
BDP1	14.7 ± 1.0	16.3 ± 1.3
	(13.6−16.7)	(14.8−17.6)
BDA	8.8 ± 1.2	9.8 ± 0.9
	(6.0−8.7)	(8.2−10.4)
MPosAD	6.7 ± 0.8	7.3 ± 0.5
	(5.2−7.6)	(7.0–7.9)
CPD	3.2 ± 0.3	3.9 ± 1.0
	(2.8−4.0)	(3.2−4.8)
YSD	9.8 ± 1.2	
	(6.8−11.3)	

globule, adjacent midventral vitelline vein, dorsal gut, and ventrally on every second postanal myosepta.[7]

POST YOLK-SAC LARVAE

Size Range
8.0 mm SL to unknown lengths;[7] illustrations of a 7.15 mm TL protolarva is not *E. bellum*, rather the specimen is an unidentified cyprinid.[8]

Myomeres
Preanal myomeres 18–19; postanal 19–20; total myomeres 37–39.[7]

Morphology
8.0 mm SL. Yolk sac absorbed.[7]

Morphometry
See Table 34.

Fin Development
8.0 mm SL. Fin rays form in the anal and caudal fins.[7]

Pigmentation
8.0 mm SL. No dorsal pigmentation is present; melanophores are present on the midopercle, oil globule, adjacent mid-ventral vitelline vein, dorsal gut, and ventrally on every second postanal myosepta.[7]

JUVENILES

Size Range
Unknown to 39.4 mm SL.[8]

Fin Development
Larger juveniles. Spinous dorsal fin X–XIII; soft dorsal rays 11–13; pectoral rays 12–15; anal fin rays II 6–9; pelvic fin rays I 5; caudal fin rays 16–17.[2–5]

Morphology
Total vertebrae count 37–39 including one urostylar element. Scales in the lateral series complete with 51–60 (48–63) pored scales in the lateral range from TN.[2–5] Gill membranes separate to narrowly joined, frenum present. Scales absent from cheeks, breast, prepectoral area, and most of nape; opercles scaled.[4,5]

Morphometry
Unknown.

Pigmentation
Juveniles. Background body color yellowish-brown and marked with ten dark horizontal lines on each

side that extend from beneath the middle of the spinous dorsal fin to the caudal fin base. In some specimens, these lines extend nearly to the head. Soft dorsal, caudal, and anal fins with dark marginal bands, pale submarginal band is positioned medially, with an orange band proximal to the body. These three bands are all about the same width and occupy the distal third of each fin. Caudal fin with two pale areas basally.[5]

TAXONOMIC DIAGNOSIS OF YOUNG ORANGEFIN DARTER

Similar species: members of subgenus *Nothonotus.*

Simon et al.[7] placed *E. bellum* in the egg-burier group along with *E. acuticeps, E. rufilineatum,* and *E. tippecanoe.*[7] These species possess <19 preanal myomeres, small (<32.0% SL) oval to ovoid yolk sacs, and no dorsal pigmentation or mid-lateral dashes near the caudal peduncle. Within this group, *E. tippecanoe* possesses an anteriorly enlarged cranium, hatches at a smaller size, and the soft dorsal fin initiation is posterior to the anus, unlike any other member of the subgenus. *Etheostoma rufilineatum* and *Etheostoma bellum* are most similar among the eggburiers, based on their morphometric features. *Etheostoma bellum* differs from *E. rufilineatum* in having more than 18 preanal myomeres, an ovoid yolk sac shape, and greater lengths at first fin ray development.[7]

Variation

Our study populations of *E. bellum* exhibited very little intraspecific variation.[7]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 31)

Eggs. Eggs are buried in the interstitial pore spaces of shallow riffles.[8,11]

Yolk-sac larvae. Yolk-sac larvae were collected from beneath overbank rootwads adjacent to pools downstream of spawning riffles.[11] Yolk-sac larvae are epibenthic and drift in the water column shortly after hatching. Yolk-sac larvae are phototactic and are attracted to light traps.[11]

Post yolk-sac larvae. Larvae remain in the shallow downstream pools and occur in underbank rootwads and rootmats. Larval densities range from 3.2 to 4.5 individuals/m^2.*

Figure 31 Distribution of orangefin darter, *E. bellum* in the Ohio River system (shaded area) and areas where early life history information has been collected (circle). Numbers indicate appropriate references. Asterisk indicates original data.

Juveniles. Juveniles occur on the downstream edges of shallow riffles by mid-September.[8,11]

Early Growth (see Table 35)
Young-of-the-year were 23–32 mm TL by mid-November and 33–42 mm TL by the following May in TN.[5] Young-of-the-year from South Fork Green River, KY, were 20.3–25.5 mm by mid-September.[8] Males grew more rapidly than females; maximum longevity was 36 months[8] (Table 35).

Feeding Habits
Diet was primarily dipteran larvae, baetid mayflies, and water mites.[5,8]

Table 35

Average calculated length (mm TL) of young orangefin darters in Tennessee and Kentucky.[5,8]

State	Age 1	Age 2	Age 3
Tennessee[5]	33–42	46–53	74
Kentucky[8]	36	48	60

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11. Floyd, K.B. et al. 1984.

Materials Examined: KY: Warren Co.: Middle Fork Drakes Creek, LRRC uncatalogued (12). Metcalfe Co.: unnamed creek (Green River drainage), at US HWY 68 and KY HWY 70 crossing near sulfur wells, April 1, 1983; Russell Co.: unnamed Creek (Green River drainage), 1.3 miles W Casey-Russell County line on KY HWY 80, April 2, 1983.

* Original fecundity data for orangefin darter from an unnamed Creek, Green River drainage, Metcalfe County, KY. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Early life history developmental series cultured from field and laboratory spawned specimens from Middle Fork Drakes Creek, Warren County, KY. Specimens curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

GREENSIDE DARTER COMPLEX

Etheostoma (*Etheostoma*) *blennioides* Rafinesque

Etheostoma: various mouth; *blennioides*: blenny-like.

RANGE

Etheostoma blennioides is widespread and abundant in upland streams from eastern KS and OK east to NY and MD, and from ON south to AR, AL, and GA.[1–3,8] The various subspecies occur as follows: *E. b. blennioides* occurs throughout the Ohio River system above the confluence of the Green River, KY, and in the Potomac and upper Genessee systems; *newmanii* occurs in the Tennessee, Cumberland, St. Francis, White, Arkansas, and Ouchita Rivers; *gutselli* occurs in the Little Tennessee and Pigeon Rivers; and *pholidotum* occurs in the Great Lakes drainage and the Wabash, Maumee, Mohawk, and Missouri River systems.[1–8]

HABITAT AND MOVEMENT

All forms of the greenside darter inhabit swift to moderate gradients, and clear to slightly turbid riffles of small streams and moderate-sized rivers.[1–6] Adults prefer boulder or coarse rubble substrates and may be associated with filamentous algae or attached aquatic vegetation.[1–7] The species can be found along the edges of clear, cool lakes.[11] They move into deep pools during cooler months.[10,11] Juveniles inhabit shallow pool areas adjacent to riffles.[1–6,9,16,19] We have collected juveniles from silted gravel substrates on the edges of riffles or from bedrock-strewn rubble in moderate current.[*,6]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma b. blennioides occurs throughout the Ohio River system above the confluence of the Green River, KY, and in the upper Genessee systems.[8] This form is associated with the old Teays River and has established its distribution in response to drainage changes in the present Ohio River.[2] This is the only subspecies in Salt River, KY. It occurs in the headwaters of the Allegheny and Monogahela River basins and has spread into the Potomac River basin through stream capture.[16] *Etheostoma b. newmanii* occurs in the Tennessee and Cumberland Rivers throughout the upper and middle Tennessee River system, but is absent in some of the western tributaries of the lower basin. A Cumberland River race of *E. b. newmanii* occupies the entire Cumberland River system, including the portions above the Falls.[7] *Etheostoma b. gutselli* occurs in the Little Tennessee and Pigeon Rivers, and *E. b. pholidotum* occurs in the Wabash River system.[1–8]

SPAWNING

Location

Etheostoma b. blennioides spawning sites are riffle habitats, typically over algal mats of *Drepanoclatus exannulatus* and *Cladophora glomerata*;[5] they also spawn over sand substrates in slight to moderate current.[16] *Etheostoma b. newmanii* spawned in a pool with bedrock overlain with gravel and rubble substrates immediately downstream of a shallow bedrock riffle covered with patches of filamentous algal mats.[4,18] *Etheostoma b. pholidotum* spawns in the swiftest portions of riffle habitats, typically over algal mats of *Cladophora* sp. attached to the upper surface or sides of rocks, or the surface of sheets of bedrock in the riffle sections of streams. Eggs are secured very close to the point of attachment of the algal strand to the rock.[10]

Season

Etheostoma b. blennioides-spawning aggregates of adult males assemble in early April on riffles in OH. The "Allegheny-type" greenside darters are reported to spawn during April to mid-May in OH,[5] and from mid-April until June in NY.[26] *Etheostoma b. newmanii*-spawning aggregates of adult males assemble by late March on riffles in MO.[29] Newman's greenside darters are reported to spawn during late February to late March in AR;[14,31] late March until the end of April in MO;[29] mid-March until April in TN;[4,18] and during April in KS.[32] *Etheostoma b. pholidotum*-spawning aggregates of adult males assemble in early-April on riffles at temperatures below 18°C. The "prairie-type" greenside darter spawns during April to mid-May in OH[5] and IN (Simon, T.P., personal observation); and mid-April until June in NY.[26]

Temperature

Etheostoma b. blennioides spawning initiated when temperatures reached 10.56°C in NY.[26] Spawning of

E. b. newmanii initiated in TN when temperatures reached 10–11.7°C.[4] Spawning of *E. b. pholidotum* initiated when temperatures reached 10.56°C[10] in NY.

Fecundity (see Table 36)
Females (42–52 mm TL) collected in late March to mid-April from Little River, Blount County, TN, had ovaries that were 12.9% of the body weight, containing 175.6 total ova averaging 1.62 mm diameter.* Females had 81–207 mature eggs.

Sexual Maturity
Sexual maturity was typically attained at age 1, but more normally at age 2.[10–13]

Spawning Act
Etheostoma blennioides is an egg attacher.[8] Males are larger than females and darken during the breeding season. Spawning occurs on a variety of substrates, including on vegetation attached to boulders or sandy substrates in riffles. Male greenside darters occupy territories, but guarding of territories has not been consistently documented. The female begins the spawning act by selecting the spawning substrate. The female nudges the male, who follows the female to the egg-deposition location. The male assumes a position beside and slightly on top of the female. Gametes are released, and the female may be either horizontal to vertical. Greenside darters are intermittent spawners that may produce several clutches of eggs during a single reproductive season. Eggs are deposited individually or in clusters of as many as eight eggs, with a range of 16–61 eggs spawned in three spawning events.[10–13] Females may lay as may as 500–2000 eggs per season, but our observations suggest that this number is greatly inflated.[10–13] Aquarium-captive adults deposited between 10 and 15 eggs on algal mats during a single spawning event. Eggs were deposited at the base of the algal attachment to the rock. A single female spawned with a single male. The spawning act lasted for several seconds, but after several minutes of rest, additional spawning was resumed. These spawning events lasted for several hours. The highest number of eggs that we observed were 200 eggs from a single female. The male and female were both observed spawning with alternate partners. No territorial guarding of the spawn was provided by the male; rather, the male seemed to defend an area that provided the maximum opportunity for observation by potential mates in the choicest habitat.*

EGGS

Description
Etheostoma b. blennioides eggs from the upper Ohio River, OH, are spherical, average 1.8 mm diameter (range: 1.7–2.0 mm), translucent, demersal, and adhesive. Eggs possess translucent clear yolk (mean = 1.4 mm diameter; range: 1.1–1.5 mm); a single oil globule (mean = 0.3 mm); a moderate perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[6]

Ovarian examination showed that ovoid latent ova were as small as 0.43 mm, early maturing small spherical cream-colored ova averaged 0.9–1.07 mm, and large mature ova averaged 1.66–1.81 mm*.

Table 36

Fecundity data for greenside darter from Little River, Blount County, TN.*

			Percent Occurrence of Ova			
Date	TL	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
March 26	58	181	589	291	204	1.81
	85	773	412	301	207	1.66
	87	712	346	264	191	1.66
	87	597	331	276	195	1.57
	96	1060	589	291	204	1.81
March 27	91	963	435	340	173	1.81
	92	909	510	409	216	1.57
April 17	105	1420	520	426	252	1.66
April 19	94	976	571	271	217	1.61
	97	753	392	256	176	1.66

Etheostoma b. newmanii eggs from the Clinch River basin, Hinds Creek, TN, are spherical, average 2.1 mm in diameter (range: 2.0–2.2 mm), translucent, demersal, and adhesive. Eggs possess translucent pale yellow yolk (mean = 2.05 mm diameter; range: 2.0–2.1 mm); a single oil globule (mean = 0.5 mm); a narrow perivitelline space (mean = 0.05 mm); and an unsculptured and unpigmented chorion.[6]

Etheostoma b. pholidotum eggs have been reported to average 1.9 mm (range: 1.8–2.0 mm) in a tributary of Lake Ontario, NY.[10,17,26] Eggs from the Embarras River, Cumberland Co., IL, are spherical, average 1.7 mm in diameter (range: 1.5–2.0 mm), translucent, demersal, and adhesive. Eggs possess translucent clear yolk (mean = 1.6 mm diameter; range: 1.5–1.8 mm); a single oil globule (mean = 0.3 mm); a moderate perivitelline space (mean = 0.12 mm); and an unsculptured and unpigmented chorion.[6]

Incubation
Etheostoma b. blennioides hatching occurs after 432 h at an incubation temperature of 12.78–14.4°C.[26] *Etheostoma b. newmanii* hatching occurs after 408 h at an incubation temperature of 13–15°C.[18] *Etheostoma blennioides pholidotum* larvae hatch after 432 h at an incubation temperature of 12.78–14.4ºC; and after 408–480 h at 13–15ºC.[10,11,33]

Development
Embryonic development is described for *E. b.pholidotum* and *E. b. newmanii*.[10,18]

YOLK-SAC LARVAE

See Figures 32, 33, 35 and 36

Size Range
Etheostoma b blennioides populations from the Ohio River hatch between 5.3–5.7 mm and yolk is absorbed by 9.0 mm;[6] *Etheostoma b. newmanii* populations from Hinds Creek, TN, hatch between 5.7–6.4 mm and yolk is absorbed by 8.5–8.8 mm;[6] *E. b. pholidotum* populations from the Embarras River, IL, hatch between 5.3–5.9 mm and yolk is absorbed by 7.2–7.3 mm.[6]

Myomeres
Etheostoma b. blennioides, preanal 19 (2), 20 (1), 21 (1), 22 (3), 23 (2), or 24 (2) (*N* = 11, mean = 21.7); postanal 21 (1), 22 (2), 23 (6), or 24 (2) (*N* = 11, mean = 22.8); with total 41 (3), 43 (1), 45 (2), 46 (3), or 47 (2) (*N* = 11, mean = 44.4).[6]

Etheostoma b. newmanii, preanal 19 (21), 20 (21), 21 (24), 22 (4), or 23 (3) (*N* = 74, mean = 20.0); postanal 21 (1), 23 (15), 24 (35), 25 (22), or 26 (1) (*N* = 74, mean = 24.1); with total 42 (1), 43 (12), 44 (31), 45 (19), 46 (9), or 47 (1) (*N* = 74, mean = 43.7).[6]

Etheostoma b. pholidotum, preanal 18 (3), 19 (15), 20 (13), 21 (5), or 22 (1) (*N* = 37, mean = 19.6); postanal myomeres 22 (1), 23 (17), 24 (10), or 25 (9) (*N* = 37, mean = 23.7); with total 42 (9), 43 (13), 44 (10), 45 (3), or 46 (2) (*N* = 37, mean = 43.4).[6]

Morphology
Etheostoma b. blennioides.
5.3–5.7 mm TL. Newly hatched larva has a terate body; blunt snout; functional jaws, upper jaw even, extending slightly past lower jaw; yolk sac moderate (37.4% TL), oval to tapered posteriorly; yolk translucent pale yellow, with a single oil globule; vitelline vein plexus mid-ventrally on yolk sac; head not deflected over the yolk sac; eyes spherical.[6]

6.3–6.4 mm TL. Digestive system functions before complete yolk absorption (6.3 mm); premaxilla and mandible form (6.3–6.4 mm).[6]

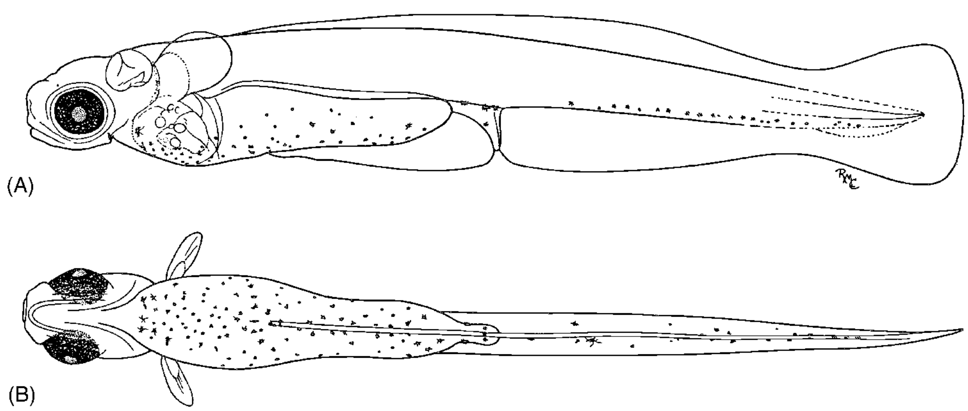

Figure 32 *Etheostoma b. blennioides*, eastern greenside darter, Ohio River, Jefferson County, OH. Yolk-sac larva, 6.5 mm TL: (A) lateral, (B) ventral views. (A–B from reference 6, with author's permission.)

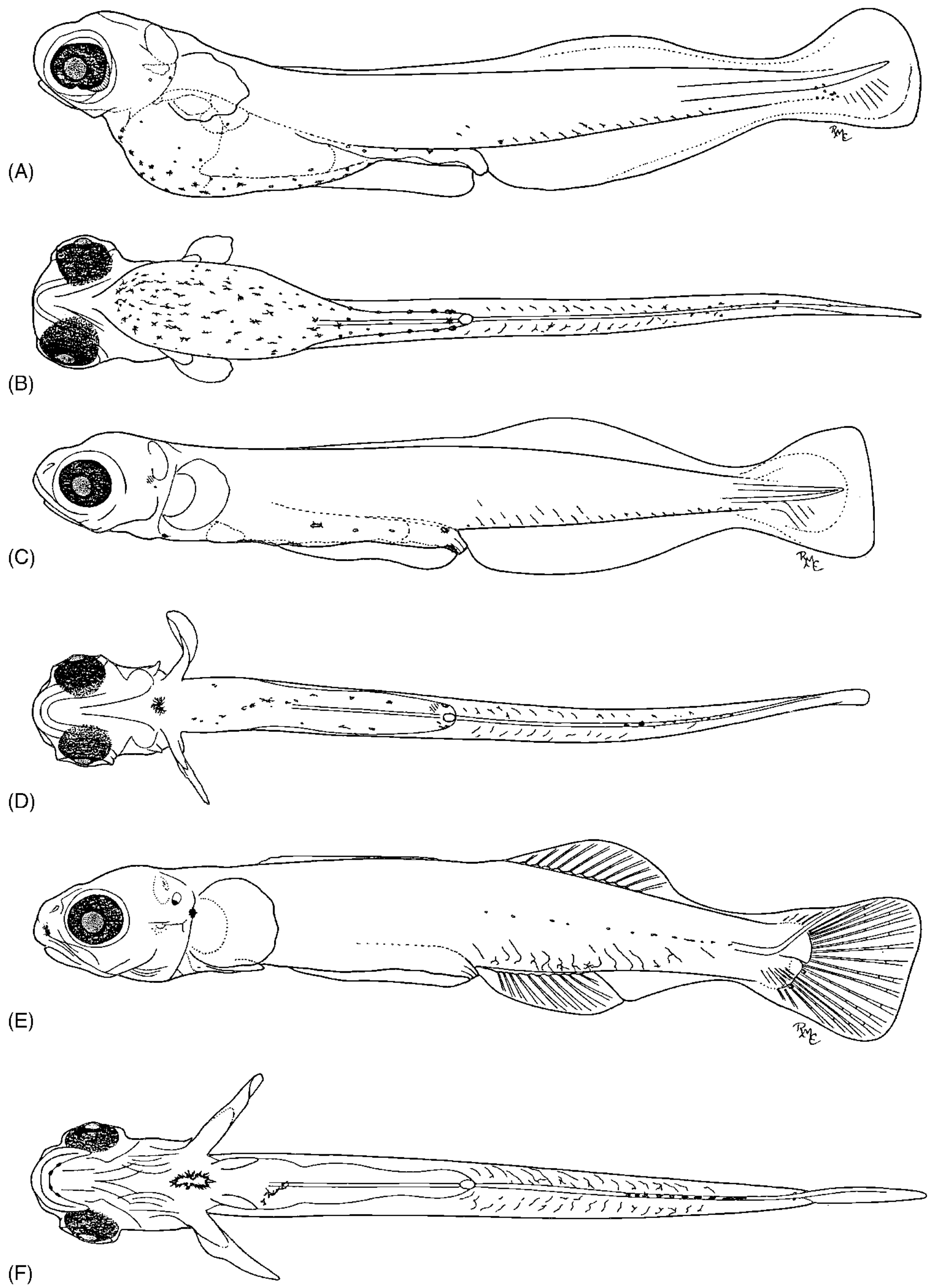

Figure 33 *Etheostoma b. newmanii*, Newman's greenside darter, Hinds Creek, Anderson County, TN: Yolk-sac larva, 7.7 mm TL (A) lateral, (B) ventral views; post yolk-sac larva, 9.7 mm TL, (C) lateral, (D) ventral views; and post yolk-sac larva, 13.9 mm TL (E) lateral, (F) ventral views. (A–F from reference 6, with author's permission.)

7.2 mm TL. Operculum and gill arches function.[6]

7.2–9.0 mm TL. No swim bladder forms; gut straight, without striations; gut posterior to stomach normal in length (7.2–9.0 mm).[6]

E. b. newmanii.

5.7–6.4 mm TL. Newly hatched larva has a terate body; blunt snout; terminal mouth, functional jaws, upper jaw even, extending slightly past lower jaw; yolk sac moderate (25.1% TL), oval to tapered posteriorly; yolk translucent pale yellow, with a single oil globule; vitelline vein plexus midventrally on yolk sac; head not deflected over the yolk sac; eyes spherical.[6]

5.7–7.7 mm TL. No swim bladder forms; gut straight, without striations, portion of gut posterior to stomach elongate, ca. 50% yolk sac length.[6]

7.6–8.3 mm TL. Digestive system functional prior to complete yolk absorption (7.6–8.3 mm).[6]

Etheostoma b. pholidotum.
5.3–5.9 mm TL. Newly hatched larvae have a terate body; blunt snout; functional jaws, upper jaw extending past lower jaw; yolk sac moderate (24.6% TL), tapered posteriorly; yolk translucent, pale yellow, with a single oil globule; vitelline vein plexus mid-ventrally on yolk sac; head not deflected over the yolk sac; eyes spherical.[6]

6.0–6.3 mm TL. Digestive system functions immediately before complete yolk absorption.[6]

6.3–6.4 mm TL. Premaxilla and mandible form.[6]

7.2 mm TL. Operculum and gill arches function.[6]

6.1–7.2 mm TL. No swim bladder forms; gut straight, without striations, portion of gut posterior to stomach short in length (6.1–7.4 mm).[6]

Morphometry
See Tables 37, 38, and 39.[6]

Fin Development
See Table 40.[6]

Etheostoma b. blennioides: 5.3–5.7 mm TL. Newly hatched larvae have well-developed pectoral fins without incipient rays.[6]

Etheostoma b. newmanii: 5.7–6.4 mm TL. Newly hatched larvae have well-developed pectoral fins without incipient rays.[6]

Etheostoma b. pholidotum: 5.3–5.9 mm TL. Newly hatched larvae have well-developed pectoral fins without incipient rays.[6]

Pigmentation
Etheostoma b. blennioides.

5.3–5.7 mm TL (*newly hatched*). Eye pigmented; no melanophores dorsally; few melanophores distributed laterally; a single melanophore typically present at otic capsule and dorsally over the gut. Ventral pigmentation consists of a midventral stripe of stellate melanophores outlining the vitelline vein on the yolk sac, and radiating melanophores along every mid-ventral postanal myosepta.[6]

6.0–7.5 mm TL. Resembles previous length interval, with the exception of ventral pigmentation; mid-ventral melanophores on the yolk sac decreasing.[6]

7.5–9.0 mm TL. A cluster of melanophores on the breast near the absorbed oil globule; anterior postanal myosepta pigmentation migrating to mid-lateral from mid-ventral myosepta.[6]

Etheostoma b. newmanii.
5.7 mm TL (*newly hatched*) *to 7.9 mm TL.* Eyes pigmented; no melanophores dorsally; several melanophores distributed laterally on the midoperculum; melanophores present dorsally over the gut and at base of ventral notochord tip. Ventral pigmentation includes a mid-ventral patch of stellate melanophores outlining the vitelline vein on the yolk sac, and radiating melanophores along every mid-ventral postanal myosepta.[6]

8.2–8.8 mm TL. Melanophores mostly absent, melanophores laterally along midpreanal sections of the stomach and gut. Mid-ventral melanophores on the breast and extending posteriorly along pelvic finfold.[6]

Etheostoma b. pholidotum.
5.3–5.9 mm TL (*newly hatched*). Eye pigmented; no melanophores dorsally; few melanophores distributed laterally; a typical single melanophore at otic capsule not present; stellate melanophores dorsally outline the gut. Ventral pigmentation extensive, stellate melanophores mid-ventrally outlining the vitelline vein on the yolk sac, and radiating melanophores along every mid-ventral postanal myosepta. Several stellate melanophores present at the ventral terminus of the notochord.[6]

6.0–6.8 mm TL. Predominantly resembles previous length interval with the exception of additional pigmentation over the gut.[6]

7.0–7.3 mm TL. A cluster of melanophores present on the operculum; laterally, a series of expanded melanophores outline the gut from the stomach posterior. Ventral melanophores clustering anterior breast extending posteriorly to the end of the stomach; anus with melanophores dorsally and ventrally; postanal myosepta pigmentation migrating to mid-lateral from mid-ventral myosepta with some pigmentation on the anal finfold.[6]

Table 37

Morphometry of Young *E. b. blennioides* grouped by selected intervals of total length (N = sample size).[6]

	Total Length (TL) Intervals (mm)									
	5.25–6.42 (N = 5)		7.23–7.47 (N = 2)		9.02–9.70 (N = 2)		14.3–14.7 (N = 2)		34.3 (N = 1)	
Characters	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean**	**Range**
Length (% of TL)										
Upper jaw[a]	19.7 ± 5.99	(0.12–0.24)	22.2	(0.24–0.24)	20.1 ± 3.68	(0.28–0.40)	31.4 ± 10.9	(0.70–1.18)		
Snout[a]	18.6 ± 3.90	(0.12–0.21)	23.7 ± 4.67	(0.22–0.27)	19.6 ± 1.27	(0.30–0.36)	19.4 ± 1.56	(0.54–0.62)	18.3	(1.30)
Eye diameter[a]	39.7 ± 3.85	(0.30–0.36)	36.6 ± 1.98	(0.38–0.38)	31.5 ± 2.12	(0.48–0.58)	31.1 ± 1.98	(0.88–0.98)	25.9	(1.84)
Head	14.1 ± 1.19	(0.72–0.90)	14.1 ± 0.42	(1.00–1.08)	17.9 ± 0.28	(1.60–1.76)	20.6 ± 0.00	(2.96–3.02)	20.8	(7.11)
Predorsal	24.2 ± 1.28	(1.26–1.68)	25.4 ± 0.42	(1.82–1.92)	27.0 ± 1.13	(2.36–2.70)	27.8 ± 1.70	(3.80–4.26)	25.2	(8.62)
Dorsal insertion							46.9 ± 2.83	(6.42–7.18)	50.3	(17.2)
D2 origin							53.0 ± 2.69	(7.32–8.07)	50.3	(17.2)
D2 insertion							72.6 ± 3.54	(7.32–8.07)	69.6	(17.2)
Preanal	52.1 ± 4.00	(2.39–3.54)	54.4 ± 2.01	(3.83–4.17)	55.0 ± 2.16	(4.82–5.48)	54.8 ± 1.55	(7.88–8.00)	53.8	(18.4)
Postanal	47.9 ± 4.09	(2.66–3.00)	45.6 ± 1.98	(3.30–3.40)	45.0 ± 2.12	(4.20–4.22)	45.2 ± 1.56	(6.32–6.80)	46.2	(15.8)
Standard	88.6 ± 16.2	(3.13–6.15)	95.6 ± 0.28	(6.93–7.13)	89.2 ± 0.85	(8.00–8.71)	87.7 ± 0.00	(12.6–12.9)	87.6	(30.0)
Yolk sac	37.4 ± 2.62	(2.08–2.48)	33.3 ± 0.99	(2.35–2.54)						
Fin length (% of TL)										
Pectoral	6.34 ± 2.75	(0.24–0.60)	3.67 ± 0.42	(0.24–0.30)	8.77 ± 0.42	(0.82–0.82)	13.9 ± 0.00	(2.00–2.04)	22.1	(7.57)
Pelvic					7.53 ± 1.84	(0.60–0.80)	8.47 ± 0.99	(1.12–1.34)	14.6	(5.00)
Spinous dorsal							19.1 ± 1.13	(2.62–2.92)	25.2	(8.62)
Soft dorsal							19.6 ± 0.85	(2.72–2.96)	19.3	(6.60)
Caudal	11.4 ± 16.2	(0.22–2.12)	4.35 ± 0.28	(0.30–0.34)	10.8 ± 0.85	(0.99–1.02)	12.3 ± 0.00	(1.76–1.80)	12.4	(4.25)
Body Depth (% of TL)										
Head at eyes	10.5 ± 0.89	(0.60–0.65)	10.1 ± 0.14	(0.72–0.76)	15.8 ± 0.28	(1.40–1.55)	13.2 ± 0.71	(1.82–2.02)	12.2	(4.18)
Head at P1	13.1 ± 0.64	(0.70–0.84)	10.5 ± 0.00	(0.76–0.78)	14.4 ± 0.14	(1.31–1.39)	14.6 ± 0.99	(2.00–2.25)	14.6	(5.00)
Preanal	6.90 ± 0.74	(0.38–0.43)	7.21 ± 0.00	(0.52–0.54)	10.8 ± 0.14	(0.96–1.06)	12.2 ± 0.85	(1.66–1.88)	12.3	(4.22)
Mid-postanal	5.35 ± 0.94	(0.26–0.36)	5.24 ± 0.14	(0.37–0.40)	7.12 ± 0.42	(0.66–0.67)	7.68	(1.10–1.10)	8.76	(3.00)
Caudal peduncle	2.85 ± 0.39	(0.16–0.18)	2.72 ± 0.00	(0.20–0.20)	6.20 ± 0.28	(0.58–0.58)	6.85 ± 0.85	(0.90–1.09)	6.42	(2.20)
Yolk Sac	8.26 ± 0.88	(0.41–0.55)	5.11 ± 0.42	(0.36–0.39)						
Body Width (% of TL)										
Head	74.3 ± 8.59	(0.52–0.72)	51.1 ± 6.93	(0.50–0.56)	78.8 ± 5.37	(1.32–1.32)	62.8 ± 4.81	(1.76–2.00)	56.3	(4.00)
Myomere Number										
Predorsal	5.00 ± 0.00	(5.00–5.00)	5.00 ± 0.00	(5.00–5.00)	5.50 ± 0.71	(5.00–6.00)	5.00 ± 0.00	(5.00–5.00)		
Soft dorsal					18.5 ± 0.71	(18.0–19.0)	19.0	(19.0–19.0)		
Preanal	22.6 ± 0.89	(22.0–24.0)	23.0 ± 1.41	(22.0–24.0)	19.0 ± 0.00	(19.0–19.0)	20.5 ± 0.71	(20.0–21.0)		
Postanal	23.2 ± 0.45	(23.0–24.0)	22.5 ± 0.71	(22.0–23.0)	23.0 ± 0.00	(23.0–23.0)	21.5 ± 0.71	(21.0–22.0)		
Total	45.8 ± 0.84	(45.0–47.0)	45.5 ± 0.71	(45.0–46.0)	41.0 ± 0.00	(41.0–41.0)	42.0 ± 1.41	(41.0–43.0)		

[a] Proportion expressed as percent head length.

Note: Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

Table 38

Morphometry of Young *E. b. newmanii* grouped by selected intervals of total length (*N* = sample size).[6]

	Total Length (TL) Intervals (mm)											
	5.74–7.90 (*N* = 40)		8.16–9.64 (*N* = 17)		10.5–12.0 (*N* = 14)		12.2–13.6 (*N* = 8)		14.2–17.5 (*N* = 4)		23.0 (*N* = 1)	
Characters	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean**	**Range**
Length (% of TL)												
Upper jaw[a]	30.5 ± 5.55	(0.20–0.48)	28.5 ± 4.40	(0.32–0.58)	26.2 ± 5.98	(0.38–0.76)	28.1 ± 3.40	(0.54–0.82)	27.1 ± 2.20	(0.73–1.06)	20.2	(1.04)
Snout[a]	13.2 ± 3.02	(0.08–0.22)	17.3 ± 2.84	(0.14–0.38)	18.4 ± 3.44	(0.24–0.50)	19.4 ± 1.50	(0.39–0.57)	22.0 ± 1.82	(0.60–0.86)	20.2	(1.04)
Eye diameter[a]	41.7 ± 4.54	(0.40–0.62)	36.3 ± 4.07	(0.52–0.78)	33.4 ± 1.48	(0.63–0.82)	33.0 ± 2.22	(0.70–0.82)	30.1 ± 2.38	(0.80–1.08)	27.9	(1.44)
Head	17.1 ± 1.22	(0.88–1.44)	18.4 ± 0.94	(1.34–1.88)	18.7 ± 0.93	(1.96–2.46)	18.8 ± 1.30	(2.04–2.67)	19.9 ± 1.14	(2.64–3.58)	22.4	(5.16)
Predorsal	26.8 ± 1.56	(1.52–2.40)	25.7 ± 1.69	(2.06–2.50)	25.7 ± 1.44	(2.74–3.40)	24.9 ± 2.38	(2.60–3.62)	26.0 ± 0.75	(3.68–4.40)	28.3	(6.52)
Dorsal insertion					26.3 ± 2.48	(2.74–3.88)	32.0 ± 11.8	(2.60–6.74)	45.0 ± 2.48	(6.00–7.80)	50.9	(11.7)
D2 origin					27.8 ± 7.81	(2.74–6.32)	35.1 ± 14.8	(2.60–7.20)	51.3 ± 2.69	(7.24–8.40)	53.2	(12.3)
D2 insertion					29.3 ± 13.4	(2.74–6.32)	42.7 ± 25.3	(2.60–7.20)	72.3 ± 2.49	(7.24–8.40)	72.9	(12.3)
Preanal	50.3 ± 1.20	(3.00–4.02)	51.0 ± 0.92	(4.06–5.04)	50.9 ± 1.99	(5.40–6.28)	49.9 ± 3.30	(5.40–6.95)	50.7 ± 1.50	(7.20–8.54)	48.3	(11.1)
Postanal	49.7 ± 1.14	(2.74–4.08)	49.3 ± 1.56	(4.06–4.96)	49.1 ± 2.01	(5.00–6.40)	48.9 ± 0.83	(5.86–6.62)	50.5 ± 2.85	(6.84–9.08)	51.7	(11.9)
Standard	97.0 ± 0.66	(5.62–7.67)	96.3 ± 1.40	(7.89–9.25)	92.1 ± 2.47	(9.90–11.4)	90.4 ± 2.02	(10.8–12.1)	86.9 ± 1.46	(12.4–14.8)	84.1	(19.4)
Yolk sac	25.1 ± 4.98	(0.50–2.23)										
Fin Length (% of TL)												
Pectoral	7.40 ± 1.14	(0.32–0.72)	9.51 ± 0.98	(0.64–1.06)	10.1 ± 1.17	(0.96–1.38)	11.0 ± 1.88	(1.05–1.76)	15.3 ± 2.85	(1.90–3.42)	24.5	(5.64)
Pelvic					3.38 ± 1.25	(0.23–0.59)	5.50 ± 2.16	(0.36–1.07)	10.4 ± 4.04	(1.04–2.84)	17.0	(3.92)
Spinous dorsal					8.61	(1.00–1.00)	19.0 ± 10.0	(1.00–3.40)	19.0 ± 2.40	(2.22–3.40)	22.6	(5.20)
Soft dorsal					21.0	(2.44–2.44)	20.2 ± 2.12	(2.44–2.92)	21.0 ± 0.77	(2.84–3.72)	19.7	(4.54)
Caudal	3.05 ± 0.66	(0.11–0.40)	3.72 ± 1.40	(0.08–0.74)	7.92 ± 2.47	(0.47–1.42)	9.64 ± 2.02	(0.70–1.48)	13.1 ± 1.46	(1.74–2.68)	15.9	(3.66)
Body Depth (% of TL)												
Head at eyes	13.4 ± 1.25	(0.73–1.30)	13.7 ± 0.74	(1.08–1.41)	12.8 ± 0.95	(1.32–1.52)	12.9 ± 0.74	(1.54–1.85)	12.6 ± 0.57	(1.73–2.35)	13.4	(3.08)
Head at P1	16.6 ± 1.95	(0.78–1.39)	12.8 ± 0.79	(0.95–1.35)	12.5 ± 0.55	(1.30–1.50)	13.9 ± 1.56	(1.63–2.19)	14.4 ± 0.65	(1.98–2.66)	15.5	(3.58)
Preanal	8.72 ± 0.79	(0.46–0.82)	9.62 ± 0.91	(0.64–1.12)	11.2 ± 0.90	(1.14–1.48)	13.0 ± 0.68	(1.54–1.82)	13.2 ± 0.39	(1.88–2.24)	12.5	(2.89)
Mid-postanal	6.45 ± 0.53	(0.33–0.56)	7.19 ± 0.62	(0.51–0.79)	8.31 ± 0.67	(0.86–1.06)	9.04 ± 0.37	(1.12–1.24)	8.95 ± 0.14	(1.24–1.58)	7.77	(1.79)
Caudal peduncle	3.06 ± 0.35	(0.16–0.29)	4.01 ± 0.65	(0.28–0.52)	2.50 ± 2.92	(0.40–0.74)	3.71 ± 4.29	(0.86–1.04)	7.27 ± 0.35	(1.00–1.26)	6.77	(1.56)
Yolk sac	11.8 ± 2.50	(0.40–1.14)										
Body Width (% of TL)												
Head	75.9 ± 6.15	(0.70–1.06)	68.9 ± 4.65	(0.98–1.28)	60.9 ± 3.92	(1.12–1.36)	66.0 ± 4.58	(1.50–1.82)	62.5 ± 1.01	(1.68–2.26)	62.4	(3.22)
Myomere Number												
Predorsal	5.10 ± 0.38	(4.00–6.00)	5.24 ± 0.44	(5.00–6.00)	5.00 ± 0.00	(5.00–5.00)	5.13 ± 0.35	(5.00–6.00)	5.00 ± 0.00	(5.00–5.00)	5.00	(5.00)
Soft dorsal			22.0 ± 0.00	(22.0–22.0)	22.1 ± 0.32	(22.0–23.0)	22.1 ± 0.38	(22.0–23.0)	22.3 ± 0.55	(22.0–23.0)	22.0	(22.0)
Preanal	19.7 ± 0.76	(19.0–21.0)	20.6 ± 0.93	(19.0–23.0)	21.5 ± 0.65	(20.0–22.0)	21.8 ± 0.75	(21.0–23.0)	21.5 ± 1.29	(20.0–23.0)	21.0	(21.0)
Postanal	24.4 ± 0.71	(23.0–26.0)	23.8 ± 0.64	(23.0–25.0)	23.9 ± 0.54	(23.0–25.0)	23.9 ± 0.64	(23.0–25.0)	23.0 ± 1.41	(21.0–24.0)	24.0	(24.0)
Total	44.1 ± 0.92	(42.0–46.0)	44.5 ± 1.07	(43.0–47.0)	45.4 ± 0.84	(44.0–46.0)	45.6 ± 0.74	(44.0–46.0)	44.5 ± 1.00	(44.0–46.0)	45.0	(45.0)

[a] Proportion expressed as percent head length.

Note: Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

Table 39

Morphometry of Young *E. b. pholidotum* grouped by selected intervals of total length (N = sample size).

	Total Length (TL) Intervals (mm)					
	5.06–6.86 (N = 32)		7.00–7.56 (N = 11)		34.4–36.5 (N = 2)	
Characters	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
Length (% of TL)						
Upper jaw[a]	28.1 ± 5.88	(0.14–0.46)	28.6 ± 6.30	(0.24–0.52)	17.9 ± 2.83	(1.18–1.24)
Snout[a]	14.3 ± 3.13	(0.10–0.22)	14.9 ± 2.56	(0.14–0.26)	23.5 ± 1.98	(1.56–1.64)
Eye diameter[a]	40.2 ± 5.41	(0.32–0.58)	37.8 ± 2.89	(0.40–0.55)	27.4 ± 2.55	(1.82–1.90)
Head	17.9 ± 1.66	(0.88–1.42)	17.6 ± 2.02	(1.00–1.62)	19.3 ± 1.56	(6.25–7.42)
Predorsal	27.4 ± 2.97	(1.16–2.20)	26.3 ± 2.20	(1.62–2.22)	26.4 ± 1.13	(8.80–9.95)
Dorsal insertion					49.5 ± 0.99	(17.2–17.8)
D2 origin					51.0 ± 0.85	(17.3–18.8)
D2 insertion					73.6 ± 0.99	(17.3–18.8)
Preanal	50.2 ± 1.75	(2.56–3.51)	49.1 ± 3.01	(3.20–3.91)	49.0 ± 2.45	(17.3–17.4)
Postanal	49.8 ± 1.74	(2.48–3.50)	49.7 ± 3.08	(3.22–4.08)	51.0 ± 2.40	(16.9–19.3)
Standard	96.2 ± 1.55	(4.86–6.65)	94.3 ± 5.67	(6.03–7.37)	82.6 ± 3.96	(29.1–29.4)
Yolk sac	24.6 ± 6.95	(0.38–2.00)	19.1 ± 8.38	(0.46–2.00)		
Fin Length (% of TL)						
Pectoral	7.54 ± 1.44	(0.28–0.64)	7.11 ± 0.87	(0.46–0.66)	19.1 ± 0.85	(6.76–6.76)
Pelvic					16.7 ± 0.00	(5.73–6.10)
Spinous dorsal					23.1 ± 2.12	(7.88–8.44)
Soft dorsal					22.6 ± 0.14	(7.75–8.30)
Caudal	3.76 ± 1.55	(0.14–0.58)	5.74 ± 5.67	(0.16–1.30)	17.4 ± 3.96	(5.00–7.36)
Body Depth (% of TL)						
Head at eyes	14.6 ± 0.94	(0.72–1.06)	13.3 ± 1.64	(0.72–1.15)	13.4 ± 1.13	(4.60–4.86)
Head at P1	15.5 ± 2.78	(0.74–1.36)	12.8 ± 1.16	(0.84–1.03)	13.3 ± 1.70	(4.40–5.00)
Preanal	7.74 ± 0.82	(0.38–0.64)	7.50 ± 1.15	(0.38–0.65)	12.3 ± 0.14	(4.18–4.54)
Mid-postanal	5.83 ± 0.64	(0.29–0.48)	5.46 ± 0.80	(0.26–0.49)	9.43 ± 1.13	(2.95–3.75)
Caudal peduncle	2.85 ± 0.39	(0.12–0.24)	2.71 ± 0.61	(0.14–0.25)	6.41 ± 1.27	(2.00–2.52)
Yolk sac	10.8 ± 4.38	(0.30–1.04)	7.50 ± 2.76	(0.26–0.83)		
Body Width (% of TL)						
Head	73.1 ± 6.28	(0.64–0.98)	73.4 ± 6.36	(0.68–1.08)	57.0 ± 14.0	(3.49–4.18)
Myomere Number						
Predorsal	4.03 ± 0.18	(4.00–5.00)	4.09 ± 0.30	(4.00–5.00)		
Soft dorsal						
Preanal	19.5 ± 0.84	(18.0–21.0)	19.9 ± 1.14	(18.0–22.0)		
Postanal	23.8 ± 0.75	(23.0–25.0)	23.7 ± 1.01	(22.0–25.0)		
Total	43.3 ± 0.93	(42.0–45.0)	43.6 ± 1.50	(42.0–46.0)		

[a] Proportion expressed as percent head length.

Note: Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

Table 40

Meristic counts and size (mm TL) at the apparent onset of development for *E. blennioides.*[6]

Attribute/event	*Etheostoma b. blennioides*	*Etheostoma b. newmanii*	*Etheostoma b. pholidotum*
Branchiostegal Rays	5,5	6,6	6,6
Dorsal Fin Spines/Rays	X−XII/10−13	XI-XIV/12−14	XIII−XIV/12−14
First spines formed	8.4−9.0	12.4−12.9	8.0
Adult complement formed	9.3−9.8	13.0−17.5	<34.7
First soft rays formed	6.7−7.2	11.2	>8.0
Adult complement formed	8.5−9.0	11.3−17.5	<34.7
Pectoral Fin Rays	15	15	15
First rays formed	8.4	11.8–12.9	8.0
Adult complement formed	8.4	12.9–14.3	<34.7
Pelvic Fin Spines/Rays	I/5	I/5	I/5
First rays formed	8.5−9.6	11.6	>8.0
Adult complement formed	8.5−9.6	11.6	<34.7
Anal Fin Spines/Rays	II/7−9	II/9	II/9
First rays formed	7.7−8.4	11.2	> 8.0
Adult complement formed	8.4−9.0	12.9–14.2	<34.7
Caudal Fin Rays	vii−xi, 8 + 7, viii−xi	viii–ix, 7–8 + 7–8, viii–xi	viii–ix, 7–8 + 7−8, viii–xi
First rays formed	6.4−7.2	10.5−11.3	8.0
Adult complement formed	8.4−9.0	12.9−17.5	<34.7
Lateral Line Scales	47−61	59−86	59−66
Myomeres/Vertebrae	38−40/38−39	42−47/44	44−44
Preanal myomeres	15−18	19–23	18–22
Postanal myomeres	22−23	21−26	22−25

POST YOLK-SAC LARVAE

See Figures 33–36

Size Range

Etheostoma b. blennioides populations from the Ohio River ranged from 9.0 to 14.7 mm;[6] *E. b. newmanii* populations from Hinds Creek, TN, ranged from 8.5 to 14.3 mm;[6] *E. b. pholidotum* populations from the Embarras River, IL, ranged between 7.3 mm and unknown length.[6]

Myomeres

Etheostoma b. blennioides preanal 19 (2), 20 (1), 21 (1), 22 (3), 23 (2), or 24 (2) in Ohio (*N* = 11, mean = 21.7); postanal 21 (1), 22 (2), 23 (6), or 24 (2) (*N* = 11, mean = 22.8); with total 41 (3), 43 (1), 45 (2), 46 (3), or 47 (2) (*N* = 11, mean = 44.4).[6]

Etheostoma b. newmanii, preanal 19 (21), 20 (21), 21 (24), 22 (4), or 23 (3) (*N* = 74, mean = 20.0); postanal 21 (1), 23 (15), 24 (35), 25 (22), or 26 (1) (*N* = 74, mean = 24.1); with total 42 (1), 43 (12), 44 (31), 45 (19), 46 (9), or 47 (1) (*N* = 74, mean = 43.7).[6]

Etheostoma b. pholidotum, preanal 18 (3), 19 (15), 20 (13), 21 (5), or 22 (1) (*N* = 37, mean = 19.6); postanal 22 (1), 23 (17), 24 (10), or 25 (9) (*N* = 37, mean = 23.7); with total 42 (9), 43 (13), 44 (10), 45 (3), or 46 (2) (*N* = 37, mean = 43.4).[6]

Morphology

Etheostoma b. blennioides: *9.0 mm TL.* Neuromast development occurs mid-laterally from the anterior trunk posteriad; yolk absorbed;[7] notochord flexion occurs.[6]

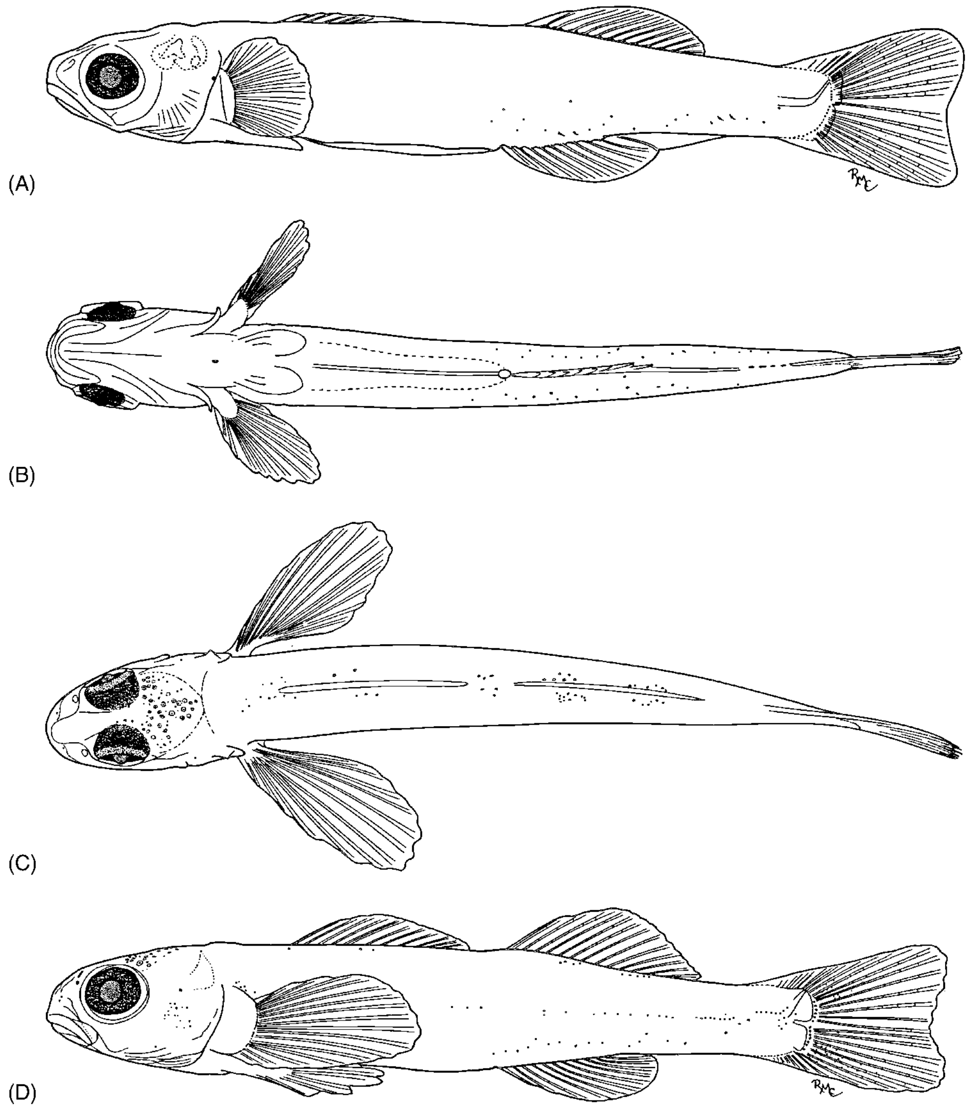

Figure 34 *Etheostoma b. newmanii*, Newman's greenside darter, Hinds Creek, Anderson County, TN: post yolk-sac larva, 16.2 mm TL (A) lateral, (B) ventral views; juvenile, 19.0 mm TL, (C) lateral, (D) ventral views. (A–D from reference 6, with author's permission.)

14.3 mm TL. Upper jaw equal with lower jaw, becoming subterminal; lateral line begins forming.[6]

14.7 mm TL. Supraorbital, infraorbital, lateral, and subtemporal head canals form (14.7 mm).[6]

Etheostoma b. newmanii: 8.5–8.8 mm TL. Yolk absorbed by 8.5–8.8 mm; premaxilla and mandible form (8.8 mm).[6]

8.9–9.5 mm TL. Neuromast development occurs midlaterally from the anterior trunk posteriad (8.9–9.3 mm); branchiostegal rays form (9.0 mm); notochord flexion (8.9–9.5 mm).[6]

9.7 mm TL. Operculum and gill arches functional.[6]

13.9 mm TL. Lateral line begins forming.[6]

14.3 mm TL. Upper jaw equal with lower jaw, becoming subterminal.[6]

Etheostoma b. pholidotum: 7.2–7.3 mm TL. Yolk absorbed.[6]

Morphometry
See Table 37, 38, 39.[6]

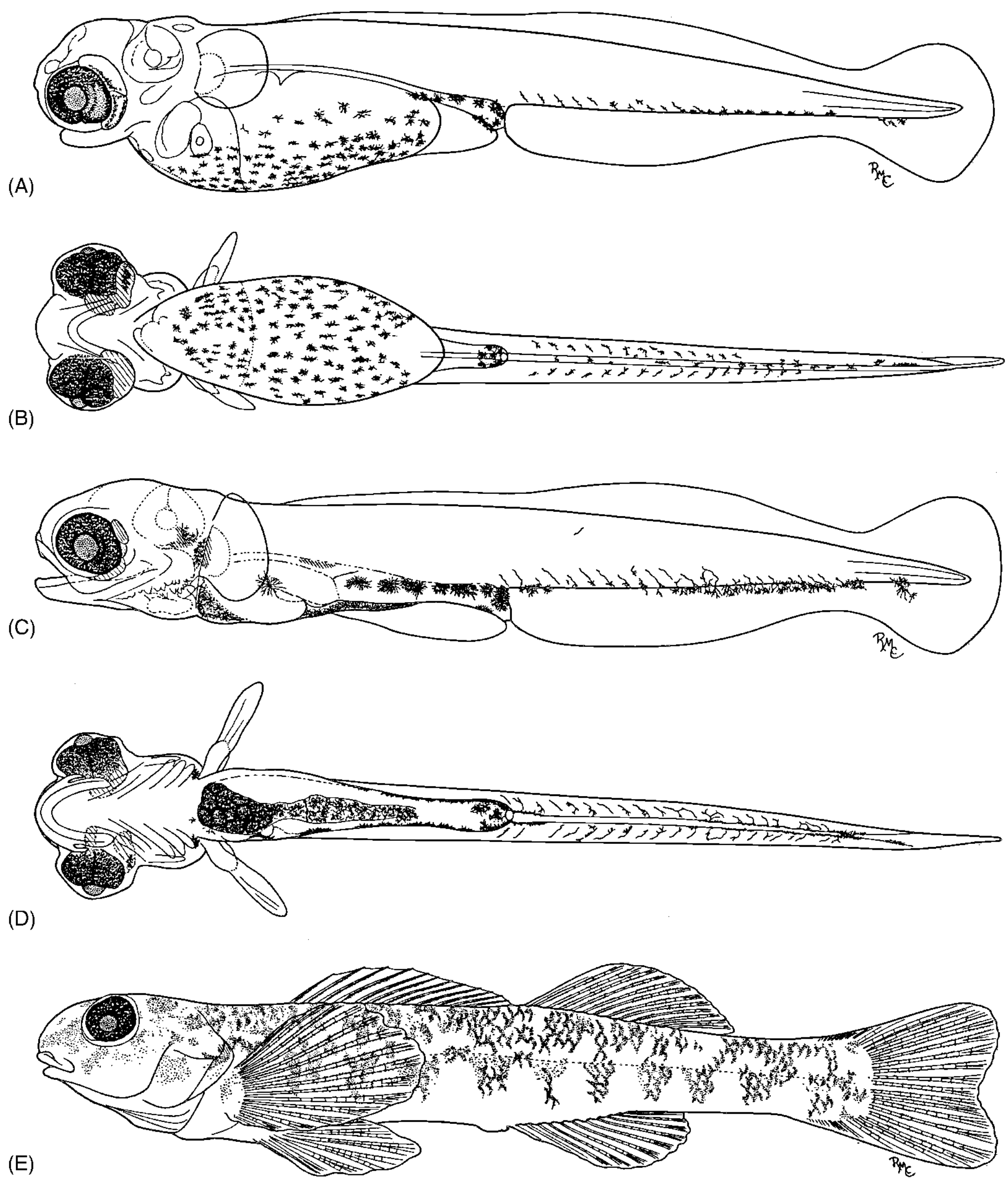

Figure 35 *Etheostoma b. pholidotum*, Central greenside darter, Embarras River, Cumberland County, IL: Yolk-sac larva, 6.1 mm TL: (A) lateral, (B) ventral views; Post yolk-sac larva, Salmon Creek, tributary Lake Ontario, NY, 6.5 mm TL, (C) lateral, (D) ventral views; and (E) lateral view juvenile, 34.7 mm TL, Embarras River, IL. (A–E from reference 6, with author's permission.)

Fin Development
See Table 40.[6]

Etheostoma b. blennioides:
9.0–9.7 mm TL. First rays form simultaneously in all median and paired fins including branchiostegal rays (9.0 mm); caudal fin ray develops (9.0 mm).[6] Pelvic fin buds form anterior to dorsal fin origin after complete yolk absorption (9.0–9.7 mm).[6]

>9.7 mm TL. Dorsal and anal finfold partially differentiated (>9.7 mm).[6]

14.3 mm TL. Dorsal and anal finfold completely differentiated; first pelvic fin ray forms and caudal fin truncate.[6]

9.0–14.3 mm TL. Spinous dorsal fin origin situated over preanal myomere 5–6, soft dorsal origin over preanal myomere 18–19 (9.0–14.3 mm). Average predorsal length 28.6% SL (range: 27.3–31.6% SL), 25.6% TL (range: 24.2–27.8% TL).[6]

14.3–14.7 mm TL. Complete adult fin ray counts in median fins.[6]

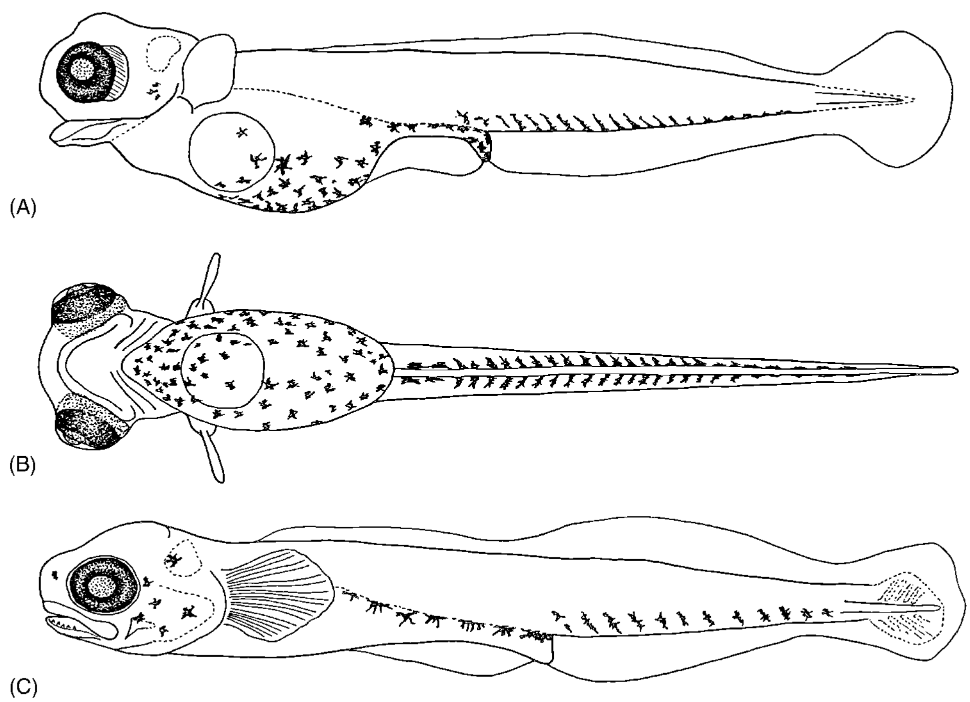

Figure 36 *Etheostoma b. pholidotum*, central greenside darter: (A,B) yolk sac larva, 6.5 mm TL, Salmon Creek tributary Lake Ontario, NY, lateral and ventral views; and (C) Larva, 8.0 mm TL, Salmon Creek, NY, lateral view. (A–C redrawn from reference 10.)

Etheostoma b. newmanii: 8.9–9.5 mm TL. Caudal fin ray development.[6]

9.7 mm TL. Caudal fin truncate.[6]

9.1–11.2 mm TL. Dorsal and anal finfold partially differentiate (9.1–11.2 mm).[6]

10.5–11.3 mm TL. First rays form in caudal fin (10.5–11.3 mm) and simultaneously in the soft dorsal and anal fins (11.2 mm); pelvic fin buds form anterior to dorsal fin origin after complete yolk absorption (11.2–11.3 mm).[6]

11.6 mm TL. First pelvic fin ray forms (11.6 mm).[6]

11.8–12.9 mm TL. Pectoral fin rays (11.8–12.9 mm) and spinous dorsal rays (12.4–12.9 mm) form.[6]

12.9 mm TL. Both dorsal and anal finfold completely differentiated (12.9 mm).[6]

13.9 mm TL. Lateral line begins forming.[6]

8.9–14.3 mm TL. Spinous dorsal fin origin situated over preanal myomere 4–6, soft dorsal origin over preanal myomere 22–23 (8.9–14.3 mm). Average predorsal length 27.6% SL (range: 27.5–33.6% SL), 26.2% TL (range: 24.9–28.3% TL).[6]

16.2 mm TL. Caudal fin becomes emarginated.[6]

Etheostoma b. pholidotum:
7.4 mm TL. Spinous dorsal fin origin situated over preanal myomere 4–5, soft dorsal origin over preanal myomere 18–19.[6]

8.0 mm TL. Pectoral and caudal fin rays form simultaneously[6].

>8.0 mm TL. Average predorsal length 28.5% SL (range: 23.9–32.0% SL), 27.1% TL (range: 26.3–27.4% TL). No further description of developmental events is possible since larval material was not available. Neuromast development; formation of fin rays in median and paired fins, including the branchiostegal rays; notochord flexion; dorsal and anal finfold differentiation occurred at lengths >8.0 mm).[6]

Pigmentation

Etheostoma b. blennioides: *9.7–14.3 mm TL.* Dorsum of cranium with pigmentation outlining the brain, ventrum of chin, and future postorbital position on the operculum; melanophores outline operculum and center of the breast; a lateral expanded cluster of melanophores extends dorsally over the gut; a lateral stripe extends along the midline from the pectoral fin to the caudal peduncle base; a second hypaxial stripe of punctate melanophores extends from the anus to the upturned notochord at each myoseptum; ventral pigment includes melanophores along anal fin; lepidiotrichia interdigitation with pterigiophores.[6]

Etheostoma b. newmanii:
10.3–13.9 mm TL. A cluster of ventral melanophores outlines the chin, and is present in the throat region and posterior pelvic fin buds; laterally, melanophores are variable, sometimes outlining the dorsum of the gut, always radiating along hypaxial postanal myosepta, and forming a mid-lateral stripe from the soft dorsal to midcaudal peduncle; ventral half of caudal peduncle base has several melanophores; several melanophores from anal fin insertion to midcaudal peduncle base.[6]

14.2–14.3 mm TL. No cranial pigmentation on dorsum; melanophores laterally outlining the hypaxial musculature from the anus to the midcaudal peduncle; a single melanophore on the breast.[6]

Etheostoma b. pholidotum: 8.0 mm TL. Cranial pigmentation laterally with a single melanophore on the preorbital and several stellate melanophores postorbitally on the cheek and operculum, and outlining the opercular margin; lateral melanophores concentrated along the midline from the pectoral fin to the caudal peduncle base; and occurring dorsally over the stomach and gut. Ventrally, radiating melanophores extending to the midline from each hypaxial postanal myosepta.[6]

JUVENILES

See Figures 34 and 35

Size Range
Etheostoma b. blennioides populations from the Ohio River ranged from 14.7 to 37.8 mm;[6] *E. b. newmanii* populations from Hinds Creek, TN; ranged from 14.3 to 45 mm;[6] *E. b. pholidotum* populations from the Embarras River, IL, were considered juveniles until 45 mm.[6]

Fin Development
Spinous dorsal fin X–XIII; soft dorsal rays 11–13; pectoral rays 12–15; anal fin rays II 6–9; pelvic fin rays I 5; caudal fin rays 16–17.[2–5]

Morphology
Etheostoma b. blennioides:
>14.7 mm TL. Infraorbital, lateral, and supratemporal head canals complete; preoperculomandibular canal complete with 10 pores: infraorbital pores 8.[3] Initiation of squamation.[6]

34.4 mm TL. Squamation complete; cheek, breast, nape, and opercle scaled; and belly scales variable, either partially naked or completely scaled.[2,3,8] Total vertebrae count 44 (N = 1), including one urostylar element. Scales in the lateral series ranging from 56 to 78 in the Ohio River, 60–71 in the upper Genessee River, and 63–72 in the Potomac River.[8] Fin ray meristics and length at appearance are included in Table 40.[6]

Etheostoma b. newmanii:
14.2–14.3 mm TL. Complete adult fin ray counts in median fins.[6]

14.7 mm TL. Supraorbital, infraorbital, lateral, and subtemporal head canals form.[6]

>19.0 mm TL. Initiation of squamation.[6]

23.0 mm TL. Squamation complete.[6]

25.9 mm TL. Infraorbital, lateral, and supratemporal head canals complete; preoperclomandibular canal complete with 10 pores; infraorbital pores, 8. Cheek, breast, nape, opercle, and belly completely scaled.[2,3,8] Total vertebrae count 44 (N = 1), including one urostylar element. Scales in the lateral series ranging from 59 to 86 in the Tennessee River and 61–86 in the Cumberland River. Fin ray meristics and length at appearance are included in Table 40.[6]

Etheostoma b. pholidotum:
34.4–36.5 mm TL. Upper jaw overhangs lower jaw, subterminal; pelvic fin rays formed, caudal fin emarginate; lateral line formed, complete; complete adult fin ray counts in median and paired fins; supraorbital, infraorbital, lateral, and subtemporal head canals formed; infraorbital, lateral, and supratemporal head canals complete; preoperculomandibular canal complete with 10 pores; infraorbital pores 8.[6] Squamation complete; cheek, breast, opercle, nape, and belly completely scaled.[2,3,8]

Total vertebrae count 44 (N = 1), including one urostylar element.[6] Scales in the lateral series ranging from 51 to 71 in the Missouri, and 51–67 in the Wabash-Great Lakes.[8] Fin ray meristics and length at appearance are included in Table 40.

Morphometry
See Tables 37–39.[6]

Pigmentation

Etheostoma b. blennioides:

14.7 mm TL. Similar to previous length interval with the exception of the mid-lateral melanophore stripe contracting from the anus to midcaudal peduncle; the second hypaxial line of pigment accumulates just above the mid-ventral melanophores of the anal fin; lepidiotrichia interdigitation with the pterigiophores.[6]

34.3 mm TL. Preorbital and suborbital bars form; melanophores concentrated on the dorsum of the cranium and ventral portion of operculum; a melanophore patch on the pectoral fin base; dorsally, 4–7 dorsal saddles across the back from the nape to caudal peduncle base; mid-laterally concentrated, 4–10, U- or W-shaped clusters of melanophores. Scattered melanophores forming either a proximal or median stripe in the spinous dorsal; 2–3 concentric stripes in the soft dorsal; 3–4 concentric stripes of lightly scattered melanophores in the pectoral fins; and 3–4 vertical stripes in the caudal fin. The pelvic and anal fins are unpigmented.[6]

Etheostoma b. newmanii:

14.7–18.1 mm TL. No cranial pigmentation on dorsum; melanophores laterally outlining the hypaxial musculature from the anus to the midcaudal peduncle; a single melanophore on the breast.[6]

19.0–19.3 mm TL. Cranial melanophores concentrate dorsally over the optic lobe and cerebellum; laterally on the ventral half of the operculum. Dorsum of body with 5–6 clusters of melanophores, anterior spinous dorsal fin origin, mid-spinous dorsal, between the gap of the spinous and soft dorsal fins, immediate posterior soft dorsal fin origin, and just anterior the soft dorsal fin insertion, and at the caudal peduncle base. Lateral pigmentation consists of a single mid-lateral stripe from mid-preanal to the beginning of the upturned notochord; a second line of hypaxial melanophores accumulates from the anus to the anal fin insertion obliquely rising towards the mid-lateral; and a vertical stripe of melanophores is present at the caudal peduncle base.[6]

25.9 mm TL. Preorbital bar well developed, but postorbital bar consists of only a few melanophores; the ventral portion of the operculum possesses a chevron-shaped cluster of melanophores; dorsum of cranium with two distinct patches of melanophores over the optic lobe and cerebellum; dorsum of body with six dorsal saddles; mid-laterally, a series of melanophores forming 7–8 U-shaped clusters; and a series of vertical hypaxial melanophores at the caudal peduncle base. The spinous dorsal fin has a single median and distal stripe of melanophores; soft dorsal membranes stippled near the base, becoming less concentrated distally; caudal fin with 3–4 concentric vertical stripes of pigment; pectoral fins with 4–6 vertical stripes of melanophores; anal and pelvic fins slightly pigmented proximally.[6]

Etheostoma b. pholidotum:

34.4–36.5 mm TL. Preorbital and suborbital bars formed; melanophores concentrated on the dorsum of the cranium and ventral portion of operculum; a melanophore patch on the pectoral fin base, dorsally forming a wavy pattern across the back from the nape to caudal peduncle base; eight mid-laterally concentrated U- or W-shaped clusters of melanophores. Scattered melanophores forming a median to distal stripe in the spinous dorsal; 2–3 concentric stripes in the soft dorsal; lightly scattered melanophores in the pectoral fins; and 4 vertical stripes in the caudal fin. The pelvic and anal fins unpigmented.[6]

TAXONOMIC DIAGNOSIS OF YOUNG GREENSIDE DARTER

Similar species: members of subgenus *Etheostoma*.

Adult. The *E. blennioides* species consists of nine populations, which have been divided into four subspecies.[8] The four subspecies include: *E. b. pholidotum* with two races, one in the Missouri and another in the Wabash-Great Lakes; *E. b. blennioides* with three races in the Upper Ohio, Potomac and Upper Genesee Rivers; *E. b. newmanii* with two races in the Tennessee and Cumberland Rivers; and *E. b. gutselli* with two races in the upper Little Tennessee and upper Pigeon Rivers.[6]

The four subspecies differ in meristic, squamation, and morphological characters.[8] *Etheostoma b. pholidotum* is distinguished by an average of 58.6–61.8 lateral line scales; 8.0–8.4 anal fin rays; 12.9 dorsal spines; 12.9–13.0 dorsal soft rays; 14.6–14.8 pectoral fin rays; 7.1–7.4 lateral blotches; lip tip either absent or tip short; completely scaled belly and opercle; bluntly rounded snout, rarely overhung; head shape narrow, snout not swollen.

Etheostoma b. blennioides possesses 65.4 lateral line scales; 8.0 anal fin rays; 13.0 dorsal spines; 12.9 dorsal soft rays; 14.6 pectoral fin rays; 7.1–7.7 lateral blotches; lip tip short; small naked area or completely scaled belly and opercles; bluntly rounded or rounded snout, rarely overhung; head shape narrow, snout not swollen.

Etheostoma b. newmanii has 70.7–77.4 lateral line scales; 8.0–8.1 anal fin rays; 13.1–13.9 dorsal spines; 13.1–13.4 dorsal soft rays; 14.8 pectoral fin rays; 7.3 lateral blotches; lip tip long; completely scaled belly and opercles; long rounded to rounded snout, usually overhung; head shape flattened, snout swollen, cheeks bulged to narrow with a normal snout.

Etheostoma b. gutselli is distinguished by 56.8 lateral line scales; 7.9 anal fin rays; 12.8 dorsal spines; 14.1 dorsal soft rays; 15.0 pectoral fin rays; 8.4 lateral blotches; lip tip absent with a distinct frenum; naked belly and opercles; long rounded snout, never overhung; head shape narrow, with a long snout that is not swollen.

Larva. The *E. blennioides* sp. complex includes four subspecies. Three subspecies are investigated for similarities in meristic, morphometric, and pigmentary characteristics and include *E. b. blennioides*, upper Ohio River race; *E. b. newmanii*, Tennessee River race; and *E. b. pholidotum*, the Wabash-Great Lakes races. The features of each subspecies are consistent with the subspecies recognition data provided by Miller.[8] Subspecies *E. b. pholidotum* and *E. b. newmanii* are most similar in myomere counts, possessing low preanal and high postanal counts, while subspecies *E. b. blennioides* has equal preanal and postanal myomeres. All three subspecies have similar pigment in yolk-sac larvae, with the exception of *E. b. pholidotum,* which does not have a postorbital melanophore. *Etheostoma b. pholidotum* also differs in larval pigmentation, with extreme amounts of melanophores clustered on the breast. Developmental series of larval *E. b. blennioides* and *E. b. newmanii* suggest that some differences in ontogenic sequences exist in egg diameter, hatching length, and absorption of the yolk sac, and minor differences in meristic characters.[6]

*Variation***.** Specimens from the upper Ohio River possess equal preanal (19–24) and postanal myomeres. Both *E. b. blennioides* and *E. b. newmanii* possess a postorbital melanophore while *E. b. pholidotum* does not. The Tennessee River race of *E. b. newmanii* possesses lower preanal (average 20) and higher postanal (average 24) myomeres than the other recognized subspecies. No differences are observed between larval specimens from Hinds and Bull Creeks in morphometric or meristic characteristics. The upper Wabash River race of *E. b. pholidotum* possess lower preanal (average 19.6) than postanal (23.7) myomeres. It is most similar in myomere counts to the Tennessee River race of *E. b. newmanii*. Pigmentation at postyolk absorbed stages is significantly more extensive on the breast than in either of the other two subspecies. This subspecies does not possess a postorbital melanophore, as do *E. b. newmanii* and *E. b. blennioides*.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 37)

Eggs. Etheostoma b. blennioides spawning sites are riffle habitats typically occurring over algal mats of *D. exannulatus* and *C. glomerata,*[5] or over sand substrates in slight to moderate current.[16] *Etheostoma b. newmanii* spawning sites include a pool with bedrock overlain with gravel and rubble substrates immediately downstream of a shallow bedrock riffle covered with patches of filamentous algal mats.[4,18] *Etheostoma b. pholidotum* spawns in the swiftest portions of riffle habitats, typically over algal mats of *Cladophora* sp. attached to the upper surface or sides of rocks, or the surface of sheets of bedrock in the riffle sections of streams.[6]

Yolk-sac larvae. Aquarium observations indicate that all greenside darter larvae are pelagic immediately after hatching.[8]

Post yolk-sac larvae. Etheostoma b. blennioides and *E. b. newmanii* larvae become demersal at lengths >14.3 mm; remaining in close association with the substrate. In the Ohio River, between ORM 53.9 and 494, larvae are collected from late April until early June from night plankton net and day beach seining. Maximum densities of eastern greenside darters collected in late May, 1987,[27] were 0.05 darters per cubic meter but were typically less than 0.010 darters per cubic meter.[28] Larvae were exclusively collected from surface portions of the water column from 1987 to 1989, and in equal proportions from surface and bottom depths in 1989.[29] In the Clinch River drainage, Hinds Creek, *E. b. newmanii* larvae were collected from early April until early May at temperatures between 12.5 and 19.8°C.[18] The maximum average density of Newman's greenside darter was 2.45 darters/10^4 collected at HCM 6.7, but was typically <0.3/10^4 at other locations.[18] Larvae in TN streams were usually collected from surface portions of the water column (R. Wallus, personal communication).

Juveniles. Early juvenile *E. b. blennioides* occur over sand and sand-gravel substrates at ORM 53.9 and 76.7.[29] Juvenile *E. b. blennioides* >33 mm TL are collected on the margins of flowing pool habitat at the crest of riffle habitat in Red River, KY.[2] In TN, early juveniles inhabit shallow pool areas adjacent to riffles.[6] Juveniles of *E. b. pholidotum* (>25 mm TL) were collected on the margins of flowing pool habitat and at the crest of riffle habitat in the Embarras River, IL.[6]

Early Growth (see Table 41)

Juvenile *E. b. pholidotum* in early August were between 30 to 37 mm.[10]

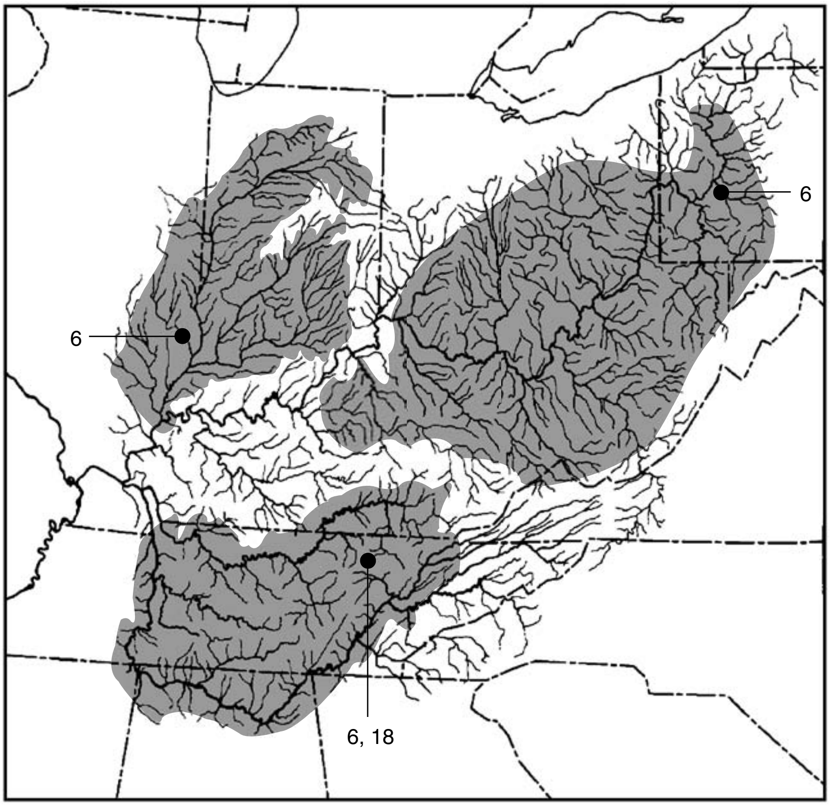

Figure 37 Distribution of members of the greenside darter complex, *E. blennioides* in the Ohio River system (shaded area) and areas where early life history information has been collected (circle). Number indicates appropriate reference.

Table 41

Average calculated length (mm TL) of young greenside darters in several states.

State	Age 1	Age 2	Age 3
Illinois	45–62	68–74	78–89
Ohio[5]	38–64		
New York[10]	45.7		

Feeding Habits
Etheostoma b. newmanii diet consists of midge larvae and microcrustaceans.[4] NY populations consumed larval stages of mayflies, stoneflies, beetles, and dragonflies,[10] or exhibited preferential selection for midges and black fly larvae;[15] and chironomids.[21]

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Material Examined: *E. b. blennioides* OH: Ohio River: Jefferson Co.: near Stratton, at ORM 53.9 just upstream of the New Cumberland Lock and Dam, ESE uncataloged (4); ESE uncataloged (3). OH: Ohio River, ORM 76.7, Pike Island Pool, near Brilliant, ESE uncataloged (2); ESE uncataloged (1); GM 49-5-14-85. KY: Wolf-Menifee Co.: Red River, trib. of Kentucky River, LRRC 768 (1).

E. b. newmanii TN. Anderson Co.: Hinds Creek, at SR 71 bridge, 4.1 mi SW Norris, TV 671 (2 eggs); TV 671 (1); TV 1268 (15); TV 1388 (2); TV 1341 (16); TV 1336 (8); TV 1419 (1); TV 1690 (1); TV 1804 (5); TV 1815 (1); TV 1832 (2); TV 1907 (1); TV 1920 (2); TV 2451 (3); TV 2455 (10); TV 2468 (6). Anderson Co.: Bull Run Creek, 0.5 mi downstream Bells campground Road, TV 2609 (1 egg); TV 2609 (9); TV 2611 (3).

Etheostoma blennioides pholidotum IL. Cumberland Co.: Embarras River, 0.5 mi N Greenup, Greenup Twp., T 9N R 9E S 10, LRRC 758 (22 eggs); LRRC 758 (3); LRRC 760 (2); LRRC 759 (1 egg); LRRC 759 (13); LRRC 761 (1); LRRC 762 (4); LRRC 763 (2 eggs); LRRC 764 (8 eggs); LRRC 765 (24 eggs); LRRC 766 (1); LRRC 767 (20). NY: Orleans Co.: Salmon Creek, near Hilton, UNC-IFR uncatalogued (2).

* Fecundity from specimens from Little River, Blount, Co. TN curated at Northeast Louisiana University, Museum of Zoology, Monroe, LA. Life history observations from T.P. Simon, unpublished data.

BLENNY DARTER

Etheostoma (*Etheostoma*) *blennius* Gilbert and Swain

Etheostoma: various mouths; *blennius*: blenny-like.

RANGE

Etheostoma blennius is confined to the middle and lower Tennessee River basin in TN and AL from the Sequatchie River downstream to the Duck River and White Oak Creek.[1–4]

HABITAT AND MOVEMENT

The preferred habitat of the blenny darter is swift gravel riffles in streams 3 to 4 m wide to medium-sized rivers.[1–4]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma blennius is confined to the Tennessee River drainage of TN and AL.[4]

SPAWNING

Location
Spawning occurred on coarse gravel riffles at depths of 10–20 cm in swift flow among scattered embedded stones.[4,5]

Season
Spawning season is March–April;[5] breeding occurred in Shoal Creek in southern TN by mid-April.[2]

Temperature
Unknown.

Fecundity (see Table 42)
Mature ova numbered between 19–120 (mean = 56) per female.[4,5]

Sexual Maturity
Males dichromatic; most females were already spent by mid-April.[2] Sexual maturity occurs at age 1.[4]

Table 42

Fecundity data for blenny darter from Buffalo River at Mouth of Grinders Creek, TN.*

			Percent Occurrence of Ova			
Date	TL	GSI	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
April 3	74	16.7	336	229	100	1.7
	71	16.8	965	212	115	1.7
	70.5	16.4	200	185	150	1.7
	66	12.7	379	147	137	1.7
	65	13.9	195	174	106	1.7
	59	13.8	103	137	79	1.7
	58	10.0	55	90	88	1.7
	54	13.0	145	100	46	1.7
	51	13.6	90	68	60	1.7
	48	6.3	53	25	41	1.7

Spawning Act
Unknown.

EGGS

Description
Mature ova were spherical and ranged between 2.0 and 2.2 mm in diameter.[5]

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Larger juveniles. Spinous dorsal fin 10–14; soft dorsal rays 11–13; pectoral rays 15–17; anal fin rays II 7–9; pelvic fin rays I 5; caudal fin rays 14–18.[4]

Morphology
Total vertebrae count 40–42 including one urostylar element. Scales in the lateral series range from 40 to 51 from TN.[2–5]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG BLENNY DARTER

Similar species: members of subgenus *Etheostoma*.[5]

Adult. *Etheostoma blennius* is similar to *Percina tanasi* and *P. vigil*. Both of the *Percina* sp. differ from *E. blennius* in having separate to narrowly joined gill membranes. *Percina tanasi* is sympatric with *E. blennius* in the lower Sequatchie River and is sympatric with *P. vigil* in the lower Duck and Buffalo rivers.

Larva. Aspects of the early life history and reproductive biology for *E. blennius* are unknown.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 38)
Eggs. Unknown.

Yolk-sac larvae. Unknown.

Figure 38 Distribution of blenny darter, *E. blennius* in the Ohio River system (shaded area).

Post yolk-sac larvae. Unknown.

Juveniles. Larvae and early juveniles probably utilize the downstream pools and backwater areas adjacent to spawning riffles as nursery habitats.

Early Growth (see Table 43)
Apparently, individuals did not exceed 3 years of age.[5]

Feeding Habits
The main components of the diet include midge, blackfly, mayfly, and caddisfly larvae.[5]

Table 43

Average calculated length (mm TL) of young blenny darters in Tennessee.

State	Age 1	Age 2	Age 3
Tennessee [4]	43–44	52–62	69

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* Original fecundity data from specimens curated at Northeast Lousiana University Museum of Zoology. Specimens were from TN: Lewis Co., Buffalo River, at mouth of Grinders Creek on CR 6263, 6.5 miles S Hohenwald, April 3, 1990.

SLACKWATER DARTER

Etheostoma (*Ozarka*) *boschungi* Wall and Williams

Etheostoma: various mouths; *boschungi*: named after Herbert T. Boschung, ichthyologist at the University of Alabama.

RANGE

Etheostoma boschungi occurs in widely separated localities in the southwestern Highland Rim region in TN and northern AL.[1–4]

HABITAT AND MOVEMENT

The preferred habitat of the slackwater darter includes sluggish portions of small-to medium-sized woodland streams that range from 3 to 10 m wide. It is associated with pools containing leaf litter and detritus[1–6] or filamentous algae.[4] The slackwater darter moves during late winter, as much as 4 km, up small tributaries to seepage areas in open fields. Adults and larvae leave the flooded fields during April and return to downstream habitats.[4]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma boschungi is known from only ten populations in the headwaters of the Buffalo River and Shoal Creek, Lawrence Co. and Cypress Creek, Wayne County, TN. In AL, the species occurs in the lower portions of these systems and in the Flint River, AL.[4]

SPAWNING

Location
Spawning occurred among the stems of rushes (*Juncus*) in very shallow waters 10–20 cm.[4,5]

Season
Spawning season is from late February and March;[4] breeding occurred in Cypress Creek by mid-March.[6]

Temperature
Spawning temperature is 14°C.[4,6]

Fecundity
Females produce as many as 300 mature ova per year.[4–6]

Sexual Maturity
Males dichromatic by January.[4] Sexual maturity occurs at age 2.[4]

Spawning Act
Males defend nest sites vigorously during spawning and through early development of the eggs. Breeding sites are among the stems of rushes (*Juncus*) in very shallow water. Eggs are laid singly or in groups of 2 or 3 on the *Juncus* stems.[4,6]

EGGS

Description
Unknown.

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Larger Juveniles. Spinous dorsal fin 9–12; soft dorsal rays 10–13; pectoral rays 12–14; anal fin rays II 6–10; pelvic fin rays I 5; caudal fin rays 14–19.[2–5]

Morphology
Total vertebrae count 35–37 including one urostylar element. Scales in the lateral series range from 24 to 44 pored scales and 42–58 scales in the lateral series from TN.[2–5]

Morphometry
Unknown.

Pigmentation
Unknown.

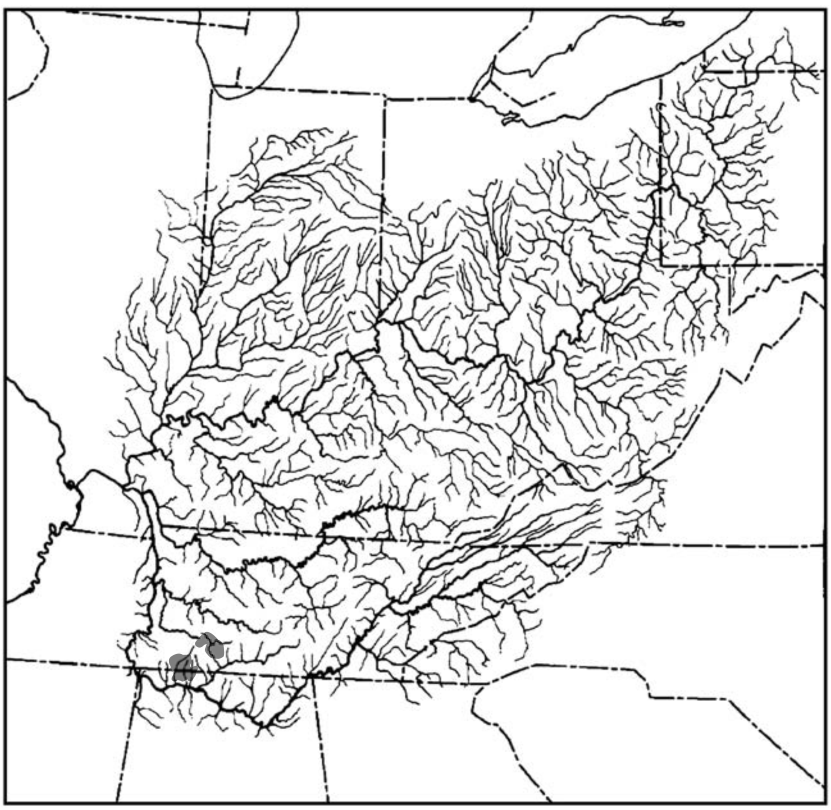

Figure 39 Distribution of slackwater darter, *E. boschungi* in the Ohio River system (shaded area).

TAXONOMIC DIAGNOSIS OF YOUNG SLACKWATER DARTER

Similar species: members of subgenus *Oligocephalus*.[7]

Adult. *Etheostoma boschungi* is similar to *E. caeruleum* and *E. spectabile.* Both of the *Oligocephalus* sp. differ from *E. boschungi* in having wider dark marginal bands on the spinous dorsal fin and red on the margins of the dorsal spines of males and a moderate to faint suborbital bar. The *E. boschungi* has a wide dark dichromatic bar on the cheek.

Larva. Aspects of the early life history and reproductive biology for *E. boschungi* are virtually unknown.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 39)
Eggs. Eggs are laid on the stems of *Juncus* either singly or in groups of 2–3.[4]

Yolk-sac larvae. Unknown.

Post yolk-sac larvae. Move from small seepage areas downstream into resident habitat.

Juveniles. Early juveniles probably utilize pools and backwater areas as nursery habitats.

Early Growth
Apparently individuals live to reach 3 years of age.[5] Young slackwater darters attain lengths of 20–25 mm TL by June and reach 35–40 mm TL at age 1[4,6,8] (Table 44).

Feeding Habits
The main components of the diet include aquatic isopods, amphipods (*Hyallela*), mayfly nymphs (*Stenonema*, *Leptophlebia*), midge larvae, and limpets.[4,6,8]

Table 44

Average calculated lengths (mm TL) of young slackwater darters in Tennessee.[4]

State	Age		
	1	2	3
Tennessee[4]	35–40	45–55	52 mm SL

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RAINBOW DARTER

Etheostoma (*Oligocephalus*) *caeruleum* Storer

Etheostoma: various mouths; *caeruleum*: blue.

RANGE

Etheostoma caeruleum is widespread and abundant in the uplands of the Mississippi River drainage throughout most of eastern and central United States. It occurs in Great Lakes tributaries and in the upper Potomac River of the Atlantic Slope.[1–5]

HABITAT AND MOVEMENT

Etheostoma caeruleum inhabits small to medium upland streams and rivers. It occurs in fast-flowing riffles as adults and slower near shore areas in runs or pools as juveniles.[1–5] Large populations occurred in moderate-sized streams of moderate or high gradients where riffles were 4.5–21.0 m in width, the average depth was 0.3 m, and the bottoms were sand, gravel, boulders,[1–5] and fine gravel,[4] or associated with gravel substrates, current speeds 0.5 m/s, and areas less than 15 cm deep.[29] In a WV population, it occured predominantly beneath rocks in run habitat.[18] In streams, males occupy the riffles throughout the year, while during the reproductive period, the females remain downstream at the base of riffles until ready to reproduce.* Migrations between pools and riffles occur during the winter months and specimens that stay on the riffles often bury themselves into the gravel to conserve energy.* It is rarely found on gravel patches overlying soft sand.[6] During drought, downstream migrations into pools and deep riffles occur, caused high temporal variation in population size.[14] Males migrate to spawning riffles in late March.[7,8]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

The species is found throughout the Highland Rim, and in a few sporadic locations in east TN from the Clinch-Powell and upper Holston Rivers, TN and VA.[4,9] Several other sporadic locations include Indian Creek (Powell River drainage) and the New River, VA and WV.[9,10] Generally distributed in KY occurring from Land-Between-the-Lakes eastward, avoiding lowlands.[11] The species occurs throughout tributaries of the Wabash River drainage, IL and IN; throughout central and southwestern OH; and in northern KY.[*,1–3,5,11,12] Genetic variation appears to be most influenced by pollution and population size.[14]

SPAWNING

Location
Spawning occurs over fine gravel in shallow stream riffles at depths <0.1–0.6 m (usually 0.25–0.35 m).[7,8,16–20,*]

Season
Spawning season occurs from late March, peaking in late April–May or June.[*,2–4,7,8,16–20,27,29]

Temperature
Spawning occurs at 16–17°C,[20] or at 15°C or higher;[4] spawning occurred in the laboratory for several months between 15 and 23°C.*

Fecundity (see Table 45)
Females (44–65 mm TL) collected in early April from Hurricane Creek, Clay County, TN, had mean ovaries that were 18.2% of the body weight, containing 126.2 total ova averaging 1.66 mm diameter.* Winn reported 500–1500 eggs from MI,[7,8] 120 mature ova were reported from Silver Creek, KY,[31] and our data from Hurricane Creek in the Cumberland River drainage, ovaries contained 660 total ova.* *Etheostoma caeruleum* had ovary weights that averaged 14% of total weight in MI[21] and 11% of the total body weight in WI.[22] The total number of mature ova reported as 167–450 eggs from WI,[22] and 508–1462 eggs from MI.[7,8]

Sexual Maturity
Adults live to reach age 4;[5,7] maturity is attained at age 1 at lengths between 40 and 45 mm TL.[4] Adult males (56–69 mm TL) from WI had testes that were 0.85% of the body weight.[22] Nuptial males developed tubercles as thickenings on scales

Table 45

Fecundity data for rainbow darter from Hurricane Creek, Cumberland River drainage, Clay County, TN.*

TL	Ovary Weight (mg)	Percent Occurrence of Ova: Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
44	79.2	149	50	44	1.66
45	71	425	50	52	1.66
55	206	350	82	111	1.66
56	410	425	159	111	1.66
59	599	626	168	137	1.66
60	522	307	152	155	1.66
61	575	400	170	146	1.66
61	548	363	174	84	1.66
65	687	363	215	212	1.66
68	974	650	370	210	1.66

on the posterior belly and lower caudal peduncle. Males exhibited sexually dimorphic traits during the reproductive season with an increase in brightly colored pigmentation.[2–5,7–8,16–20]

Spawning Act

The reproductive mode of *E. caeruleum* is a burier.[3] Males defended spawning territories and were generally aggressive only toward other rainbow darter males that entered into their reproductive space. The male created a moving territory that moved 0.5–1.5 m around the female as she moved through the spawning ground. Male territories may be from 0.12 to 0.30 m diameter. On the spawning riffle, males may outnumber the females 4 or 5:1. Age 3 males did not spawn with age 1 females, but age 2 males did mate. Females enter the spawning ground and are followed by a male, who approaches from behind and follows her. If multiple males follow the same female, the males display to each other by lifting themselves upon their pectoral fins and exposing their brilliantly colored breast and pelvic fin. The dorsal fins are also erect. A defending male may attack an intruder, or, if the males are about the same size, rival males will swim side by side in a sham battle similar to territorial battles. The male swims parallel to the female and prods her side with his snout by vibrating his head 4–8 times/s. This does not occur during every spawning attempt. When the female is ready to spawn, she buries her head in the gravel and raises her caudal region at an angle of 45° to nearly vertical to the substrate. With a few vigorous strokes of the caudal fin she pushes herself downward and forward so that the ventral portion of her body and pectoral fins are buried in the gravel. The pectoral fins anchor the female to prevent displacement from the current. The position of the female stimulates the male to mount her. If the male attempts to mount her before she has buried herself she will swim away. The male when mounted places his pelvic fin in front of the female's spinous dorsal fin and on her sides. The male uses his pectoral fin for stability, and his caudal fin is placed alongside the anal fin of the female. The gametes are released simultaneously as the pair vibrate and swim forward. The female will continue to swim forward and be mounted again by the same male or another; 3–7 eggs are released into the gravel. After the female has completed several spawnings she may return to the base of the riffle to rest. Supernumerary or "sneaker" males may follow the female and unless chased away by the territorial male, may be seen next to the spawning pair going through the same motions, and possibly even releasing sperm while the pair is spawning.[7,8,16–20,22,27,29]

EGGS

Description

Ovarian eggs included latent white, ovoid eggs that ranged from 0.71 to 0.83 mm; early maturing ova were peach colored and ranged from 1.11 to 1.25 mm; large mature ova averaged 1.66 mm.* Egg diameters, from WI, were 1.0–1.8 mm, and were yellow to orange in color with a single, large oil globule.[22] Fertilized eggs were spherical and averaged 1.8 mm diameter (range: 1.7–1.9 mm), and possessed a yellow, translucent yolk with a single translucent oil globule; the chorion and the yolk were finely reticulate.[23] Eggs from Hurricane Creek were spherical, mean = 1.66 mm diameter (range: 1.6–1.8 mm); translucent; demersal; and nonadhesive. Eggs possess translucent, pale amber yolk (mean = 1.5 mm diameter; range: 1.45–1.7 mm); a single oil globule (mean = 0.3 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.*

Incubation

Hatching occurs after 240–276 h at an incubation temperature of 17–18.5°C;[7,8] eggs hatched in 168–240 h at 16.5–18.5°C;* 72–144 h at 23 ± 3°C.[29]

Development

Cooper reported embryonic development during the morula, embryonic axis, tail-free embryo, and late embryonic stages 23.

YOLK-SAC LARVAE

See Figures 40, 41

Size Range

PA populations from Elk Creek hatch between 6.0–6.2[23] and yolk is absorbed by 8.0 mm.[23]

Myomeres

Preanal 16–18 (N = 8, mode = 17); postanal 18 or 19 (N = 8, mode = 18); with total 35 or 36 (N = 8, mode = 35).[22]

Morphology

6.0–6.2 mm TL. Newly hatched yolk-sac larvae with body terete; snout blunt; functional jaws, upper jaw overhangs lower jaw, without teeth; yolk sac moderate (28.4% TL), oval to tapered posteriorly; yolk translucent clear to pale amber, with a single oil globule; complex plexus of vitelline veins midventrally on yolk sac; head not deflected over the yolk sac; and eyes oval.[*,23]

6.8-8.0 mm TL. Digestive system nonfunctional; yolk sac absorbed by 8.0 mm.[*,23]

Morphometry (see Table 46)

Yolk-sac larva with head length 17.7% and preanal lengths 50.1% TL.[20,24,25]

Fin Development (see Table 47.[23])

6.0–6.2 mm TL. Well-developed pectoral fins without incipient rays.[20,23–25]

Pigmentation

6.0–6.2 mm TL. Eyes pigmented; no melanophores dorsally over either the anterior or posterior cerebellum or nape; no melanophores distributed laterally, or dorsally over the gut posterior to the yolk sac; ventral pigmentation consists of scattered melanophores over the yolk sac mixed within the vitelline vein on the yolk sac; seven punctate melanophores at mid-ventral from postanal myomeres 9–16.[20,23–25]

6.8 mm TL. No dorsal pigmentation. Ventral pigmentation consists of single mid-ventral melanophores from the breast to the anus, including the

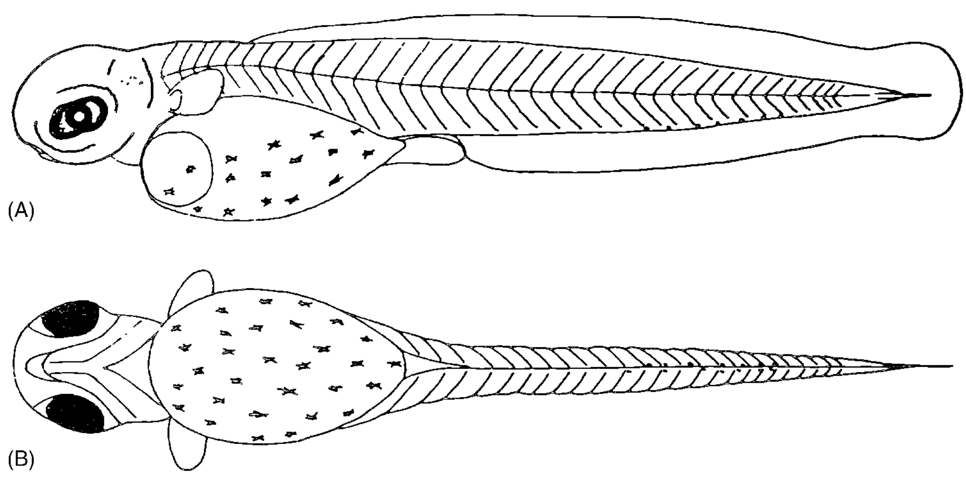

Figure 40 *Etheostoma caeruleum*, rainbow darter, Elk Creek, PA. Yolk-sac larva, 6.0 mm TL, lateral, ventral views. (A–B redrawn from reference 23, with author’s permission.)

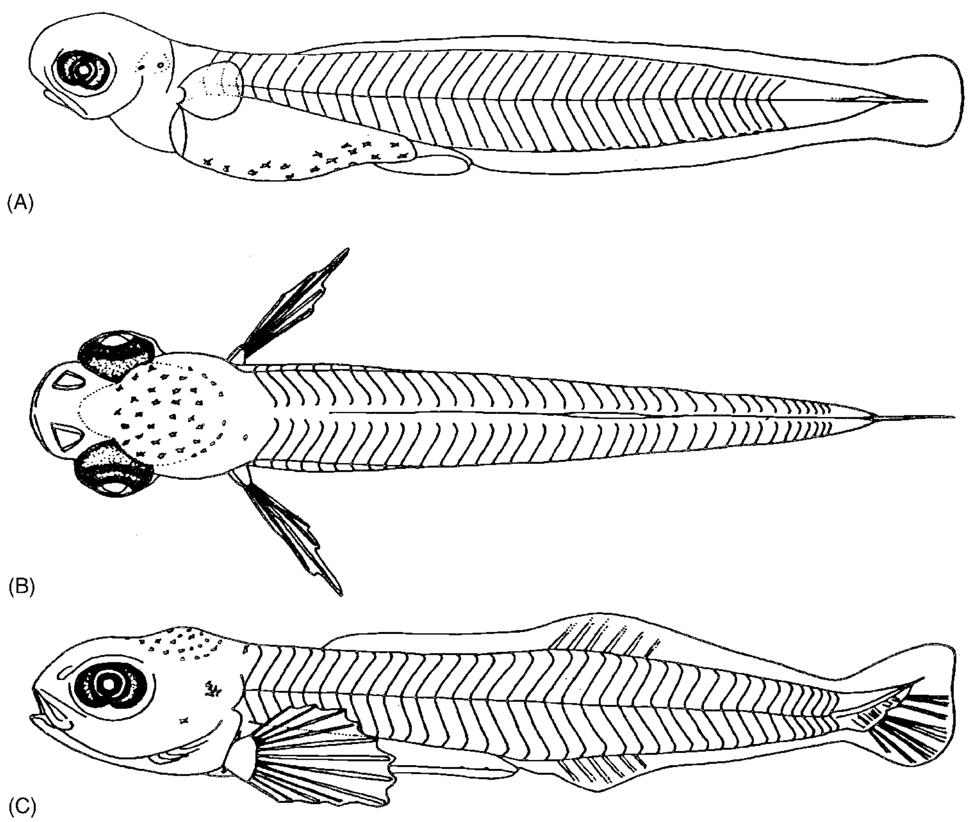

Figure 41 *Etheostoma caeruleum*, rainbow darter, Elk Creek, PA: (A) yolk-sac larva, 6.8 mm TL, lateral view, (B–C) Post yolk-sac larva, 8.0 mm TL, dorsal and lateral views. (A–C redrawn from reference 23, with author's permission.)

Table 46

Morphometric data expressed as percent TL for young *E. caeruleum* from Pennsylvania.[23] A single standard deviation is expressed in parentheses.

	TL Groupings				
Length Range (mm)	**6.0–7.5**	**7.6–9.5**	**9.6–11.5**	**11.6–15.5**	**18.0**
N	**8**	**3**	**1**	**3**	**1**
As Percent TL					
ED	6.0	7.0	7.0	7.0	5.0
	(0.6)	(1.0)	(0)	(0)	(0)
HL	13.0	20.0	24.0	23.0	22.0
	(1.2)	(2.1)	(0)	(0)	(0)
Preanal	48.0	51.0	53.0	50.0	50.0
	(1.4)	(0.6)	(0)	(0.7)	(0)
PosAL	52.0	49.0	47.0	50.0	50.0
	(1.4)	(0.6)	(0)	(0)	(0)
SL	96.0	95.0	86	85	83.0
	(1.5)	(2.3)	(0)	(2.1)	(0)

Table 47

Meristic counts and size (mm TL) at the apparent onset of development for *E. caeruleum.*[23]

Attribute/event	*Etheostoma caeruleum*[23]	Literature
Branchiostegal Rays	6,6	6,6[2–5,22,23,26–29]
Dorsal Fin Spines/Rays	X–XI/12	VIII–XIII/10–15[2–5,22,23,26–29]
First spines formed	10.2–10.5	
Adult complement formed	10.5	
First soft rays formed	7.8–8.2	
Adult complement formed	10.5	
Pectoral Fin Rays	12–13	10–15[2–5,22,23,26–29]
First rays formed	7.8–8.2	
Adult complement formed	18.0	
Pelvic Fin Spines/Rays	I/5	I/5[2–5,22,23,26–29]
First rays formed	9.0	
Adult complement formed	10.5	
Anal Fin Spines/Rays	II/7–10	II/5-9,[2–5,22,23,26–29]
First rays formed	7.8–8.2	
Adult complement formed	11.6–15.5	
Caudal Fin Rrays	vii–xi, 8 + 7–8,viii–xi	14–17[2–5,22,23,26–29]
First rays formed	7.6–9.5	
Adult complement formed	11.6–15.5	
Lateral Line Scales	48–55	39–67[2–5,22,23,26–29]
Myomeres/Vertebrae	35-36/36-37	Unknown/35–38[2–5,22,23,26–29]
Preanal myomeres	16–18	
Postanal myomeres	18–20	

gut; melanophores exist from the postanal myomeres 4 to 18 near the caudal peduncle.*[,20,24,25]

POST YOLK-SAC LARVAE

See Figures 41 and 42.

Size Range

8.0–13.0 mm TL.*[,23]

Myomeres

Preanal 16 to 17 (N = 4, mode = 16), postanal 18 to 20 (N = 4, mode = 19), with total 35 or 36 (N = 4, mode = 35).[23]

Morphology

8.0 mm TL. Yolk absorbed;[23] notochord flexion occurred.*[,20,23–25]

8.5 mm TL. Snout rounded and jaws with minute teeth[23]; operculum and gill arches function and premaxilla and mandible form.*

Morphometry (see Table 46.[23])

Larvae with head lengths 21.2% TL; preanal lengths 51.6% TL; and maximum depth 15.2% TL.[20,24–25]

Fin Development

8.0–8.5 mm TL. First rays form in pectoral, anal, caudal fin, and soft dorsal fins and branchiostegal rays form (8.0 mm); first spines form in spinous dorsal fin (8.5 mm).[23] Segmented rays in caudal and pectoral fins (8.5 mm).[23]

8.5 mm TL.. Dorsal and anal finfolds partially differentiated.[23]

10.5 mm TL. Pelvic fin buds form anterior to dorsal fin origin after complete yolk absorption;[23] adult

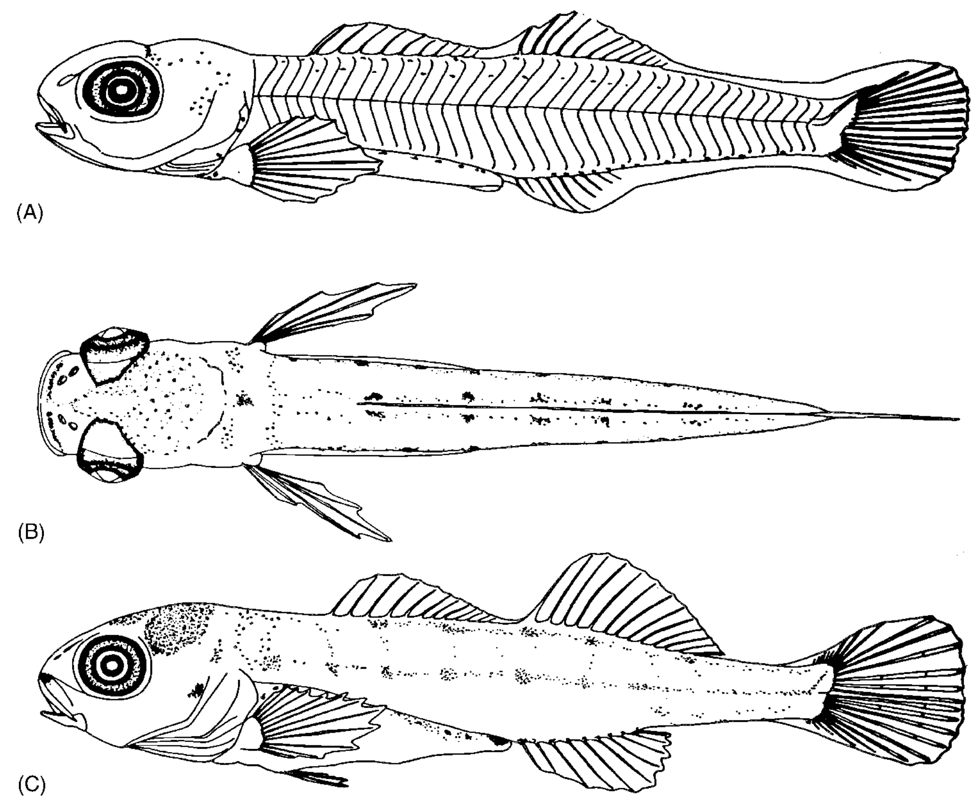

Figure 42 *Etheostoma caeruleum*, rainbow darter, Elk Creek, PA: (A–B) Post yolk-sac larva, 8.5 mm TL, lateral and dorsal view: (C) Juvenile, 10.5 mm TL, lateral and dorsal views. (C redrawn from reference 23, with author's permission.)

complement of pectoral fin rays formed.[23] Dorsal and anal finfold completely differentiated; first pelvic fin ray forms; both finfolds completely differentiate.[23,*]

11.6–13.0 mm TL. Complete adult fin ray counts in median fins. Spinous dorsal fin origin situated over preanal myomere 4, soft dorsal origin over preanal myomere 17.*

Pigmentation

8.5–9.0 mm TL. A series of melanophores outline both sides of the gut, becoming less dense posteriorly. Ventral pigmentation consists of melanophores from the anal fin to the caudal fin and beneath the dorsal fins. A small concentration of melanphore present on the preopercle and head.[23]

10.5 mm TL. Pigment is present on the snout; dorsum of cranium has several large melanophore clusters on cerebellum; melanophones present beneath the dorsal fins and along the horizontal septum. Melanophores are concentrated at the base of the anal fin rays. Internal pigment present posterior to the pelvic fins and along the rays of the spinous dorsal fin.[23]

JUVENILES

See Figure 42

Size Range

13.0 mm TL[23] to 40–45 mm TL.[4]

Fin Development

13.0 mm TL. Complete adult fin ray counts in median fins and rays segmented; dorsal and anal finfolds completely differentiated.[*,23]

>13.0 mm TL. Average predorsal length 33.9% TL.*

14.0 mm TL. Pelvic fin rays complete.[23]

18.5 mm TL. Segmentation of principal rays of median fins.[23]

Larger juveniles. Spinous dorsal fin VIII–(IX–XI)–XIII; soft dorsal rays 10–(12–14)–15; pectoral rays 10–(13)–15; anal fin spines/rays II/5–(6–8)–9; pelvic fin spines/rays I/5; caudal fin rays 14–(16)–17.[2–5,22,–23,26–29]

Morphology
13.0 mm TL. Squamation initiated near the caudal peduncle base extending to second dorsal fin.[23]

15.0 mm TL. Squamation complete.[23]

19.0 mm TL. Teeth begin to form around the margins of both jaws. Squamation intiated on opercles, but lacking on the dorsal surface near the spinous dorsal fin.[23] Allometric growth of snout may be associated with feeding, as it results primarily as an expansion of the dermal bones of the jaws.[20,24,25]

Larger Juvenile. Total vertebrae count 35–38 including one urostylar element. Scales in the lateral series incomplete with 22–34 pored scales and 40–51 total scales in the lateral range from TN.[2–4] Gill membranes separate to narrowly joined, frenum present. Breast and prepectoral area without scales; opercles and belly scaled; nape varying from covered with embedded scales to partially naked; cheeks usually naked or may possess a few scales behind the eye.[2–5,22,23,26–29]

Morphometry (see Table 46.*)
Juveniles with snout length 41% TL; head length 23.7% TL; preanal lengths 51.9% TL; maximum depth 15.7% TL; and caudal peduncle depth 5.6% TL.[20,24,25]

Pigmentation
13 mm TL. A horizontal band of melanophores was present anterior and posterior to the eye. Dense pigmentation was present on the dorsal surface of the head and patches had formed under the dorsal fins and on the lateral line. The lateral line patches were elongated vertically.[23]

17–18 mm TL. A suborbital bar present. Two bands of pigment present on the spinous dorsal fin, similar to adult pigmentation;[23] body with 8–10 dark dorsal saddles, with 2 anterior nape, 3 between the dorsal fins, and 5 posterior the soft dorsal fin. 10 mid-lateral dark blotches with 5–7 posterior the anus. Three fused basicaudal spots form a trident. Rays of soft dorsal and anal fins are speckled.[2–5]

TAXONOMIC DIAGNOSIS OF YOUNG RAINBOW DARTER

Similar species: members of subgenus *Oligocephalus.*[3]

Adult. *Etheostoma caeruleum* is similar to *E. spectabile. Etheostoma spectabile* differs from *E.caeruleum* in not having any red coloration in the anal fin, and lacks horizontal lines on the upper sides. Caudal fin rays of *E. spectabile* possess 15–16 principal caudal rays, while *E. caeruleum* possesses 17 principal caudal rays.* *Etheostoma caeruleum* possesses a complete infraorbital head canal while *E. spectabile* does not.[25]

Larva. The early life history of *E. spectabile* is similar to *E. caeruleum.* The two species can be differentiated by their pigmentation, preanal myomere counts, and postanal myomere counts. *Etheostoma spectabile* possesses 16 preanal and between 19 and 20 postanal myomeres, while *E. caeruleum* possesses 16–18 preanal and 18–20 postanal myomeres.* *Etheostoma caeruleum* has more postanal melanophore pigment than *E. spectabile.*

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 43)
Eggs. Buried in fine gravel in flowing runs and riffles.[*,2–15]

Yolk-sac larvae. Yolk-sac larvae remain buried in gravel pore spaces; the species is benthic and rarely collected from the pelagic drift.* The vitelline vein plexus on the ventral yolk sac is consistent with other burier species.[16]

Post yolk-sac larvae. Larval drift is benthic; staying in close association with the substrate. The precocious development of fin rays enables the species to inhabit the slower flowing margins of natal habitats along the edges of riffles or flowing pools.* Larval densities of *E. caeruleum* reached 20 individuals/30 min during mid-May in Shoal Creek, TN.[32]

Juveniles. Early juveniles utilize the downstream pools and run and riffle margins of areas adjacent to spawning areas as nursery habitats.* Mean densities from Shoal Creek, TN, were 4 individuals/30 min.[32]

Early Growth (see Table 48)
Apparently, individuals do not exceed 4 years of age.[4] During their first year of life, young darters

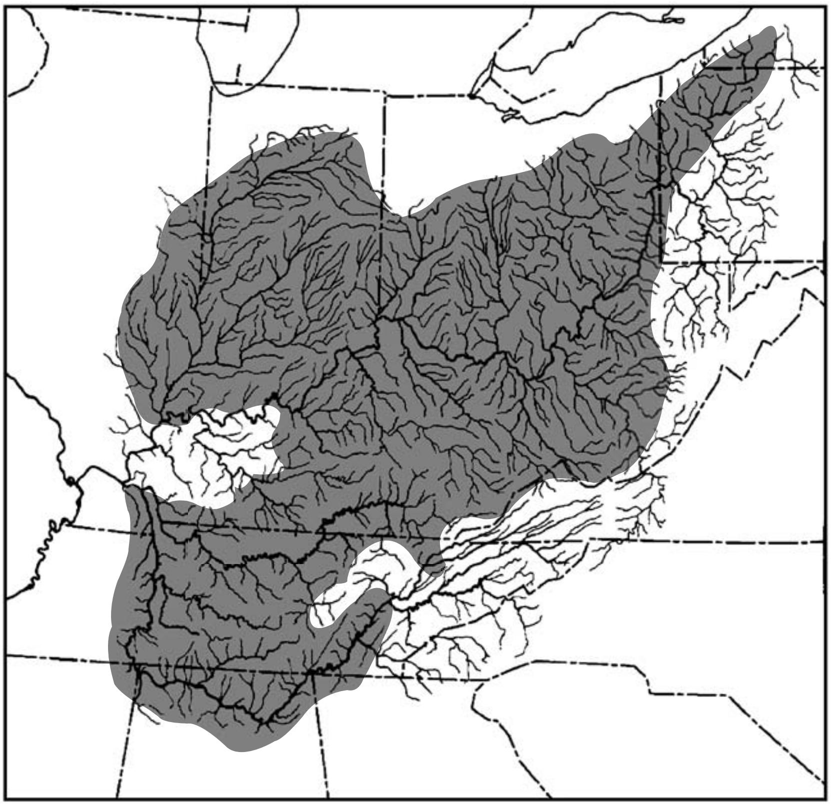

Figure 43 Distribution of rainbow darter, *E. caeruleum* from the Ohio River (shaded area).

attained 20–26 mm TL by June and 27–37 mm TL by August in southern WI.[22] Rainbow darters from TN attained 40–45 mm TL during their first year of life.[4] The length–weight relationship for *E. caeruleum* is $\log W = -13.1003 + 3.4288 \log L$, where W is in g and TL in mm.[22]

Feeding Habits

Juveniles up to 15 mm ate large amounts of copepods, while individuals 15–20 mm consumed 40% copepods and 60% midge larvae; 20–25 mm fish ate 37% midge larvae and 42% mayfly nymphys; 25–30 mm juveniles ate 57% mayfly nymphs and 33% midge larvae; 30–35 mm fish consumed 36% midge larvae and 53% mayfly nymphs; and 35–40 mm fish ate 0.25% copepods.[33] Food consistsed mostly of cladocerans and copepods, while crustaceans (*Hyallela* and *Gammarus)* formed about 25% of the biomass.[34] The main components of the diet in OH included *Simulium*, midge, *Chimarra*, and fish eggs;[35] positive selection was observed for chironomid larvae, *Simulium*, and *Baetis*.[36] *Etheostoma caerulem* consumed a wider variety of food sizes than other darters;[36] however, in WV, they consistently fed on prey items <6 mm.[38] Feeding occurred primarily during morning until late afternoon.[35] Feeding behavior was more active in pools than riffles and fewer eye movements were observed in riffles.[37]

Table 48

Average calculated lengths (mm TL) of young rainbow darter from several locations.

State	Age 1	2	3	4
Wisconsin[22]	34–52	43–64	48–74	57–63
Indiana (Richland Creek)*	37–42	50–54	57–62	56–66
Tennessee[4]	40–45	50–55		

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* Original fecundity data for rainbow darter from Hurricane Creek, Cumberland River drainage, Clay County, TN. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Original early life history developmental series cultured from laboratory spawned specimens from Fleming Creek, Washtenaw County, MI (T.P. Simon, unpublished data). Specimens curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

BLUEBREAST DARTER

Etheostoma (*Nothonotus*) *camurum* (Cope)

Etheostoma: various mouths; *camurum*: blunt-headed.

RANGE

Etheostoma camurum is widespread but generally uncommon, distributed throughout the Ohio, Cumberland, and Tennessee River drainages.[1–7] It is distributed from south TN and NC north through KY, eastern IL, IN, OH, and WV, and the Allegheny River and French Creek in northwestern PA.[1–7]

HABITAT AND MOVEMENT

Etheostoma camurum inhabits moderate to swift current over boulder, cobble, and gravel riffles in large streams and small rivers.[1–7] It prefers deep riffles, runs, and flowing pools;[8] it is also found in shoal areas with substrates of large gravel, cobble, and pebble.[7] It migrates upstream during the breeding season, and retreats to the lower reaches in the late fall or winter.[5]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma camurum is fairly common in the Tennessee River drainage, occurring in parts of the Clinch, Holston, French Broad, Sequatchie, and Little Rivers in east TN, and the Duck and Elk Rivers in middle TN. It has been collected from the Ft. Loudon Reservoir near a gravel island just above the mouth of George's Creek. In the Cumberland River drainage it continues to be common in the area below Cumberland Falls not affected by Lake Cumberland, KY, and in the Big South Fork drainage, TN;[4] it occurs in the Red River, KY;[15] is occasional in the upper Kentucky River and sporadic and rare in the Licking River, KY;[7] commonly occurs in the Tippecanoe, middle Wabash, East Fork White, and Blue Rivers, IN;* occurs in French Creek, PA;[1] and in NY, two specimens have been collected from the Allegheny River near Westons Mills and Portville.[5]

SPAWNING

Location

Nests are prepared by a male beneath slab rock or flattened boulders.[9] Females were observed ovipositing the eggs, which often results in a wedge-shaped, multilayered egg mass rather than a single layer as observed in *Boleosoma* and *Catonotus*.[8]

Season

Spawning occurs during mid-May until mid-June in OH;[5,8] until late July in IN;[9] and between late May and early August in TN.[4,10]

Temperature

Spawning occurs at temperatures between 21 and 24°C[5,8] and males initially show brilliant coloration in April when temperatures reach 13–15°C.[8] Spawning in the Tippecanoe River, Pulaski County, IN, occurs at temperatures between 22 and 25°C.[7]

Fecundity (see Table 49)

Females (57–65 mm TL) collected in mid-April from Nolichucky River, Greene County, TN, had ovaries that were 8.45% of the body weight, containing 100 total ova averaging 1.50 mm in diameter.* Females had 64–161 mature eggs.

Sexual Maturity

The length at which sexual maturity is attained is unknown; however, specimens that attained age 2 were sexually mature.* Specimens 57–65 mm TL are sexually mature.*

Spawning Act

Etheostoma camurum is an egg clumper.[8,9] Large territorial males guarded areas around the nest stone, which was located in swift, shallow water. Males established poorly defined territories and defend them against intruding males. Females selected the spawning site and initiated spawning.[8] During courtship, the female swam close to the bottom in short bursts. The male then followed the female,

Table 49

Fecundity data for bluebreast darter from Nolichucky River, Greene County, TN.*

		Percent Ocurrence of Ova			
TL	Ovary Weight (mg)	Ripening oocytes (LA)	Mature oocytes (EM, MA, LM)	Ripe eggs (MR, RE)	Egg Diameter (mm)
57	291	158	57	64	1.42
57	123	338	130	0	—
60	110	160	112	0	—
60	299	340	122	80	1.66
62	197	170	159	0	—
63	224	205	75	80	1.42
63	183	180	178	0	—
63	344	357	123	73	1.66
64	341	341	359	142	1.42
65	365	459	158	161	1.42

sometimes for as much as an hour, during which time the pair occasionally swam to the surface.[9] The female partially buried herself until her back was level with the surface of the gravel. The male came and lay on top of her although the position of the male's lower fin could not be determined. The pair vibrated vigorously for 3–5 s, then rested for 3–5 min before another spawning episode began.[8] Females were observed to wedge their body between the aquarium glass and filter, and spawning sometimes occurred in the open over gravel substrates.[9] A large male would mount the female and keep his body parallel to hers. The female remained more or less stationary during the spawning act, producing a partially buried, grape-like mass of eggs. After spawning, the female wiggled forward and lifted her tail, appearing to expose her genital papilla to the male. The male joined her and spawned again. Each spawning act lasted about 15 s, with about 30 s between the acts. The female swam forward a few centimeters between each spawning act. The female spawned in a hidden site.[6,7,9] Males sometimes protected the spawning site for several hours after spawning, but were never observed protecting the same site on successive days.[11] Females spawned as frequently as three times during the season, throughout the day, but most frequently during the afternoon and evening.[8]

EGGS

Description

Ovarian examination showed that ovoid, latent ova averaged 0.5–0.65 mm, small spherical early maturing ova averaged 1.11 mm, and large mature ripe ova averaged 1.42–1.66 mm in diameter.* The mean diameter of spawned eggs from the Tippecanoe River, Pulaski County, IN, was 1.8 mm (1.6–2.2 mm),[9] while eggs from OH were 2.0 mm in diameter.[8] Eggs of *E. camurum* are demersal, adhesive, and spherical; have unpigmented yolks; and possess a single oil globule, a narrow perivitelline space, and a sculptured and unpigmented chorion.[9]

Incubation

Eggs incubated at 22°C hatched in 168–240 h.[9]

Development

Unknown.

YOLK-SAC LARVAE

Size Range

Unknown.

Myomeres

Unknown.

Morphology

Unknown.

Morphometry

Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Larger juveniles. Spinous dorsal fin IX–XV; soft dorsal rays 10–14; pectoral rays 13–15; anal fin spines/rays II/ 6–9; pelvic fin rays I/ 5; caudal fin rays 16–17.[2–6]

Morphology
Total vertebrae count 37–40 including one urostylar element. Scales in the lateral series complete with 50–57 (47–70) pored scales in the lateral range.[2–6] Gill membranes separate, frenum well developed. Scales absent from cheeks, nape, breast, and prepectoral area. Head canals complete.[4,6]

Morphometry
Unknown.

Pigmentation
Ten poorly developed dorsal saddles, with only two saddles on the nape persisting until adulthood. Sides marked with ten small W-shaped midlateral blotches. Sides marked with dark horizontal lines between scale edges on posterior two thirds of the body.[4]

TAXONOMIC DIAGNOSIS OF YOUNG BLUEBREAST DARTER

Similar species: members of subgenus *Nothonotus*

Etheostoma camurum is a member of the egg-clumper group along with *E. maculatum, E. aquali,* and *E. vulneratum.*[7,13,14] These species possess more than 19 preanal myomeres, large (>32.0% SL) spherical yolk sacs, dorsal pigmentation in either a single or double row, and a series of mid-lateral dashes near the caudal peduncle. Within this group, *E. vulneratum* exhibits the largest egg diameter and size at hatching, while *E. maculatum* is almost similar to *E. vulneratum,* but hatches at 5.0 mm SL. Larvae of *E. aquali* can be distinguished from the other species based on the cross-hatched or brushed melanophores that cover the vitelline vein.[7]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (see Figure 44)
Eggs. Eggs are clumped in the interface spaces between stones along the channel border.[9]

Yolk-sac larvae. Unknown.

Larvae. Unknown.

Juveniles. Unknown.

Early Growth
Males grow more rapidly than females; young-of-the-year specimens in late fall attain lengths of 30–43 mm.[11]

Feeding Habits
Preferred diet was chironomids in July, and the diet consisted of four or more taxa. Diet was primarily hydropsychid caddisflies, midge larvae, mayfly nymphs, blackfly larvae, and a variety of other immature insects and snails.[4,12]

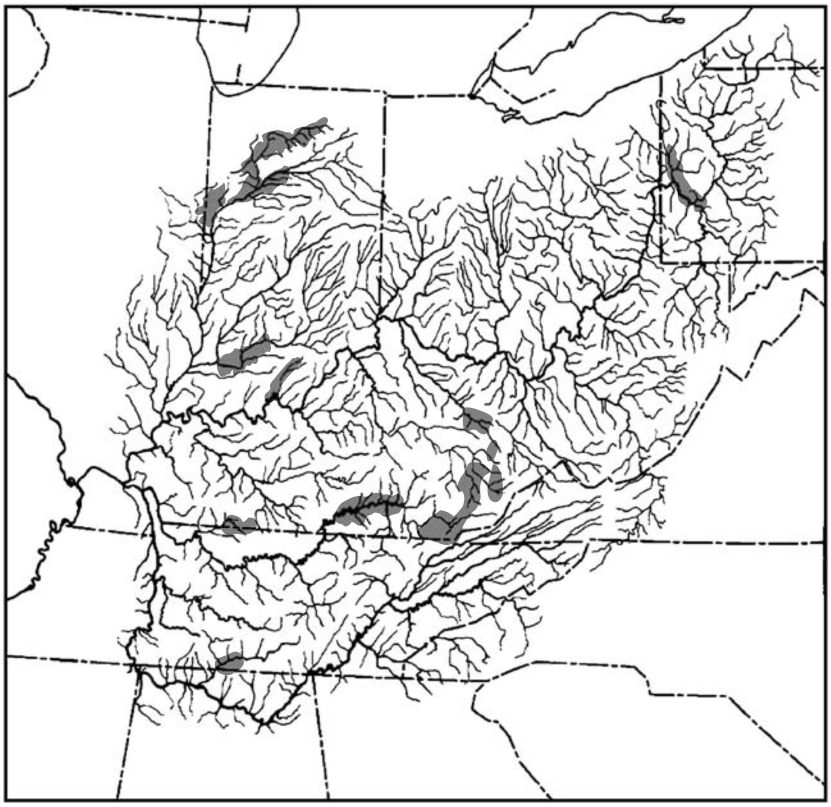

Figure 44 Distribution of bluebreast darter, *E. camurum* in the Ohio River system (shaded areas).

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* Original fecundity data curated by Northeast Louisiana University's Museum of Zoology, Monroe from TN: Greene Co.: Nolichucky River, at Hale bridge on CR N Parrottsville. Original 1999 data from T.P. Simon, unpublished data.

GREENFIN DARTER

Etheostoma (*Nothonotus*) *chlorobranchium* Zorach

Etheostoma: various mouths; *chlorobranchium*: green fin

RANGE

Etheostoma chlorobranchium is restricted to the upper Tennessee River drainage,[1–5] confined to Blue Ridge habitats, but occurs in the upper Ridge and Valley among cooler rivers.[4]

HABITAT AND MOVEMENT

Etheostoma chlorobranchium inhabits cool to cold high-elevation creeks and rivers, where it is associated with swift currents over bedrock, boulder, or coarse rubble substrates[1–4] in fast riffles. It prefers shallow riffles with depths of 9–30 cm often associated with gravel and large stones.[5]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

The occurence of *E. chlorobranchium* extends into the upper Holston River system, but not the North Fork, and south through the French Broad and Little Tennessee Rivers.[1–5]

SPAWNING

Location
Nests are associated with large flat rocks.[5]

Season
Spawning possibly occurs from mid-April* until early June in TN.[5]

Temperature
Unknown.

Fecundity (see Table 50)
Females (71–89 mm TL) collected in mid-April from Middle Fork Pigeon River, Sevier County, TN, had ovaries that were 5.3% of the body weight, containing an average of 145 total ova averaging 1.42 mm in diameter.*

Table 50

Fecundity data for greenfin darter from Middle Fork Pigeon River, Sevier County, TN.*

		Number of Ova			
TL	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature oocytes (EM, MA, LM)	Ripe eggs (MR, RE)	Egg Diameter (mm)
71	226	600	150	0	—
72	162	535	240	0	—
73	167	1021	106	0	—
73	59.8	1518	0	0	—
74	211	892	134	0	—
75	95.2	937	0	0	—
77	239	1080	126	0	—
84	525	1016	241	130	1.42
87	68.5	1889	0	0	—
89	626	1654	201	160	1.42

Sexual Maturity
The length at which sexual maturity is attained is unknown; however, specimens that attained age 2 were sexually mature.* Specimens 57–65 mm TL are sexually mature.*

Spawning Act
Etheostoma chlorobranchium is an egg clumper.* Spawning behavior based on aquarium observations show that the spawning act is similar to *E. camurum.* Large territorial males guarded areas around the nest stone, which was located in swift, shallow water. Males established poorly defined territories and defended them against intruding males. Females selected the spawning site and initiated spawning.[8] During courtship, the female swam close to the bottom in short bursts. The male then followed the female, sometimes for an hour.*

The female partially buried herself until her back was level with the surface of the gravel. The male came and lay on top of her although the position of the male's lower fin could not be determined. The pair vibrated vigorously for 3–5 s, then rested for 2–3 min before another spawning episode.[8] Females were observed to occasionally wedge their body between the aquarium glass and filter and spawning occurred frequently in between two flat rocks.* A large male mounted the female and kept his body parallel to hers. The female remained more or less stationary during the spawning act, producing a partially buried, grape-like mass of eggs. The female swam a few centimeters forward between each spawning act. The female spawned in hidden sites.* Males sometimes protected the spawning site for several hours after spawning, but were never observed protecting the same site on successive days.*

EGGS

Description
Ovarian examination showed that ovoid, latent ova averaged 0.3–0.63 mm, small spherical early maturing ova averaged 0.9–1.25 mm in diameter, and large mature ripe ova averaged 1.42 mm.* Eggs of *E. chlorobranchium* are demersal, adhesive, and spherical, averaging 1.9 mm in diameter (range: 1.8–2.1 mm); have unpigmented yolks: and possess a single oil globule, a narrow perivitelline space, and a sculptured and unpigmented chorion.[9]

Incubation
Eggs incubated at 21°C hatched in 174–258 h.*

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Larger juveniles. Spinous dorsal fin X–XIV; soft dorsal rays 11–14; pectoral rays 13–15; anal fin spines/rays II/ 7–10; pelvic fin rays I/5; caudal fin rays 16–18.[2–5]

Morphology
Total vertebrae count 38–40 including one urostylar element. Scales in the lateral series complete with 55–70 (52–72) pored scales in the lateral range.[2–5] Gill membranes separate, frenum present. Scales absent from cheeks, nape, breast, and prepectoral area. Head canals complete.[4,5]

Morphometry
Unknown.

Pigmentation

Juveniles. Ten poorly developed dorsal saddles, with only two saddles on the nape persisting until adulthood. Sides marked with ten small W-shaped mid-lateral blotches. Sides marked with dark horizontal lines between scale edges on posterior two thirds of the body.[4]

Variation

Unknown.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 45)

Eggs. Eggs are clumped in the interface spaces between stones along the channel border.[5]

Yolk-sac larvae. Unknown.

Larvae. Unknown.

Juveniles. Unknown.

Early Growth

Males grow more rapidly than females; young-of-the-year specimens in late fall attain lengths of 45 mm.[4] Maximum longevity may be 4–5 years.[4]

Feeding Habits

Diet may include as many as 10–15 different taxa in a single gut tract and consist of aquatic arthropods, mostly immature insects.[4]

TAXONOMIC DIAGNOSIS OF YOUNG GREENFIN DARTER

Similar species: members of subgenus *Nothonotus*

Etheostoma chlorobranchium is a member of the egg-clumper group along with *E. maculatum, E. aquali, E. camurum*, and *E. vulneratum.*[6–8] These species possess more than 19 preanal myomeres, large (>32.0% SL) spherical yolk sacs, dorsal pigmentation in either a single or double row, and a series of mid-lateral dashes near the caudal peduncle. Within this group, *E. vulneratum* exhibits the largest egg diameter and size at hatching, while *E. maculatum* is almost similar to *E. vulneratum* but hatches at 5.0 mm SL. Larvae of *E. aquali* can be distinguished from the other species based on the cross-hatched or brushed melanophores that cover the vitelline vein.[8]

Figure 45 Distribution of greenfin darter, *E. chlorobranchium* in the Ohio River system (shaded area).

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* Original fecundity data for greenfin darter from TN: Sevier Co.: Middle Fork Pigeon River, 20 mi NE Gatlinburg. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Specimens curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

BLUNTNOSE DARTER

Etheostoma (Vaillantia) chlorosoma (Hay)

Etheostoma: various mouths; *chlorosoma*; refers to the greenish cast which appears in subdued tones.

RANGE

Etheostoma chlorosoma ranges from tributaries of the Mississippi River from southern MN east to the Little Calumet River basin;* south to the San Antonio River; and the Mobile Bay system, AL.[1,2] *Etheostoma chlorosoma* is a lowland species much more abundant in southern portions of its range.[2]

HABITAT AND MOVEMENT

The bluntnose darter inhabits low-gradient, clear, small streams to moderate-sized rivers. Adults most commonly occur over sand, mud, clay, or organically enriched substrates with accumulations of woody debris in backwaters or oxbow habitats (T.P. Simon, personal observation).

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma chlorosoma occurs in the lower Tennessee River and tributaries from the Big Bend, AL, to the Ohio River, KY.[6] The bluntnose darter occurs sporadically in the lower Wabash River from Knox County, IN, to the Ohio River mouth.*

SPAWNING

Location

Egg sites are emergent plants and other aquatic vegetation in areas ranging from absent to slow current;[11] spawning substrates are plants or plant debris.[16]

Season

Individuals approaching spawning condition are collected during April in KS;[12] during April in MS;[13] during May in IL;[14] during April and May in AR.[7] Breeding tubercles were found on males in March and April in TX and LA.[15] Reproduction in the Cache River, AR, occurs over a period of several weeks in April.[10]

Temperature

Spawning temperatures range from 22 to 26°C.[10]

Fecundity (see Table 51)

Females (38–49 mm TL) collected in April had a mean ovary weight that was 17.1% of the body weight, containing a mean of 117.6 total ova that average 0.83 mm in diameter. Female *E. chlorosoma* showed statistically significant increasing fecundity (ANOVA $F = 11.25$, $p = 0.01$) with increasing length (Table 51). Females 38–49 mm had 73–171 large mature ova (Simon, T.P., unpublished data).*

Sexual Maturity

No information. Female specimens 39 mm were sexually mature.*

Table 51

Fecundity data for *E. chlorosoma* from unnamed creek, Union Parish, LA.*

Length TL	Ovary Weight (mg)	Number of Ova: Ripening oocytes (LA)	Mature eggs (EM, MA, LM)	Ripe (mm) (MR, RE)	Egg Diameter (mm)
38	63.8	983	95	73	0.83
39	68.5	1106	114	74	0.83
41	88	1128	179	83	0.83
42	77.8	1120	160	76	0.83
43	88	1017	152	120	0.83
43	150	1156	300	171	0.83
45	122	1262	224	152	0.83
46	113	1398	239	142	0.83
47	107	1142	147	140	0.83
49	153	1054	156	145	0.83

Spawning Act
The bluntnose darter is an egg attacher.[10,11] Adults maintain a head-to-head orientation, with the male maintaining a serpentine position alongside the female, their vents juxtaposed.[11] During courtship, males became aggressive, exhibiting lateral displays to females approximately 3 cm above a sand substrate. Reproductive behavior is similar to other egg-attaching darters: the female selects the site of egg deposition, the male closely follows her to the site and mounts her, and then the pair vibrate. Often, the male would mount the female while she was horizontal to the substrate, beating her with his pectoral fins until she swam into the plant material. Usually, 1–3 eggs are laid during a spawning event and all are attached to plant material such as twigs, algae or dead leaves, and logs.

EGGS

Description
Ovarian examination showed that latent eggs were light orange, spherical and ranged from 0.29 to 0.33 mm; early maturing ova were small, spherical, and averaged 0.63 mm; and large ripe mature ova were transparent, slightly yellow-green and averaged 0.83 mm.* Eggs from the Cummins Creek and various Neches River tributaries, TX , average 1.05 mm in diameter.[17] Eggs from LA are spherical, mean = 1.0 mm diameter (range: 0.9–1.1 mm); translucent, demersal, and nonadhesive. Eggs possess a translucent pale-yellow yolk (mean = 0.9 mm in diameter; range: 0.8–1.0 mm); a single oil globule (mean = 0.3 mm; range: 0.25–0.33 mm); a narrow perivitelline space ($x = 0.1$ mm); and an unsculptured and unpigmented chorion.[10]

Incubation
Hatching occurs after 156–211 h at an incubation temperature of 26°C.[17]

Development
No information.

YOLK-SAC LARVAE

See Figure 46

Size Range
Specimens from MS and LA hatch at 3.8–4.3 mm TL; and Yolk is obsorbed between 5.6–5.8 mm TL.[10]

Myomeres
Preanal 18 (8), 19 (4), 20 (13; $N = 25$, mean = 19.2); postanal 20 (4), 21 (4), 22 (17; $N = 25$, mean = 21.5); with total 39–42 ($N = 25$, mean = 40.6).[10]

Morphology
3.8–4.3 mm TL. Newly hatched larvae have a laterally compressed body; rounded snout; functional jaws, upper jaw even, with slightly overhanging lower jaw; well-developed pectoral fins without incipient rays; yolk sac small, elongate (21.6% TL) to rectangular; yolk translucent, clear to pale yellow, with a single oil globule; single mid-ventral vitelline vein on yolk sac; head not deflected over the yolk sac; eyes oval.[10]

5.6 mm TL. Digestive system functions prior to yolk absorption.[10]

Morphometry
See Table 52.[10]

Fin Development
3.8–4.3 mm TL. Newly hatched larvae have well-developed pectoral fins without incipient rays.[10]

Pigmentation
3.8–4.3 mm TL. (newly hatched): eye pigmented; no other pigmentation present on body or yolk sac.[10]

4.5–5.0 mm TL. Dorsal and lateral melanophores absent. Several stellate melanophores occur ventrally on the yolk sac and outline the gut; a double row of melanophores is present from the anus to the caudal peduncle.[10]

LARVAE

See Figures 46 and 47

Size Range
5.6–14.0 mm TL.[10]

Myomeres
Preanal 18 (8), 19 (4), 20 (13; $N = 25$, mean = 19.2); postanal 20 (4), 21 (4), 22 (17; $N = 25$, mean = 21.5); with total 39–42 ($N = 25$, mean = 40.6).[10]

Morphology
5.8–6.5 mm TL. Operculum and gill arches functional (5.8–6.5 mm); yolk absorbed (5.6–5.8 mm).[10]

6.8 mm TL. Notochord flexion precedes caudal fin ray development.[10]

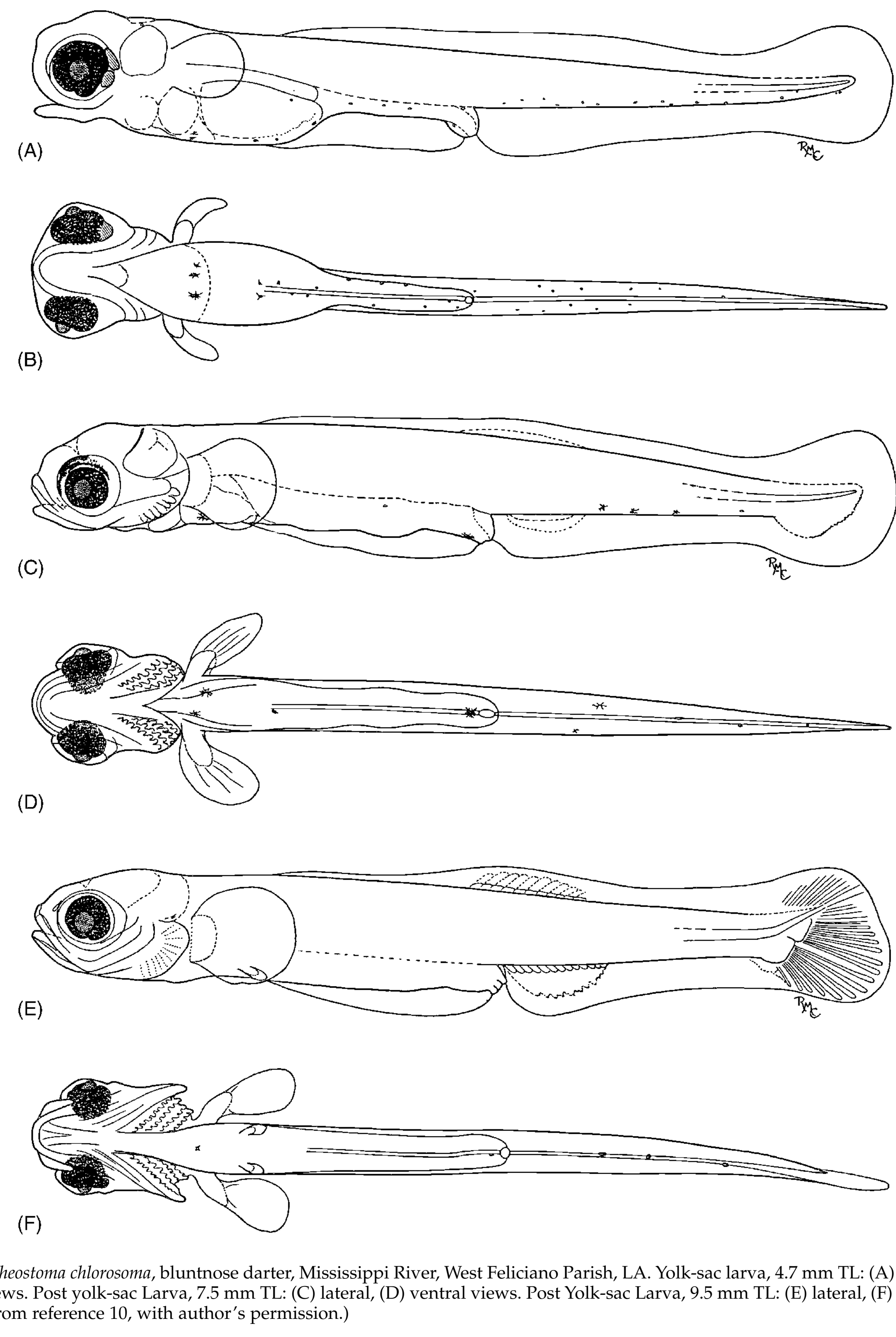

Figure 46 *Etheostoma chlorosoma*, bluntnose darter, Mississippi River, West Feliciano Parish, LA. Yolk-sac larva, 4.7 mm TL: (A) lateral, (B) ventral views. Post yolk-sac Larva, 7.5 mm TL: (C) lateral, (D) ventral views. Post Yolk-sac Larva, 9.5 mm TL: (E) lateral, (F) ventral views. (A–F from reference 10, with author's permission.)

7.8–8.2 mm TL. Neuromast development occurs midlaterally from the anterior trunk posteriad (7.8 mm);[10] premaxilla and mandible form (7.8–8.0 mm).[10]

8.8 mm TL. Snout blunt, remains neotenic.[10]

7.8–10.9 mm TL. No swim bladder forms; gut straight, with striations, portion of gut posterior to stomach elongate in length (8.7 mm); lateral line begins forming (8.8 mm).[10] Upper jaw overhangs lower jaw, mouth terminal (10.6–10.9 mm).[10]

Table 52

Morphometry of Young *E. chlorosoma* grouped by selected intervals of total length (*N*=sample size).

	Total Length (TL) Intervals (mm)											
	4.31—5.84 (*N*=6)		6.48—7.76 (*N*=3)		8.02—10.9 (*N*=6)		11.3–14.0 (*N*=8)		16.9 (*N*=1)		22.3—26.1 (*N*=6)	
Characters	**Mean±SD**	**Range**	**Mean±SD**	**Range**	**Mean±SD**	**Range**	**Mean±SD**	**Range**	**Mean**	**Range**	**Mean±SD**	**Range**
Length (% of TL)[a]												
Upper Jaw[a]	21.8±3.08	(0.12–0.22)	18.7±4.20	(0.17–0.32)	26.9±4.09	(0.26–0.62)	28.8±3.53	(0.54–0.82)	27.6	(1.08)	26.4±2.25	(1.20−1.44)
Snout [(a)]	16.5±1.43	(0.09–0.18)	17.7±3.58	(0.16–0.34)	19.4±1.89	(0.22–0.45)	20.0±1.48	(0.40–0.69)	14.8	(0.58)	18.3±2.40	(0.76−1.10)
Eye diameter (a)	38.6±6.84	(0.28–0.35)	31.5±3.67	(0.41–0.47)	29.7±1.97	(0.44–0.60)	27.9±0.97	(0.62–0.82)	30.6	(1.20)	27.1±1.98	(1.19−1.60)
Head	16.5±2.09	(0.56−1.05)	19.7±2.07	(1.18−1.71)	18.8±1.10	(1.38−2.11)	20.1±1.04	(2.16−3.04)	23.2	(3.92)	20.1±1.13	(4.34−5.32)
Predorsal	23.7±4.15	(0.81–1.63)	27.5±3.03	(1.63–2.40)	28.2±1.69	(2.06–3.00)	28.1±0.64	(3.06–4.00)	27.4	(4.62)	27.2±1.49	(6.00−7.00)
Dorsal insertion							42.0±6.03	(3.14–6.40)	44.2	(7.46)	43.8±2.03	(9.80−11.4)
D2 origin							47.4±7.92	(3.14–7.00)	45.5	(7.68)	46.4±2.14	(10.5−12.1)
D2 insertion							61.6±13.7	(3.14–7.00)	66.6	(7.68)	63.1±3.08	(10.5−12.1)
Preanal	53.3±0.60	(2.25–3.12)	52.6±3.12	(3.59–3.82)	54.7±2.09	(4.46–5.89)	53.9±0.66	(6.02–7.62)	47.4	(8.00)	49.1±2.05	(11.1−13.0)
Postanal	46.7±0.59	(2.05–2.72)	47.4±3.08	(2.89–3.94)	45.3±2.08	(3.55–5.08)	46.1±0.66	(5.18–6.40)	52.6	(8.88)	48.9±3.26	(10.4−13.2)
Standard	96.0±0.25	(4.13–5.60)	96.5±0.26	(6.26–7.50)	91.6±4.31	(7.78–9.66)	87.0±1.16	(9.75–12.1)	82.9	(14.0)	82.4±4.22	(18.1−21.9)
Yolk sac	21.6±1.79	(0.82–1.04)										
Fin Length (% of TL)												
Pectoral	8.26±1.22	(0.32–0.58)	10.9±1.73	(0.65–1.00)	11.8±1.77	(0.73–1.54)	14.2±1.71	(1.22–2.20)	17.4	(2.94)	17.3±2.51	(3.54−4.82)
Pelvic			3.09	(0.24–0.24)	4.34±0.70	(0.39–0.51)	7.63±2.12	(0.51–1.52)	15.9	(2.68)	13.4±2.31	(2.50−3.92)
Spinous dorsal							15.9±1.49	(1.60–2.40)	16.8	(2.84)	16.6±0.61	(3.80−4.44)
Soft dorsal							16.1±1.33	(1.62–2.42)	21.1	(3.56)	16.8±1.47	(3.53−4.70)
Caudal	4.00±0.25	(0.16–0.24)	3.53±0.26	(0.22–0.26)	8.38±4.31	(0.24–1.28)	13.0±1.16	(1.26–1.93)	17.1	(2.88)	17.6±4.22	(3.42−6.42)
Body Depth (% of TL)												
Head at eyes	13.3±0.50	(0.56–0.76)	13.8±0.87	(0.86–1.15)	13.8±0.41	(1.10–1.49)	13.5±0.40	(1.51–1.96)	13.3	(2.25)	10.7±0.73	(2.32−2.88)
Head at P1	12.4±0.64	(0.56–0.72)	11.3±1.50	(0.74–0.83)	15.9±4.88	(1.10–2.06)	14.7±0.74	(1.59–2.22)	16.4	(2.76)	13.0±1.10	(2.74−3.56)
Preanal	6.67±1.12	(0.26–0.50)	10.6±3.77	(0.52–1.16)	10.6±1.31	(0.72–1.23)	11.9±0.40	(1.28–1.70)	14.3	(2.42)	11.1±0.74	(2.33−3.00)
Mid-postanal	4.70±0.28	(0.18–0.29)	6.56±0.82	(0.38–0.58)	7.37±0.81	(0.53–0.83)	8.18±0.32	(0.85–1.20)	9.95	(1.68)	8.39±0.54	(1.92−2.30)
Caudal peduncle	2.45±0.46	(0.08–0.18)	4.02±1.22	(0.21–0.42)	7.43±3.45	(0.32–1.03)	7.32±0.45	(0.80–1.02)	8.89	(1.50)	6.56±0.38	(1.50−1.76)
Yolk sac	8.42±0.69	(0.32–0.40)										
Body Width (% of HL)												
Head	79.0±12.6	(0.50–0.76)	66.9±4.27	(0.82–1.06)	69.8±3.61	(1.00–1.42)	65.5± 4.02	(1.40–1.93)	54.3	(2.13)	48.8±3.72	(2.20−2.72)
Myomere Number												
Predorsal	5.17±0.75	(4.00–6.00)	4.33±0.58	(4.00–5.00)	5.00±0.00	(5.00–5.00)	5.00±0.00	(5.00–5.00)	5.00	(5.00)		
Soft dorsal							18.7±0.82	(17.0–19.0)	18.0	(18.0)		
Preanal	19.3±1.03	(18.0–20.0)	19.3±1.16	(18.0–20.0)	19.3±0.82	(18.0–20.0)	19.1±0.99	(18.0–20.0)	18.0	(18.0)		
Postanal	21.2±0.98	(20.0–22.0)	21.7±0.58	(21.0–22.0)	21.3±1.03	(20.0–22.0)	21.5±0.76	(20.0–22.0)	22.0	(22.0)		
Total	40.5±0.84	(40.0–42.0)	41.0±1.73	(39.0–42.0)	40.7±0.82	(40.0–42.0)	40.6±1.19	(39.0–42.0)	40.0	(40.0)		

[(a)] Proportion expressed as percent head length.
Note: Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

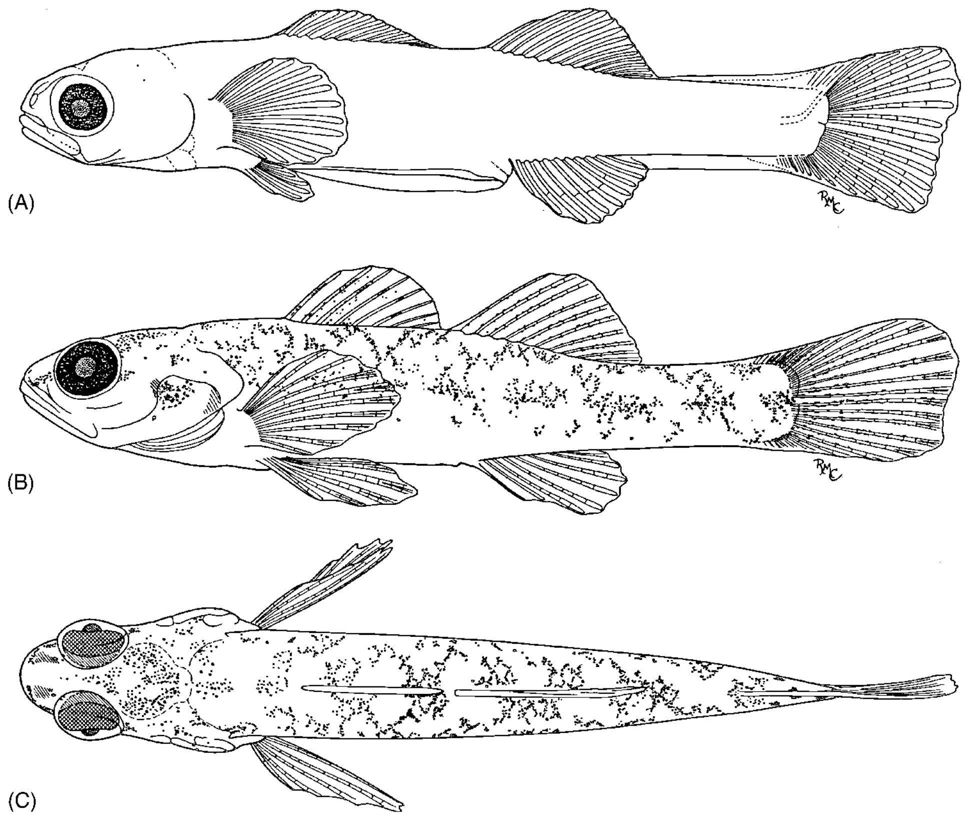

Figure 47 *Etheostoma chlorosoma*, bluntnose darter, Mississippi River, West Feliciano Parish, LA. Post yolk-sac larva, 13.9 mm TL: (A) lateral view. Juvenile, 18.5 mm TL, Buffalo River, Wilkinson County, MS. (B) lateral and (C) dorsal views. (A–C from reference 10, with author's permission.)

Morphometry
See Table 52.[10]

Fin Development
See Table 53.[10]

5.8–6.5 mm TL. First rays form in caudal fin (5.8–8.2 mm).[10]

6.8 mm TL. Notochord flexion precedes caudal fin ray development.[10] Pectoral fin rays form (6.8–8.0 mm).[10]

7.8–8.2 mm TL. Anal fin and branchiostegal rays develop (7.8–8.2 mm).[10]

7.8–10.9 mm. Pelvic fin buds form anterior to dorsal fin origin after complete yolk absorption (7.8–10.9 mm); soft dorsal fin rays form (8.7 mm).[10] Spinous dorsal rays form (9.9 mm); first pelvic fin ray forms (10.6 mm); complete adult fin ray counts in median fins (9.9–10.6 mm); dorsal and anal finfold partially differentiated (10.9 mm).[10]

11.2–11.3 mm TL. Both dorsal and anal finfolds completely differentiated (11.2 to 11.3 mm).[10]

11.3–14.0 mm TL. Spinous dorsal fin origin over preanal myomere 4 to 6, soft dorsal fin origin over preanal myomere 17 to 19 (11.3 to 14.0 mm).[10] Average predorsal length 30.1% SL (range: 26.4 to 33.4% SL) and 27.0% TL (range: 23.7 to 29.9% TL). Caudal fin rays segmented and fin emarginate (12.8 to 13.8 mm).[10]

Pigmentation
5.8–7.8 mm TL. Several melanophores become apparent on the breast, at the origin of the pelvic finfold, and at the anus. Melanophore frequency diminishes mid-ventrally at the postanal myoseptum.[10]

8.0–10.9 mm TL. Melanophore frequency reduces, only a single melanophore on the breast and anterior anus; several mid-ventral melanophores from the future anal fin insertion to caudal fin base (Figure 46).[10]

11.3–14.0 mm TL. (early juvenile): no melanophores apparent on entire body or fins.[10]

JUVENILES

See Figure 47

Size Range
14–39 mm TL.[10]

Table 53

Meristic counts and size (mm TL) at the apparent onset of development for *E. chlorosoma.*

Attribute/event	*E. chlorosoma*	Literature
Branchiostegal Rays	6,6	6,6[1–8]
Dorsal Fin Spines/Rays	VIII–XI/10–12	VIII–XI/9–12[1–8]
First spines formed	9.9	
Adult complement formed	9.9	
First soft rays formed	8.7	
Adult complement formed	9.9	
Pectoral Fin Rays	13	12–15[1–7]
First rays formed	6.8–8.0	
Adult complement formed	9.9	
Pelvic Fin Spines/Rays	I/5	I/5[1,2,5–9]
First rays formed	10.6	
Adult complement formed	10.6	
Anal Fin Spines/Rays	I–II/7–9	I–II/7–9[1–3,5–9]
First rays formed	7.8–8.2	
Adult complement formed	10.6–10.9	
Caudal Fin Rays	vii–xii, 8-9+7-8, vii–x	13–17[6–9]
First rays formed	5.8–8.2	
Adult complement formed	9.9–10.6	
Lateral Line Scales	49–69	47–64[1-3,5–9]
Myomeres/Vertebrae	39–42/38–40	Unknown/38–40[1,2,4,6–9]
Preanal myomeres	18–20	
Postanal myomeres	20–22	

Fin Development
Branchiostegal rays 6,6;[1–8,10] dorsal fin spines/rays VIII–XI/9-(10–12);[1–8,10] pectoral fin rays 12-(13)[10]–15;[1–7] pelvic fin spines/rays I/5;[1,2,5–9,10] anal fin spines/rays I–II/7–9;[1–3,5–9,10] caudal fin rays VII–XII, 8-9+7-8, VII–X[10] or 13–17;[6–9] lateral line scales 49–69[10] or 47–64.[1–3,5–9]

Morphology
Total vertebrae count 40 ($N = 2$), including one urostylar element.[10] Scales in the lateral series range from 49[11] to 69 (Buffalo River, MS).

< 16.9–16.9 mm TL. Supraorbital, infraorbital, lateral, and subtemporal head canals form (<16.9 mm); initiation of squamation occurs across dorsum and mid-lateral (16.9 mm).[10]

21.5 mm TL. Infraorbital, lateral, and supratemporal head canals complete, preoperculomandibular canal complete with ten pores, infraorbital pores six; squamation complete.[10] Cheek, opercle and prepectoral area scaled, nape is partially scaled to naked; belly is fully scaled or scaled anteriorly and naked posteriorly.[1,2]

26.1 mm TL. Infraorbital pores interrupted, 2–4 pores anteriorly, and either 0–1 posteriorly, supratemporal pores interrupted, preoperculomandibular pores ten.[10]

Morphometry
See Table 52.

Pigmentation
16.9–26.1 mm TL. Dorsum of head with melanophores covering the anterior cerebellum and optic lobe; 6 dorsal saddles present. Preorbital and postorbital bars form; a series of 7–8 clusters of melanophores forming X-, Y-, or W-markings along the mid-lateral; and a series of vertical melanophores along the caudal fin base. Spinous dorsal fin with

membranous melanophores anteriorly and distally; proximally on the soft dorsal membranes; and scattered on the caudal fin. No melanophores present on the pectoral, pelvic, or anal fins.[10]

TAXONOMIC DIAGNOSIS OF YOUNG BLUNTNOSE DARTER

Similar species: members of subgenus *Boleosoma*

Adult. The *Vaillantia* group was originally recognized as a monotypic subgenus,[18] and was expanded to two taxonomically recognized species[19] including *E. davidsoni* and *E. chlorosoma*. The subgenus is characterized by the presence of a black bridle (formed from the anterior fusion of the preorbital bars) around the snout, an incomplete lateral line, the presence of palatine and prevomerine teeth, the absence of a premaxillary frenum, modally six branchiostegal rays, and branchiostegal membranes that are moderately joined across the isthmus.[1,2]

The bluntnose darter differs from the Choctawhatchee darter by the presence of an interrupted supratemporal canal, scaled prepectoral area, interrupted infraorbital pores, broadly interrupted infraorbital canal, a single anal fin spine, and breeding tubercles on anal and pelvic fins of the males.[1,2]

Larva. The bluntnose darter possesses a rectangular body shape and shows a relatively slow ontogenetic development of fin elements. The species can be differentiated from sympatric percids by the high number of preanal (18–20) and postanal (20–22) myomeres, the lack of melanophores dorsally and laterally, small yolk sac, and slow ontogenetic development. It is easily distinguished from members of the subgenus *Boleosoma* by its preanal myomere number, yolk-sac shape and depth proportions, and body shape characteristics.[10]

Variation

Specimens from AR hatch at a smaller length interval than LA specimens, at 4.3–5.6 mm. No geographical variation was discernable in meristic, morphometric, or ontogenetic event characters between Mississippi River, LA, and Cache River, AR, populations.[10]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 48)

Eggs. Egg sites are emergent plants and other aquatic vegetation in areas ranging from absent

Figure 48 Distribution of bluntnose darter, *E. chlorosoma* in the Ohio River system (shaded area).

to slow current;[11] or spawning substrates such as plants or plant debris.[16]

Yolk-sac larvae. Aquarium observations show that bluntnose darter larvae are pelagic immediately after hatching.[10]

Post Yolk-sac larvae. Demersal only at lengths greater than 12 mm and remain in close association with the substrate.[10]

Juveniles. In the Cache River, AR, larvae drift at the surface of the water column, settling as early juveniles in the downstream pools and backwater oxbows adjacent to spawning areas, which function as nursery habitats. Juveniles greater than 21 mm TL are the smallest individuals found on the margins of the main channel river habitat in the Buffalo River, MS.[10]

Early Growth, (see Table 54)
Young-of-the-year specimens from TN were 30 mm TL by mid-August.[6]

Feeding Habits
Young TN specimens ate hydropsychid caddisflies, dytiscid beetles, and midge larvae.[6]

Table 54

Average calculated lengths (TL mm) of young bluntnose darter in Tennessee.

State	Age 1	2	3
Tennessee[6]	37–41	46–50	61

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Material examined: LA: West Feliciano Parish: Mississippi River, near St. Francisville; FEL 2289-1 (1); FEL 2309-1 (1); FEL 2323-1 (1); FEL 2210 (1); FEL 2207-1 (4); FEL 2250 (1); CT-LT-16 (3); CRBLT5 (1); FEL 2252-1 (5); FEL 2306-2 (1); FEL 2320 (3); JVC 871 (1); JVC 875 (1). AR: Woodruff County: Cache River, Rex Hancock/Black Swamp Wildlife Management Area, 3 mi SE Gregory, Point Twp. T 6N R 3W; CT-Lt-16 (3); CRBLT5 (1). MS: Wilkinson County; Buffalo River, 200 m N of Jackson Point bridge near Ft. Adamas; UNO 8835 (1); UNO 2236 (4).

* Original fecundity data for *E. chlorosoma* from an unnamed Creek, Union Parish, LA. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe, LA. Early life history specimens curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN. Habitat and distribution data based on T.P. Simon, unpublished data.

ASHY DARTER

Etheostoma (*Allohistium*) *cinereum* Storer

Etheostoma: various mouths; *cinereum*; ashy gray, which is typical of the preserved specimens but not of living material.

RANGE

Etheostoma cinereum occurs sporadically in the Highland Rim and the Ridge and Valley portions of the Tennessee and Cumberland River drainages, and in the lower reaches of some Cumberland Plateau rivers in KY, TN, VA, GA, and AL.[1–6] The species range prior to impoundment probably included the main channel areas of the Tennessee and Cumberland Rivers.[4]

HABITAT AND MOVEMENT

The preferred habitats of the ashy darter are small to medium upland rivers, where it occurs locally in areas of bedrock or gravel substrate with boulders, water willow, and other covers with minimal silt deposits. Depths in these areas are 0.5–2 m, with sluggish currents. The ashy darter is associated with slab rock boulders in slow backwaters where stones have a slight silt layer.[1–6]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Only five river systems have viable populations[5], while ten historic populations are either extirpated or no recent specimens have been collected.[4,5] The species is rare over most of its range; however, it can be regularly found in the Rockcastle River and Big South Fork (Cumberland River drainage), and in the Little River, Blount County, TN (Tennessee River drainage).[3]

SPAWNING

Location
Etnier and Starnes suggested that deposition of eggs on the side of a clear plastic filter box could reflect spawning on the sides of boulders or water willow stems as deposition sites.[4]

Season
Spawning season is between late January and April;[4–5] breeding occurred in aquariums in specimens collected from Little River (TN) in mid-February and early March.[6]

Temperature
Spawning temperatures are 9–20°C.[6]

Fecundity (see Table 55)
Females produce 50–250 mature ova per year.[4,5] Two ripe females contained 150 and 249 mature ova, respectively, with an average of 53 mature ova per gram adjusted body weight. Females collected in May had the lowest gonadosomatic index (GSI), which was 2.4.[5]

Sexual Maturity
Males dichromatic by January.[4] Sexual maturity occurs at lengths of 60 mm TL for males and 58 mm TL for females.[4,5,*] Nuptial tubercles were found on the anal fin soft rays and on ventral surfaces of the second and third pelvic soft ray.[5]

Spawning Act
Spawning occurred in an aquarium by a single pair. Courting by both sexes usually led to the mounting of the female and spawning. Oviposition was usually a single egg per spawning event that occurred on the vertical side of a clear plastic box filter.[6]

EGGS

Description
Ovarian examination showed that mature ova were orange or translucent and averaged 2.0 mm in diameter (range: 1.7–2.4 mm, $N = 20$).[5]

Incubation
Unknown.

Development
Unknown.

TABLE 55

Fecundity data for ashy darter from Little River and Buffalo River, TN.*

Date	TL	GSI	Number of Ova: Ripening oocytes (LA)	Mature oocytes (EM,MA, LM)	Ripe eggs (MR, RE)	Egg Diameters (mm)
January 5	58	74	—	149	—	—
March 5	63	119	—	150	--	—
	64	225	—	106	—	—
	70	224	—	249	—	—
April 5	58	54	—	43	—	—
	60	49	—	51	—	—
April 8	72	5.3	0	4	34	1.7
April 10	80	13.9	0	54	0	0.83–1.0
	96	7.1	0	41	0	0.83–1.0
	103	12.4	0	50	0	0.83–1.0

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown to 58–60 mm TL.*[,4,5]

Fin Development
Larger juveniles. Spinous dorsal fin 9–14; soft dorsal rays 11–14; pectoral rays 14–16; anal fin rays II 7–9; pelvic fin rays I 5; caudal fin rays 16–18.[2–4,6]

Morphology
Total vertebrae count 39–41 including one urostylar element. Scales in the lateral series complete, range from 50 to 63 scales in the lateral series from TN.[2–4,6]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG ASHY DARTERS

Similar species: Adults are unlike any darter with its distinctive color patterns and snout shape.[4,7]

Aspects of the early life history and reproductive biology for *E. cinereum* are virtually unknown.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (see Figure 49)
Eggs. Eggs are speculated to be laid on the stems of plants or the sides of rocks singly.[4,7]

Yolk-sac larvae. Unknown.

Larvae. Unknown.

Juveniles. Unknown.

Early Growth
Apparently, individuals live to reach 3–4 years of age.[4,5] Young ashy darters attain lengths of 40–75 mm TL by age 1[4,6,7] (Table 56).

Feeding Habits
The main components of the diet include midge larvae, with the burrowing mayfly *Ephemera* a significant food item in the Cumberland River drainage.[4] Major food items are burrowing mayfly larvae and oligochaete worms; large adults ingest fewer midges than smaller fish.[5,7] Etnier and Starnes found a considerable amount of incidental detritus and sand grains in several digestive tracts.[4]

Table 56

Average calculated lengths (mm TL) of young ashy darter in Tennessee.

	Age			
State	1	2	3	4
Tennessee[4]	40–75	50–94	70–99	100 mm (SL)

Figure 49 Distribution of ashy darter, *E. cinereum* in the Ohio River system (shaded area).

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* Original fecundity data for ashy darter from specimens curated from Northeast Louisiana University, Museum of Zoology, Monroe. Specimens were from the Little River, Blount County, TN and Buffalo River, Lewis County, TN.

CROWN DARTER

Etheostoma (*Catonotus*) *corona* Page and Ceas

Etheostoma: various mouths; *corona*: a crown; in reference to the golden margin of the soft dorsal fin of breeding males.

RANGE

Etheostoma corona is limited to the Cypress Creek system of northern AL and Wayne County, TN.[1]

HABITAT AND MOVEMENT

The preferred habitats of the crown darter are small to medium upland rivers, where it occurs locally in areas of bedrock or gravel substrate in riffles or margins of riffles. Depths in these areas are 0.5–1 m with slow-sluggish currents.[1,2]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma corona is limited to Cypress Creek, AL, and Wayne County, TN.[1,2]

SPAWNING

Location
Etnier and Starnes suggested that males in breeding condition were collected from beneath rocks. This is consistent with other members of *Catonotus*.[3]

Season
Spawning season is mid-April.[3]

Temperature
Unknown.

Fecundity
Unknown.

Sexual Maturity
Males dichromatic by mid-April.[3] Nuptial males have a yellow margin on soft dorsal fin.[1–3]

Spawning Act
Spawning probably occurs as in other *Catonotus* species, beneath slab rocks.[3]

EGGS

Description
Unknown.

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Larger juveniles. Spinous dorsal fin 8–10; soft dorsal rays 13–15; pectoral rays 11–13; anal fin rays II 6–9; pelvic fin rays I 5; caudal fin rays 16–18.[1–3]

Morphology
Scales in the lateral series incomplete, with 25–44 pored scales and 40–55 scales in the lateral series from TN.[2,3]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG CROWN DARTER

Similar species: similar to other members of the *E. squamiceps* complex. Early life stages may be indistinguishable from other populations.[3] In Cypress Creek it is sympatric with *E. flabellare.*[3]

Adult. E. corona is similar to *E. flabellare.* Both of the *Catonotus* species differ based on myomere counts and differences in pigmentation.

Larva. Aspects of the early life history and reproductive biology for *E. corona* are unknown.

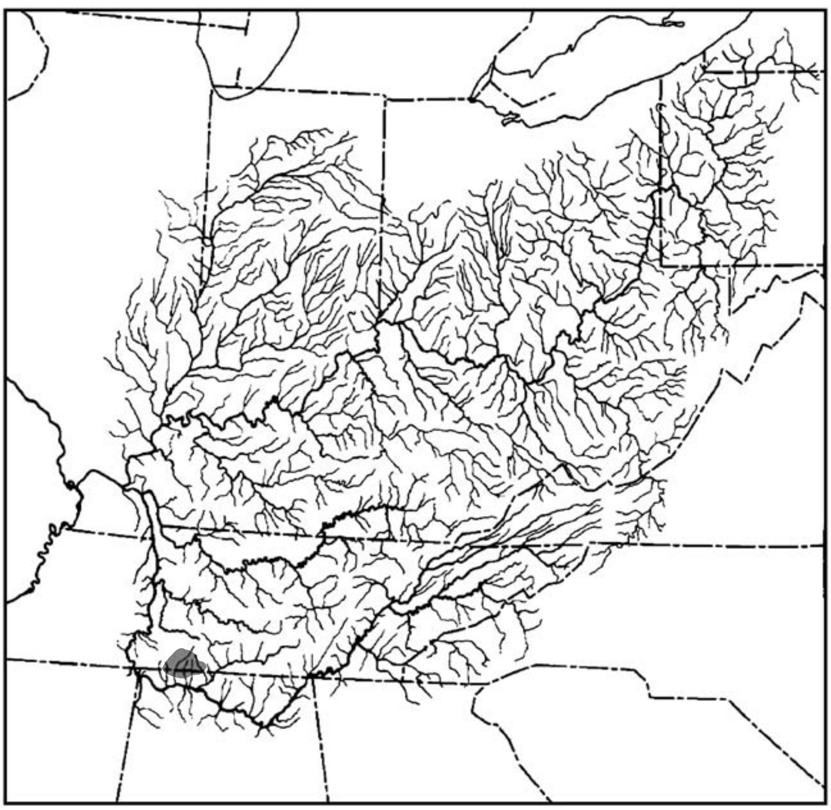

Figure 50 Distribution of crown darter, *E. corona* in the Ohio River system (shaded area).

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 50)
Eggs. Eggs are speculated to be laid on the underside of slab rocks.[3]

Yolk-sac larvae. Unknown.

Larvae. Unknown.

Juveniles. Unknown.

Early Growth
Largest specimen reaches 78 mm TL.[2,3]

Feeding Habits
Unknown.

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FRINGED DARTER

Etheostoma (*Catonotus*) *crossopterum* Braasch and Mayden

Etheostoma: various mouths; *crossopterum*: fringed fin, in reference to the fringed soft dorsal fin of breeding males.

RANGE

Etheostoma crossopterum is common in the Highland Rim and Nashville Basin, in tributary streams of the middle and lower Cumberland River, KY; Shoal Creek, AL in southern tributaries of the upper Buffalo River, and in the middle Duck River system of the Tennessee River drainages, TN.[1–3]

HABITAT AND MOVEMENT

The preferred habitats of the fringed darter are gently flowing pool areas or riffles with slab rock rubble substrates in small streams.[1–3,5]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma crossopterum occurs in tributary streams of the middle and lower Cumberland River, KY, and Shoal Creek, southern tributaries to upper Buffalo River, and middle Duck River system of the Tennessee River drainages, TN.[1,2] In addition, disjunct populations occur in the lower Barren Fork, Cumberland River drainage, Warren County, KY; and in Bear Creek, Tipton County, MS.[1,3]

SPAWNING

Location
Underside of slab rocks.[1–3,5]

Season
Spawning occurs from late March–May. Gravid females (42–52 mm TL) collected in early- to mid-April from Ferguson Creek, KY.[1–3,5]

Temperature
Spawning occurs at temperatures between 14 and 19˚C.[3,5]

Fecundity
Females (47–58 mm TL) collected in early- to mid-April had ovaries that were 10.6% of the body weight, containing 258 total ova averaging 0.57 mm in diameter.* Etnier and Starnes reported that females had 30–350 ova, depending on their size.[3]

Sexual Maturity
Adults live to reach age 3,[1–3] however, maturity is suspected to be at age 1 for females and age 2 for males.[2] An adult male (66.3 mm TL) from TN had testes that were 0.89% of the body weight on April 12.* Male tuberculation was absent and females had a long tubular genital papilla. Males exhibited sexually dimorphic traits during the reproductive season, with an increase in large spherical swellings on the tips of the elongate soft dorsal fin rays.[*,2,3]

Spawning Act
Adults deposit their eggs on the underside of slab rocks where they are guarded by a male.[3] Page and Bart suggest that the male uses egg mimics to entice females into the nest.[4] Males court females by erecting fins, intensifying their color, tail wagging, and probably egg mimicking with the swollen tips of soft dorsal fin rays. When a female enters a nest she assumes a belly-up position. The male joins her, pressing alongside, and spawning occurs with 2–5 eggs deposited during each encounter. A nest may contain as many as 1500 eggs from several different females.[*, 2,3,5]

EGGS

Description
Eggs from the Duck River, TN, are spherical, mean = 2.2 mm in diameter (range: 2.0–2.7 mm), translucent, demersal, and adhesive. Eggs possess translucent, amber yolk (mean = 2.1 mm in diameter; range: 1.9–2.6 mm); a single oil globule (mean = 0.5 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.*

Incubation
Hatching occurs after 240–264 h at an incubation temperature of 19.4–20°C.[5]

Development
Unknown.

YOLK-SAC LARVAE

Size Range
6.5 mm[3,5] to unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown to 47–58 mm TL.*

Fin Development
Larger juveniles. Spinous dorsal fin VII–X; soft dorsal rays 11–15; pectoral rays 10–13; anal fin rays II 6–9; pelvic fin rays I 5; caudal fin rays 16–19.[1–3]

Morphology
Scales in the lateral series incomplete, with 7–44 pored scales and 38–64 total scales in the lateral series from TN.[2,3]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG FRINGED DARTER

Similar species: similar to other members of the *Catonotus* subgenus.[3]

Adult. Etheostoma crossopterum is similar to *E. oophylax*, *E. nigripinne*, and *E. neopterum*.[3]

Larva. Aspects of the early life history for *E. crossopterum* are unknown. *Catonotus* species differ from others darters based on myomere counts and differences in pigmentation.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (see Figure 51)
Eggs. Eggs are laid on the underside of slab rocks.[3]

Yolk-sac larvae. Yolk-sac larvae, probably like other *Catonotus*, remain buried in the gravel interstitial pores beneath the nest stone until the yolk sac is absorbed.*

Larvae. Larvae, probably like other *Catonotus*, are benthic, remaining in close association with the substrate.

Juveniles. Juveniles were found in the gently flowing pools and riffle edges among the slab rocks.*

Early Growth
Specimen reaches 35–50 mm TL at age 1[3] (Table 57).

Feeding Habits
The diet consists of aquatic insect immatures, including midge and caddisfly larvae and mayfly nymphs, and crustaceans including isopods, amphipods, and small crayfish. Juveniles feed on microcrustaceans and midge larvae.*[,2,3]

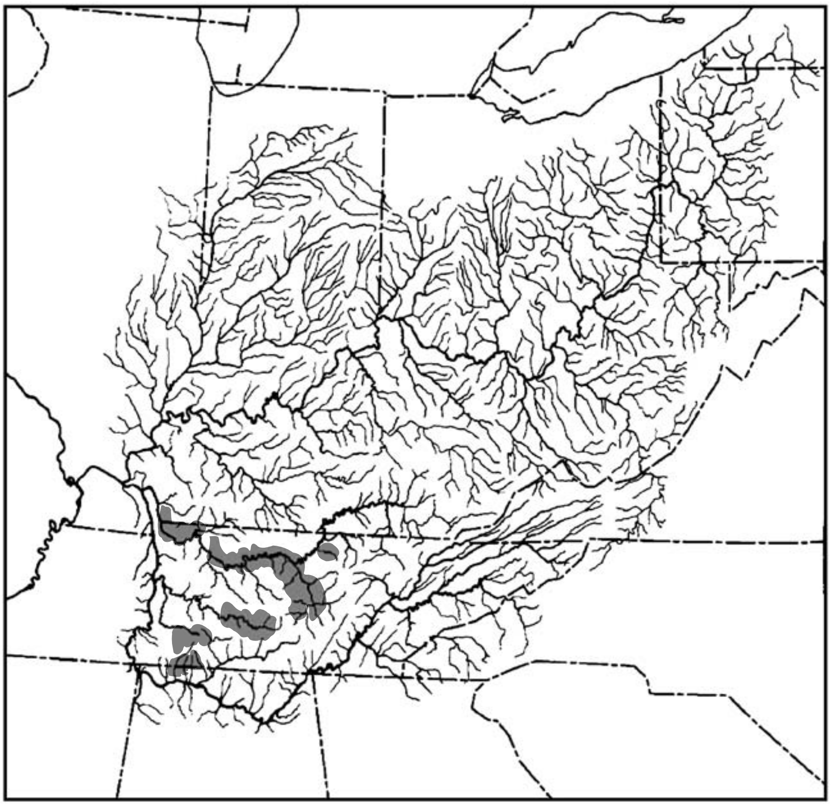

Figure 51 Distribution of fringed darter, *E. crossopterum* in the Ohio River system (shaded area).

Table 57

Average calculated length (TL mm) of young fringed darter in Tennessee.

	Age			
State	**1**	**2**	**3**	**4**
Tennessee[5]	35–50	60–70	74–80	106

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* T.P. Simon, unpublished data.

BLACKSIDE SNUBNOSE (BLACK) DARTER

Etheostoma (*Ulocentra*) *duryi* Henshall

Etheostoma: various mouths; *duryi*: named after the species original collector, Charles Dury.

RANGE

Etheostoma duryi occurs in the Tennessee River system of TN, AL, GA, and probably MS.[1–4]

HABITAT AND MOVEMENT

The blackside snubnose darter inhabits moderate-gradient, clear, small- to medium-sized streams. Adults prefer rubble pools and unsilted gravel substrates in riffles and runs with moderate current.[2,4]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma duryi is found in the Tennessee River basin, and is ubiquitous in the lower bend of the River in AL. In TN, it ranges from the Chattanooga area to portions of the lower Clinch River. In middle TN, it occurs from the Little Duck River and Crumpton Creek, through the Elk River system and eastern tributaries of the lower Tennessee River to the mouth of the Duck River.[1–3] The species occurs in middle portions of the Tennessee River principally from tributaries draining the north, such as the Sequatchie River and Shoal Creek.[2]

SPAWNING

Location
Spawning occurs in pools with moderate current in AL.[6]

Season
Ripe females were collected from mid-March until early May in AL.[6] Late April is assumed to be the peak spawning period in southern TN, as breeding-colored males and females with large-yolked eggs were collected then.[2] Spawning throughout its range occurs from early-March until late-May.[5,6] Spawning activity initiates in Butler Creek, Lauderdale County, AL, and Factory Creek, Lawrence County, TN, in early March.[6]

Temperature
Spawning in Hurricane Creek, Limestone County, AL, occurred when temperatures reached 18–20°C (T.P. Simon, unpublished data).[6]

Fecundity (see table 58)
Female blackside snubnose darter showed statistically significant increasing fecundity (ANOVA, $F = 20.563$, $p = 0.002$) with increasing length. A 57 mm female had 221 large mature ova, while a 52 mm female had 164 large mature ova.*

Sexual Maturity
Blackside snubnose darter reached maturity at age 1 when fish were between 28 and 35 mm SL.[4]

Spawning Act
Etheostoma duryi is an egg attacher. Spawning was observed in adults from Butler and Factory Creek, Lauderdale Co., AL, and in spawning pairs maintained in laboratory aquaria from Hurricane Creek, Limestone Co., AL. Egg sites include the slight depressions on the vertical sides of rocks, and less often, the horizontal tops of rocks in flowing pool habitats, in slight to moderate current.[5] In aquarium observations, reproduction is similar to *E. atripinne.* Prior to spawning, the female swims slowly over the substrate examining the sides of rocks for places to deposit eggs. A male usually follows closely behind defending the female from other males. When the female is ready to spawn, she orients herself vertically and is mounted by the male. The body movements of the male resemble an S-shape, with the caudal peduncle of the male wrapped around that of the female. Adults maintain a head-to-head orientation with vents juxtaposed and press against the rock surface. Eggs are

Table 58

Fecundity data for blackside snubnose darter from the Elk River drainage, Lincoln County, TN.*

		Number of Ova			
Length (TL)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
39	70	616	99	35	1.25
43	84.4	724	246	0	—
45	122	518	227	80	1.25
45	107	1151	100	0	—
46	141	1355	188	29	1.25
48	154	1138	261	84	1.25
50	221	1113	298	139	1.25
52	233	926	187	70	1.25
52	231	1420	204	164	1.25
57	498	2024	347	221	1.25

laid individually on the vertical surface of the rock, generally 3–5 during a single spawning event. The pair is observed to switch positions on the rock, depositing eggs on different sections of the same and different rocks. Each adult was promiscuous, spawning with multiple partners on different rocks. The female, when left unattended, spawns with any male available. This sometimes occurs when a dominant male defends the moving territory by chasing away other males. Neither cleaning of the rock surface nor parental care is provided before or after the eggs are laid.[5]

EGGS

Description
Ovarian examination showed that ovoid latent ova were 0.4 mm in diameter, early maturing ova averaged 0.71 mm, and large mature ova averaged 1.25 mm.[6] Eggs from an unnamed spring, Roane Co., TN, are spherical, average 1.3 mm in diameter (range: 1.2–1.4 mm), translucent, demersal, and adhesive. Eggs possess translucent, pale-yellow yolk (mean = 1.1 mm diameter; range: 0.8–1.25 mm); a single oil globule (mean = 0.3 mm); a moderate perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[6]

Incubation
Hatching occurs after 144–150 h at an incubation temperature of 20–22°C;[6] and after 192 h at 12.8–26.7°C (R. Wallus, personal communication).*

Development
Unknown.

YOLK-SAC LARVAE

See Figure 52

Size Range
AL populations from an unnamed spring, tributary to the Little Emory River, hatch between 4.5–4.9 mm and yolk is absorbed by 5.8 mm TL.[6]

Myomeres
TN specimens: preanal 15 (1), 16 (39), 17 (18), or 18 (4)($N = 62$, mean = 16.4), postanal 22 (4), 23 (33), or 24 (25)($N = 62$, mean = 23.3); with total 38 (1), 39 (17), 40 (41), or 41 (3)($N = 62$, mean = 39.7). AL specimens: preanal myomeres 15 (12) or 16 (2)($N = 14$, mean = 15.1); postanal 23 (2) or 24 (12)($N = 14$, mean = 23.9); with total 38 (2), 39 (10), or 40 (2)($N = 14$, mean = 39.0).[6]

Morphology
4.5–4.9 mm TL. (Newly hatched): body terete; snout blunt; functional jaws, upper jaw even, slightly extending past lower jaw; well-developed pectoral fins without incipient rays; yolk sac small (20.9% TL), oval to tapered posteriorly; yolk translucent, pale yellow, with a single oil globule; single serpentine vitelline vein mid-ventrally on yolk sac;

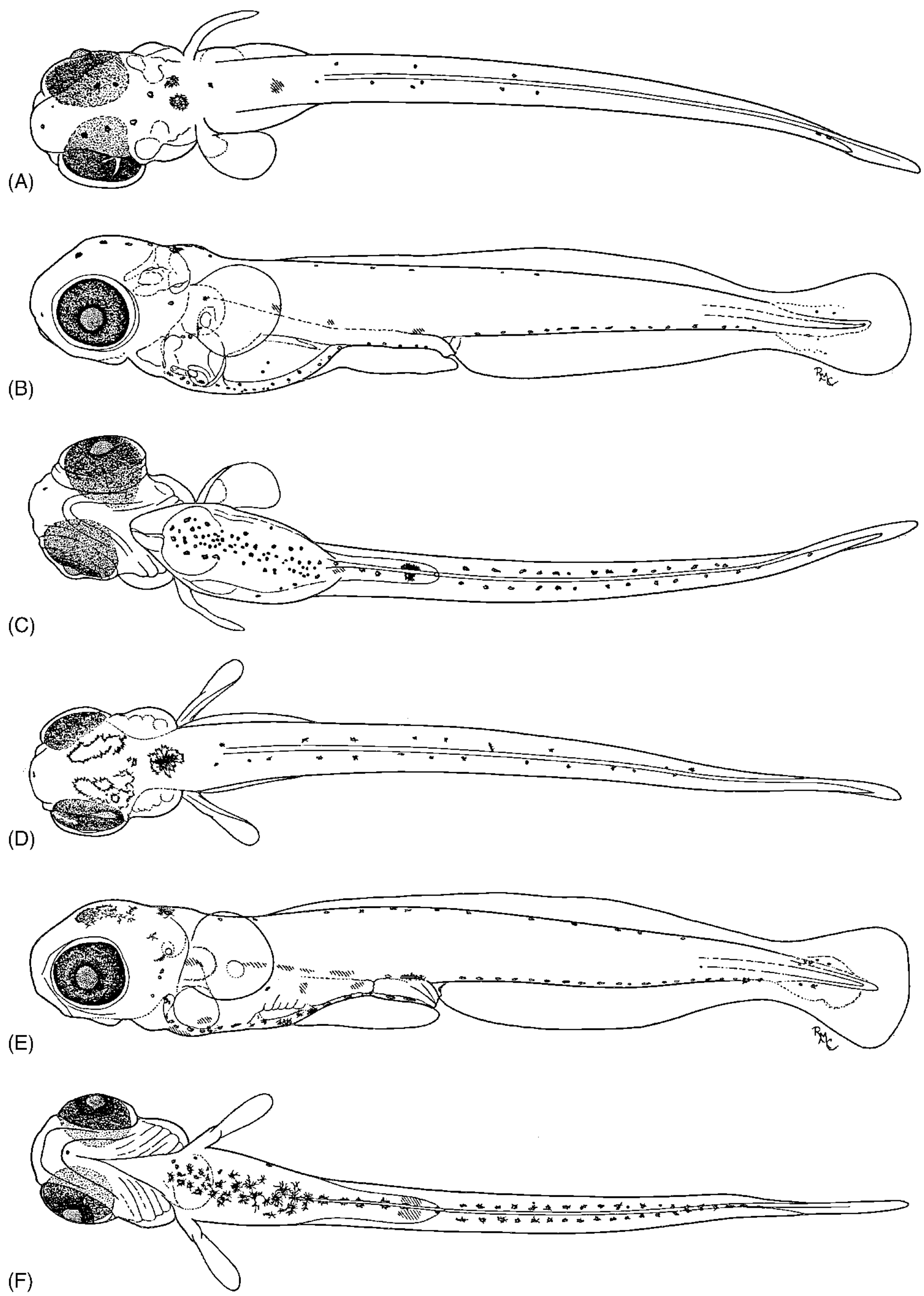

Figure 52 *Etheostoma duryi*, blackside snubnose darter, unnamed tributary Little Emory River, Roane County, TN. Yolk-sac larva, 4.9 mm TL: (A) dorsal, (B) lateral, (C) ventral views. Yolk-sac larva, 5.6 mm TL: (D) dorsal, (E) lateral, (F) ventral views. (A–F from reference 6, with author's permission.)

head not deflected over the yolk sac; and eyes spherical.[6]

5.6 mm TL. Digestive system functions prior to complete yolk absorption.[6]

Morphometry
See Table 59.[6]

Fin Development
4.5–4.9 mm TL. Pectoral fin developed without incipient rays; median finfold complete.[6]

Pigmentation
4.5–4.9 mm TL (newly hatched): Eye pigmented; melanophores dorsally outlining the optic lobe and over posterior cerebellum or nape; dorsal melanophores

Table 59

Morphometry of *E. duryi* larvae grouped by selected intervals of total length (*N*=sample size).[6]

	Total Length (TL) Intervals (mm)					
	4.29–5.90 (*N*=66)		6.10–7.67 (*N*=14)		8.43–9.87 (*N*=4)	
Characters	**Mean±SD**	**Range**	**Mean±SD**	**Range**	**Mean±SD**	**Range**
Length (% of TL)						
Upper jaw[a]	27.7±6.11	(0.15–0.42)	31.7±5.01	(0.30–0.58)	22.8±2.97	(0.39–0.50)
Snout[a]	14.6±2.17	(0.10–0.23)	15.9±1.76	(0.14–0.28)	16.5±0.92	(0.27–0.37)
Eye diameter[a]	45.1±3.71	(0.38–0.49)	41.0±1.63	(0.50–0.62)	37.0±2.14	(0.68–0.75)
Head	19.2±1.32	(0.72–1.36)	19.7±0.91	(1.20–1.57)	21.1±0.56	(1.72–2.14)
Predorsal	28.8±2.17	(1.10–1.98)	29.7±1.09	(1.80–2.27)	28.3±0.69	(2.45–2.78)
Dorsal Insertion					44.6±10.4	(2.45–4.86)
D2 origin					46.6±11.7	(2.45–5.14)
D2 insertion					61.5±21.7	(2.45–5.14)
Preanal	48.2±1.69	(2.06–3.18)	49.4±1.53	(2.96–3.83)	51.0±0.27	(4.30–5.07)
Postanal	51.9±1.72	(2.22–2.98)	50.6±1.52	(2.89–3.88)	49.0±0.25	(4.13–4.82)
Standard	95.7±1.18	(4.07–5.60)	95.7±0.95	(5.80–7.41)	90.1±1.21	(7.68–8.79)
Yolk sac	20.9±3.99	(0.22–1.38)				
Fin length (% of TL)						
Pectoral	9.80±1.45	(0.28–0.76)	10.9±0.78	(0.60–0.92)	13.5±1.07	(1.04–1.46)
Pelvic			2.71±0.00	(0.20–0.21)	5.47±0.54	(0.42–0.59)
Spinous Dorsal					21.8±0.61	(2.00–2.16)
Soft Dorsal					20.0±1.49	(1.86–1.96)
Caudal	4.33±1.18	(0.09–0.38)	4.31±0.95	(0.20–0.42)	9.93±1.21	(0.75–1.08)
Body Depth (% of TL)						
Head at eyes	15.5±0.74	(0.64–1.00)	15.5±0.61	(0.90–1.24)	15.4±0.46	(1.34–1.52)
Head at P1	15.6±1.67	(0.53–0.96)	14.8±0.51	(0.85–1.16)	15.9±0.37	(1.31–1.60)
Preanal	8.35±0.75	(0.25–0.57)	10.3±1.04	(0.56–0.92)	13.6±0.22	(1.12–1.35)
Mid-postanal	6.27±0.39	(0.24–0.42)	7.58±0.75	(0.38–0.69)	8.83±0.23	(0.73–0.89)
Caudal peduncle	2.36±0.80	(0.12–0.21)	4.37±0.73	(0.23–0.46)	7.24±0.18	(0.60–0.73)
Yolk Sac	8.88±2.15	(0.22–0.62)				
Body Width (% of HL)						
Head	75.9±10.6	(0.60–1.02)	69.1±2.79	(0.78–1.12)	63.4±2.27	(1.04–1.36)
Myomere Number						
Predorsal	3.82±0.46	(3.00–5.00)	4.36±0.75	(4.00–6.00)	4.25±0.55	(4.00–5.00)
Soft dorsal			18.5±0.71	(18.0–19.0)	18.3±0.58	(18.0–19.0)
Preanal	16.0±0.64	(15.0–18.0)	16.7±0.73	(16.0–18.0)	17.0±0.82	(16.0–18.0)
Postanal	23.7±0.48	(23.0–24.0)	23.2±0.58	(22.0–24.0)	22.5±0.58	(22.0–23.0)
Total	39.7±0.54	(38.0–41.0)	39.9±0.62	(39.0–41.0)	39.5±0.58	(39.0–40.0)

[a]Proportion expressed as percent head length.
Note: Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

distributed posteriorly, past yolk-sac insertion, to the anus; laterally, over the gut dorsum, subdermal pigment extends from the pectoral origin to the anus; several melanophores on the caudal finfold above the notochord terminus. Ventral pigmentation consists of a mid-ventral series of scattered punctate melanophores forming a stripe near the vitelline vein on the yolk sac; punctate melanophores ventrally outline the gut; and paired punctate melanophores along almost every mid-ventral postanal myosepta.[6]

5.0–5.8 mm TL. Similar to previous length interval with exception of dorsum melanophores on body becoming more numerous; dermal melanophore cluster near base of anus; ventrally a series of large stellate melanophores on the breast and midbelly (not forming a single large macromelanophore as in *E. flavum*), not forming a continuous line from the posterior stomach to the anus but rather single stellate melanophores.[6]

POST YOLK-SAC LARVAE

See Figure 53

Size Range
5.8–6.1 to 11 mm TL.[6]

Myomeres
TN specimens: preanal myomeres 15 (1), 16 (39), 17 (18), or 18 (4)(N = 62, mean = 16.4); postanal 22 (4), 23 (33), or 24 (25) (N = 62, mean = 23.3); with total 38 (1), 39 (17), 40 (41), or 41 (3) (N = 62, mean = 39.7). AL specimens: preanal myomeres 15 (12) or 16 (2) (N = 14, mean = 15.1); postanal 23 (2) or 24 (12)(N = 14, mean = 23.9); with total 38 (2), 39 (10), or 40 (2) (N = 14, mean = 39.0).[6]

Morphology
5.8–6.1 mm TL. Yolk absorbed; operculum and gill arches function (5.6–6.0 mm).[6]

6.0–8.4 mm TL. Premaxilla and mandible form; upper jaw equal with lower jaw, becoming subterminal (7.5 mm); no swim bladder forms; gut straight, without striations, portion of gut posterior to stomach normal in length (7.4–8.4 mm).[6]

8.4–8.6 mm TL. Neuromast development occurs mid-laterally from the anterior trunk posteriad.[6]

Morphometry
See Table 59.[6]

10.8 mm. Average predorsal length 30.3% SL (range: 26.8 to 30.5% SL), and 28.9% TL (range: 25.6 to 29.1% TL) ; lateral line begins to form (10.8 mm).[6]

Fin Development
7.1–7.8 mm TL. First rays form in caudal fin (7.1–7.8 mm); notochord flexion simultaneous to preceding caudal fin ray development (7.4–7.7 mm); soft dorsal fin (7.5–7.6 mm); pectoral fin and anal fin (7.5 –7.7 mm); pelvic fin buds form, anterior to dorsal fin origin after complete yolk absorption (7.5–7.7 mm).[6]

8.4–9.0 mm TL. Branchiostegal rays form; dorsal and anal finfold partially differentiated (8.4 mm); spinous dorsal forms (8.4–9.0 mm); first pelvic fin rays form (9.0 mm).[6]

9.0–9.9 mm TL. Both finfolds completely differentiated (9.0–9.9 mm); complete adult fin ray counts in median fins (9.9 mm).[6]

7.5–10.8 mm TL. Spinous dorsal fin origin situated over preanal myomere 3 to 6, soft dorsal origin over preanal myomere 16 to 19 caudal fin slightly emarginated.[6]

Pigmentation
5.9–6.7 mm TL. Similar to previous length interval with the exception of dorsum melanophores on body becoming more numerous; dermal melanophore cluster near base of anus; ventrally, a series of large stellate melanophores on the breast and midbelly (not forming a single large macromelanophore as in *E. flavum*), not forming a continuous line from the posterior stomach to the anus but rather single stellate melanophores.[6]

6.8–8.8 mm TL. Dorsum of cranium with several large melanophore clusters; laterally, the line of melanophores over the gut disappearing or becoming subdermal; a single melanophore at the attachment site of anus to body; a mid-lateral series of melanophores from pectoral fin origin to caudal peduncle; melanophores extending from caudal peduncle base into ventral caudal fin; ventral pigmentation includes a series of melanophores mid-ventrally on the breast to the anus; paired mid-ventral postanal melanophores from anus to anal fin insertion, with single melanophores from the anal insertion to the caudal peduncle along each myosepta.[6]

8.9–9.7 mm TL. Similar to previous length interval, with the exception of melanophores forming on the snout and disappearing over the dorsum of gut.[6]

JUVENILES

Size Range
> 11 mm TL[6] to 28–35 mm SL.[6]

Fin Development
Fin ray meristics and length at appearance are included in Table 60.[6]

Spinous dorsal X–XII; soft dorsal rays 10–13 (11–13); Pectoral fin rays 12–15 (13); Pelvic fin spines/rays I/5; Anal fin spines/rays II/6 (7–8); Caudal fin

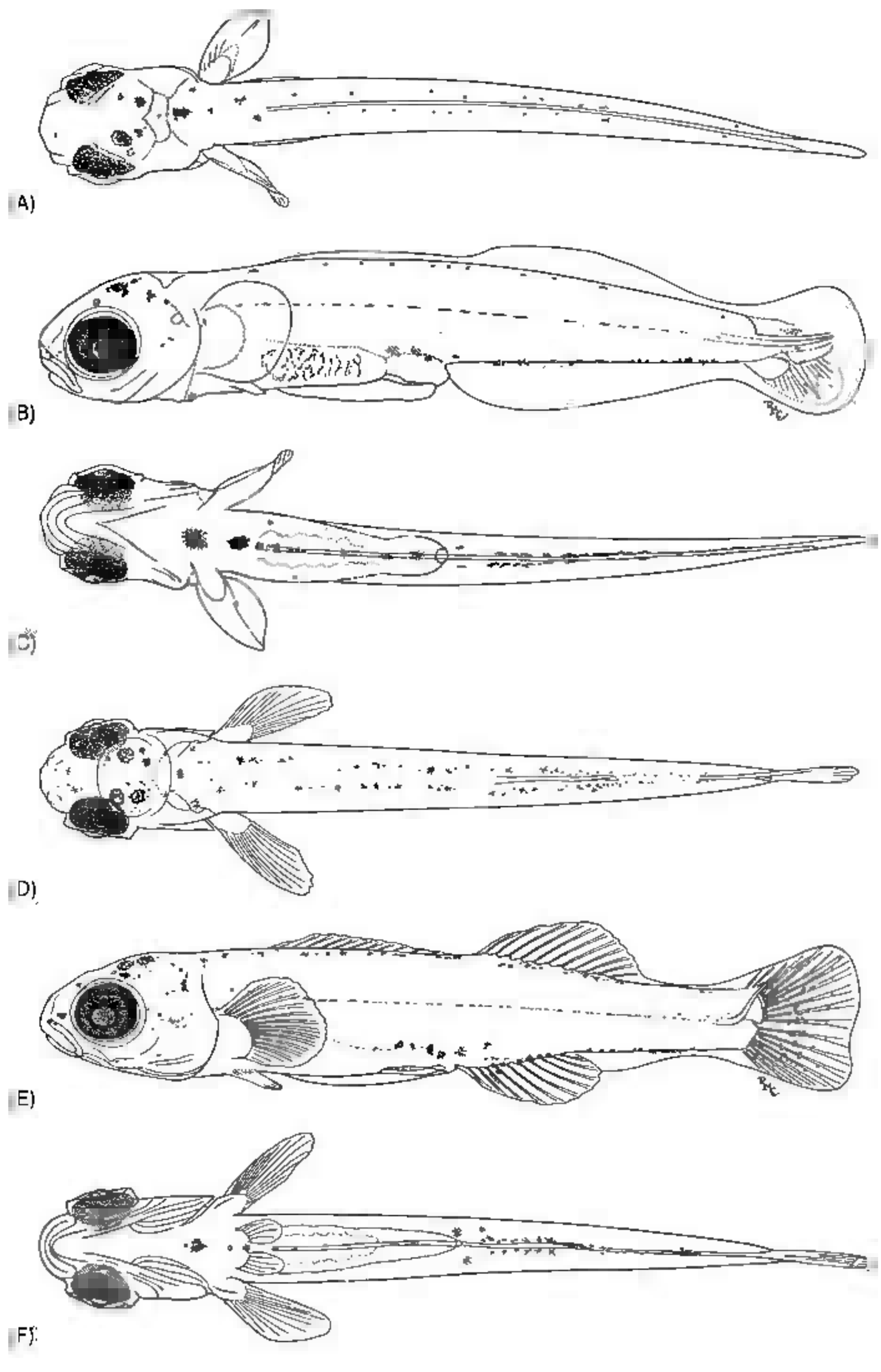

Figure 53 *Etheostoma duryi*, blackside snubnose darter, unnamed tributary Little Emory River, Roane County, TN. Post yolk-sac larva, 8.4 mm TL: (A) dorsal, (B) lateral, (C) ventral views. Post yolk-sac larva, 10.8 mm TL: (D) dorsal, (E) lateral, (F) ventral views. (A–F from reference 6, with author's permission.)

rays VII–XI, 8-9+7-8, VIII–XI; Lateral line scales 39 (42–51)-57; branchiostegal rays 5,5.[1–6]

7.5–10.8 mm TL. Caudal fin slightly emarginated.[6]

Morphology

Total vertebrae count 38–39 (N = 2, $x = 38.5$), including one urostylar element. Scales in the lateral series ranging from 39 to 57 (usually 42–51) in the Tennessee River drainage.[2–4,6]

>10.8 mm. Infraorbital, lateral, subtemporal and preoperculomandibular head canals form; initiation of squamation.[6]

Juveniles. Infraorbital, lateral, and supratemporal head canals not interrupted, preoperculomandibular

TABLE 60

Meristic counts and size (mm TL) at the apparent onset of development for *E. duryi.*

Attribute/Event	*E. duryi*	Literature
Branchiostegal Rays	5,5 [6]	5,5[1–3]
Dorsal Fin Spines/Rays	X–XII/10–13[6]	X–XII/11–13[1–3]
First spines formed	8.4–9.0[6]	
Adult complement formed	9.0 [6]	
First soft rays formed	7.5–7.6 [6]	
Adult complement formed	9.0 [6]	
Pectoral Fin Rays	13[6]	12–15[2,3]
First rays formed	7.5–7.7 [6]	
Adult complement formed	7.5–7.7[6]	
Pelvic Fin Spines/Rays	I/5 [6]	I/5[a 2,3]
First rays formed	9.0 [6]	
Adult complement formed	8.5–9.6 [6]	
Anal Fin Spines/Rays	II/7–8 [6]	II/6–8[1–3]
First rays formed	7.5–7.7 [6]	
Adult complement formed	9.0 [6]	
Caudal Fin Rays	vii–xi, 8–9+7–8, viii–xi[6]	15–18[1]
First rays formed	7.1–7.8[6]	
Adult complement formed	8.4–9.0 [6]	
Lateral Line Scales	42–51[6]	39–57[1–3]
Myomeres/Vertebrae	38–41/38–39[6]	Unknown/37–39[2,3,7]
Preanal myomeres	15–18[6]	
Postanal myomeres	22–24[6]	

canal complete with 8–10 pores, infraorbital pores 7–9.[3,6] At juvenile stages, cheek scales are usually embedded (may be absent dorsally); cheek, opercle, nape, and belly are completely scaled; breast scalation variable, either naked to scaled on posterior half.[2–4,6]

Morphometry
No information.

Pigmentation
9.8–11.8 mm TL. Preorbital bar forms; double row of melanophores present from the nape to the base of the caudal peduncle; laterally, additional melanophores present on cheek and subopercuIum, extending onto first rays of the anal fin and scattered on the caudal fin membranes; distinct melanophore cluster on the throat extending posteriorly along mid-ventrum to anus. Two mid-ventral melanophore clusters over the anal fin and near caudal peduncle.[6]

TAXONOMIC DIAGNOSIS OF YOUNG BLACKSIDE SNUBNOSE DARTER

Similar species: members of the subgenus *Ulocentra*.[6]

Etheostoma duryi can be differentiated from the other members of the *E. duryi* species group by the fused dark longitudinal bars on the upper half of the body; variably scaled breast, ranging from naked to embedded scales posteriorly on the breast;[3] brighter color than *E. flavum*; and lack of a frenum.[2] *Etheostoma duryi* has modes of 44–50 lateral line scales and usually 11–14 scales around the caudal peduncle. *Etheostoma duryi* occurs in the Tennessee River system of TN, AL, GA, and probably MS.[2,3,6]

Larva: *Etheostoma duryi* is virtually identical with other members of the *E. duryi* species group in pigmentation, development, and myomere counts. All members of the species group have overlapping, low preanal (15–17) myomere counts, while *E. duryi* typically has higher postanal (23–24) myomere counts. The species is distinguished from *E. flavum* by the possession of a smaller yolk sac, and reduced lateral and ventral pigmentation on the yolk sac.[6]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (see Figure 54)

Eggs. Egg sites include the slight depressions on the vertical sides of rocks and, less frequently, the horizontal tops of rocks in flowing pool habitats, in slight to moderate current.[5,6]

Yolk-sac larvae. Aquarium observations indicate that blackside snubnose darter larvae are epibenthic immediately after hatching.[6]

Post Yolk-sac Larvae. Larvae become demersal at lengths greater than 9.0 mm, and remain in close association with the substrate. Blackside snubnose darter larvae from Roane County, TN, were collected from eddy areas in pool habitats, nearshore, and downstream of riffles in water 0.1–0.3 m deep from early- to late-May (R. Wallus, personal communication).[6]

Juveniles. Early juveniles utilize the downstream pools and riffle margins adjacent to spawning riffles as nursery habitats. All length intervals, less than 10.8 mm, are collected in epibenthic dipnet samples from the near shore habitats usually associated with tree roots or rubble in AL.[6]

Table 61

Average calculated lengths (mm SL) of young blackside snubnose darters in Tennessee.[1]

	Age		
State	1	2	3
Tennessee[1]	28–35	40–48	50+

Figure 54 Distribution of blackside snubnose darter, *E. duryi* in the Ohio River system (shaded area).

Early Growth
Etheostoma duryi is 28–35 mm SL after the first year of growth.[1]

Feeding Habits
Unknown.

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Material examined: TN: Roane Co.: Unnamed spring, trib. Little Emory River, 5 mi from Oliver Springs near State Hwy 61, ca. 3 mi NE Little Emory River embayment bridge, TVA uncatalogued (24); TVA uncatalogued (21); TVA reference series (12); TVA, uncatalogued (16). AL: Limestone Co.: Hurricane Creek, LRRC 563 (31); LRRC 563 (4 eggs).

* Original fecundity data for blackside snubnose darter from Elk River drainage, Lincoln County, TN. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Early life history developmental series cultured from laboratory spawned specimens curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN, and from Tennessee Valley Authority.

CHERRY DARTER

Etheostoma (Ulocentra) etnieri Bouchard

Etheostoma: various mouths; *etnieri*: named after taxonomist and ichthyologist, David A. Etnier, University of Tennessee.

RANGE

Etheostoma etnieri is a Cumberland River endemic restricted to the upper Caney Fork River system of TN.[1,2] This species has not been collected from the slightly acidic eastern headwaters or near the mouth of Caney Fork.[2]

HABITAT AND MOVEMENT

The cherry darter inhabits moderate-gradient, clear, small- to medium-sized streams. Adults prefer bedrock pools and unsilted gravel substrates in riffles and runs with moderate current (R. Wallus, personal observation).[2–4]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma etnieri is restricted to the upper Caney Fork River system of the Cumberland River drainage in the eastern Highland Rim, where it is common in large, cool streams. Although the species has a restricted distribution, it is apparently under no current threats.[1]

SPAWNING

Location
Eggs are deposited in rock crevices or horizontal surfaces in slab bedrock pools in areas ranging from slow to moderate current.[5]

Season
Ripe females were collected in moderate current from pools during April and early May, which is assumed to be the peak spawning period.[1] Spawning occurs throughout its range from early- to mid-April until early May.[5]

Temperature
Spawning initiates at 13°C.[5]

Fecundity (see Table 62)
Female cherry darters showed significant increasing fecundity (ANOVA, $F = 37.093$, $p \geq 0.0001$) with increasing length. A 55 mm female had 37 large mature ova and a 53 mm female had 89 large mature ova.*

Sexual Maturity
Cherry darter survive to spawn for 2 years, with age 1 fish averaging 42 mm at the first reproduction.[1]

Spawning Act
Etheostoma etnieri is an egg-attacher.[5] Egg sites include the vertical sides and horizontal tops of rock in flowing pool habitats in slight to moderate current (R. Wallus, personal communication).[5] In aquarium observations, a single male follows a single female to the egg site and in a complex series of movements intertwines her body and presses against the vertical sides of slab rocks. The male body movements resemble an S-shape, with the caudal peduncle of the male wrapped around that of the female. Adults maintain a head-to-head orientation, with vents juxtaposed, and press against the rock surface. Eggs are laid individually on the vertical surface of the rock, generally 3–5 during a single spawning event. The pair is observed to switch positions on the rock, depositing eggs on different sections of the same and different rocks. Each adult was promiscuous, spawning with multiple partners on different rocks, as noted by Page and Mayden in their observations of *E. atripinne*. No cleaning of the rock surface or parental care is provided before or after the eggs are laid.[5]

EGGS

Description
Ovarian examination showed that ovoid latent ova were 0.5 mm, early maturing ova averaged 0.83 mm, and large mature ova averaged 1.11 mm.* Eggs from Cherry Creek, White County, TN, are spherical, mean = 1.4 mm diameter (range: 1.2–1.6 mm); translucent; demersal; and adhesive. Eggs possess translucent, pale-yellow yolk (mean = 1.3 mm diameter; range: 1.1–1.5 mm); a single oil globule

Table 62

Fecundity data for cherry darter from the Calf Killer River, Putnam County, TN.*

		Number of Ova			
Length (TL)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
35	32	332	67	22	1.11
37	43	419	92	34	1.11
39	52.1	400	96	42	1.11
42	103	610	127	73	1.11
42	90	839	175	32	1.11
50	152	769	183	78	1.11
52	186	947	225	104	1.11
53	201	1211	252	89	1.11
55	190	1262	293	37	1.11
56	168	880	212	69	1.11

(mean = 0.3 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[5]

Incubation
Hatching occurs after 216–240 h at an incubation temperature of 19.4–20°C.[5]

Development
No information.

YOLK-SAC LARVAE

See Figure 55

Size Range
Specimens from Cherry Creek, TN, hatch at 4.1 and yolk is absorbed by 5.7 mm TL.[5]

Myomeres
Preanal 16 (48) or 17 (16) (N = 64, mean = 16.3); postanal 22 (57), 23 (6), or 24 (1) (N = 64, mean = 22.8); with 38 (42), 39 (20), or 40 (2) total (N = 64, mean = 39.6).[5]

Morphology
4.1–4.6 mm TL. Newly hatched larva have a terete body; snout blunt; functional jaws, upper jaw even, slightly extending past lower jaw; yolk sac small (23.3% TL), oval to tapered posteriorly; yolk translucent clear to pale yellow, with a single oil globule; single serpentine vitelline vein mid-ventrally on yolk sac; head not deflected over the yolk sac; and eyes oval.[5]

5.1–5.3 mm TL. Digestive system functions prior to yolk absorption.[5]

5.4–5.6 mm TL. Premaxilla and mandible form.[5]

Morphometry
See Table 63.[5]

Fin Development
4.1–4.6 mm TL. Well-developed pectoral fins without incipient rays.[5]

Pigmentation
4.3–4.7 mm TL. Newly hatched larva with pigmented eye; melanophores dorsally over posterior to cerebellum or nape; melanophores distributed laterally, dorsally over the gut posterior to the yolk sac. Ventral pigmentation consists of a mid-ventral paired series of punctate melanophores forming a stripe near the vitelline vein on the yolk sac, and punctate melanophores along every mid-ventral postanal myosepta.[5]

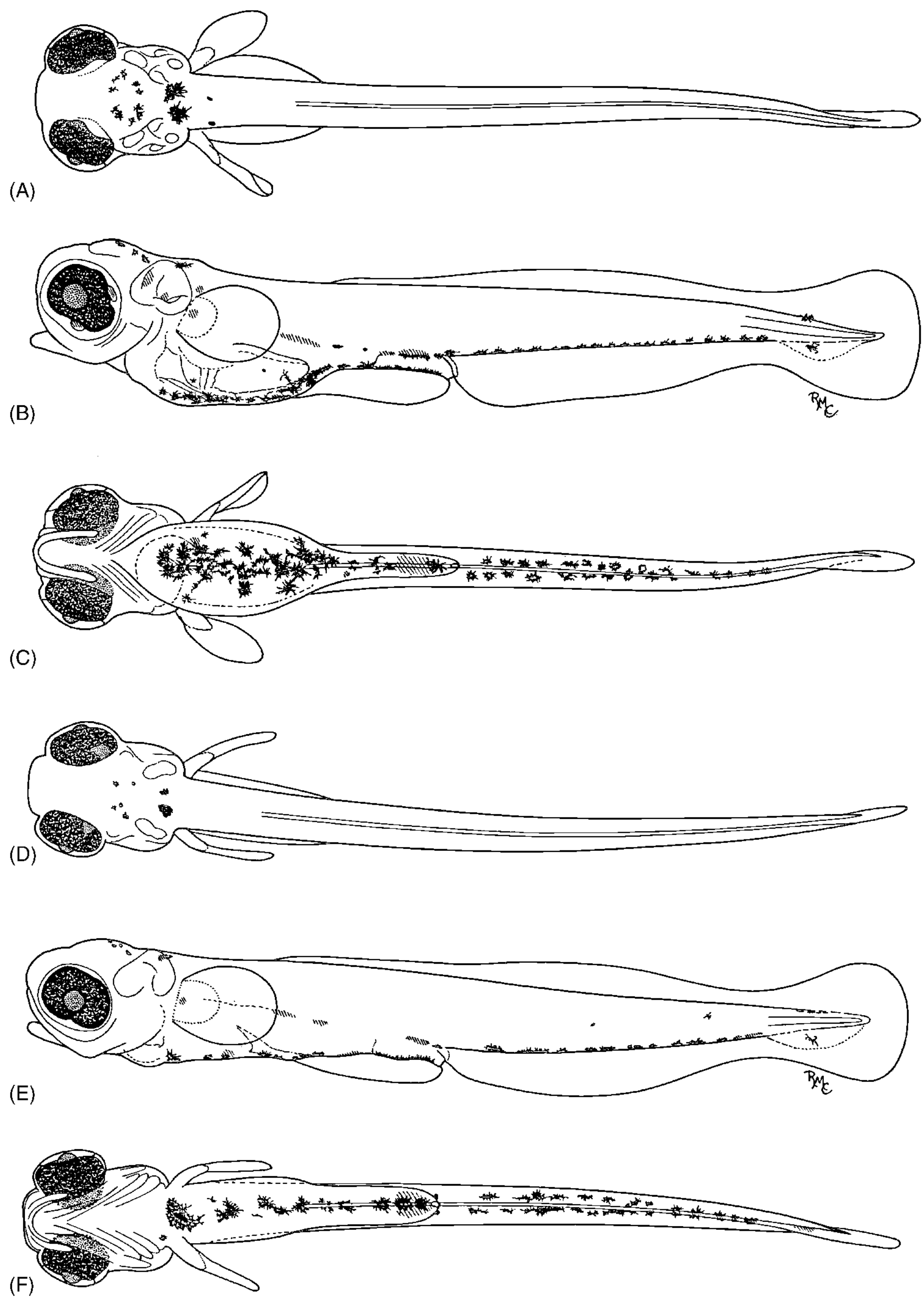

Figure 55 *Etheostoma etnieri*, cherry darter, Cherry Creek, White County, TN. Yolk-sac larva, 4.6 mm TL, (A) dorsal, (B) lateral, (C) ventral views. Post yolk-sac larva, 5.9 mm TL, (D) dorsal, (E) lateral, and (F) ventral views. (A–F from reference 5, with author's permission.)

POST YOLK-SAC LARVAE

See Figures 55 and 56

Size Range
5.8 to 11.9 mm TL.[5]

Myomeres
Preanal 16 (48) or 17 (16) (N = 64, mean = 16.3); postanal 22 (57), 23 (6), or 24 (1) (N = 64, mean = 22.8); with 38 (42), 39 (20), or 40 (2) total (N = 64, mean = 39.6).[5]

Morphology
5.8–6.1 mm TL. Yolk absorbed (5.8–6.1 mm); operculum and gill arches function (5.8–6.0 mm).[5]

7.4–8.6 mm TL. Neuromast development occurs midlaterally from the anterior trunk posteriad

Table 63

Morphometry of young *E. etnieri* grouped by selected intervals of total length (N = sample size).[5]

Characters	4.11–5.94 (N=8) Mean ± SD	Range	6.14–7.96 (N=11) Mean ± SD	Range	8.02–9.78 (N=24) Mean ± SD	Range	10.1–12.9 (N=19) Mean ± SD	Range	13.2–14.7 (N=9) Mean ± SD	Range	15.4–23.6 (N=13) Mean±SD	Range
Length (% of TL)												
Upper jaw[a]	20.4 ± 3.54	(0.16–0.28)	22.2 ± 2.31	(0.25–0.37)	22.4 ± 4.33	(0.24–0.56)	23.4 ± 2.79	(0.44–0.74)	27.3 ± 7.09	(0.62–0.82)	24.1 ± 1.10	(0.86–1.12)
Snout[a]	13.6 ± 1.75	(0.09–0.20)	14.9 ± 1.90	(0.16–0.28)	16.0 ± 1.52	(0.20–0.32)	18.3 ± 1.07	(0.32–0.57)	20.0 ± 3.78	(0.46–0.62)	19.5 ± 1.10	(0.67–0.92)
Eye diameter[a]	45.7 ± 3.63	(0.38–0.54)	42.0 ± 1.66	(0.52–0.64)	39.0 ± 1.47	(0.60–0.75)	35.1 ± 3.76	(0.54–0.95)	36.9 ± 8.79	(0.91–1.10)	31.5 ± 1.53	(1.10–1.50)
Head	19.5 ± 1.25	(0.78–1.18)	19.6 ± 0.52	(1.20–1.60)	19.6 ± 0.54	(1.52–1.92)	20.7 ± 0.68	(1.97–2.78)	20.0 ± 3.22	(1.53–3.26)	20.9 ± 1.25	(3.52–4.66)
Predorsal	28.6 ± 1.95	(1.25–1.74)	28.6 ± 1.57	(1.75–2.34)	28.6 ± 1.73	(1.92–2.78)	28.7 ± 0.80	(2.80–3.77)	28.6 ± 0.55	(3.70–4.22)	27.6 ± 0.95	(4.68–6.42)
Dorsal insertion							37.9 ± 10.1	(2.80–6.33)	47.8 ± 1.36	(6.10–7.22)	47.0 ± 1.28	(7.70–11.2)
D2 origin							40.1 ± 12.5	(2.80–6.93)	52.4 ± 1.80	(6.70–7.70)	50.1 ± 1.46	(8.20–11.8)
D2 insertion							49.6 ± 22.7	(2.80–6.93)	72.4 ± 1.30	(6.70–7.70)	68.9 ± 2.06	(8.20–11.8)
Preanal	49.6 ± 0.29	(2.03–2.94)	50.1 ± 1.14	(2.94–4.06)	50.6 ± 0.56	(4.02–4.88)	50.3±0.82	(5.00–6.59)	49.8 ± 0.70	(6.41–7.33)	48.3 ± 1.22	(7.00–11.4)
Postanal	50.4 ± 0.29	(2.08–3.00)	49.9 ± 1.14	(3.14–4.00)	49.4 ± 0.56	(4.00–4.92)	49.7 ± 0.81	(5.06–6.63)	50.2 ± 0.69	(6.50–7.44)	51.7 ± 1.22	(8.41–12.1)
Standard	95.8 ± 0.46	(3.93–5.69)	96.3 ± 0.68	(5.94–7.64)	93.5 ± 3.09	(7.12–8.82)	87.9 ± 1.71	(8.92–11.9)	86.3 ± 1.02	(11.5–12.6)	84.8 ± 3.16	(12.7–19.9)
Yolk sac	23.3 ± 2.05	(1.00–1.22)	4.56	(0.28–0.28)								
Fin Length (% of TL)												
Pectoral	9.67 ± 2.17	(0.34–0.64)	9.86 ± 1.60	(0.40–0.96)	11.6 ± 1.02	(0.78–1.18)	15.2 ± 3.58	(1.00–2.69)	18.4 ± 1.65	(2.00–3.06)	19.5 ± 1.69	(2.92–4.62)
Pelvic			2.53	(0.20–0.20)	3.27 ± 0.95	(0.14–0.50)	8.03 ± 2.34	(0.41–1.52)	11.4 ± 1.69	(1.22–2.05)	15.4 ± 1.99	(2.44–4.48)
Spinous dorsal							19.6 ± 0.84	(2.02–2.71)	19.2 ± 1.05	(2.40–3.00)	19.4 ± 0.91	(3.02–4.82)
Soft dorsal							19.9 ± 1.34	(2.30–2.63)	20.0 ± 1.00	(2.56–3.24)	18.8 ± 0.87	(3.20–4.46)
Caudal	4.23 ± 0.46	(0.18–0.25)	3.74 ± 0.68	(0.18–0.38)	6.46 ± 3.09	(0.30–1.57)	12.1 ± 1.71	(0.72–1.72)	13.7 ± 1.02	(1.68–2.32)	15.2 ± 3.16	(1.08–3.76)
Body Depth (% of TL)												
Head at eyes	15.2 ± 0.69	(0.62–0.90)	15.1 ± 0.76	(0.86–1.23)	15.1 ± 0.48	(1.22–1.52)	14.5 ± 1.26	(1.35–2.04)	14.9 ± 0.80	(1.80–2.39)	13.9 ± 0.90	(2.47–3.12)
Head at Pl	17.1 ± 4.94	(0.74–1.13)	14.4 ± 0.74	(0.86–1.20)	15.1 ± 0.46	(1.18–1.54)	15.7 ± 1.47	(1.36–2.25)	16.4 ± 0.66	(2.00–2.52)	16.9 ± 0.57	(2.79–3.90)
Preanal	8.31 ± 0.78	(0.32–0.54)	10.4 ± 1.00	(0.57–0.90)	12.1 ± 0.77	(0.87–1.32)	13.6 ± 1.48	(1.15–1.98)	14.0 ± 0.35	(1.78–2.14)	14.0 ± 0.40	(2.25–3.24)
Mid-postanal	6.20 ± 0.41	(0.24–0.40)	7.60 ± 0.55	(0.44–0.68)	8.82 ± 0.51	(0.63–0.92)	9.10 ± 0.84	(0.82–1.32)	9.27 ± 0.33	(1.18–1.43)	9.63 ± 0.38	(1.56–2.22)
Caudal peduncle	2.58 ± 0.51	(0.12–0.18)	4.16 ± 0.57	(0.19–0.38)	3.80 ± 2.14	(0.32–0.74)	4.64 ± 2.94	(0.60–1.00)	7.27 ± 0.23	(0.94–1.06)	7.53 ± 0.46	(1.26–1.72)
Yolk sac	12.0 ± 3.16	(0.49–0.72)	4.89	(0.30–0.30)								
Body Width (% of HL)												
Head	75.6 ± 5.97	(0.62–0.84)	71.5 ± 4.01	(0.84–1.15)	70.3 ± 3.68	(1.10–1.52)	65.3 ± 5.35	(1.24–1.90)	66.7 ± 12.6	(1.52–2.10)	56.5 ± 3.96	(1.92–2.72)
Myomere Number												
Predorsal	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)
Soft dorsal	16.0	(16.0–16.0)					16.1 ± 0.37	(16.0–17.0)	16.3 ± 0.50	(16.0–17.0)	16.3 ± 0.49	(16.0–17.0)
Preanal	16.0 ± 0.00	(16.0–16.0)	16.0 ± 0.00	(16.0–16.0)	16.0 ± 0.21	(16.0–17.0)	16.2 ± 0.42	(16.0–17.0)	16.4 ± 0.53	(16.0–17.0)	17.0 ± 0.00	(17.0–17.0)
Postanal	22.1 ± 0.35	(22.0–23.0)	22.1 ± 0.30	(22.0–23.0)	22.2 ± 0.48	(22.0–24.0)	22.1 ± 0.23	(22.0–23.0)	22.0 ± 0.00	(22.0–22.0)	22.0 ± 0.00	(22.0–22.0)
Total	38.1 ± 0.35	(38.0–39.0)	38.1 ± 0.30	(38.0–39.0)	38.2 ± 0.51	(38.0–40.0)	38.3 ± 0.45	(38.0–39.0)	38.4 ± 0.53	(38.0–39.0)	39.0 ± 0.00	(39.0–39.0)

[a] Proportion expressed as percent head length.

Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

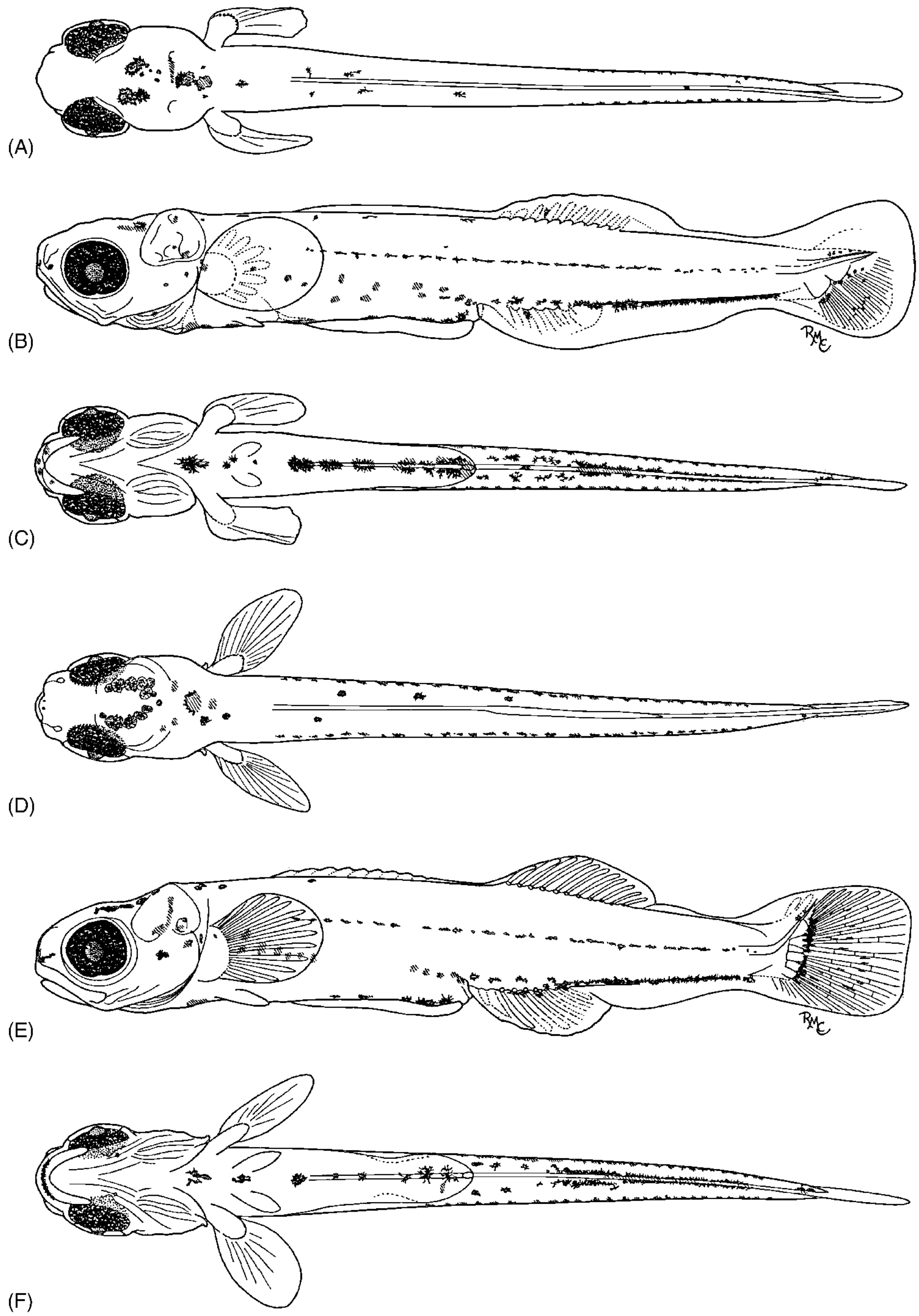

Figure 56 *Etheostoma etnieri*, cherry darter, Cherry Creek, White County, TN. Post yolk-sac larva, 9.0 mm TL; (A) dorsal, (B) lateral, and (C) ventral views. Post yolk-sac larva, 10.7 mm TL, (D) dorsal, (E) lateral, and (F) ventral views. (A–F from reference 5, with author's permission.)

(7.4–8.6 mm); notochord flexion preceding caudal fin ray development (7.9–8.1 mm).[5]

7.4–10.1 mm TL. No swim bladder forms; gut straight, without striations, portion of gut posterior to stomach normal in length.[5]

11.7 mm TL. Infraorbital and supraorbital canals form.[5]

Morphometry
See Table 63.[5]

Fin Development
See Table 64.[5]

7.4–7.5 mm TL. First rays form in caudal fin.[5]

7.4–8.6 mm TL. Notochord flexion precedes caudal fin ray development (7.9–8.1 mm); soft dorsal fin

Table 64

Meristic counts and size (mm TL) at the apparent onset of development for *E. etnieri*.[5]

Attribute/event	*Etheostoma etnieri*[5]	Literature
Branchiostegal Rays	5,5	5,5[1,2,6]
Dorsal Fin Spines/Rays	IX–XII/10–13	IX–XII/10–12[1,2,6]
First spines formed	9.0–9.4	
Adult complement formed	9.8	
First soft rays formed	7.9–8.3	
Adult complement formed	8.7–9.0	
Pectoral Fin Rays	15	14–15[1,2,6]
First rays formed	9.1–9.3	
Adult complement formed	9.1–9.3	
Pelvic Fin Spines/Rays	I/5	I/5[1,2,6]
First rays formed	10.1	
Adult complement formed	10.1	
Anal Fin Spines/Rays	II/7–9	II/6-8[1,2,6]
First rays formed	8.3	
Adult complement formed	9.4–9.7	
Caudal Fin Rays	vii–xi, 7−8+7−8, viii–xi	16–18[1]
First rays formed	7.4-7.5	
Adult complement formed	9.1–12.5	
Lateral Line Scales	49–55	44-57[1,2,6]
Myomeres/Vertebrae	38–40/38–39	Unknown/38–39[1–3,6]
Preanal myomeres	16–17	
Postanal myomeres	22–24	

rays and branchiostegal rays form (7.9–8.3 mm); pelvic fin buds formed anterior to dorsal fin origin after complete yolk absorption (7.9–8.5 mm); anal fin ray forms (8.3 mm).[5]

9.0–9.4 mm TL. Spinous dorsal forms (9.0–9.4 mm); pectoral fin forms (9.1–9.3 mm).[5]

9.7–10.1 mm TL. Complete adult fin ray counts in median fins (9.8 mm); dorsal and anal finfold partially differentiated (9.7–10.0 mm); first pelvic fin ray forms (10.1 mm).[5]

10.9–11.9 mm TL. Both finfolds completely differentiated (10.9–11.9 mm).[5]

Pigmentation

5.0–6.7 mm TL. Similar to the previous length interval, with the exception of lateral melanophore pigmentation that extends further over the gut; ventrally, a series of large melanophores on the breast and midbelly; and a continuous line from the posterior stomach to the anus.[5]

6.8–8.8 mm TL. Dorsum of cranium with two large melanophore clusters on the cerebellum; laterally, a line of melanophores over the gut; a single melanophore at the attachment of anus to body; a mid-lateral series of melanophores from anus to caudal peduncle; ventral pigmentation includes a series of four melanophores mid-ventrally on the breast to the anus; mid-ventral postanal melanophores from anus to caudal peduncle distributed along each myosepta.[5]

8.9–9.7 mm TL. Cranial melanophores over the optic lobe, several melanophores present on the nape, and along future spinous soft dorsal. Melanophores form a mid-lateral stripe from the shoulder to the caudal fin base; subdermal melanophores present over the gut; melanophores present in hypaxial portion of the caudal fin. Melanophores form a single mid-ventral stripe from breast to the anus, scattered from the anus to the caudal peduncle.[5]

9.8–11.8 mm TL. Similar to previous interval, with the exception that a preorbital bar forms; additional vertical melanophores present at the base of the caudal fin, radiating along the caudal ray membranes.[5]

JUVENILES

See Figure 57

Size Range
11.9[5] to 42 mm TL.[1]

Fin Development
Branchiostegal rays 5,5;[1,2,5,6] dorsal fin spines/rays IX–XII/10–12 (13);[1,2,5,6] pectoral fin rays 14–(15);[1,2,5,6] pelvic fin spines/rays I/5;[1,2,5,6] anal fin spines/rays II/6 (7–8)9;[1,2,5,6] caudal fin rays vii-xi, 7−8+7−8, VIII–XI[5] or 16–18;[1] lateral line scales 44–(49–55) –57.[1,2,5,6]

11.9–12.5 mm TL. Spinous dorsal fin origin situated over preanal myomere 4, soft dorsal origin over preanal myomere 16–17.[5]

13.9–14.6 mm TL. Caudal fin slightly emarginated.[5]

27.6–30.3 mm TL. Average predorsal length 31.4% SL (range: 30.4–33.4% SL), and 28.5% TL (range: 27.6–30.3 mm).[5]

Morphology
11.9–12.6 mm. TL. Upper jaw equal with lower jaw, becoming subterminal.[5]

18.0 mm TL. Lateral line begins to form.[5]

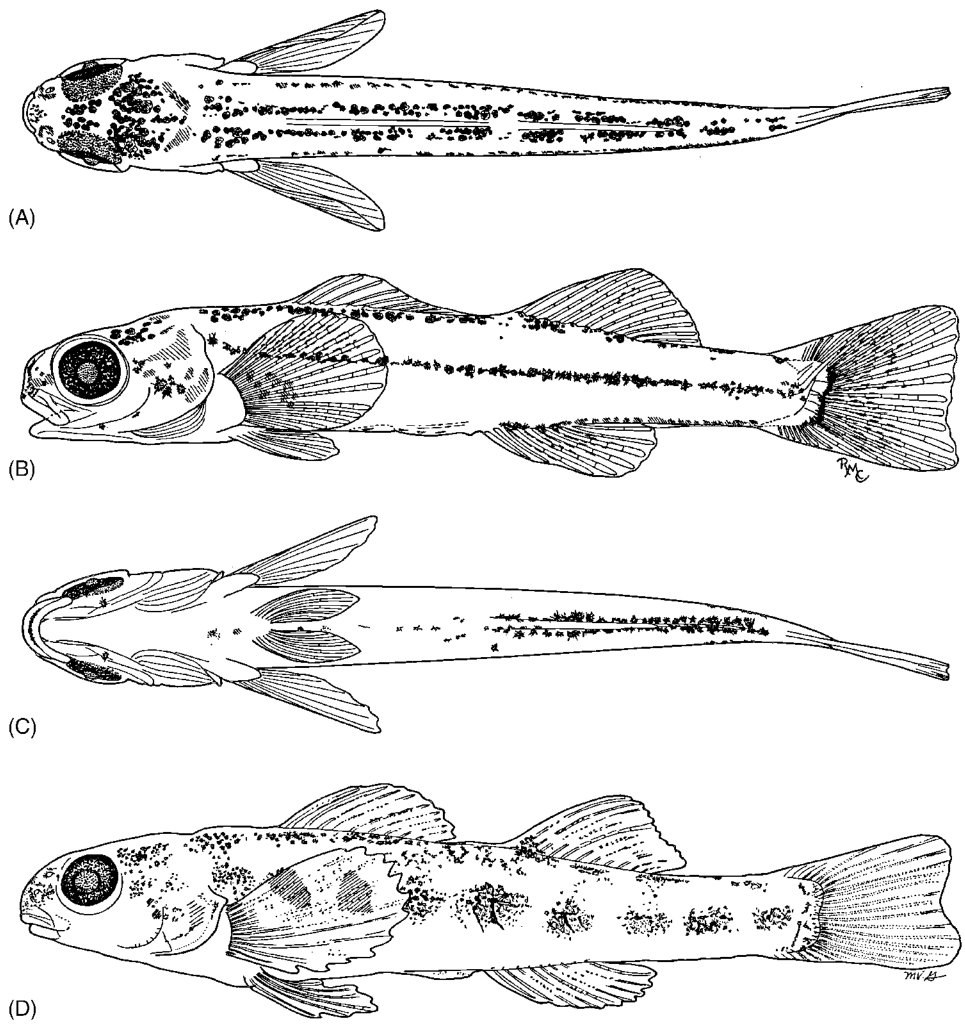

Figure 57 *Etheostoma etnieri*, cherry darter, Cherry Creek, White County, TN. Juvenile, 14.8 mm TL; (A) dorsal, (B) lateral, (C) ventral views. Juvenile, 20.0 mm TL, (D) lateral view. (A–D from reference 5, with author's permission.)

18.5–18.6 mm TL. Initiation of squamation (18.5 mm); lateral, subtemporal and preoperculomandibular head canals form (18.6 mm).[5]

19.4–20.1 mm TL. Squamation complete.[5]

22.5 mm TL. Infraorbital, lateral, and supratemporal head canals not interrupted, preoperculomandibular canal complete with 8–10 pores, infraorbital pores 7–9 (22.5 mm).[5]

27.6–30.3 mm TL. Average predorsal length 31.4% SL (range: 30.4–33.4% SL), and 28.5% TL (range: 27.6 –30.3 mm).[5]

Larger Juveniles. Cheek scales, usually embedded (may be absent dorsally); cheek, opercle, nape, and belly are completely scaled; breast squamation variable, either naked to scaled on posterior half.[1–3,6] Total vertebrae count 38–39 ($N = 2$, mean = 38.5), including one urostylar element. Scales in the lateral series 49–55 from Cherry Creek population, ranging from 45 to 57 (usually 46–53) in the Caney Fork River drainage.[1–3,6]

Morphometry
See Table 63.[5]

Pigmentation
12.1–14.7 mm TL. Cranium with melanophores outlining the maxillae, cerebellum, and optic lobe. Discrete clusters of melanophores from nape to the caudal peduncle base, forming nine saddles. Lateral melanophores forming preorbital and postorbital bar; mid-lateral stripe extends from the operculum to the caudal fin base; vertical stripe of melanophores outlines the caudal fin base and extends onto membranes. Ventral pigmentation consisting of several melanophores on the chin and cheek; extending posteriorly from the breast to the anus, outlining the anal fin and forming a mid-ventral cluster from the anal fin insertion to the hypural plate. Anal fin lepidiotrichia interdigitation, with the ptexygiophores outlined with melanophores.[5]

15.4–23.6 mm TL. Preorbital and postorbital bars well developed; dorsum of cranium with melanophores covering the optic lobe and the cerebellum; mid-dorsum with nine clusters of elongate melanophore clusters, distributed at the nape, spinous dorsal origin, mid-spinous dorsal fin, spinous dorsal fin insertion, between dorsal fins, posterior soft dorsal origin, midsoft dorsal fin, just anterior soft dorsal insertion, and caudal peduncle base, five clusters of melanophores from the pectoral fin origin to the tip of the pectoral fin, from the stomach to the anal fin insertion, a single continuous mid-lateral cluster of melanophores, two additional clusters mid-laterally on the caudal peduncle; ventrally, a series of melanophores at the interdigitation of the anal fin lepidiotrichia with the pterigiophores; a continuous stripe of melanophores from the anal fin insertion to the caudal peduncle base; caudal peduncle base with a vertical series of melanophores forming a black band. Spinous and soft dorsal fins with a medial stripe; scattered melanophores distributed on the pectoral and caudal fins; anal fin with a medial stripe. Pelvic fin unpigmented.[5]

TAXONOMIC DIAGNOSIS OF YOUNG CHERRY DARTER

Similar species: members of subgenus *Ulocentra.*

Adult. Etheostoma etnieri is a Cumberland River endemic and a member of the *E. duryi* species group. *Etheostoma etnieri* can be differentiated from the other members of the *E. duryi* species group by the dark longitudinal lines on the upper half of the body; embedded scales on the breast;[6] and in either possessing a weakly developed or lacking a frenum.[2] *Etheostoma etnieri* has modes of 46–53 lateral line scales and usually 18–19 scales around the caudal peduncle. *Etheostoma etnieri* occurs in the upper Cumberland River system in TN.[2,3,6]

Larva. Etheostoma etnieri is virtually identical to species *E. atripinne* in pigmentation and myomere counts. Both species have overlapping, low preanal (15–17) myomere counts, while *E. etnieri* has higher postanal (22–24) count.[5]

Variation
No intraspecific variation of *E. etnieri* could be studied due to the limited material from Cherry Creek.[5] The species differs from the *E. duryi* species group in myomere count modes and ontogenetic events. *Etheostoma etnieri* has preanal myomeres counts similar to the other species; however, the mode for postanal myomeres is lower (22). Pigmentation is substantially different from the other taxa, consisting of paired melanophores ventrally on the yolk sac becoming clustered laterally at larger length intervals.[5]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (See Figure 58)
Eggs. Egg sites are rock crevices or horizontal surfaces in slab bedrock pool areas ranging from slow to moderate current.[5]

Figure 58 Distribution of cherry darter, *E. etnieri* in the Ohio River system (shaded area).

Yolk-sac larvae. Aquarium observations show that cherry darter larvae are epibenthic, suspended about 0.1 m from the substrate immediately after hatching.[5] Cherry darter larvae from Cherry Creek are collected from gently flowing riffles and pools in water 0.3–0.5 m from late April to early June (R. Wallus, personal communication).

Post yolk-sac Larvae. Demersal only at lengths greater than 13 mm and remain in close association with the substrate.[5] Larval stages and are collected from water less than 0.3 m, usually over rock ledges, but occasionally over sand; larger larvae and juveniles are collected over leaf and detritus piles from water 0.6 m deep at the edges of deeper pools. These larvae are darkly pigmented and actively swim in water approximately 0.1 m below the surface, appearing to be actively feeding. All larva of length intervals less than 13 mm are collected in epibenthic dipnet samples from the nearshore habitats usually associated with slab rock substrates or rubble. (R. Wallus, personal observation).

Juveniles. Early juveniles utilize the downstream pools and backwater areas adjacent to spawning riffles as nursery habitats. By mid-May, juveniles greater than 15 mm TL move off the leaf piles and are the smallest individuals found on the margins of riffles and flowing pool habitats in Cherry Creek in water approximately 1.0 m deep. By early June, juveniles are benthic, and are collected in water 0.5–0.7 m deep by scraping them off the tops of horizontal slab rocks. By mid-June, they are capable of maintaining themselves in gentle current, and are found on the edges of slab shelves near the middle of the stream (R. Wallus, personal observation).

Early Growth (see Table 65)
Young-of-the-year specimens from TN were 28 mm TL by mid-August.[5]

Feeding Habits
Young TN specimens ate caddisflies, mayflies, and midge larvae.[5]

Table 65

Average calculated lengths (mm TL) of young cherry darter in Tennessee.

State	Age 1	Age 2	Age 3
Tennessee[1]	42	52	62 (maximum 76)

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2. Kuehne, R.A. and R.W. Barbour. 1983.
3. Bouchard, H.T. 1977.
4. Platania, S.A. 1980.
5. Simon, T.P. 1994.
6. Page, L.M. 1983.

Material Examined: TN: White Co.: Cherry Creek, at TN Hwy 84 bridge, 5.7 mi NE from intersection with US Hwy 70 in Sparta, TVA uncatalogued (83); Cherry Creek, at CR 45 bridge, 2.5 mi N Yankeetown, TVA 3078 (3); TVA 3078 (1 egg).

* Original fecundity data for cherry darter from the Calf Killer River, Putnam County, TN. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Early life history developmental series cultured from laboratory spawned specimens by TVA and from R. Wallus field collections are curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

FANTAIL DARTER COMPLEX

Etheostoma (Catonotus) flabellare Rafinesque

Etheostoma: various mouths; *flabellare*: fanlike, referring to the caudal fin.

RANGE

Etheostoma flabellare is common from southern QU across the Great Lakes to the headwaters of the Mississippi River basin in WI and MN, south to northern AR, and east throughout the Ohio River basin. Occurs in rivers of the Atlantic slope from the Pee Dee north to the upper Hudson River.[1–3] Type locality is the Falls of the Ohio River, near Louisville, KY.

HABITAT AND MOVEMENT

The fantail darter inhabits upland creeks, streams, and rivers, avoiding the lowlands of the Shawnee Hills, much of the coastal plain, and big rivers. Most often associated with slow to moderate currents of shallow riffles over substrates of mixed pebble, gravel, or sand.[6,12,13] Migration from deep, fast riffles to shallow, more slowly flowing riffles to establish territories occurs from 7 to 14°C.[12,16]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Three subspecies occur in the Ohio River drainage. Populations in the Pee Dee, Roanoke, and New Rivers, and parts of the upper Tennessee River, are subspecies, *brevispina*;[2] virtually all of the Ohio River basin populations are considered subspecies, *flabellare*;[2] subspecies found in the upper Wabash and White Rivers, IN, are subspecies *lineolatum*,* also found in the Guyandot and Big Sandy Rivers, KY.[4–6]

SPAWNING

Location

Spawning occurs beneath slab rocks where the female attaches the adhesive eggs to the underside of the rock. Adult males guard the eggs until hatching, picking off fungused eggs and gently massaging and fanning the eggs with pectoral and spinous dorsal fin knobs. Egg slabs are usually located along the margins and in the slower portions of river and stream riffles and runs.[3,7–12,22]

Season

Spawning begins in early May and continues through mid-July.[3,10,22]

Temperature

Spawning occurs between 13 and 17°C in northern latitudes, to temperatures as high as 25°C in IL;[3,22] spawning occurs from 7 to 14°C in WI.[12]

Fecundity (see Table 66)

Each female lays approximately 450 eggs in a single breeding season. Spawning occurs with the same or multiple males;[2] In NY, 23 females laid on an average of 226 eggs;[7] five different egg sizes were observed, indicating that they had developed in stages during the spawning period.[7] It was assumed that all eggs were spawned; however, ten females were found to contain between 5 and 100 ova after the spawning season was complete.[8] Females 44–66 mm TL had mature ova numbering between 45 and 103. Females (44–66 mm TL) collected in early April had mean ovaries that were 16.1% of the total body weight, and contained 139.0 total ova averaging 2.0 mm diameter. Female *E. flabellare* showed statistically significant increasing fecundity (ANOVA, $F = 51.31$, $p > 0.0001$) with increasing length.*

Sexual Maturity

Males and females were sexually mature at age 2; however, age 1 females exhibited considerable ova development.[6,7]

Spawning Act

At temperatures ranging from 7 to 14°C, males migrate from deeper portions of the riffle to the shallow, more slowly flowing portions; territories are established by the males and a hierarchy is established, the dominant males selecting the

Table 66

Fecundity data for *Etheostoma flabellare* from Hurricane Creek (Cumberland River drainage), Clay County, TN.*

		Number of Ova			
Length (mm TL)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
44	154	81	27	45	2.0
45	201	94	47	51	2.0
48	175	228	50	45	2.0
53	235	195	57	52	2.0
57	436	242	98	64	2.0
57	304	214	52	72	2.0
60	401	248	81	65	2.0
65	502	343	102	94	2.0
66	262	345	82	92	2.0
66	546	361	105	103	2.0

preferred localities.[7,8,12] If a suitable habitat is not available, males may move to deeper portions of the riffle or range over the entire spawning area without establishing territories.[13] Territories are fiercely defended from conspecifics and intruders. Nests are usually located halfway between the shore and midstream. Nest cavities usually have 13–25 mm height clearance, which enables the resting female, while inverted, to support herself on the dorsal fin, while her belly and pelvic fins maintain contact with the nest stone. Females enter the breeding area approximately a week after the males establish territories remaining in the runs. Breeding females mate with the most active males. The bulbous dorsal tips on the spinous rays of the male have been suggested to be egg dummys that attract females and massage the eggs, keeping them free of fungus. Courting to spawning takes about 1 min. When the female is in the nest and ready to spawn, she rotates 180° and inverts. The male nudges her caudal peduncle to stimulate egg laying. As she gets ready to deposit an egg, she pushes against the rock and starts to vibrate. Simultaneously, the male flips over and assumes a vent-to-vent position, and amid much vibration, an egg and sperm are dispelled. Only a single egg is laid at a time. The same female may remain in the nest, with a 1–3 min rest, until as many as 35–45 eggs have been deposited. The fantail darter is polygamous, males and females spawning with a number of partners. Females are known to spawn with as many as five different males in one season.[7,8,12] Parental care is provided by the attending male.[7,8,12]

EGGS

Description

The smallest ova ranged from 1.0 to 1.5 mm, were spherical, opaque, and pale yellow. Intermediate ova were ovoid, opaque, and pale yellow, and ranged between 1.5 and 2.0 mm. Ovarian examination of specimens from Hurricane Creek, TN showed that ovoid latent ova averaged 0.5 mm, early maturing small spherical ova were 1.1 mm, and large mature ova were 2.0 mm.* Mature eggs from Coulee Creek, WI, ranged from 2.0 to 2.8 mm. Mature ova are spherical, demersal, and adhesive with translucent yellow yolk. Mature eggs have a single oil globule, a narrow perivitelline space, an unsculptured chorion, and were unpigmented.[3,22] Eggs from Elk Creek, PA, and Greenbrier River, WV, ranged from 2.5 to 2.9 mm.[10]

Incubation

Eggs incubated at 20°C hatched after 24 h, while at 23°C hatching occurred in 144 h.[3,22] At 17–20°C hatching occurred in 30–35 days; at 21–22°C hatching occurred in 21 days; and at 24°C, hatching occurs in 14–16 days.[7]

Development

No information exists on the development of *E. f. lineolatum;* Cooper provides information on *E. f. flabellare*.[10]

YOLK-SAC LARVAE

See Figures 59, 60 and 62

Size Range

E. f. flabellare newly hatched, Cat Run, OH, 4.75 mm;[14] Elk Creek, PA, 6.2 mm;[10] Gennesee River, NY, 6.4 mm;[15] Black Creek, NY, 7.0 mm;[7] and in Great Lakes basin, 5.8–7.0 mm;[16] yolk absorbed by 7.8–8.0 mm.[3,22] Newly hatched *E. f. lineolatum* from Coon Creek, Spring Coulee Creek, WI, Root River, MN, and Fox River, IL hatched at 4.5–5.9;[3,22] yolk absorbed by 7.8–8.0 mm.[3,22]

Myomeres

Etheostoma f. flabellare preanal myomeres 15, postanal myomeres 19–21, total myomeres 34–36.[10]

Etheostoma f. lineolatum preanal myomeres 15, postanal myomeres 19–21, total myomeres 34–36.[3,22]

Morphology

Etheostoma f. flabellare.

4.75–7.0 mm TL. Newly hatched larvae with a large yolk sac, 31% TL, containing a single oil globule.[7,10] Gills and rudimentary opercles formed at hatching.

7.2 mm TL. Notochord flexion occurs.[7,10]

Etheostoma f. lineolatum.

4.5–5.9 mm TL. Newly hatched larva with large yolk sac, spherical (ca. 42% TL); yolk amber with a single anterior oil globule; head not deflected over the yolk sac; jaws developed; eyes oval.[3,22]

Morphometry

See Table 67 and 68.[3,10,22]

Etheostoma f. flabellare preanal length 52.8% and head length 19.7%.[23,24]

Fin Development

See Table 69.[3,10,22]

Etheostoma f. flabellare.

4.75–7.0 mm TL. No incipient rays at hatching.[10,23,24]

7.2–7.5 mm TL. First rays formed in spinous and soft dorsal, anal, caudal, and pectoral fins.[10,23,24]

8.8 mm TL. Pelvic fin buds present just posterior to the oil globule.[10,23,24]

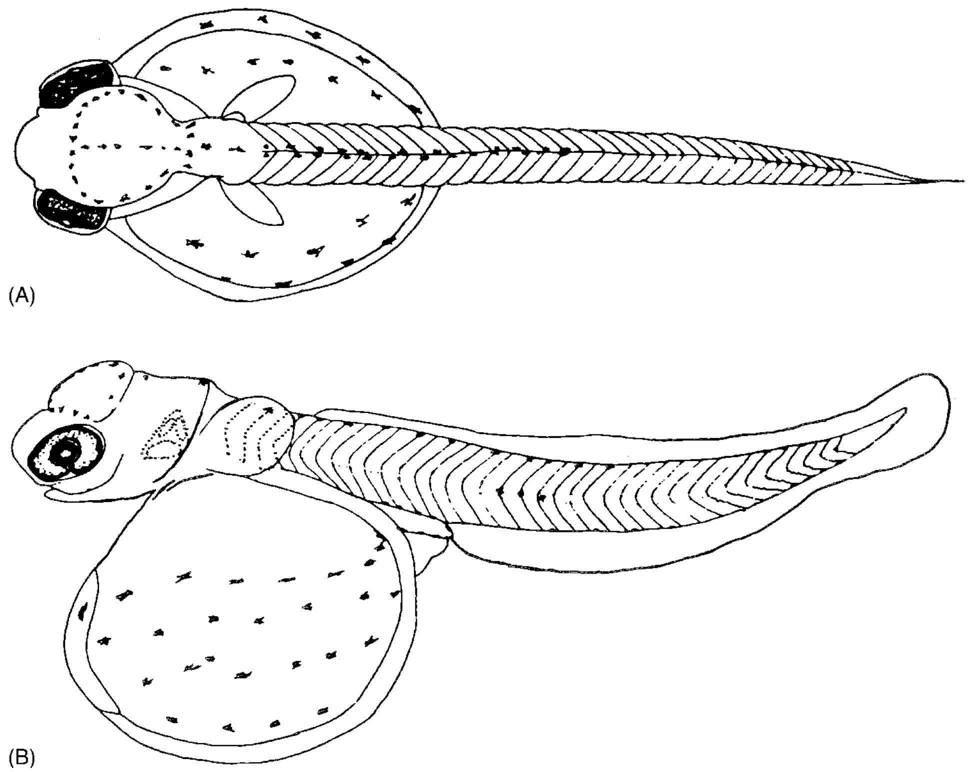

Figure 59 *Etheostoma flabellare flabellare*, barred fantail darter Elk Creek, PA (newly hatched yolk-sac larva), 6.2 mm TL, dorsal and lateral views. (A–B redrawn from reference 10, with author's permission.)

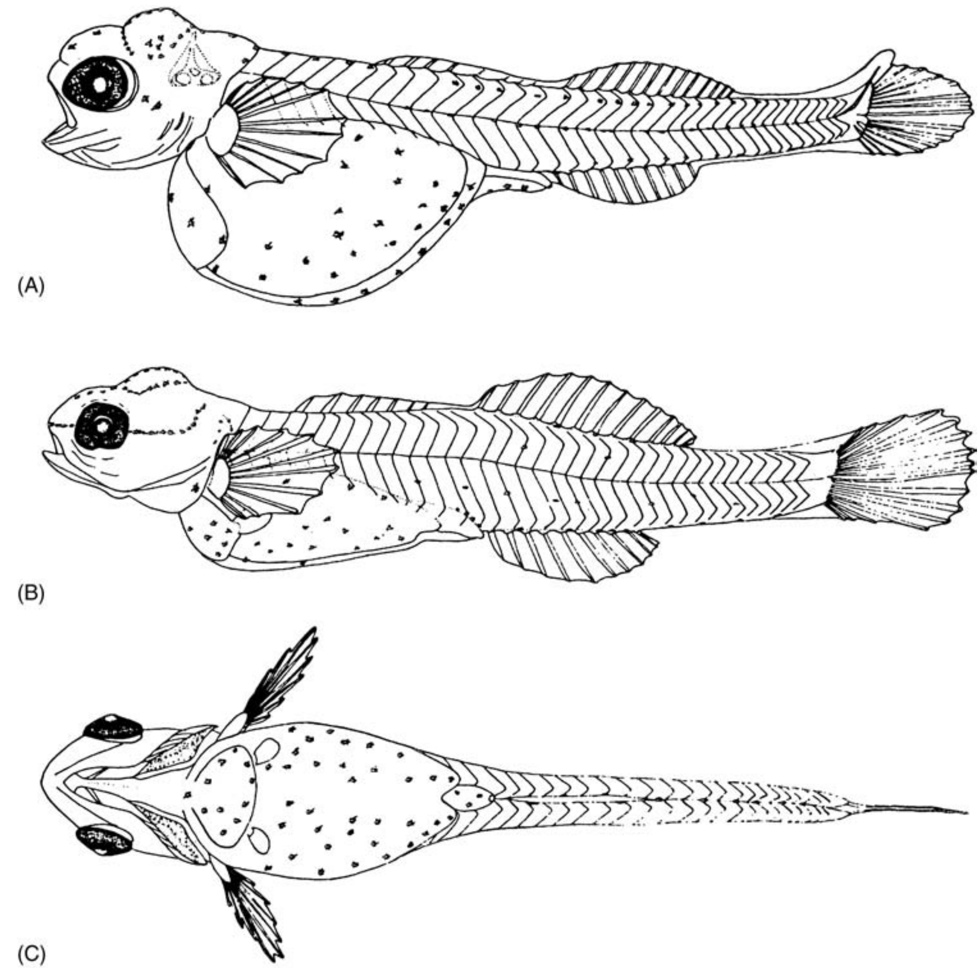

Figure 60 *Etheostoma flabellare flabellare*, barred fantail darter Elk Creek, PA, and Greenbrier River, WV: (A) yolk sac larva 7.8 mm TL, lateral view; (B-C) yolk sac larva, 8.8 mm TL, lateral and ventral view. (A-C redrawn from reference 10, with author's permission.)

Etheostoma f. lineolatum.

5.0–5.6 mm TL. Pectoral fin rays form.[3,22]

5.3–5.9 mm TL. First rays formed in anal fin; first rays form in caudal fin.[3,22]

Pigmentation

4.5–5.9 mm TL. Retinae black; scattered melanophores on a large yolk sac with highest concentration laterally. Stellate melanophores present on cranium, encircling optic lobe. Several melanophores present laterally, rising obliquely near the base of the caudal peduncle. Ventral melanophores present on the gut and from the anus to about postanal myomere 9. Dorsal melanophores in two blotches located just anterior of anus and initiating near posterior of ventral postanal melanophores. Majority of preanal myomeres without pigmentation.[3,22]

6.0–7.5 mm TL. Cranium with a concentration of melanophores dorsally encircling optic lobe. Postorbital bar formed, with additional horizontal pigmentation on the operculum. Yolk sac with stellate mealnophores on lower half. Dorsally, pigmentation on the nape and at the base of soft dorsal. Lateral pigmentation outlining preanal myomeres posteriad of yolk sac, extending to middle of soft dorsal. A mid-lateral stripe formed from single melanophores present at almost every postanal myoseptum, with several extending dorsally to mid-lateral. Melanophores present at the base of the caudal fin.[3,22]

7.8–9.2 mm TL. Optic lobe outlined with melanophores. Horizontal preorbital and postorbital bars with additional pigment present on operculum. Additional cranial pigment present dorsally on the nape. Melanophores outline lateral myosepta of preanal and postanal myomeres just posterior to soft dorsal. Ventral pigmentation concentrated at mid-ventral of the gut, and beneath the operculum and branchiostegal rays.[3,22]

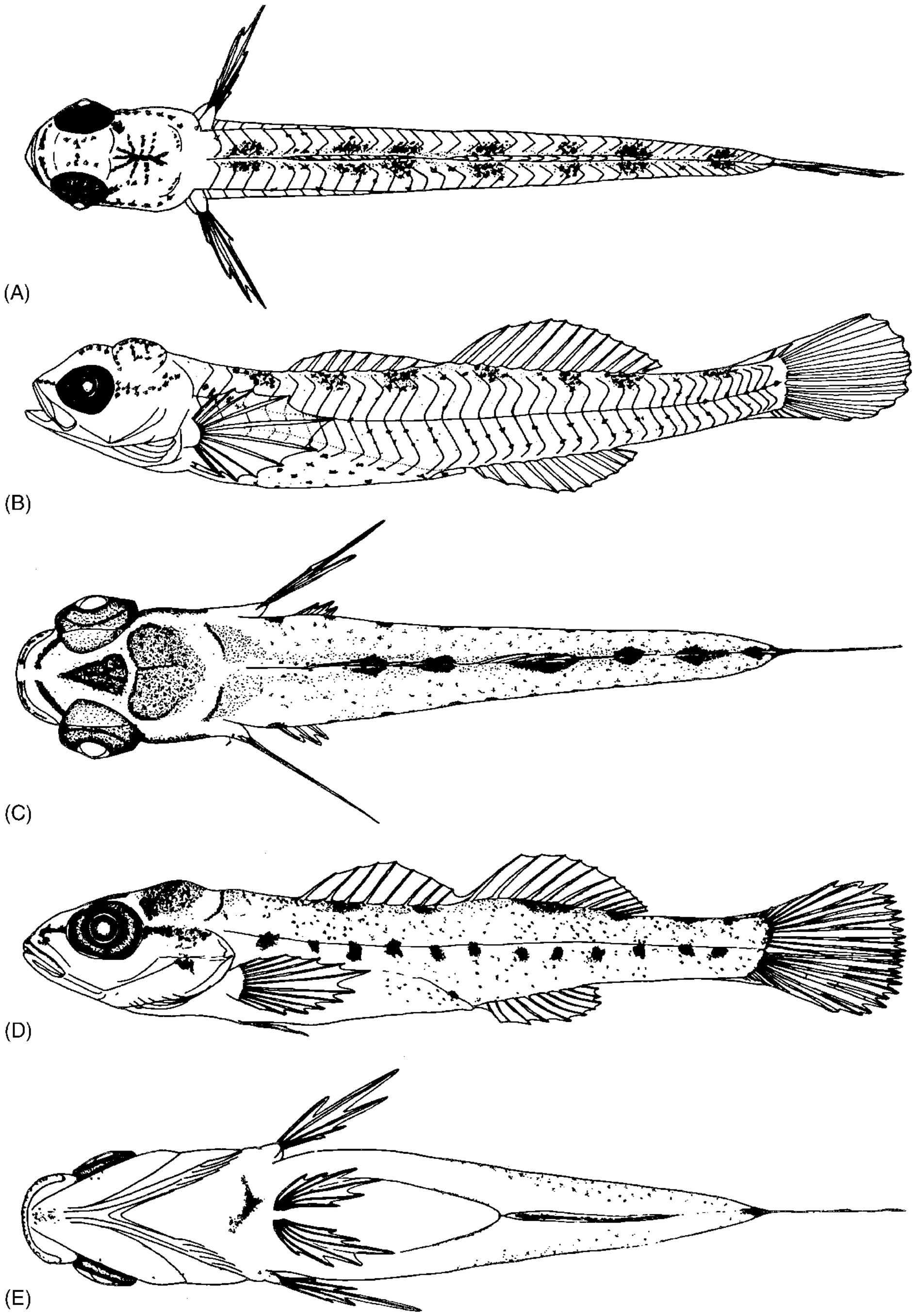

Figure 61 *Etheostoma flabellare flabellare*, barred fantail darter, Elk Creek, PA, and Greenbrier River, WV: (A-B) Post Yolk-sac larva, 9.5 mm TL, dorsal and lateral view; (C-D) Post Yolk-sac larva, 11.5 mm TL, dorsal and lateral view, and (E) Post Yolk-sac larva, 14.5 mm TL, ventral view. (A-E redrawn from reference 10, with author's permission.)

POST YOLK-SAC LARVAE

See Figures 61, 63 and 64

Size Range

Etheostoma f. flabellare, 10[10]–18.5 mm.[10,23,24]

Etheostoma f. lineolatum, 8.0–14.5 mm.[3,22]

Myomeres

Etheostoma f. flabellare, preanal 15, postanal 19–21, 34–36 total.[10]

Etheostoma f. lineolatum, preanal 15, postanal 19–21, 34–36 total.[3,22]

Morphology

8.2 mm TL. No swim bladder formed, remains rudimentary; gut straight.[3,22]

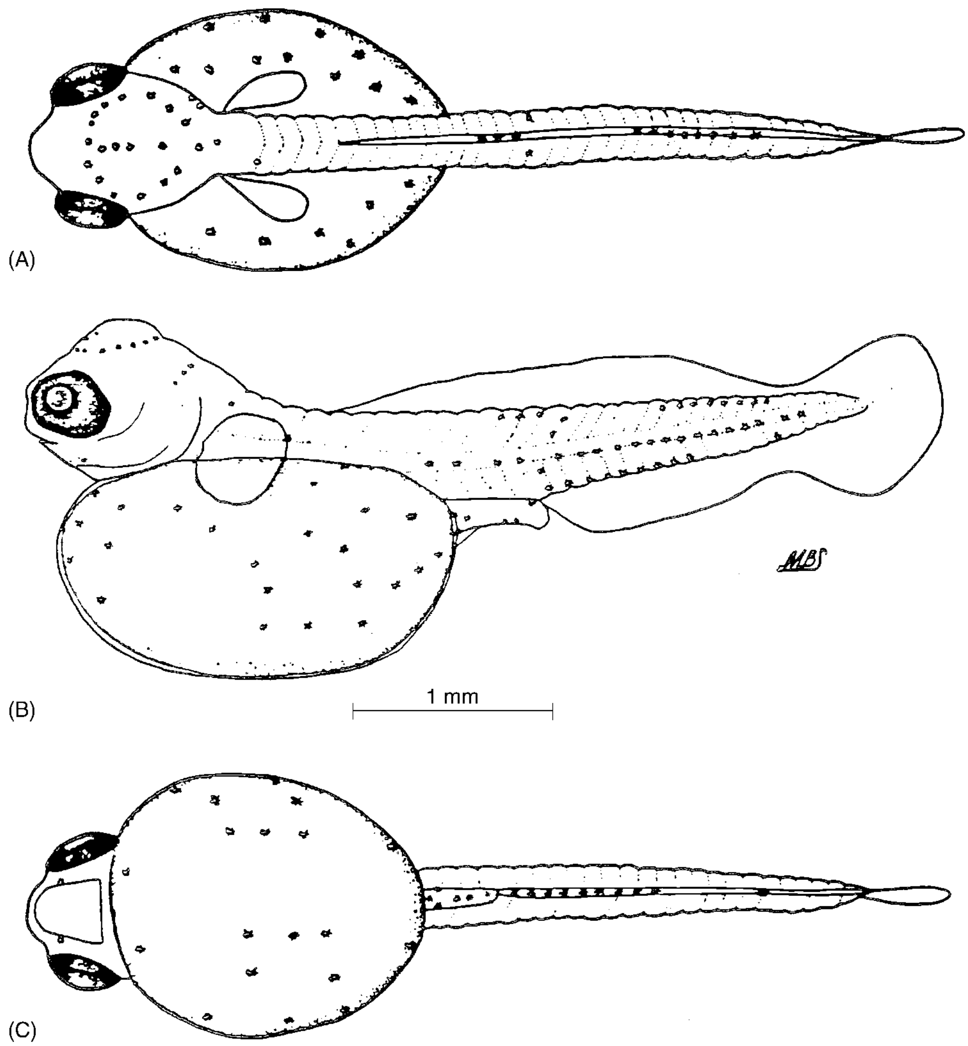

Figure 62 *Etheostoma flabellare lineolatum*, striped fantail darter (A–C) (newly hatched yolk-sac larvae), 4.8 mm TL: dorsal, lateral, and ventral views, Coon Creek, WI. (A–C redrawn from reference 3, with author's permission.)

10.0–10.8 mm TL. Scales present at 10.0 mm; infraorbital canal formed with 8 pores by 10.8 mm.[3,22]

10.8–11.8 mm TL. Preoperculomandibular canals formed, with ten pores.[3,22]

11.0–12.6 mm TL. Supraorbital, infraorbital, and lateral head canals formed; suprorbital completely formed.[3,22]

12.6–13.8 mm TL. Preoperculomandibular completely formed. [3,22]

14.0–14.2 mm TL. Lateral line begins forming.[3,22]

Morphometry

See Tables 67 and 68.[3,10,22]

Fin Development

See Table 69.[3,10,22]

Etheostoma f. lineolatum.

8.8 mm TL. First pelvic fin rays formed.[3,22]

Etheostoma f. flabellare

7.2 mm TL. pelvic fin buds present just posterior to the oil globule.[10]

14.0 mm TL. Pelvic fin rays completely formed.[10]

Pigmentation

9.5–10.9 mm TL. Horizontal preorbital and postorbital bars present on cranium. Chevron-shaped blotches present on the dorso-anteriorad to orbit, and on the optic lobe. Dorsally, eight rectangular blotches extend from nape to base of caudal peduncle. Oval blotches become continuous anteriorly

Table 67

Morphometric data expressed as percentage of HL and TL for young *E.f. lineolatum* from Illinois, Wisconsin, and Minnesota.[3]

	TL Groupings				
Length range (mm)	**4.5–6.9**	**7.0–10.9**	**11.0–15.9**	**16.0–19.1**	**20.5–26.1**
N	**61**	**122**	**41**	**5**	**8**
Mean	**6.19**	**7.27**	**12.8**	**17.5**	**23.2**
Ratios/actual Measures[a]	**(Range)**	**(Range)**	**(Range)**	**(Range)**	**(Range)**
As Percent HL					
SnL	8.6	15.1	19.1	19.8	20.0
	(0.05–0.25)	(0.22–0.5)	(0.4–0.7)	(0.71–0.86)	(1.0–1.4)
ED	43.7	38.0	29.4	23.9	22.8
	(0.4–0.65)	(0.55–0.9)	(0.75–0.86)	(0.86–1.1)	(1.1–1.5)
As Percent TL					
HL	19.0	22.3	24.6	23.1	24.4
	(0.8–1.5)	(1.2–2.8)	(2.6–3.7)	(3.5–4.3)	(5.2–6.3)
Preanal	53.6	51.3	50.8	50.0	50.4
	(2.6–3.8)	(3.4–5.6)	(5.7–7.9)	(7.9–9.5)	(10.3–13.2)
PosAL	46.4	48.7	49.2	50.0	49.6
	(1.9–3.1)	(3.6–5.3)	(5.3–8.0)	(7.9–9.5)	(10.2–12.7)
SL	90.5	83.8	82.7	84.7	85.7
	(4.0–6.3)	(5.9–9.1)	(9.0–13.3)	(13.5–16.3)	(17.2–22.0)
BDG	31.3	19.3	18.9	16.9	16.5
	(1.70–2.4)	(1.2–2.2)	(1.7–2.6)	(2.6–3.4)	(3.1–4.7)
BDA	10.7	12.4	13.8	14.6	14.1
	(0.45–0.85)	(0.75–1.7)	(1.2–2.4)	(2.2–2.7)	(3.1–4.0)
CPD	6.8	7.9	9.8	10.0	9.5
	(0.25–0.60)	(0.35–1.2)	(0.9–1.5)	(1.5–1.8)	(1.7–2.8)

[a] Range in parentheses is expressed as actual measurement (mm).

Table 68

Morphometric data expressed as percentage of HL and TL for young *E. f. flabellare* from Elk Creek, PA, and Greenbrier River, WV.[10]

	TL Groupings				
Length range (mm)	**5.5–7.5**	**7.51–9.5**	**9.51–11.5**	**11.51–14.0**	**18.7–19.0**
N	**11**	**15**	**11**	**13**	**2**
As Percent TL					
ED	9.45	7.3	8.0	8.0	6.0
	(0.6)	(0.3)	(0.45)	(0.1)	(0)
HL	19.0	19.0	22.5	23.5	24.5
	(1.0)	(1.2)	(0.8)	(0.9)	(0.5)
Preanal	51.2	48.0	49.6	50.9	50
	(1.8)	(1.4)	(1.2)	(0.7)	(0.5)
PosAL	48.8	52.0	50.8	49.1	50
	(1.8)	(1.4)	(1.2)	(0.7)	(0.5)
SL	94.4	85.5	83.6	83.5	81.5
	(1.2)	(1.8)	(1.1)	(0.5)	(0.7)

A singe standard deviation is expressed in parentheses.

Table 69

Meristic counts and size (mm TL) at the apparent onset of development for *E. f. flabellare*[10,23–24] and *E. f. lineolatum*.[3, 22]

Attribute/event	*Etheostoma f. lineolatum*[3,22]	*Etheostoma f. flabellare*[10,23,24]
Branchiostegal Rays	5,5[3,22]	5,5[10,23,24]
Dorsal Fin Spines/Rays	VIII–IX/12–14[3,22]	VIII–XI/10–13[10,23,24]
First spines formed	5.9[3,22]	7.8
Adult complement formed	7.6[3,22]	12.8
First soft rays formed	5.7[3,22]	7.2
Adult complement formed	7.2[3,22]	8.5–9.4
Pectoral Fin Rays	12–13[3,22]	12–13[10,23,24]
First rays formed	5.0–5.6[3,22]	7.2
Adult complement formed	7.0[3,22]	9.5–10.2
Pelvic Fin Spines/Rays	I/5[3,22]	I/5[10,23,24]
First rays formed	8.8–9.2[3,22]	9.0
Adult complement formed	8.8-9.2[3,22]	14.0
Anal Fin Spines/Rays	II/9–11[3,22]	II/9–11[10,23,24]
First rays formed	5.3–5.9[3,22]	7.2
Adult complement formed	7.0–7.2[3,22]	10.7–11.5
Caudal Fin Rays	viii–x, 8–9+7–8, viii–ix[3,22]	12–15[10,23,24]
First rays formed	5.3–5.5[3,22]	7.2
Adult complement formed	7.0–7.5[3,22]	Unknown
Lateral Line Scales	42–57[3,22]	42–49[10,23,24]
Myomeres/Vertebrae	34–36/33–34[3,22]	34–36/38–40[10,23,24]
Preanal myomeres	15[3,22]	15
Postanal myomeres	19–21[3,22]	19–21

along mid-lateral, with scattered melanophores on the gut. Multiple melanophores outline preanal and postanal myomeres hypaxially and epaxially. Melanophores extend onto the caudal and the soft dorsal fin. Ventral pigmentation limited to five areas of concentration, from just after the anus to the base of the caudal peduncle. Spinous dorsal, pectoral, pelvic, and anal fins devoid of pigmentation.[3,22]

11.0–13.9 mm TL. Cranium with horizontal preorbital and postorbital bars formed, with an oblique bar extending towards the nape. Cerebrum and optic lobe covered with clustered melanophores. Dorsally, 9–10 rectangular blotches with obliquely scattered melanophores connecting 12–13 rectangular mid-lateral blotches. Lateral epaxial with scattered melanophores outlines the scales. Pectoral girdle with a blotch near cleithra. Lepidotrichia of spinous, soft dorsal, anal, and base of caudal fins with melanophores. Mandible, maxillary, and interopercle with scattered melanophores. Pectoral and pelvic fins without pigment.[3,22]

JUVENILES

See Figure 64

Size Range

Etheostoma f. flabellare juvenile stage begins at 18.5 mm,[10,17,23,24] while for *E. f. lineolatum* stage begins at 14.5–44 mm TL.[12]

Fins

See Table 69.

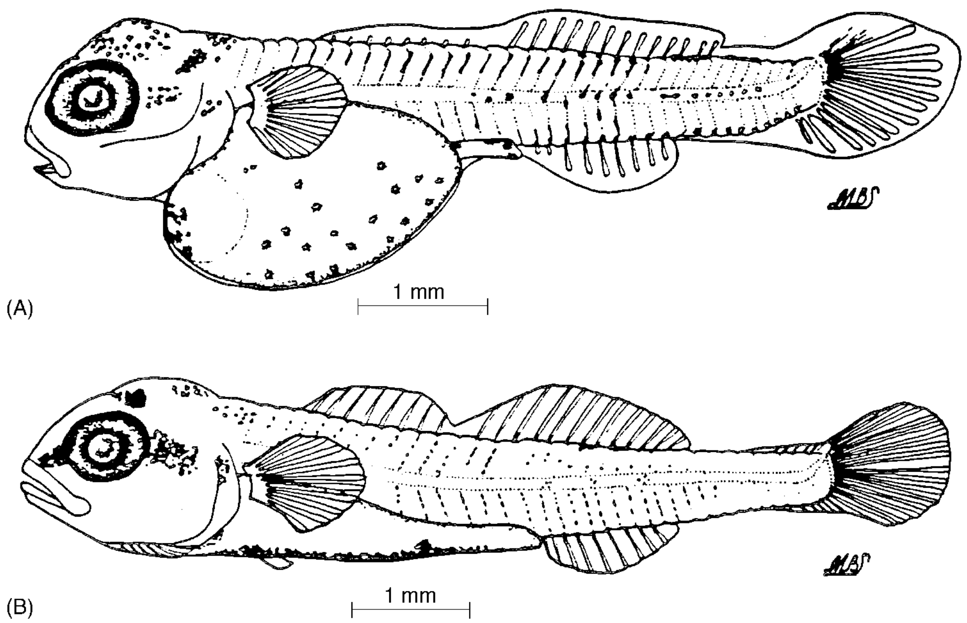

Figure 63 *Etheostoma flaellare lineolatum*, striped fantail darter: (A) Yolk-sac larva 7.1 mm TL, lateral view, Spring Creek, WI, (B) Post Yolk-sac larva, 8.2 mm TL, lateral view, Root River, MN. (A–B redrawn from reference 3, with author's permission.)

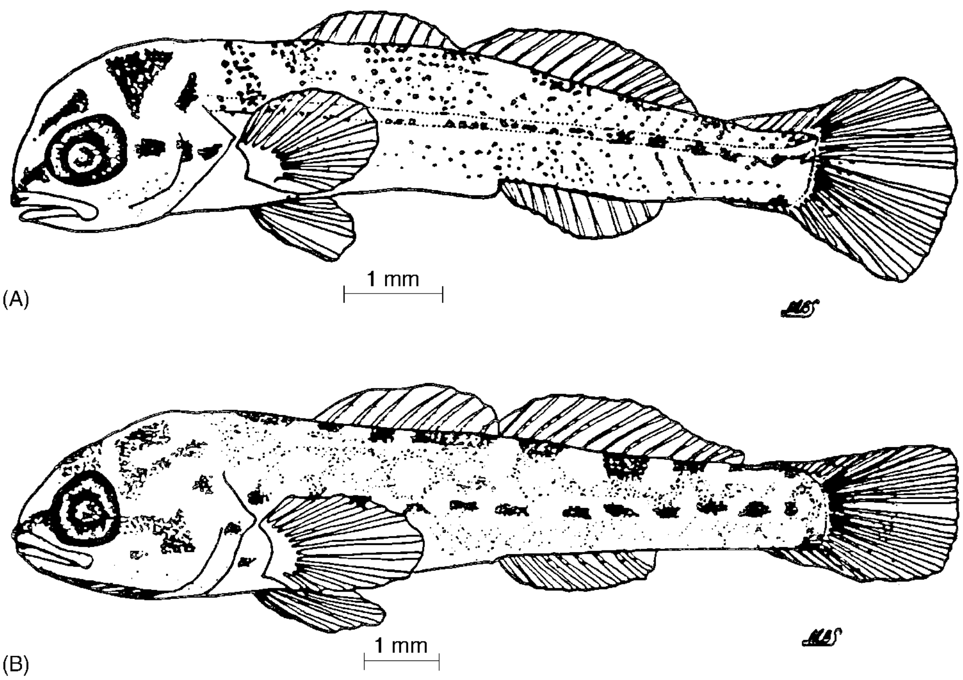

Figure 64 *Etheostoma flaellare lineolatum*, striped fantail darter: (A) Post Yolk-sac larva, 10.3 mm TL, lateral view; Spring Creek, WI, (B) early juvenile, 14.4 mm TL, lateral view. (A–B redrawn from reference 3, with author's permission.)

Etheostoma f. flabellare:

Spinous dorsal VI–IX; soft dorsal rays 10-13; pectoral rays 11–14; pelvic spines/rays I/5; anal fin spines/rays II/6-9.[9–13]

18.5 mm TL. Segmentation of principal rays in median fins evident.[10]

Etheostoma f. lineolatum:

Spinous dorsal VII–VIII; soft dorsal rays 11–12; pectoral rays 12–13; pelvic spines/rays I/5; anal fin spines/rays II/6–7; primary caudal rays 8 + 6–7, secondary rays XI–XII, IV–XII.[3,22]

Morphometry
See Tables 67 and 68

Etheostoma f. flabellare

Snout length 5.1%; head length 22.5%; preanal length 53.0%; maximum depth 16.2%; caudal peduncle depth 8.2%.[23,24]

Morphology
Etheostoma f. flabellare, total lateral line scales 41–60; total vertebrae 32–35.[1,2,12,16,19]

19.0 mm TL. Teeth present around the margins of both the jaws. Scales formed on the opercles but were lacking on the dorsum near the spinous dorsal fin.[10,23,24]

Etheostoma f. lineolatum, total lateral line scales 42–57, total vertebrae 33–34.[3,22]

Etheostoma f. lineolatum, 14.4–14.6 mm TL. Infraorbital canal with retrogression to interrupted condition of 4 pores anteriorly and 2 pores posteriorly; scales complete at 14.7 mm. No scales present on the nape, cheek, opercle, breast, and prepectoral areas.[1–3,22]

Pigmentation
14.5–24.6 mm TL. Cranium with concentrated melanophores over optic lobe and cerebrum. Distinct preorbital and postorbital bars formed, no suborbital tear drop formed. A chevron-shaped cluster of melanophores parallel to postorbital bar, scattered melanophores on cheek. Lateral pigmentation with 11–13 rectangular blotches, connecting 8 dorsal bands. The last rectangular blotch may be divided, forming two spots near mid-lateral of caudal peduncle base. Horizontal lines of melanophores extend from the head to caudal peduncle, formed from individual melanophores on the outer margins of the scales. Distinct humeral spot formed posterior of opercular spine. Spinous dorsal, pectoral, and anal fins with pigmentation scattered on rays. Horizontal stripes 4–5 on soft dorsal distributed on pterigiophore. Caudal fin with 6–8 vertical stripes formed on the interstitial membranes. Pelvic fin without pigmentation.[3,22]

25–45.6 mm TL. Black-brown to olive-brown; sides lighter; belly yellow to white; 9–13 irregular vertical bars on sides, meshing on back into saddles of equal widths. Lengthwise rows of dotted lines on sides and back. First dorsal fin with dark pigment along base. Second dorsal fin heavily speckled, caudal fin with 4–7 bars curving with contour of fin; remaining fins lightly pigmented to transparent.[12,17]

TAXONOMIC DIAGNOSIS OF YOUNG FANTAIL DARTER

Similar species: members of *Catonotus*

Cooper described differences within the Lake Erie darter assemblage[10] and Simon and Layman[22] described differences with the similar *E. percnurum.*

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (see Figure 65)
Eggs. Eggs are attached to the underside of slab rocks in shallow riffles and the edges of runs, and are guarded by the paternal and often unrelated resident male.[3,10–12,15,16,22]

Yolk-sac larvae. Remain in close association with the guarded nest, remaining in the interstitial spaces of the nest until postyolk absorption. Yolk-sac larvae possess extensive vitelline vein networks, which is consistent with a subterranean, benthic life style.[20,22,*]

Post Yolk-sac larvae. Demersal, remain in close association with the substrate along the edges of riffles in extremely shallow, interstitial pore spaces. Larvae

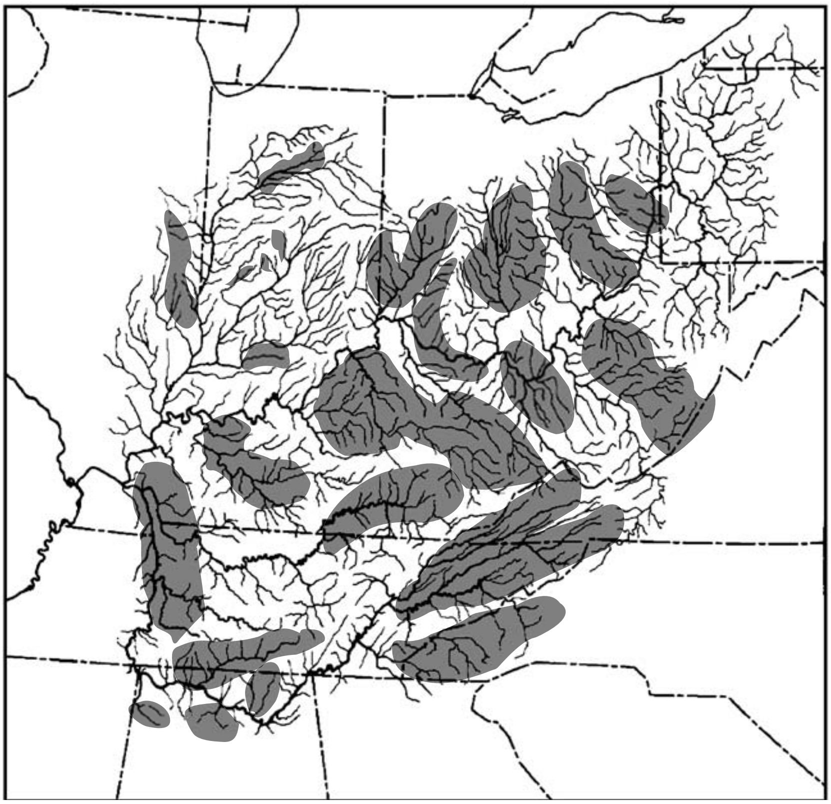

Figure 65 Distribution of fantail darter, *Etheostoma flabellare* in the Ohio River system (shaded area).

are seldom found among rootmats, aquatic macrophytes, and submerged roots.*[,16,21,22]

Juveniles. No distinction is evident between the habitats of young juveniles and adults.[3,10,16,22]

Early Growth

Young-of-the year from southern WI ranged from 24–36 mm TL in September;[12] *E. f. lineolatum* reached one half of the first year's mean growth in about 10 weeks.*

Feeding Habits

Fantail darters 13 mm TL consumed Ephemeroptera and Diptera larvae as long as the fish themselves.[18] Major food items included Diptera, Ephemeroptera, Tricoptera, and Plecoptera.[12]

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* Original fecundity data from Hurricane Creek, Clay Co., TN. Specimens curated at Northeast Louisiana University, Museum of Zoology, Monroe. Original life history data from T.P. Simon, unpublished data.

SAFFRON DARTER

Etheostoma (Ulocentra) flavum Etnier and Bailey

Etheostoma; various mouths; *flavum*: golden.

RANGE

Etheostoma flavum is confined to the lower Cumberland and lower Tennessee River drainages.[1–5]

HABITAT AND MOVEMENT

The saffron darter inhabits moderate-gradient, clear, small-to medium-sized streams. Adults prefer areas with coarse substrate usually in slow to gentle current riffles and runs.[2,5]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma flavum occurs in the Cumberland and Tennessee River drainages. In the Cumberland River drainage, the species occurs from the mouth upstream into the Harpeth and Sycamore Creek drainages, Cheatham County, TN. In the Tennessee River drainage it occurs in the mouth of Duck River, and in all eastern tributaries, but is absent from all western tributaries to the lower Tennessee River. *Etheostoma flavum* occurs throughout the lower and middle part of the Duck River system and its major tributary, the Buffalo River.[5]

SPAWNING

Location
Egg sites include the vertical sides, and less often the horizontal tops of rocks in flowing pool habitats, in slight to moderate current.[7] Spawning occurs on clean cobble in swift runs.[8]

Season
The collection of juveniles and breeding males suggests that the reproductive season initiates in March or April[1] and continues until mid-May.[7] Spawning throughout its range occurs from early April until early May.[7] Piney River, TN specimens were ripe in early April.[7]

Temperature
Spawning activity initiated in Warren Fork, Christian County, KY, when temperatures reached 23°C.[6]

Fecundity (see Table 70)
Female saffron darter showed a statistically significant increase in fecundity (ANOVA, $F = 19.493$, $p = 0.002$) with an increase in length. A 60 mm female had 155 large mature ova and a 57 mm female had 148 large mature ova.*

Sexual Maturity
Saffron darters survive to spawn for 2 years, with age 1 females averaging 27–44 mm at first reproduction in a coldwater stream and 30–45 mm in warmwater streams.[1]

Spawning Act
Etheostoma flavum is an egg attacher.[7] Egg sites include the vertical sides, and less often, the horizontal tops of rocks in flowing pool habitats, in slight to moderate current. In aquarium observations, the female is sometimes nudged by the male to stimulate reproduction.[6] The male rubs his chin on the top of the female's head to stimulate her. The pair swims along the substrate examining potential egg-attachment sites. Once the female assumes a head-up position, the male mounts the female with an S-shaped body orientation, and in a complex series of movements, presses against the vertical sides of the slab rocks. The male's body movements resemble an S shape, with the caudal peduncle of the male wrapped around that of the female. Adults maintain a head-to-head orientation with vents juxtaposed and pressed against the rock surface. Eggs are laid individually on the vertical surface of the rock, generally 3–4 during a single spawning event. Field observations confirm aquarium spawning positions, and indicate that *E. flavum* moves along cobble substrates, with the pair occasionally wiggling into cracks and crevices in rocks. The pair is observed to switch positions on the rock, depositing eggs on different sections of the same and different rocks. Each adult was promiscuous, spawning with multiple partners on different rocks, as noted by Page and Mayden with observations of *E. atripinne*. No cleaning of the rock surface or parental care is provided before or after the eggs are laid.[7]

Table 70

Fecundity data for saffron darter from Big Rock Creek, Marshall County, TN.

Length (TL)	Ovary Weight (mg)	Number of Ova: Ripening Oocytes (LA)	Number of Ova: Mature Oocytes (EM, MA, LM)	Number of Ova: Ripe Eggs (MR, RE)	Egg Diameter (mm)
47	134	726	128	106	1.11
48	145	929	107	97	1.11
48	171	738	233	79	1.11
50	120	998	115	108	1.11
52	175	931	270	96	1.11
52	241	1061	276	190	1.11
55	236	1091	236	131	1.11
57	301	2116	333	148	1.11
58	254	1148	253	128	1.11
60	302	2158	317	155	1.11

EGGS

Description
Ovarian examination showed that ovoid latent ova were 0.4 mm, early maturing ova averaged 0.71 mm, and large mature ova averaged 1.11 mm.* Eggs from Blue Creek, Humpheries Co., TN, are spherical, mean = 1.1 mm diameter.[7] Eggs from Piney River, Hickman Co., TN, are spherical, and larger than Blue Creek eggs, averaging 1.4 mm diameter (range: 1.2–1.6 mm); translucent; demersal; and adhesive. Eggs possess translucent, pale-yellow yolk (mean = 1.3 mm diameter; range: 1.1–1.5 mm); a single oil globule (mean = 0.5 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[7]

Incubation
Hatching occurs after 216–240 h at an incubation temperature of 18.3–19.4°C.[7]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 66

Size Range
Hatching at 4.8–4.9 yolk absorbed by 5.2–5.5 mm TL.[7]

Myomeres
Preanal 16 (9) or 17 (2)(N = 11, mean = 16.2); postanal 23 (8) or 24 (3)(N = 11, mean = 23.3); with total 39 (6) or 40 (5) (N = 11, mean = 39.5).[7]

Morphology
4.8–4.9 mm TL. Newly hatched larva with terete body; snout blunt; with functional jaws, upper jaw slightly extending past lower jaw; yolk sac small (18.0% TL), similar to other *Ulocentra*, oval to tapered posteriorly; yolk translucent pale yellow, with a single oil globule; single serpentine vitelline vein mid-ventrally on yolk sac; head not deflected over the yolk sac; and eyes spherical.[7]

5.1–5.3 mm TL. Digestive system functions prior to complete yolk absorption (5.1–5.3 mm).[7]

5.2–5.5 mm TL. Yolk absorbed.[7]

Morphometry
See Table 71.[7]

Fin Development
See Table 72.[7]

4.8–4.9 mm TL. Well-developed pectoral fins without incipient rays.[7]

Pigmentation
4.8–4.9 mm TL. Newly hatched larva with pigmented eyes; melanophores present dorsally over

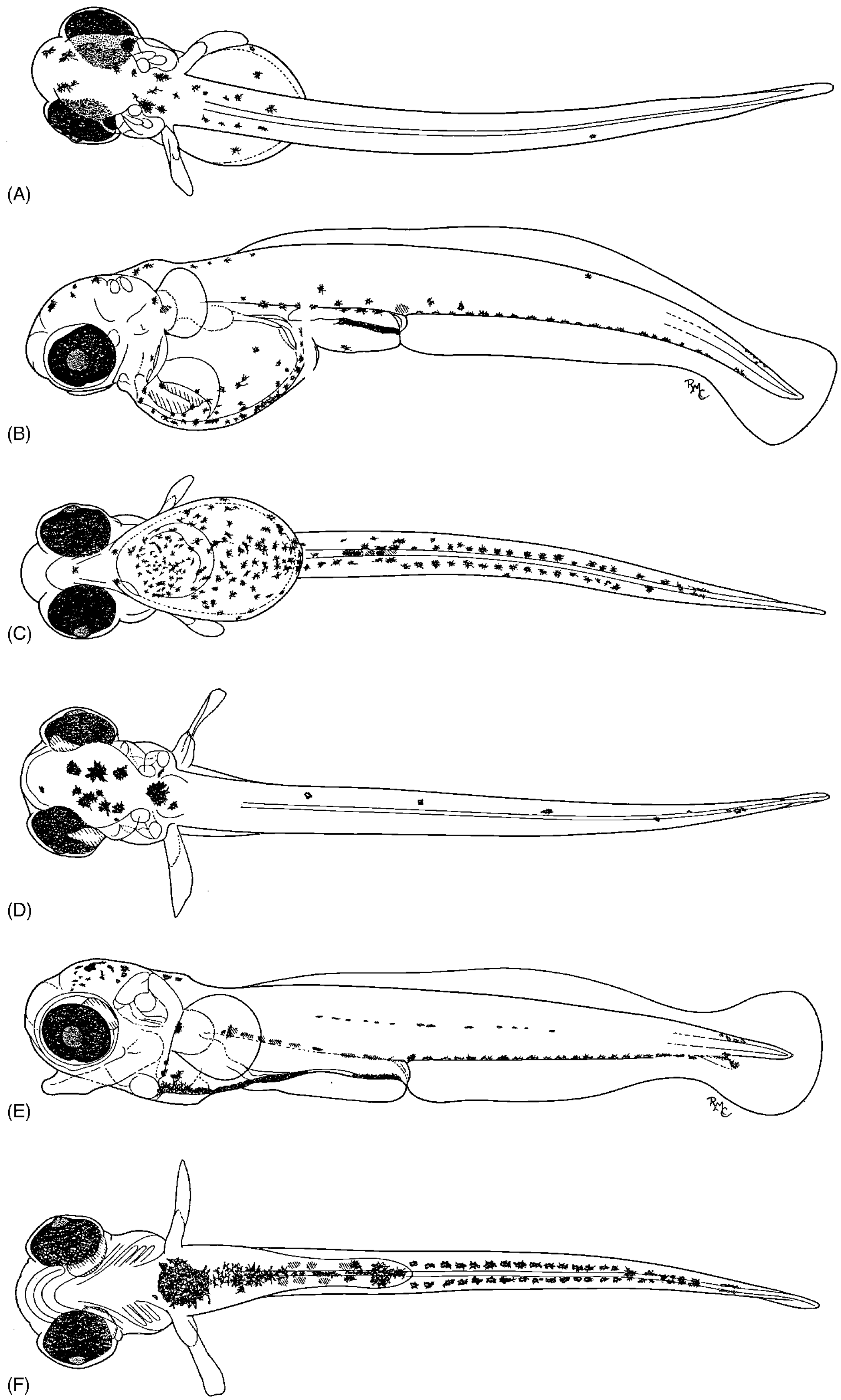

Figure 66 *Etheostoma flavum*, saffron darter, Piney River, Hickman County, TN. Yolk-sac larva, 4.9 mm TL: (A) dorsal, (B) lateral, (C) ventral views; Post yolk-sac larva, 5.3 mm TL (D) dorsal, (E) lateral, (F) ventral view. (A–F from reference 7, with author's permission.)

Table 71

Morphometry of young *E. flavum* (*N* = sample size).

	Total Length (mm)	
	4.46–5.54 (*N*=11)	
Characters	**Mean±SD**	**Range**
Length (% of TL)		
Upper jaw[a]	25.9 ± 6.11	(0.10–0.40)
Snout[a]	12.7 ± 1.80	(0.10–0.15)
Eye diameter[a]	42.8 ± 3.30	(0.36–0.52)
Head	20.4 ± 1.21	(0.88–1.14)
Predorsal	28.4 ± 2.08	(1.22–1.64)
Dorsal insertion		
D2 origin		
D2 insertion		
Preanal	48.0 ± 0.98	(2.11–2.72)
Postanal	52.0 ± 0.98	(2.28–2.82)
Standard	96.2 ± 0.69	(4.29–5.34)
Yolk sac	18.0 ± 6.08	(0.59–1.14)
Fin Length (% of TL)		
Pectoral	9.50 ± 1.37	(0.38–0.60)
Pelvic		
Spinous dorsal		
Soft dorsal		
Caudal	3.76 ± 0.69	(0.12–0.24)
Body Depth (% of TL)		
Head at eyes	15.8 ± 1.28	(0.65–0.98)
Head at P1	15.7 ± 3.72	(0.54–0.99)
Preanal	8.29 ± 0.68	(0.36–0.49)
Mid-postanal	6.15 ± 0.48	(0.28–0.34)
Caudal peduncle	3.07 ± 0.31	(0.13–0.18)
Yolk sac	9.98 ± 3.34	(0.32–0.72)
Body Width		
(% of HL)		
Head	70.6 ± 5.90	(0.60–0.80)
Myomere Number		
Predorsal	4.27 ± 0.47	(4.00–5.00)
Soft dorsal		
Preanal	16.2 ± 0.40	(16.0–17.0)
Postanal	23.3 ± 0.47	(23.0–24.0)
Total	39.5 ± 0.52	(39.0–40.0)

[a] Proportion expressed as percent head length.

Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

posterior cerebellum or nape extending posterior to margin of yolk sac; melanophores distributed laterally, dorsally and ventrally around the gut posterior to the yolk sac. Ventral pigmentation consists of a mid-ventral band of stellate melanophores forming a stripe around the vitelline vein of the yolk sac, and paired stellate melanophores along every mid-ventral postanal myosepta.[7]

5.0–5.2 mm TL. Additional melanophores combine to form macromelanophores on the optic lobe and cerebellum; dorsum of body with a single series of melanophores from the dorsal finfold origin to the caudal peduncle. Laterally, pigmentation develops along the mid-lateral from the stomach to the midanal finfold; a distinct melanophore is present on the prepectoral base; dorsally, pigment outlines the gut, becoming subdermal; ventrally, a series of large melanophores on the breast becomes continuous with the midbelly, and a continuous line forms from the posterior stomach to the anus.[7]

POST YOLK-SAC LARVAE

See Figures 66 and 67

Size Range
5.3 mm TL to unknown length.[7]

Myomeres
Preanal 16 (9) or 17 (2)(*N* = 11, mean = 16.2); postanal 23 (8) or 24 (3)(*N* = 11, mean = 23.3); with total 39 (6) or 40 (5) (*N* = 11, mean = 39.5).[7]

Morphology
5.3–6.0 mm TL. Operculum and gill arches function.[7] First rays form in caudal fin; premaxilla and mandible form. No swim bladder forms; gut straight, without striations, portion of gut posterior to stomach normal in length (6.0 mm). Spinous dorsal fin origin situated over preanal myomere 4–5, soft dorsal origin over preanal myomere 16–17.[7]

>6.0 mm TL. Due to the limited nature of the material, the development of first fin rays; notochord flexion; formation of branchiostegal rays; cephalic and lateral line development; and absorption of the dorsal and anal finfold can not be studied. These structures develop at lengths greater than 6.0 mm.[7]

Morphometry
See Table 71.[7]

Table 72

Meristic counts and size (mm TL) at the apparent onset of development for *E. flavum.*

Attribute/event	*Etheostoma flavum*	Literature
Branchiostegal Rays	5,5 [7]	5–6,5–6[1,2,5]
Dorsal Fin Spines/Rays	X–XII/10–12[7]	IX–XII/9–13[1,2,5]
First spines formed	>6.0[7]	
Adult complement formed	>6.0[7]	
First soft rays formed	>6.0[7]	
Adult complement formed	>6.0[7]	
Pectoral Fin Rays	15[7]	13–16[1,2,5]
First rays formed	>6.0[7]	
Adult complement formed	>6.0[7]	
Pelvic Fin Spines/Rays	I/5[7]	I/5[1,2,5]
First rays formed	>6.0[7]	
Adult complement formed	>6.0[7]	
Anal Fin Spines/Rays	II/7–8[7]	II/6–9[1,2,5]
First rays formed	>6.0[7]	
Adult complement formed	>6.0[7]	
Caudal Fin Rays	vii–xi, 9+8, viii–xi[7]	16–18[1,5]
First rays formed	6.0[7]	
Adult complement formed	>6.0[7]	
Lateral Line Scales	45–54[7]	42–59[1,2,5]
Myomeres/Vertebrae	39–40/37–40[7]	Unknown/37–40[1,2,5]
Preanal myomeres	16–17[7]	
Postanal myomeres	23–24[7]	

Average predorsal length 29.5% SL (range: 28.5 to 30.8% SL), and 28.4% TL (range: 27.4–29.6% TL).[7]

Fin Development

6.0 mm TL. Spinous dorsal fin origin situated over preanal myomere 4–5, soft dorsal origin over preanal myomere 16–17 (6.0 mm).[7]

Pigmentation

5.2–5.7 mm TL: Additional melanophores combine to form macromelanophores on the optic lobe and cerebellum; dorsum of body with a single series of melanophores from the dorsal finfold origin to the caudal peduncle. Laterally, pigmentation develops along the mid-lateral from the stomach to the mid-anal finfold; a distinct melanophore present on the prepectoral base; dorsally, pigment outlines the gut, becoming subdermal; ventrally, a series of large melanophores on the breast becomes continuous with the midbelly, and a continuous line forms from the posterior stomach to the anus.[7]

5.8–6.0 mm TL. Similar to the previous stage, with the exception that the dorsum of the body acquires additional paired melanophores from the nape to the caudal peduncle; ventral belly pigmentation becomes subdermal.[7]

JUVENILES

Size Range

Unknown to 44 mm.[1]

Fin Development

Branchiostegal rays 5–6,5–6;[1,2,5,7] dorsal fin spines/rays IX– (X–XII)/9–(10–12)–13;[1,2,5,7] pectoral fin rays

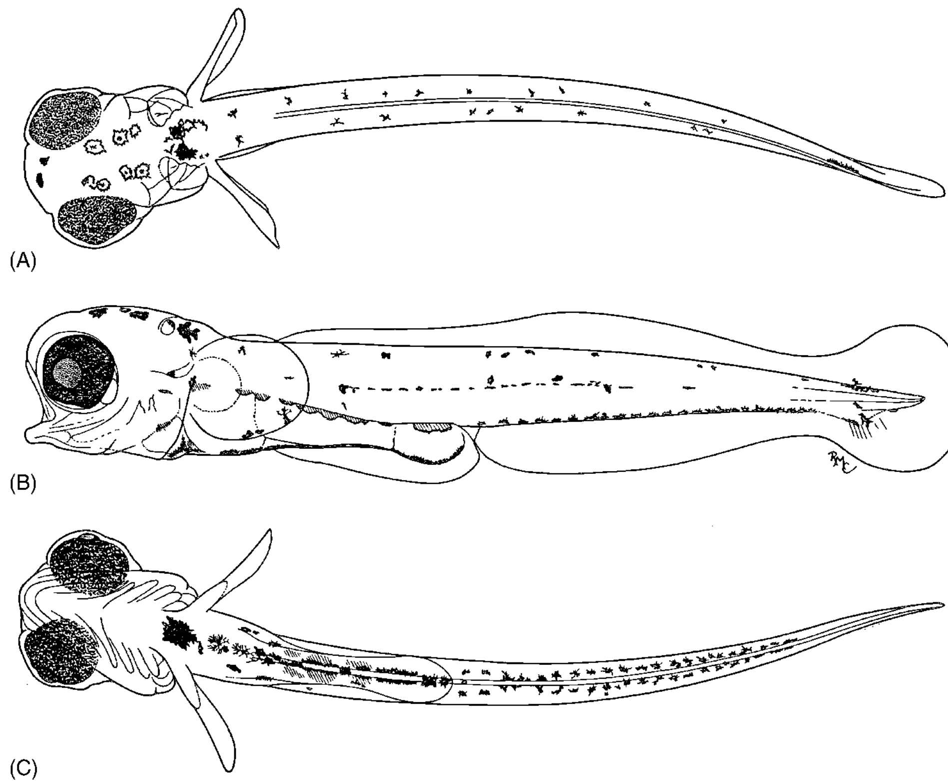

Figure 67 *Etheostoma flavum*, saffron darter, Piney River, Hickman County, TN. Post yolk-sac larva, 6.0 mm TL (A) dorsal (B) lateral, (C) ventral views. (A–C from reference 7, with author's permission.)

13–(15)–16;[1,2,5,7] pelvic fin spines/rays I/5;[1,2,5,7] anal fin spines/rays II/6–(7–8)–9;[1,2,5,7] caudal fin rays vii–xi, 9+8, viii–xi[7] or 16–18.[1,5]

Morphology

Total vertebrae count 37 (2), 38 (56), 39 (97), or 40 (11)(N = 166, x = 38.7); scales in the lateral series 42–59 (usually 45–54)[7] in the Duck River drainage.[1,2,5]

Early juveniles. Infraorbital, supraorbital, lateral, subtemporal and reoperculomandibular head canals complete; preoperculomandibular canal complete with 8–10 pores, infraorbital pores 7–9, lateral canal pores 5, supratemporal pores 3, and a single coronal pore. Cheek scales, usually embedded (may be absent dorsally); cheek, opercle, nape, and belly are completely scaled; breast squamation variable, either naked to scaled on posterior half.[1,2,5]

Morphometry

Unknown.

Pigmentation

Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG SAFFRON DARTERS

Similar species: members of subgenus *Ulocentra*

Adult. *Etheostoma flavum* is a member of the *E. duryi* species group. *Etheostoma flavum* can be differentiated from the other members of the *E. duryi* species group by the lack of any red coloration, except in the membranes of the soft dorsal fin. They possess less than 25 dark marks (including lateral blotches on both sides and dorsal saddles), and the color of the lips is yellow to orange.[5] *Etheostoma flavum* has modes of 11 soft dorsal fin rays; typical ranges of 45–54 lateral line scales and usually 11 scales around the caudal peduncle. *Etheostoma flavum* occurs in the lower Cumberland and lower Tennessee River drainages, KY and TN.[2,5]

Larva. *Etheostoma flavum* is virtually identical to species *E. duryi* in pigmentation and myomere counts. Both species have overlapping low preanal (16–17) myomere counts, and higher postanal (22–24) myomere counts. *Etheostoma flavum* has a larger yolk sac at hatching, more ventral pigment on the yolk sac and dorsally over the yolk sac and gut, and more dorsal pigmentation over the cranium and nape area, lacking posterior pigmentation.[6]

Variation
No intraspecific variation of *E. flavum* could be studied due to availability of limited material from Piney River.[6] The species differs from *E. duryi* species group in pigmentation and ontogenetic events. *Etheostoma flavum* has equivalent preanal myomeres counts with the other members of the species group; however, the mode for postanal myomeres was lower (22). Pigmentation is substantially different from the other taxa, consisting of large macromelanophores on the cerebellum and nape, large macromelanophores on the breast and belly, and paired melanophores at each postanal myosepta.[6]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (see Figure 68)
Eggs. Egg sites include the vertical sides, and less often, the horizontal tops of rocks in flowing pool habitats, in slight to moderate current.[7]

Yolk-sac larvae. Aquarium observations show that saffron darter larvae are epibenthic immediately after hatching.[7]

Post Yolk-sac larvae. Larvae become demersal only at lengths greater than 9 mm, when they remain in close association with the substrate. Saffron darter larvae from Piney River are collected in eddy areas adjacent to riffles, and from behind tree roots and other structures that act as obstructions in flowing pool habitats from late- April to early- May.[7] All larvae less than 20 mm are collected in epibenthic dipnet samples from the nearshore habitats usually associated with tree roots or rubble.[7]

Juveniles. Early juveniles utilize the downstream pools and backwater areas adjacent to spawning riffles as nursery habitats. Juveniles greater than 20 mm TL are the smallest individuals found on the margins of the riffle and flowing pool habitats in TN utilizing adult habitat.[1]

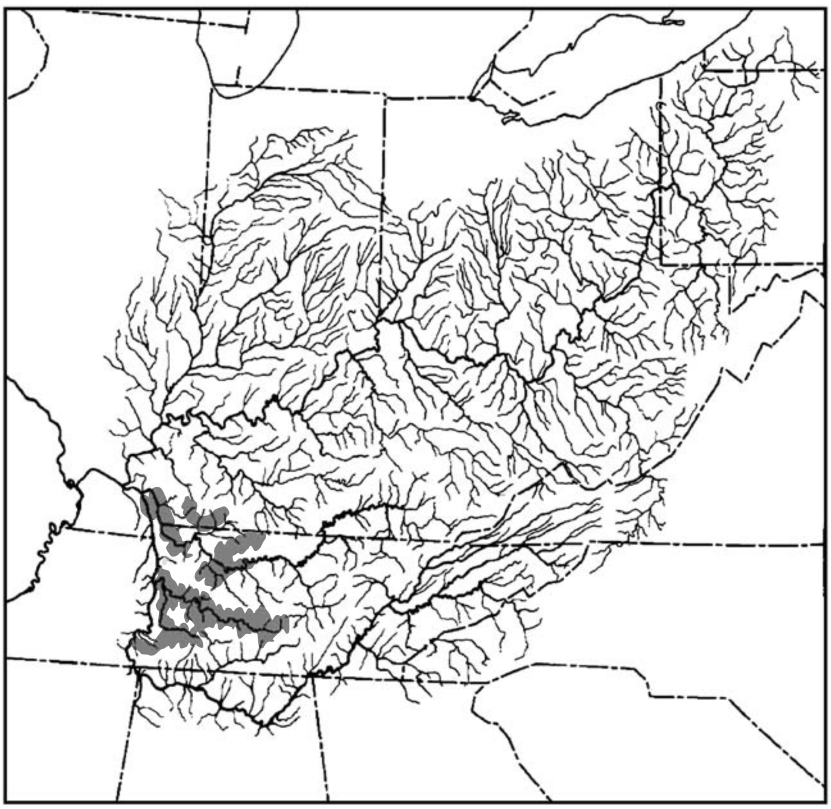

Figure 68 Distribution of saffron darter, *Etheostoma flavum* in the Ohio River system (shaded area).

Table 73

Average calculated lengths (mm TL) of young saffron darter in Tennessee.

State	Age		
	1	2	3
Tennessee[1]	24–35	54	65 (maximum 71 mm)

Early Growth (see Table 73)
Males average about 3 to 5 mm longer than females, and the largest males are 65 mm.[1]

Feeding Habits
Unknown.

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Material Examined: TN: Hickman Co.: Piney River, at mouth of Big Spring Creek, Plunders Creek Road bridge, 10.7 miles N Centerville, TV 3093 (7); TV 3093 (1 egg); TV 3094 (2); TV 3093 (1 egg); TV uncatalogued (2).

* Original fecundity data for saffron darter from the Big Rock Creek, Marshall County, TN. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Early life history developmental series cultured from TVA laboratory spawned specimens are curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

BARRENS DARTER

Etheostoma (Catonotus) forbesi Page and Ceas

Etheostoma: various mouths; *forbesi*: in honor of Stephen A. Forbes, founding ichthyologist of the Illinois Natural History Survey.

RANGE

Etheostoma forbesi is limited to headwater tributaries of the Barren Fork River and Hickory Creek system, and the Cumberland drainage of Cannon, Coffee, and Warren Counties, TN.[1,2]

HABITAT AND MOVEMENT

The preferred habitats of the barrens darter are small upland creeks where it occurs locally in gently flowing riffles and pools with slab rock rubble substrates.[1,2]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma forbesi is limited to Barren Fork River and Hickory Creek, TN.[1,2]

SPAWNING

Location
Underside of slab rocks.[1–3]

Season
Spawning occurs in late- April through May.[1–3]

Temperature
Unknown.

Fecundity
Unknown.

Sexual Maturity
Unknown.

Spawning Act
Adults deposit their eggs on the underside of slab rocks, where they are guarded by a male.[3]

EGGS

Description
Unknown

Incubation
Unknown

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Larger juveniles: Spinous dorsal fin 7–10; soft dorsal rays 11–15; pectoral rays 10–13; anal fin rays II 6–9; pelvic fin rays I 5; caudal fin rays 15–18.[1–3]

Morphology
Scales in the lateral series incomplete with 21–28 scales and with 43–51 total scales in the lateral series from TN.[2,3]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG BARRENS DARTER

Similar species: members of subgenus *Catonotus* of *E. squamiceps* complex

Similar to other members of the *E. squamiceps* complex. In the study zone it is sympatric with *E. flabellare*.[3]

Adult. *Etheostoma forbesi* is similar to *E. flabellare.* Both *Catonotus* species differ based on myomere counts and differences in pigmentation.

Larva. Aspects of the early life history and reproductive biology for *E. forbesi* are unknown.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (see Figure 69)
Eggs. Eggs are laid on the underside of slab rocks.[3]

Figure 69 Distribution of barrens darter *Etheostoma forbesi* in the Ohio River drainage (shaded area).

Yolk-sac larvae. Unknown.

Larvae. Unknown.

Juveniles. Unknown.

Early Growth
Largest specimen reaches 75 mm TL.[3]

Feeding Habits
Unknown.

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SLOUGH DARTER

Etheostoma (*Boleichthys*) *gracile* (Girard)

Etheostoma: various mouths; *gracile*: slender.

RANGE

Etheostoma gracile occurs along the Gulf Coastal Plain from the Pascagoula River, MS, westward to the Nueces River, TX, and northward throughout the Mississippi River Embayment and adjacent areas above the Fall Line.[1–14] It occurs disjunctly below the Fall Line in the upper Tombigbee and Alabama River drainages, MS and AL. *Etheostoma gracile* is found in tributaries of the Mississippi River from LA, north to central IL, southwest IN, and southeast MO.[1–4]

HABITAT AND MOVEMENT

Etheostoma gracile was found in slow, moderately flowing or quiet waters often associated with pools.[1–14] Waters are muddy, or murky, clear, and brown.[1–4] No aquatic vegetation was present in half of the collections and most of the rest had only slight to moderate amounts of *Myriophyllum, Potamogeton, Typha, Cladophora,* and water lilies. Aquatic vegetation was abundant in only 8% of the collections, composed of *Ceratophyllum*, rushes, and filamentous algae.[3] Mud and silt were the dominant bottom substrates occurring at 77% of the sites.[3,4] Individuals were found during winter in deep sand-bottomed pools when shallow pools were frozen.[7]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma gracile is commonly found in creeks, streams, sloughs, and lakes that border the lower Ohio River, lowland portions of the Wabash River south of the WI glaciation, and in TN it occurs throughout the Coastal Plain.[1–14]

SPAWNING

Location
Eggs are attached to leaf petioles, small twigs, and exposed tree roots.[7]

Season
Spawning in IL, IN, and TX, occurs from late March to April[1–6] or until late May.[7]

Temperature
Stream temperatures at the time of capture of ripe adults ranged from 12.5 to 21.6°C.[7]

Fecundity (see Table 74)
Females produced between 30 and 50 eggs per year, although more than 2500 eggs are produced in each ovary in one season; however, only about 20 % of the ova ever reach maturity and only a few of these are actually laid.[7] Females 38–53 mm TL had mature ova numbering between 49 and 280. Females (38–53 mm TL) collected in mid-April had mean ovaries that were 6.0% of the body weight, containing 139.0 total ova averaging 0.71 mm diameter. Female *E. gracile* showed statistically significant increasing fecundity (ANOVA $F = 27.014$, $p = 0.001$) with increasing length. Females between 38–53 mm had 49–280 large mature ova*.

Sexual Maturity
Males and females were sexually mature at age 1. Females from AR had mature occytes and ripe eggs by 38 mm TL (Table 74).[7]

Spawning Act
Etheostoma gracile is an egg-attacher. Female *E. gracile* is passive to most of the courtship of the male. During courtship, the male pursues the female and places himself on her back or alongside her with his head above hers. When on top of the female, the male rapidly vibrates his pectoral fins along the female's sides, stroking her. At intervals, the male leans forward, opens his mouth very wide, rapidly bobs his head, and rubs his chin tubercles over the top of the head and snout of the female. The male rubs the top of the head and nape of the female with his breast. The male rubs his anal and pelvic fin while its tuberculate anal fin remains in contact with the female's caudal peduncle. All stimulation by the male is tactile rather than visual. No color displays are made by the male. When the female has been stimulated, she swims to a suitable object, such as a leaf petiole or small twig, makes a pass over it and attaches a single egg

Table 74

Fecundity data for *E. gracile* from Little Creek (Little Red River drainage), White County, AR*.

Length (mm TL)	Ovary Weight (mg)	Number of Ova: Ripening Oocytes (LA)	Number of Ova: Mature Oocytes (EM, MA, LM)	Number of Ova: Ripe Eggs (MR, RE)	Egg Diameter (mm)
38	31.2	854	137	76	0.71
39	23.6	747	84	49	0.71
40	43.6	916	98	79	0.71
44	105	3079	292	183	0.71
44	27.9	889	103	79	0.71
45	24.3	968	115	83	0.71
47	87.4	2662	186	179	0.71
48	117	3251	282	188	0.71
51	128	2568	241	194	0.71
53	149	3492	323	280	0.71

to it. The male follows closely behind and passes over the egg and fertilizes it. The female may make a wide circle, return, and deposit another egg next to the first so that a number of eggs may be found on a single object, usually arranged precisely. However, sometimes only a single egg is deposited on an object. During aquarium observations, females laid between 30 and 50 eggs and were not observed spawning more than once. No territoriality, guarding, or postspawning care was provided.[7]

EGGS

Description
Ovarian examination showed that ovoid latent ova were 0.2 mm, early maturing small spherical ova were 0.50 mm, and large mature ova were 0.71 mm.* Mature ova are ovoid and sometimes indented near the point of egg attachment, including the primary egg envelope. Mature ova are demersal, adhesive, with translucent yolk, a single yellow oil globule, a narrow perivitelline space, and an unsculptured chorion.[7] Eggs ranged from 0.85[7] to 1.0 mm in diameter.[4]

Incubation
Hatching occurred in 120 h at 25°C.

Development
Unknown.

YOLK-SAC LARVAE

See Figure 70

Size Range
Yolk-sac larvae hatched at 2.8 mm[7] to unknown lengths

Myomeres
Preanal 15, postanal 21–22, 36–37 total.*,[7]

Morphology
2.8 mm TL. Body laterally compressed, yolk sac oval, anterior tapering posteriorly; single anterior oil globule; head not deflected over the yolk sac; jaws not developed; eyes spherical.*,[7]

Morphometry
See Table 75.

Fin Development
2.8 mm TL. Well-developed pectoral fin buds with no incipient rays.[7]

Pigmentation
See Figure 70

2.8 mm TL. Moderately pigmented; retinae black; concentration of melanophores dorsally over the

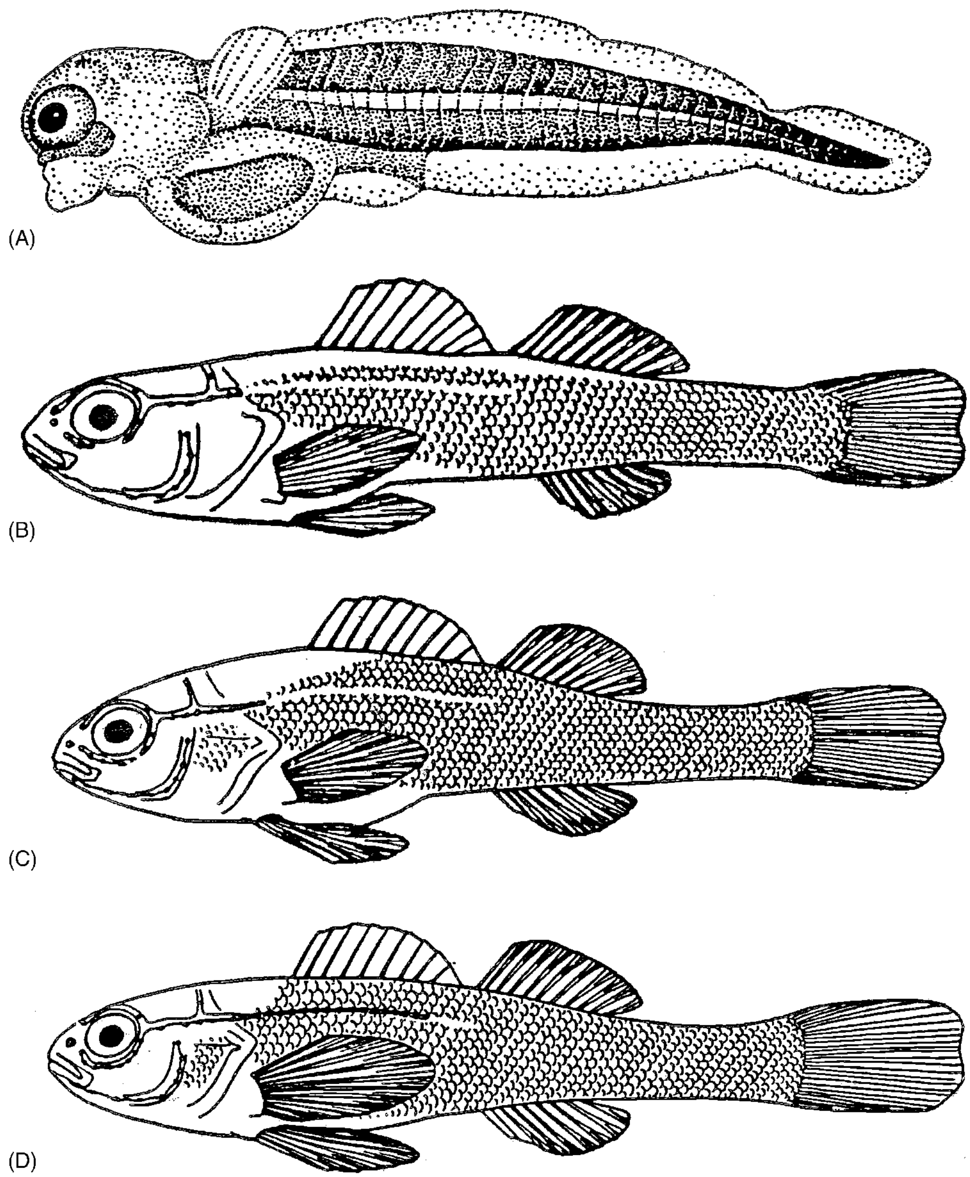

Figure 70 *Etheostoma gracile*, slough darter, Dismal Creek, IL; (A) newly hatched yolk sac larva, 2.8 mm TL, lateral view, (B) 17 mm early juvenile, lateral view, (C) juvenile, 20 mm TL, lateral view, (D) juvenile, 25 mm TL, lateral view, (A–D redrawn from reference 7, with authors' permission.)

gut from the posterior yolk sac to midpostanal. Several melanophores from distal pectoral fin and from future soft dorsal from above the notochord to caudal peducle. Yolk sac clear with exception of yellow oil globule.[7]

POST YOLK-SAC LARVAE

Size Range
Unknown to 14 mm.[7]

Myomeres
Preanal 15, postanal 21–22; 36–37 total.[*,7]

Morphology
12.5 mm TL. Supratemporal canal is incomplete, although the extreme ends of each portion are present.[4] Two infraorbital pores are present in the anterior portion of the canal and only an open groove in the posterior portion of the canal (12.5 mm).[3,4]

<14 mm TL. Yolk sac absorbed; notochord flexion occurred; eyes, mouth, and presumably the digestive tract were fully developed, and fins were present within 7 days after hatching.[7]

14.0 mm TL. Scales developed on the side but not on the belly, back, or opercles. The sensory canals of the head were formed, but the opercular spine had not appeared. No swim bladder formed; gut straight.[7,*]

Morphometry

See Table 75.

Fin Development

14.0 mm TL. Full complement of adult rays formed in median and paired fins.[7]

Pigmentation

12.5 mm TL. Preorbital and postorbital bars chevron-shaped; body mottled with melanophores connecting along the mid-lateral forming a series of irregular horizontal lines extending from the head to the caudal peduncle. A mid-lateral concentration of melanophores forms 9 lateral blotches; dorsally 8–9 saddles; posteriorly, a single line of melanophores ventrally from the anus to caudal peduncle expanding into a small cluster at the tip. Specks of melanophores scattered between pectoral fin rays; spinous and soft dorsal fin rays each with 4 oblique stripes; caudal fin with 4–6 diagonal stripes.*

14 mm TL. Melanophores posterior to orbit and several others on cleithra. Melanophores dorsally form eight distinct areas of concentration.*

Table 75

Morphometric data expressed as percentage of HL and TL for young *E. gracile* from Dismal Creek, IL.

	TL Groupings			
Length range (mm)	**2.8–3.2**	**12.5–16.9**	**17.0–19.7**	**20.2–25.5**
N	**3**	**12**	**18**	**15**
Mean	**3.0**	**14.8**	**18.3**	**22.8**
Ratios/actual measures	**(Range)**	**(Range)**	**(Range)**	**(Range)**
As Percent HL				
SnL	5.9	16.2	18.2	20.0
	(0.16–0.19)	(0.54–0.97)	(3.1–3.6)	(0.95–1.2)
ED	35.3	30.4	26.7	25.0
	(0..99–0.3)	(0.81–1.1)	(0.6–1.1)	(1.2–1.5)
As Percent TL				
HL	21.3	19.4	22.8	23.5
	(0.59–0.68)	(2.4–3.3)	(3.9–4.5)	(4.7–6.0)
Preanal	46.3	46.8	49.3	47.1
	(1.3–1.5)	(5.9–7.9)	(8.4–9.7)	(9.5–12.0)
PosAL	53.7	53.2	50.7	52.9
	(1.5–1.7)	(6.6–9.0)	(8.6–10.0)	(10.7–13.5)
SL	96.3	89.6	85.5	83.5
	(2.7–3.1)	(11.2–15.1)	(14.5–16.8)	(16.9–21.3)
P1	12.5	14.8	17.4	20.6
	(0.35–0.40)	(1.9–2.50)	(3.0–3.4)	(4.2–5.3)
BDG	19.4	18.8	18.8	17.6
	(0.56–0.7)	(2.35–1.7)	(3.2–3.7)	(3.6–4.5)
BDA	11.3	12.9	13.8	13.2
	(0.2–0.3)	(0.38–1.1)	(2.3–2.7)	(2.7–3.4)
CPD	4.7	6.3	8.0	7.6
	(0.12–0.16)	(0.8–1.1)	(1.4–1.6)	(1.5–1.9)
MAX-Y	22.5			
	(0.63–0.72)			
MAX-YD	12.5			
	(0.35–0.40)			

JUVENILES

See Figure 70

Size Range
14.2* to 30 mm TL.[7]

Fins
Spinous dorsal VII–XIII; soft dorsal rays 9–14; pectoral rays 12–14; pelvic spines/rays I/5; anal spines/rays II/5–8; primary caudal rays 8+7.[2–5]

Morphology
See Table 75.

14.2–14.9 mm TL. Lateral line begins to form, without pored scales; caudal peduncle scaled, extending along lateral line; scales are absent on the ventral part of the caudal peduncle, nape, pectoral fin base, opercle, preopercle, belly, and dorsally and ventrally from the lateral line anterior to the first dorsal fin origin.[3,4] A few embedded scales appear on the opercle and squamation of the ventral half of the belly (14.6 mm).[3,4]

14.6–19.0 mm TL. Three infraorbital pores in the anterior portion and two in the posterior (2 + 3)[3,4] are present.

15.9–17.1 mm TL. Possess between 0 and 1 pored lateral line scales.[3,4]

17.4–18.0 mm TL. Lateral line scales 0 to 13; infraorbital pores with a groove extending between the anterior and posterior portions of the canal; infraorbital pores 3+4.[3,4]

18.1–20.7 mm TL. Lateral line scales from 10 to 16 pored lateral line scales; squamation of the opercle, preopercle, and the posterior part of the belly is complete (19.0–20.7 mm). Development of infraorbital canal proceeds from the nostril posteriorly and from the junction with the lateral canal anteriorly.[3,4]

21.2–30 mm TL. Lateral line incomplete with 13–29 pores; vertebrae 37–38; frenum present, gill membranes slightly connected; cheeks, opercles, and prepectoral area scaled, nape and belly often with naked areas anteriorly, breast naked.[*,3,4]

Pigmentation
See Figure 70.

14.2–30 mm TL. Body is straw-colored, dark pigment consists of dorsal mottling and about ten lateral blotches are present. A faint suborbital bar and three basicaudal spots present (14.2–15.1 mm). Rays of soft dorsal and caudal fin are speckled. The ventral head and body possess numerous small melanophores. Preorbital, postorbital, and suborbital bars well developed. Pelvic and pectoral fins unpigmented, except small melanophores that outline the pectoral rays. Soft dorsal and caudal fins have vertical bands, forming stripes. The pored region of the lateral line is lightly colored.[3,4,14]

TAXONOMIC DIAGNOSIS OF YOUNG SLOUGH DARTER

Superficially similar larvae: members of subgenus *Boleichthys*

Adult. Etheostoma gracile is most similar to *E. proeliare. Etheostoma gracile* has a complete infraorbital canal with eight pores as rather than six pores as in *E. proeliare.*

Larvae. Etheostoma gracile possesses more (21–22) postanal myomeres than *E. proeliare* (19-20).

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (see Figure 71)
*Eggs***:** Eggs are attached to leaves, twigs, and other objects, either singly or in precise rows.[2–8]

Yolk-sac larvae. Remain in close association with filamentous algae and aquatic macrophytes after hatching.*

Larvae. Larvae are demersal and remain in close association with the substrate, aquatic macrophytes, and submerged roots.*

Juveniles. No distinction is evident between the habitat of young and adults.*

Early Growth (see Table 76)
Young-of-the year reach 20 mm TL by mid-summer, are sexually mature and average 35 mm at age 1. Young fish had attained half of their first year's growth in about 1 week.[7] This growth rate is improbable and probably represents specimens

Figure 71 Distribution of slough darter, *E. gracile*, in the Ohio River system (shaded area).

Table 76

Average calculated lengths (mm TL) of young slough darter in Illinois.

State	Age 1	2	3
Illinois[7]	27–32	29–39	38–43

spawned in late March, which are actually 60 days old. Juveniles from Dismal Creek, IL, were 14–16 mm by late May and by mid-June were 16–20 mm.[7]

Feeding Habits

Dietary preferences depend on the season. Spring diets include isopods, copepods, and amphipod crustaceans. Summer diets include chironomid larvae and copepods, while fall diets include cladocerans, copepods, and amphipods.[15]

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* Original fecundity data for *E. gracile* from Little Creek, Little Red River drainage, White County, AR (N=5), and Peery Branch, (Little River drainage), La Winn Parish, LA, Hwy 449, 13 mi SE Winnfield. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Original descriptive data came from T.P. Simon; early life history developmental series cultured from laboratory spawned specimens from Dismal Creek, Illinois. Specimens curated at the Illinois Natural History Survey, Center for Biodiversity, Champaign, IL.

HARLEQUIN DARTER

Etheostoma (*Poecilichthys*) *histrio* Jordan and Gilbert

Etheostoma: various mouths; *histrio*: latinized term for harlequin, after the masked face, shaven head, and multicolored tights worn by the harlequins of Italian comedy.

RANGE

Etheostoma histrio occurs in lowland portions of the Mississippi River basin from the Red River, northeastern TX and southeastern OK; along the western Gulf Slope to the Neches River, TX; east of the Mississippi River to the Escambia River, FL; northward above the Fall Line into the Poteau River, OK; and to the Embarras River, IL, and the lower White River and East Fork, IN.[1–5,*]

HABITAT AND MOVEMENT

The harlequin darter inhabits moderate to high-gradient, clear to slightly turbid, small- to large-sized rivers. Adults prefer unsilted riffles or runs with coarse firm substrates and woody debris.[17,18,*] Ripe adults from Pedro Creek, TX, were found along riffles with margins of woody debris, clay and sand banks, fallen branches, or roots covered with detritus;[6] the species also occurs in swift riffles over gravel bottoms;[7] and in both upland and lowland habitats.[8] It has been collected from Otter Creek, the Muscatatuck River basin, over bedrock with aufwuchs and swift current, and from the lower White River, Knox County, IN, a single adult male was collected from a brush pile over coarse sand substrates.[9] In the Black Warrior and lower Tombigbee Rivers, adults were associated with tree roots and organic debris, and in the Cahaba River, AL, with bedrock.[10–12] Young-of-the-year are commonly collected on clay riffles in the main channel border habitat of the Mississippi River, TN.[13] Seasonally, juveniles and adults occupy different habitats.[13] The species is speculated to move considerable distances into big rivers and reservoirs during colder months and into smaller rivers during reproductive periods.[13]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma histrio occurs from the Wabash, IN and IL, and Green River, KY, south into TN where it occurs in western tributaries of the Tennessee River and the lower Duck River system.[13] The species is widespread in IN, occurring throughout the East Fork White River, lower Wabash River, lower Patoka River, and lower West Fork White River.*

SPAWNING

Location

Aquarium observations showed that spawning pairs chose algae or moss-covered rocks and that vegetation (based on the presence of algae) was more important than current.[23] Based on field observations, we believe that these fish showed aberrant behaviors. Our field observations showed that egg sites included riffle margin habitats over woody debris or algal mats in slight to moderate current.[16] None of our collections found *E. histrio* to be associated with aquatic plants.*

Season

Spawning aggregates of adults assemble between mid-February[6] and late March on riffles in TX.[14] Females were reported to be ready to spawn in mid-March in MS.[2] Spawning was estimated to occur from April to May based on gonadal development.[15] Spawning in Plummer Creek, IN, occurs during several weeks from late April to late May.* In KY, spawning occurs from February to March;[18] a ripe female was collected from the Tombigbee River, MS, in late April.[13]

Temperature

Spawning activity initiates in Plummer Creek, IN, when temperatures reach 13.2°C.*

Fecundity (see Table 77)

Ranged from 90 to 450 ova in females from KY.[18] The female harlequin darter showed a statistically significant increase in fecundity (ANOVA, $F = 51.26$, $p \geq 0.0001$) with increasing length. A 48 mm female had 173 large mature ova and a 47 mm female had 166 large mature ova.*

Table 77

Fecundity data for harlequin darter *E. histrio* from Big Creek, Grant Parish, LA.*

		Number of Ova			
Length (mm TL)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
41	60	452	120	1	1.00
42	109	492	170	118	0.90
42	111	398	154	85	1.00
42	13.2	400	103	108	1.00
44	85.6	589	405	118	0.83
44	125	847	117	154	1.00
46	125	872	135	143	1.00
47	116	977	164	166	1.00
48	132	991	181	157	1.00
49	156	916	158	173	1.00

Sexual Maturity
Males and females were sexually mature at age 2, while some females were sexually mature at age 1.* In KY, sexual maturity in females apparently occurs at age 1 (40–50 mm TL).[18]

Spawning Act
Etheostoma histrio is an egg attacher.[16,23] Based on the shape of the elongate, tubular genital papillae, the species appears to be adapted for the placement of eggs among aquatic macrophytes or woody debris. The collection of larvae in the backwaters of the Tallapoosa River, AL, also corroborates this observation. Other members of the subgenus have a simple egg-attaching reproductive mode.[16] Aquarium observations of ripe adults collected from Plummer Creek, a tributary of the West Fork White River, IN, showed that reproduction occurs along the vertical edge of large pieces of woody debris. The male and female maintained a head-to-head orientation with vents juxtaposed. The male typically courts the female by lateral display and then follows the female as she rises along the woody debris. The female selects the spawning site, which is the vertical side beneath the exposed log on the current side of the log. The female hovers along the log to spawn and the male presses his vent against her and mounts her in the usual serpentine manner. Eggs are laid individually, with generally 2–3 eggs laid during a single spawning event.*

EGGS

Description
Information on the egg morphology of this species is unavailable.[16] Other members of the subgenus possess large spherical eggs 1.6–2.0 mm in diameter; translucent; demersal; and nonadhesive. Eggs possess a single oil globule; either a narrow or moderate perivitelline space; and an unsculptured and unpigmented chorion.[16] Ovarian examination showed that ovoid latent ova were 0.3 mm, early maturing ova averaged 0.66 mm, and large mature ova averaged 1.00 mm.*

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

See Figure 72

Size Range
Yolk-sac larvae from wild-caught AL specimens ranged from 5.2 to 6.0 mm.[16]

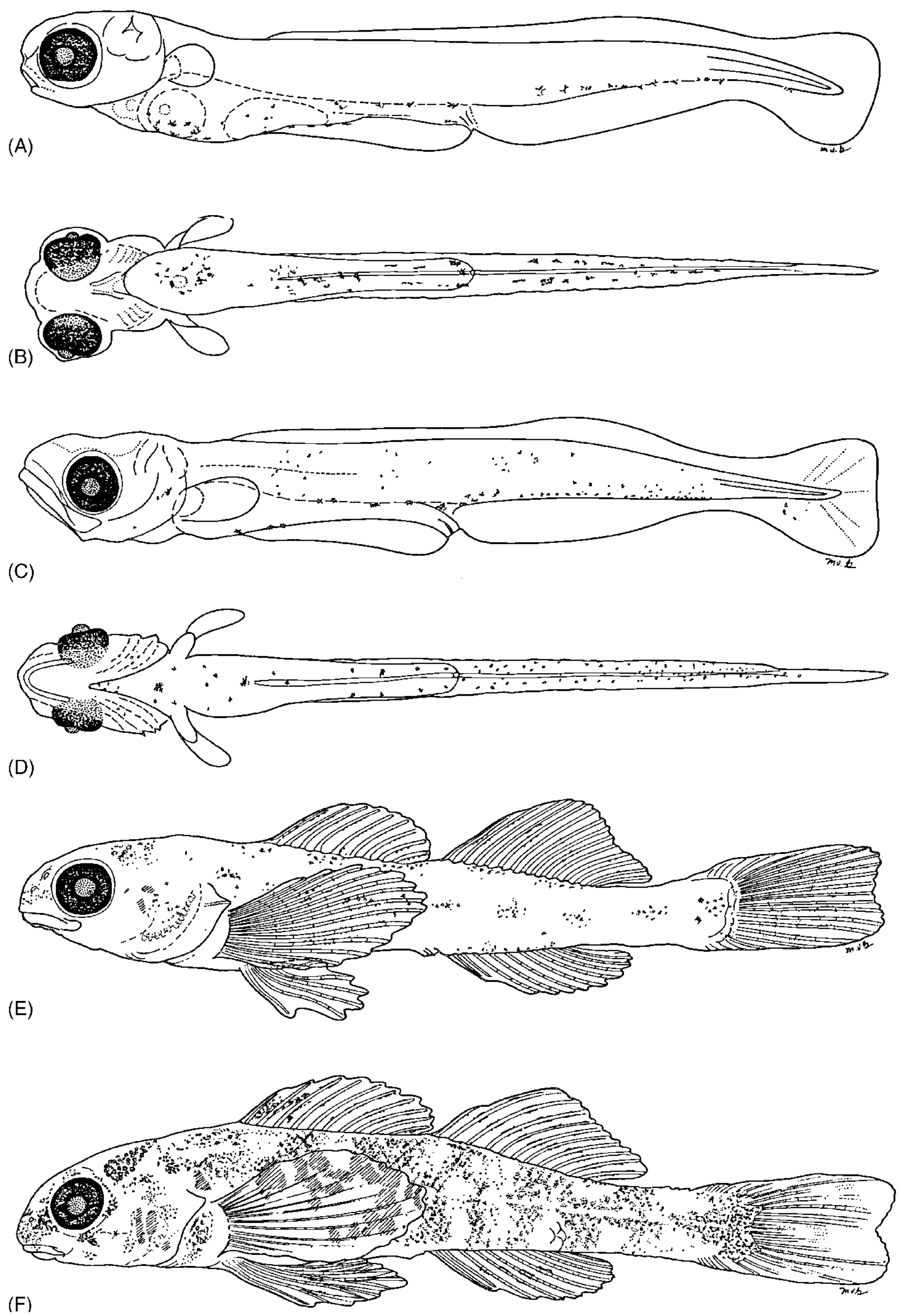

Figure 72 *Etheostoma histrio*, harlequin darter, Tallapoosa River, Elmore County, AL: Yolk-sac larva, 5.2 mm TL: (A) lateral, (B) ventral view, Post yolk-sac larva, 8.1 mm TL, (C) lateral, (D) ventral view, Mississippi River, TN, early juvenile, 14.7 mm TL, (E) lateral view; Juvenile, 23.0 mm TL, (F) lateral view. (A–F from reference 16, with author's permission.)

Myomeres
Preanal myomeres 17–18 (N = 7, mean = 17.9); postanal 20–22 (N = 7, mean = 21.4); with total 38–41.[16]

Morphology
5.2 mm TL. AL specimen had a terete body; snout blunt; functional jaws, upper jaw even with lower jaw; yolk sac moderate (19.2% TL), tapered posteriorly; yolk translucent pale yellow, with a single oil globule; vitelline vein single mid-ventrally on yolk sac; head not deflected over the yolk sac; eyes oval to spherical.[16]

6.0 mm TL. Digestive system functions prior to complete yolk absorption.[16]

Table 78

Morphometry of young *E. histrio* grouped by selected intervals of total length (*N*=sample size).

	Total Length (TL) Intervals (mm)											
	5.20–6.94 (*N*=8)		7.12–8.04 (*N*=20)		14.8–15.0 (*N*=4)		17.3–19.6 (*N*=8)		20.3–24.9 (*N*=28)		25.6–27.9 (*N*=6)	
Characters	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean±SD**	**Range**	**Mean ± SD**	**Range**
Length (% of TL)												
Upper jaw[a]	24.7 ± 0.32	(0.22–0.30)	22.3 ± 5.12	(0.22–0.50)	20.1 ± 0.12	(0.62–0.74)	26.8 ± 2.92	(0.88–1.24)	24.5 ± 2.55	(0.92–1.38)	26.0 ± 3.81	(1.20–1.58)
Snout[a]	15.7 ± 0.21	(0.14–0.19)	20.7 ± 3.79	(0.24–0.44)	16.9 ± 0.23	(0.53–0.61)	23.6 ± 1.91	(0.80–1.12)	22.9 ± 2.77	(0.86–1.44)	26.1 ± 4.67	(1.30–1.56)
Eye diameter[a]	31.8 ± 9.73	(0.28–0.36)	30.8 ± 6.83	(0.32–0.62)	30.3 ± 2.19	(1.00–1.04)	27.0 ± 0.67	(1.06–1.20)	27.2 ± 1.67	(1.20–1.62)	29.0 ± 2.64	(1.44–1.78)
Head	17.3 ± 0.43	(0.88–1.23)	20.4 ± 1.19	(1.30–1.68)	22.7 ± 1.96	(3.11–3.66)	23.0 ± 0.50	(3.86–4.62)	22.3 ± 0.85	(4.53–5.52)	20.6 ± 1.32	(4.86–5.82)
Predorsal	25.4 ± 1.18	(1.38–1.69)	26.2 ± 2.03	(1.72–2.20)	27.5 ± 0.35	(4.02–4.16)	27.9 ± 0.69	(4.80–5.50)	27.9 ± 0.89	(5.62–7.00)	27.8 ± 0.31	(7.08–7.70)
Dorsal insertion					47.8 ± 1.50	(6.97–7.26)	46.8 ± 0.56	(8.16–9.32)	47.8 ± 1.14	(9.56–12.0)	48.5 ± 0.79	(12.3–13.3)
D2 origin					49.1 ± 1.50	(7.17–7.46)	48.0 ± 0.45	(8.35–9.50)	49.0 ± 1.17	(9.84–12.3)	49.5 ± 0.24	(12.6–13.7)
D2 insertion					73.6 ± 2.31	(7.17–7.46)	71.4 ± 0.90	(8.35–9.50)	72.9 ± 1.63	(9.84–12.3)	73.4 ± 0.34	(12.6–13.7)
Preanal	53.8 ± 0.49	(2.82–3.70)	51.9 ± 1.33	(3.78–4.20)	47.1 ± 0.23	(7.00–7.04)	48.4 ± 0.92	(8.35–9.48)	48.6 ± 1.05	(9.89–12.3)	49.5 ± 0.27	(12.6–13.7)
Postanal	46.2 ± 0.53	(2.38–3.24)	48.1 ± 1.32	(3.34–3.89)	52.7 ± 0.46	(7.74–7.96)	50.6 ± 2.18	(8.70–9.44)	51.6 ± 1.22	(10.4–12.6)	50.5 ± 0.24	(12.8–14.1)
Standard	95.5 ± 1.07	(5.02–6.56)	95.6 ± 0.60	(6.86–7.72)	81.2 ± 0.69	(11.9–12.3)	81.6 ± 0.63	(14.0–16.1)	82.5 ± 0.95	(16.6–20.7)	83.7 ± 0.27	(21.3–23.3)
Yolk sac	19.2 ± 0.00	(1.00–1.00)										
Fin Length (% of TL)												
Pectoral	6.77 ± 2.35	(0.24–0.62)	5.99 ± 1.02	(0.34–0.62)	21.7 ± 4.62	(2.66–3.80)	22.9 ± 2.48	(3.32–4.62)	23.6 ± 3.49	(3.28–6.28)	25.0 ± 1.18	(6.14–6.82)
Pelvic					8.26 ± 0.12	(1.20–1.26)	14.4 ± 5.91	(0.84–3.26)	17.5 ± 1.81	(2.44–4.62)	17.7 ± 0.41	(4.57–4.80)
Spinous dorsal					20.3 ± 1.85	(2.81–3.24)	18.9 ± 0.56	(3.16–3.82)	19.9 ± 0.47	(3.94–5.00)	20.7 ± 0.93	(5.12–5.64)
Soft dorsal					24.5 ± 0.69	(3.58–3.72)	23.4 ± 0.62	(4.02–4.50)	23.9 ± 1.15	(4.64–6.00)	23.8 ± 0.50	(5.94–6.66)
Caudal	4.47 ± 1.07	(0.18–0.38)	4.35 ± 0.60	(0.26–0.42)	18.8 ± 0.69	(2.74–2.87)	18.4 ± 0.63	(3.22–3.52)	17.5 ± 0.95	(3.59–4.35)	16.3 ± 0.27	(4.10–4.53)
Body Depth (% of TL)												
Head at eyes	13.7 ± 1.07	(0.66–1.02)	13.7 ± 1.21	(0.82–1.18)	13.5 ± 0.12	(2.01–2.01)	13.6 ± 1.25	(2.26–2.80)	12.9 ± 0.48	(2.40–3.42)	13.4 ± 0.00	(3.42–3.72)
Head at P1	12.3 ± 1.71	(0.72–0.74)	10.7 ± 0.80	(0.66–0.90)	16.0 ± 0.12	(2.36–2.42)	15.1 ± 0.46	(2.58–2.84)	15.6 ± 0.55	(2.98–4.20)	16.2 ± 0.63	(4.02–4.74)
Preanal	7.64 ± 0.43	(0.42–0.50)	7.40 ± 0.63	(0.50–0.62)	10.2 ± 0.81	(1.42–1.61)	11.2 ± 0.57	(1.80–2.34)	12.8 ± 0.83	(2.29–3.32)	13.6 ± 0.14	(3.42–3.82)
Mid-postanal	5.81 ± 0.32	(0.32–0.38)	5.79 ± 0.71	(0.39–0.55)	7.85 ± 0.00	(1.16–1.18)	8.11 ± 0.58	(1.26–1.66)	8.35 ± 1.31	(1.00–2.31)	8.50 ± 0.62	(2.06–2.60)
Caudal peduncle	2.52 ± 0.21	(0.12–0.19)	2.25 ± 0.31	(0.15–0.21)	7.18 ± 0.23	(1.04–1.10)	6.84 ± 0.62	(1.03–1.46)	7.48 ± 0.54	(1.40–2.04)	7.39 ± 0.39	(1.82–2.02)
Yolk sac	8.46 ± 0.00	(0.44–0.44)										
Body Width (% of HL)												
Head	75.2 ± 2.24	(0.68–0.90)	64.5 ± 0.84	(0.84–1.10)	50.2 ± 3.70	(1.66–1.72)	50.2 ± 5.31	(1.84–2.38)	52.8 ± 4.86	(2.00–3.20)	61.3 ± 6.12	(3.00–3.78)
Myomere Number												
Predorsal	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)	5.00 ± 0.00	(5.00–5.00)	4.75 ± 0.51	(4.00–5.00)	4.9 ± 0.29	(4.00–5.00)	5.00 ± 0.00	(5.00–5.00)
Soft dorsal	23.0 ± 0.00	(23.0–23.0)	21.4 ± 1.05	(20.0–23.0)	17.5 ± 0.58	(17.0–18.0)	17.3 ± 0.51	(17.0–18.0)	17.6 ± 0.49	(17.0–18.0)	18.0 ± 0.00	(18.0–18.0)
Preanal	18.0 ± 0.00	(18.0–18.0)	17.8 ± 0.41	(17.0–18.0)	17.5 ± 0.58	(17.0–18.0)	17.3 ± 0.51	(17.0–18.0)	17.5 ± 0.51	(17.0–18.0)	18.0 ± 0.00	(18.0–18.0)
Postanal	21.0 ± 1.07	(20.0–22.0)	21.6 ± 0.50	(21.0–22.0)	22.5 ± 0.58	(22.0–23.0)	22.5 ± 0.53	(22.0–23.0)	23.3 ± 0.46	(23.0–24.0)	24.0 ± 0.00	(24.0–24.0)
Total	39.0 ± 1.07	(38.0–40.0)	39.4 ± 0.50	(39.0–40.0)	40.0 ± 0.00	(40.0–40.0)	39.8 ± 0.94	(39.0–41.0)	40.8 ± 0.73	(40.0–42.0)	42.0 ± 0.00	(42.0–42.0)

[a] Proportion expressed as percent head length.

Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

Morphometry
See Table 78.[16]

Fin Development
See Table 79.[16]

5.2 mm TL. Well-developed pectoral fins without incipient rays.[16]

Pigmentation
5.2–6.0 mm TL. Newly hatched larva with pigmented eyes; no melanophores dorsally; laterally, melanophores over yolk sac from the yolk-sac terminus to the end of the anus; mid-ventrally several melanophores on the yolk sac; and a mid-ventral stripe of melanophores at every postanal myosepta.[16]

POST YOLK-SAC LARVAE

See Figure 72

Size Range
6.0–8.1 mm TL.[16]

Myomeres
Preanal 17–18 ($N=7$, mean = 17.9); postanal 20–22 ($N=7$, mean = 21.4); with total 38–41.[16]

Morphology
6.0 mm TL. Yolk absorbed.[16]

6.9–7.6 mm TL. Premaxilla and mandible form (6.9 –7.1 mm); operculum and gill arches functional (6.9 mm).[16] No swim bladder forms; gut straight, without striations; portion of gut posterior to stomach normal in length (*6.9–7.6* mm TL).[16]

Morphometry
See Table 78.[16]

Table 79

Meristic counts and size (mm TL) at the apparent onset of development for *E. histrio.*[16]

Attribute/event	*E. histrio*	Literature
Branchiostegal Rays	6,6[16]	6,6[2,3,13,15]
Dorsal Fin Spines/Rays	X–XI/12–14[16]	IX–XI/11–14[2,3,13,15,20–22]
First spines formed	> 8.1[16]	
Adult complement formed	14.8[16]	
First soft rays formed	> 8.1[16]	
Adult complement formed	14.8[16]	
Pectoral Fin Rays	13–15[16]	13–16[2,3,15,20]
First rays formed	> 8.1[16]	
Adult complement formed	< 14.8[16]	
Pelvic Fin Spines/Rays	I/5[16]	I/5[2,3,15,20]
First rays formed	14.8[16]	
Adult complement formed	14.8[16]	
Anal Fin Spines/Rays	II/7–8[16]	II/6–8[2,3,13,15,20–22]
First rays formed	14.8[16]	
Adult complement formed	14.8[16]	
Caudal Fin Rays	viii–xi, 7+7, viii–x[16]	14–17[15,20]
First rays formed	8.1[16]	
Adult complement formed	< 14.8[16]	
Lateral Line Scales	48–62[16]	45–58[2,3,13,15,20–22]
Myomeres/Vertebrae	38–41/37–39[16]	Unknown/37–39[2,3,13,15,19]
Preanal myomeres	17–18[16]	
Postanal myomeres	20–22[16]	

Fin Development
See Table 79.[16]

6.9 to 8.1 mm. First rays form in caudal fin (6.9–7.7 mm).[16] Spinous dorsal fin origin situated over preanal myomere 4–5, soft dorsal at myomeres 20–23 (5.2–7.9 mm).[16] Average predorsal length 31.0% SL (range: 26.6–33.8% SL), 27.1% TL (range: 25.4–27.9% TL).[16]

Pigmentation
6.7–8.1 mm TL. Several melanophores on midoperculum, no melanophores dorsally. Laterally, melanophores scattered along mid-lateral and posteriorly in caudal finfold. Ventral melanophores distributed at isthmus, outlining absorbed oil globule and posterior gut to the anus. Scattered melanophores distributed from the anus to the caudal peduncle base.[16]

JUVENILES

See Figure 72

Size Range
>8.1 mm TL–40 mm TL.[18]

Fin Development
See Table 79.

Morphology
14.7 mm TL. All median and paired fin rays form; segmentation apparent in caudal fin; all finfolds absorbed; pelvic fin formed with spine and rays present.[16]

17.1 mm TL. Squamation initiated.[16]

Early juvenile. Infraorbital, lateral, supratemporal, and preoperculomandibular canals complete; infraorbital with 6–9 pores (usually 7), preoperculomandibular pores 7–11 (usually 9), lateral canal pores 5.[3,4] Cheek, opercle, and belly variably scaled; breast naked; nape scaled;[1,3,4] vertebral counts between 37 and 39 (usually 38).[3] Scales in the lateral series ranging from 45 to 58 lateral line scales.[2–4]

Morphometry
See Table 78.

Pigmentation
14.8–17.3 mm TL. Preorbital bar as well as melanophores formed dorsally over the optic lobe; five distinct dorsal clusters of melanophores anterior to the spinous dorsal fin origin, mid-spinous dorsal fin, immediately anterior spinous dorsal fin insertion, immediately posterior soft dorsal fin origin, and anterior soft fin insertion. Mid-lateral clusters of melanophores usually eight. Ventral melanophores limited to the outline of the anal fin lepidiotrichia with the anal pterigiophores.[16]

19.6–27.9 mm TL. Pigmentation similar to adult, well-developed preorbital bar, weak postorbital bar, and obliquely rising bar extending toward nape. Dorsum with 6–8 dorsal saddles; lateral usually with 9 alternating brown to greenish wavy bands extending from the dorsum to ventrum of juvenile. Concentration of pigmentation at base of caudal peduncle forming a chevron anteriorly. Spinous dorsal fin with a melanophore concentration anteriorly and a midstripe, soft dorsal fin with two oblique stripes, anal fin with several melanophores forming a weak midstripe, and caudal fin with several vertical bands.[16]

TAXONOMIC DIAGNOSIS OF YOUNG HARLEQUIN DARTER

Similar species: similar to other members of the subgenus *Poecilichthys.*

Adult. *Etheostoma histrio* is a part of the *E. variatum* species group and is very closely related to *E. rupestre*. It does not have any designated subspecies.[4,15] The harlequin darter is diagnosed from the subgenus based on the lack of breeding tubercles; unscaled breast, scaled nape, and variably scaled cheek, opercle, and belly; dorsal spines usually 10; 45–58 lateral line scales; 7 anal rays; 7 infraor-bital canal pores; and 9 preoperculomandibular pores.[3]

Larva. The species is distinguished from all other members of the *E. variatum* species group based on myomere count differences and pigmentation. *Etheostoma histrio* has lower myomere counts than any other member of the subgenus, being most similar to *E. rupestre* and *E. variatum*, possessing low preanal (18) and high postanal (22–23) myomere counts.[16] The harlequin darter is mostly unpigmented, but still has more pigment than *E. rupestre*, with only stellate melanophores present mid-ventrally on the yolk sac and at every postanal myosepta. All other known saddleback darter species, *E. variatum* and *E. tetrazonum*, possess numerous scattered melanophores ventrally on the yolk sac.[16]

Variation
Study of the intraspecific variation of *E. histrio* could not be conducted due to limited study material.[16] No differences in meristic characters were observed between AL and TN specimens. The species is most similar to the rock darter *E. rupestre*. It can be distinguished by the fewer preanal and postanal myomere counts and greater pigmentation on the mid-ventral postanal myosepta.[16]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 73)
Eggs. The harlequin darter attaches eggs to the vertical sides of large woody debris in streams with moderate current (T.P. Simon, and B.E. Fisher, unpublished data).

Yolk-sac larvae. Yolk-sac larval specimens were collected during light-trap sampling in a backwater area adjacent to a broad riffle on the lower Tallapoosa River, AL, during March (T.P. Simon, personal observation). Specimens were epibenthic, occurring along the root and detrital leaf packs along the edge of the river.

Post Yolk-sac larvae. Larval specimens were collected during light-trap sampling in a backwater area adjacent to a broad riffle on the lower Tallapoosa River, AL, during March (T.P. Simon, personal observation).

Juveniles. Young-of-the-year were commonly collected on clay riffles in the main channel border habitat of the Mississippi River, TN.[13] Seasonally, juveniles and adults occupy different habitats.[13]

Early Growth (see Table 80)
In TN, juveniles 14–27 mm were collected in mid-May from the Tennessee River.[13] Growth of harlequin darters in TN is listed in Table 80.

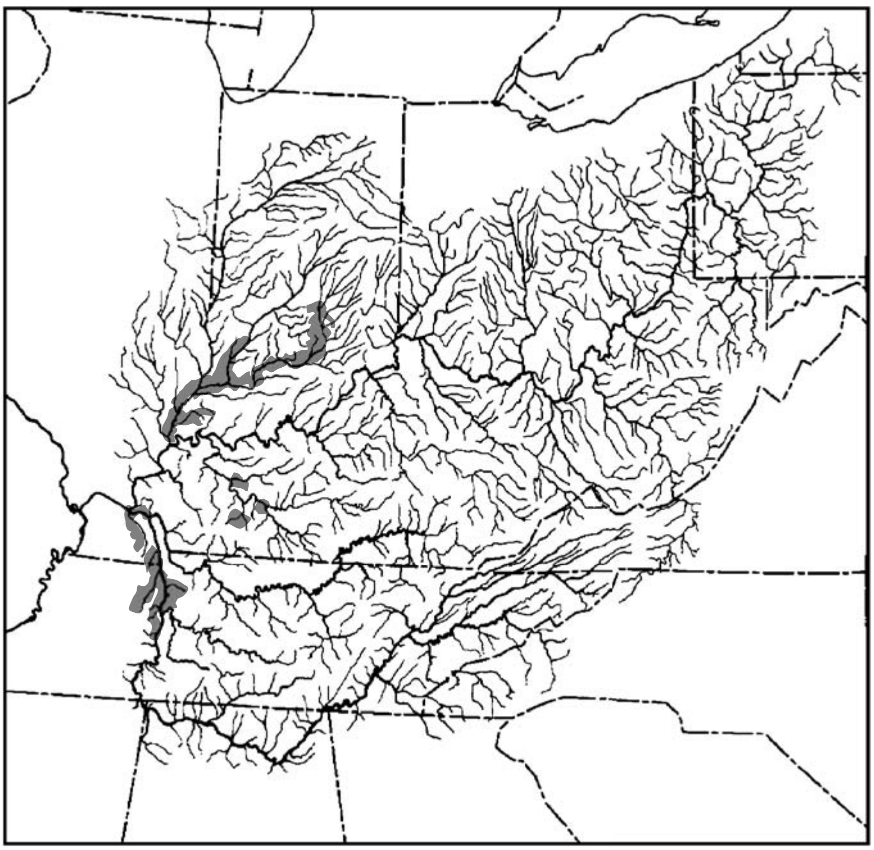

Figure 73 Distribution of harlequin darter, *E. histrio*, in the Ohio River system (shaded area).

Table 80

Average calculated total length (mm TL) of young harlequin darter from Tennessee.

	Age			
State	1	2	3	4
Tennessee[13]	40–50			76

Feeding Habits
Diet consists of midges, blackfly, caddisfly larvae, and mayfly nymphs.[13]

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Material Examined: AL: Elmore County: lower Tallapoosa River, below Thurlow Dam, LRRC 660 (2); APC uncatalogued (4); APC uncatalogued (1). TN: Randolph-Tipton County: Mississippi River, at Boat Access, UT 91.2382 (18). AR: Drew Co: Saline River, at Bradley, 7 miles SSE Warren, UT 91.1395 (16). MS: Leake County: Pearl River, 0.25 mi N SR 16, Edinbourough, UT 91.3422 (4).

* Original fecundity data for harlequin darter from Big Creek, Grant Parish, LA. Specimens curated at Northeast Louisiana University, Museum of Zoology, Monroe. Early life history developmental series cultured from laboratory spawned specimens are curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN. Personal observations from Plummer Creek, East Fork White River drainage, IN (T.P. Simon and B.E. Fisher, unpublished data).

BLUESIDE DARTER

Etheostoma (Doration) jessiae (Jordan and Brayton)

Etheostoma: various mouth; *jessiae*: named in honor of the collector's wife, Mrs. Jessie D. Brayton.

RANGE

Etheostoma jessiae occurs in the middle- to upper-Tennessee River system from Bear Creek, AL, into NC, VA, and GA. The species is absent from the Clinch and Powell Rivers.[1–4]

HABITAT AND MOVEMENT

The blueside darter inhabits moderate to high-gradient, clear, small streams and moderate-sized rivers. Adults prefer the unsilted gravel and sand substrates in riffles, and flowing pools below riffles.[4]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etnier and Starnes[5] recognize *E. jessiae* as either a valid species or as a part of a complex within species *stigmaeum* with multiple subspecies. *Etheostoma jessiae* occupies the majority of the Tennessee River drainage, excluding the upper Clinch and Powell Rivers. The taxon occurs from Whiteoak Creek, Humphreys County, TN, upstream into the French Broad River system, NC, and the North Fork Holston River, VA.[5]

SPAWNING

Location
Eggs sites include riffle habitats over fine gravel or coarse sand substrates in moderate current.[6]

Season
In TN spawning aggregates of adults assemble between mid-February and mid-March on riffles.[6] Spawning occurs in March and April throughout their range.[2,3] Reproduction in TN occurs during April to early May.[5]

Temperature
Spawning temperatures range from 21 to 23°C.[6]

Fecundity (see Table 81)
Female blueside darter showed statistically significant increasing fecundity (ANOVA, $F = 43.453$, $p \geq 0.0001$) with increasing length. A 66 mm female had 169 large mature ova, while a 61 mm female had 107 large mature ova.[*]

Sexual Maturity
Large 1-year-old females are sexually mature, but 2-year-old adult males averaging 41 mm SL and females averaging 38 mm SL were dominant.[5]

Spawning Act
Etheostoma jessiae is an egg burier.[6] Reproductive behavior is typical of the burier mode of spawning.[7] Eggs sites include riffle habitats over fine gravel or coarse sand substrates in moderate current; adults maintain a head-to-head orientation with vents juxtaposed. A territorial male pursues a female and mounts her. Eggs are laid one at a time in gravel substrates, generally 3–5 during a single spawning event.[6]

EGGS

Description
Eggs from TN are spherical, average 1.7 mm in diameter (range: 1.4–2.4 mm);[6] or 1.28 mm in diameter (range: 1.25–1.42 mm).[*] Eggs are translucent, demersal, and nonadhesive. Eggs possess translucent clear to pale yellow yolk, 1.6 mm in diameter (range: 1.3–1.8 mm); a single oil globule (mean = 0.3 mm; range: 0.2–0.4 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[6]

Incubation
Hatching occurs after 211–224 h at an incubation temperature of 22–23°C.[6]

Development
Unknown.

Table 81

Fecundity data for blueside darter from Pigeon River, Sevier County, TN.*

		Number of Ova			
Length (TL)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
45	87.4	306	99	26	1.42
46	110	355	96	36	1.25
48	137	368	100	56	1.25
49	115	344	155	19	1.42
54	219	324	127	65	1.25
57	294	417	140	77	1.25
57	198	728	133	102	1.25
59	162	710	124	78	1.25
61	323	648	197	107	1.25
66	484	747	310	169	1.25

YOLK-SAC LARVAE

See Figure 74

Size Range
5.3–6.0 mm (newly hatched) to 6.7 mm.[6]

Myomeres
Preanal 17 (2), 18 (62), 19 (1), 20 (1), and 21 (1) (*N* = 67, mean = 18.1); postanal 21 (66), and 23 (1)(*N* = 67, mean = 21.0); with 38 (2), 39 (61), 40 (1), 41 (2), and 42 (1)(*N* = 67, mean = 39.1) total.[6]

Morphology
5.3–6.0 mm TL. Newly hatched larvae have a laterally compressed body; round snout; functional jaws, upper jaw even, to slightly overhanging lower jaw; yolk sac moderate (26.4% TL), rectangular; yolk translucent clear to pale yellow, with a single oil globule; single mid-ventral vitelline vein on yolk sac; head not deflected over the yolk sac; eyes oval.[6]

6.3–6.7 mm TL. Digestive system functions immediately before complete yolk absorption.[6]

Morphometry
See Table 82.

Fin Development
(See Table 83)

5.3–6.0 mm TL. Well-developed pectoral fins without incipient rays.[6]

Pigmentation
5.3–6.0 mm TL. Newly hatched larva with pigmented eyes; no melanophores dorsally; a single melanophore on the otic capsule; a line of melanophores dorsally over the gut; a pair of melanophores surrounding the anus; a pair of dense melanophores postanally along mid-ventral myosepta near area of future anal fin insertion. Ventral melanophores form a mid-ventral band.[6]

POST YOLK-SAC LARVAE

See Figure 74

Size Range
6.8–13 mm TL.[6]

Myomeres
Preanal 17 (2), 18 (62), 19 (1), 20 (1), and 21 (1) (*N* = 67, mean = 18.1); postanal 21 (66), and 23 (1)(*N* = 67, mean = 21.0); with 38 (2), 39 (61), 40 (1), 41 (2), and 42 (1)(*N* = 67, mean = 39.1) total.[6]

Morphology
6.8–7.1 mm TL. Yolk absorbed.[6]

7.3 mm TL. Operculum and gill arches function.[6]

7.9–8.6 mm TL. Notochord flexion preceding caudal fin ray development.[6]

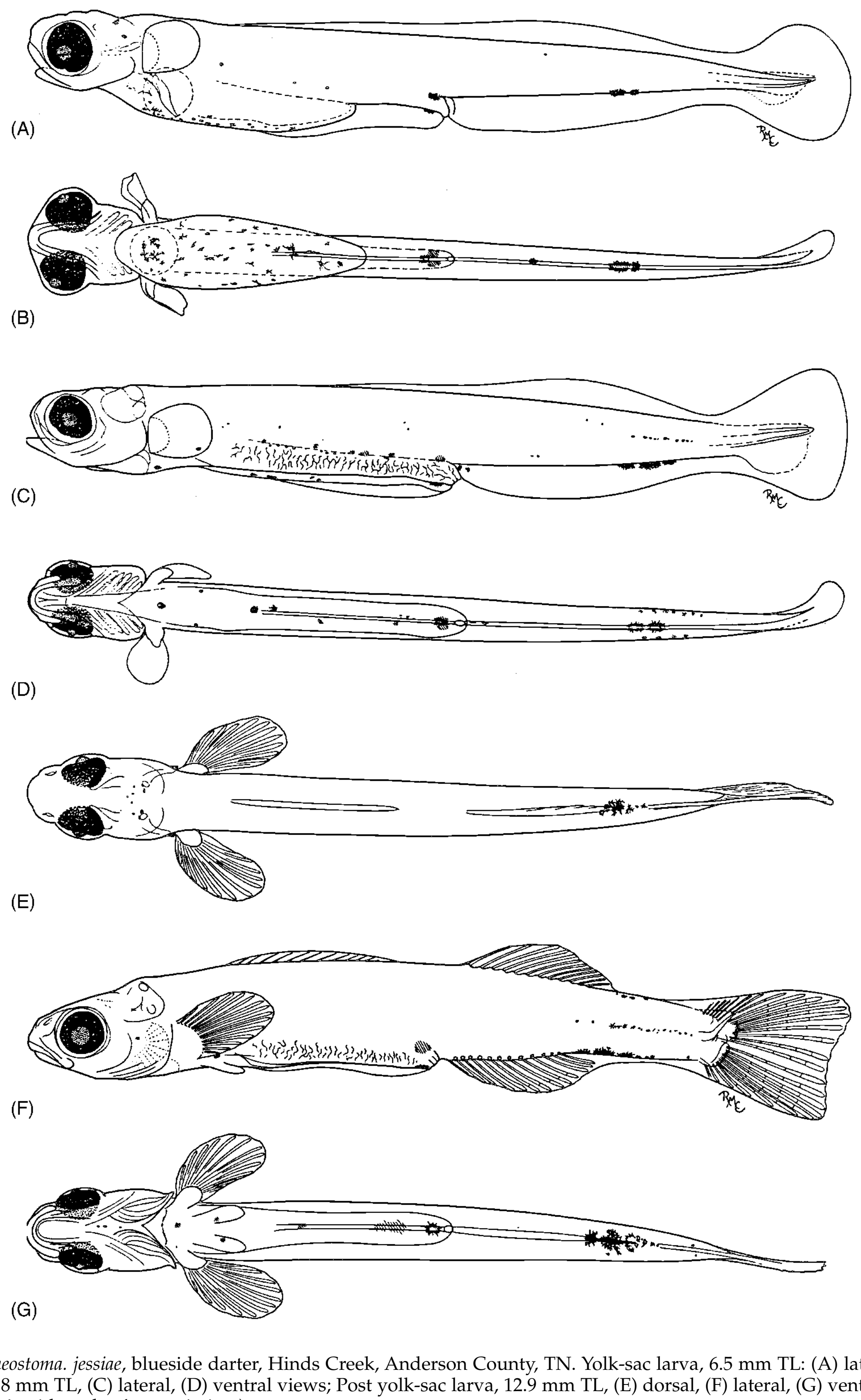

Figure 74 *Etheostoma. jessiae*, blueside darter, Hinds Creek, Anderson County, TN. Yolk-sac larva, 6.5 mm TL: (A) lateral, (B) ventral views, larva; 8.8 mm TL, (C) lateral, (D) ventral views; Post yolk-sac larva, 12.9 mm TL, (E) dorsal, (F) lateral, (G) ventral views. (A–G from reference 6, with author's permission.)

7.4–8.0 mm TL. No swim bladder formed; gut straight, without striations; portion of gut posterior to stomach normal in length.[6]

7.0–8.4 mm TL. Neuromast development occurs mid-laterally from the anterior trunk posteriad (7.0–8.4 mm); lateral line begins to form (7.7–

Table 82

Morphometry of young *E. jessiae* larvae grouped by selected intervals of total length (N=sample size).

	Total Length (TL) Intervals (mm)											
	5.34–6.87 (N=27)		7.01–8.57 (N=17)		9.10–12.0 (N=8)		12.5 (N=1)		15.0–19.8 (N=3)		20.5–23.7 (N=7)	
Characters	**Mean±SD**	**Range**	**Mean±SD**	**Range**	**Mean±SD**	**Range**	**Mean**	**Range**	**Mean±SD**	**Range**	**Mean±SD**	**Range**
Length (% of TL)												
Upper jaw[a]	17.3 ± 3.44	(0.10–0.33)	22.1 ± 6.34	(0.12–0.44)	22.8 ± 4.51	(0.28–0.58)	26.5	(0.70)	43.3 ± 16.6	(1.18–2.08)	23.3 ± 1.92	(1.06–1.29)
Snout[a]	14.6 ± 3.67	(0.08–0.22)	15.5 ± 2.62	(0.14–0.28)	17.2 ± 2.87	(0.20–0.43)	20.5	(0.54)	24.9 ± 6.50	(0.72–1.27)	25.0 ± 2.78	(1.10–1.56)
Eye diameter[a]	39.9 ± 3.67	(0.32–0.51)	35.8 ± 2.69	(0.42–0.51)	33.7 ± 0.80	(0.50–0.72)	30.7	(0.81)	35.4 ± 1.82	(1.14–1.55)	28.4 ± 1.29	(1.35–1.54)
Head	16.2 ± 1.33	(0.78–1.26)	16.3 ± 0.77	(1.10–1.44)	17.4 ± 0.70	(1.46–2.14)	21.1	(2.64)	21.6 ± 1.63	(3.42–4.26)	22.8 ± 0.77	(4.83–5.34)
Predorsal	28.0 ± 3.31	(1.20–2.26)	26.2 ± 1.93	(1.76–2.50)	24.4 ± 2.15	(2.00–3.21)	30.3	(3.80)	29.0 ± 2.46	(4.49–5.92)	30.6 ± 0.59	(6.20–7.33)
Dorsal insertion					30.5 ± 13.0	(2.00–6.21)	50.9	(6.38)	50.8 ± 2.82	(7.77–10.2)	50.5 ± 1.10	(10.1–12.4)
D2 origin					31.3 ± 14.4	(2.00–6.61)	55.7	(6.98)	53.1 ± 3.03	(8.19–10.5)	52.8 ± 1.05	(10.5–12.8)
D2 insertion					35.7 ± 22.7	(2.00–6.61)	74.2	(6.98)	71.7 ± 4.50	(8.19–10.5)	69.1 ± 1.66	(10.5–12.8)
Preanal	53.0 ± 1.31	(2.86–3.71)	5.37 ± 1.18	(3.59–4.71)	53.4 ± 0.93	(4.86–6.22)	53.4	(6.70)	52.0 ± 1.53	(8.00–10.0)	56.3 ± 11.9	(10.6–19.0)
Postanal	47.0 ± 1.32	(2.43–3.25)	46.4 ± 1.11	(3.36–3.92)	46.6 ± 0.93	(4.24–5.75)	46.6	(5.84)	48.0 ± 1.60	(6.94–9.83)	48.5 ± 1.32	(9.87–11.5)
Standard	96.3 ± 2.03	(4.89–6.65)	96.7 ± 0.75	(6.84–8.33)	92.9 ± 3.49	(8.82–10.6)	86.3	(10.8)	84.3 ± 2.06	(13.0–16.5)	83.1 ± 0.13	(17.0–19.7)
Yolk sac	26.4 ± 7.95	(0.04–2.00)										
Fin Length (% of TL)												
Pectoral	6.15 ± 1.03	(0.28–0.50)	7.25 ± 1.29	(0.40–0.80)	10.7 ± 2.59	(0.62–1.64)	16.7	(2.10)	24.4 ± 3.81	(4.06–4.75)	19.6 ± 0.79	(4.00–4.94)
Pelvic			0.50 ± 0.85	(0.01–0.16)	2.82 ± 2.35	(0.01–0.53)	11.1	(1.39)	15.5 ± 0.32	(2.34–3.02)	16.4 ± 1.86	(3.20–3.99)
Spinous dorsal					24.5 ± 0.85	(2.68–3.00)	20.6	(2.58)	21.8 ± 0.36	(3.28–4.24)	19.9 ± 0.74	(3.86–5.02)
Soft dorsal					17.9 ± 0.57	(1.96–2.20)	18.5	(2.32)	18.7 ± 1.60	(3.03–3.59)	16.4 ± 1.30	(3.28–4.10)
Caudal	3.74 ± 2.03	(0.06–0.61)	3.29 ± 0.75	(0.16–0.38)	7.06 ± 3.49	(0.28–1.34)	13.7	(1.72)	15.7 ± 2.06	(2.00–3.33)	16.9 ± 0.13	(3.47–4.00)
Body Depth (% of TL)												
Head at eyes	12.6 ± 1.89	(0.58–1.21)	11.9 ± 1.73	(0.80–1.27)	12.7 ± 2.20	(1.07–1.78)	12.5	(1.57)	14.0 ± 0.87	(2.19–2.76)	13.0 ± 0.98	(2.49–3.36)
Head at P1	12.8 ± 1.60	(0.58–0.90)	11.3 ± 0.86	(0.70–1.04)	12.5 ± 0.64	(1.03–1.56)	15.2	(1.90)	15.7 ± 0.57	(2.44–3.02)	14.3 ± 1.45	(2.62–3.56)
Preanal	7.88 ± 0.62	(0.39–0.58)	9.18 ± 0.81	(0.58–0.87)	11.5 ± 0.85	(0.98–1.50)	13.0	(1.63)	11.4 ± 0.81	(1.63–2.36)	11.7 ± 0.32	(2.38–2.84)
Mid-postanal	5.81 ± 0.63	(0.26–0.42)	6.85 ± 0.71	(0.40–0.68)	8.42 ± 0.43	(0.72–1.06)	8.61	(1.08)	8.12 ± 0.47	(1.16–1.66)	8.35 ± 0.38	(1.66–2.04)
Caudal peduncle	2.04 ± 0.67	(0.11–0.19)	3.39 ± 0.43	(0.20–0.36)	5.53 ± 1.15	(0.38–0.83)	7.66	(0.96)	6.58 ± 0.20	(0.96–1.30)	6.79 ± 0.40	(1.40–1.66)
Yolk sac	7.78 ± 1.90	(0.24–0.64)										
Body Width (% of HL)												
Head	70.1 ± 6.84	(0.60–0.80)	67.0 ± 4.75	(0.68–0.98)	64.2 ± 4.89	(1.04–1.38)	58.3	(1.54)	64.0 ± 1.39	(2.16–2.69)	57.3 ± 4.40	(2.60–3.22)
Myomere Number												
Predorsal	4.89 ± 0.32	(4.00–5.00)	5.00 ± 0.00	(5.00–5.00)	5.00 ± 0.00	(5.00–5.00)	5.00	(5.00)	5.00 ± 0.00	(5.00–5.00)	5.00 ± 0.00	(5.00–5.00)
Soft dorsal	18.0 ± 0.00	(18.0–18.0)			18.0 ± 0.00	(18.0–18.0)	18.0	(18.0)	18.0 ± 0.00	(18.0–18.0)	18.0 ± 0.00	(18.0–18.0)
Preanal	17.9 ± 0.27	(17.0–18.0)	18.2 ± 0.73	(18.0–21.0)	18.3 ± 0.74	(18.0–20.0)	19.0	(19.0)	18.0 ± 0.00	(18.0–18.0)	18.0 ± 0.00	(18.0–18.0)
Postanal	21.0 ± 0.00	(21.0–21.0)	21.0 ± 0.00	(21.0–21.0)	21.0 ± 0.00	(21.0–21.0)	21.0	(21.0)	21.7 ± 1.16	(21.0–23.0)	21.0 ± 0.00	(21.0–21.0)
Total	38.9 ± 0.27	(38.0–39.0)	39.2 ± 0.73	(39.0–42.0)	39.3 ± 0.74	(39.0–41.0)	40.0	(40.0)	39.7 ± 1.16	(39.0–41.0)	39.0 ± 0.00	(39.0–39.0)

[a] Proportion expressed as percent head length.

Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

8.4 mm). Premaxilla and mandible formed (8.0–8.4 mm).[6]

11.2 mm TL. Upper jaw equal with lower jaw, becoming subterminal.[6]

11.9 mm TL. Initiation of squamation across dorsum and mid-laterally.[6]

Morphometry
See Table 82.[6]

Fin Development
See Table 83.[6]

7.0–8.4 mm TL. Pelvic fin buds formed anterior to dorsal fin origin after complete yolk absorption (8.0–8.4 mm).[6]

9.1 mm TL. First rays form in caudal fin.[6]

9.5 mm TL. Anal fin rays form.[6]

9.8–10.0 mm TL. Pectoral fin rays form (9.8–10.0 mm); soft dorsal fin rays form (9.9–10.0 mm); branchiostegal rays form (9.9 mm).[6]

9.8–10.4 mm TL. Dorsal and anal finfold partially differentiated.[6]

11.2 mm TL. Spinous dorsal rays form; upper jaw equal with lower jaw, becoming subterminal;[6] caudal fin emarginate.[6]

11.2–11.9 mm TL. Both dorsal and anal finfolds completely differentiated (11.2–11.9 mm). Spinous dorsal fin origin situated over preanal myomere 4–5, soft dorsal origin over preanal myomere 18 (10.4–11.9 mm).[6]

Table 83

Meristic counts and size (mm TL) at the apparent onset of development for *E. jessiae.*

Attribute/event	*E. jessiae*	Literature
Branchiostegal Rays	6,6[6]	6,6[2–5]
Dorsal Fin Spines/Rays	X–XIV/11–14[6]	X–XIV/11–13[2–5]
First spines formed	11.2[6]	
Adult complement formed	11.9[6]	
First soft rays formed	9.9–10.0[6]	
Adult complement formed	11.2–11.9[6]	
Pectoral Fin Rays	15–16[6]	12–16[2–4]
First rays formed	9.8–10.0[6]	
MAdult complement formed	9.9–11.2[6]	
Pelvic Fin Spines/Rays	I/5[6]	I/5[2–4]
First rays formed	11.9–12.5[6]	
Adult complement formed	11.9–12.5[6]	
Anal Fin Spines/Rays	II/8–9[6]	II/8–10[2–5]
First rays formed	9.5[6]	
Adult complement formed	9.9–11.2[6]	
Caudal Fin Rays	vii–xii, 9+8, viii–xiii[6]	
First rays formed	9.1[6]	
Adult complement formed	9.7–11.9[6]	
Lateral Line Scales	44–56[6]	44–53[2–5]
Myomeres/Vertebrae	38–40/40–41[6]	Unknown/40–42[2–4,8]
Preanal myomeres	17–21[6]	
Postanal myomeres	21–23[6]	

Pigmentation

6.6–8.8 mm TL. Melanophores distributed over the gut more numerous; mid-ventral melanophores form a single series from the breast to the anus. A distinct anal spot and anal fin insertion cluster is present.[6]

9.1–11.9 mm TL. Cranium with an accumulation of melanophores on posterior optic lobe; and posterior soft dorsal fin insertion with a cluster of melanophores. Lateral melanophores over gut become subdermal; a few melanophores form a mid-lateral stripe from the anal fin insertion to the hypural plate. Ventral melanophores between isthmus, pelvic region, and gut subdermal; a distinct ventral melanophore at anus tip, becoming subdermal dorsally. A large cluster of melanophores at anal fin insertion.[6]

JUVENILES

See Figure 75

Size Range

11.9[6] mm TL to 38 mm SL.[5]

Fin Development

11.9–12.5 mm TL. First pelvic fin ray formed (11.9–12.5 mm); complete adult fin ray counts in median fins (11.9 mm).[6]

Morphology

19.2 mm TL. Supraorbital, infraorbital, lateral, and subtemporal head canals formed; squamation complete; cheek naked or partially scaled, opercle scaled, breast scaled, nape partially to fully scaled.[2,3,6]

23.5 mm TL. Infraorbital, lateral, and supratemporal head canals complete, preoperculomandibular canal complete with 10 pores, infraorbital pores 6.[6]

Morphometry

See Table 82.[6]

Average predorsal length 29.2% SL (range: 23.4–32.3% SL), and 27.4% TL (range: 22.0–30.3% TL).

Pigmentation

11.9–12.5 mm TL. Cranium with an accumulation of melanophores on posterior optic lobe; and posterior soft dorsal fin insertion with a cluster of melanophores. Lateral melanophores over gut become subdermal; a few melanophores form a mid-lateral stripe from the anal fin insertion to the hypural plate. Ventral melanophores between isthmus, pelvic region, and gut subdermal; a distinct ventral melanophore at anus tip, becoming subdermal dorsally. A large cluster of melanophores at anal fin insertion.[6]

15.0–19.8 mm TL. Early juvenile with preorbital and postorbital bars formed; maxillae outlined, cerebellum, and optic lobe covered with melanophores; a series of six dorsal saddles posterior from the nape to the caudal peduncle. Lateral melanophores outline the subopercle, forming a mid-lateral series from the shoulder to the hypural plate; and a vertical series of melanophores extends along the caudal fin base. Ventral melanophores outline the anal fin; lepidiotrichia interdigitation with the pterigiophores.[6]

20.5–23.7 mm TL. A chevron of melanophores form in the hypaxial portion of the operculum; dorsum scales outlined, forming less distinct saddle pattern; a series of X-, Y-, and W markings along the side formed from the melanophore outline of the scales. No pigmentation ventrally, except, as previously noted, around the anal fin. Spinous dorsal fin with a medial stripe; all other fins unpigmented.[6]

TAXONOMIC DIAGNOSIS OF YOUNG BLUESIDE DARTER

Similar species: members of subgenus *Doration***.**

Adult. The *E. stigmaeum* group consists of three populations[4] that have been divided into two species, *E. jessiae* and *E. stigmaeum,* and either one takes on two additional forms.[2,3] *Etheostoma jessiae* has a premaxillary frenum, most likely the result of the more pronounced snout; a nape that is partially to fully scaled; either a partially scaled or naked cheek; and an average of 34–45 pored lateral line scales. Another undescribed subspecies is known from 30 specimens collected from the Stones River below the dam at Walter Hill, 6.5 miles north of Murfreesboro, Rutherford County, TN, where it is sympatric with *E. stigmaeum*. The status of the subspecies is uncertain and may be extinct.[5]

Larva. *Etheostoma jessiae* can be distinguished from *E. stigmaeum* based on pigmentation and ontogenetic events. Yolk-sac larval *E. jessiae* has a characteristic cluster of melanophores at the future insertion of the anal fin, while *E. stigmaeum* has radiating melanophores at almost every mid-ventral postanal myoseptum. Both species possess a rectangular body shape characteristic of genus *Ammocrypta*,[9] including a tubular, elongate, yolk sac.[6]

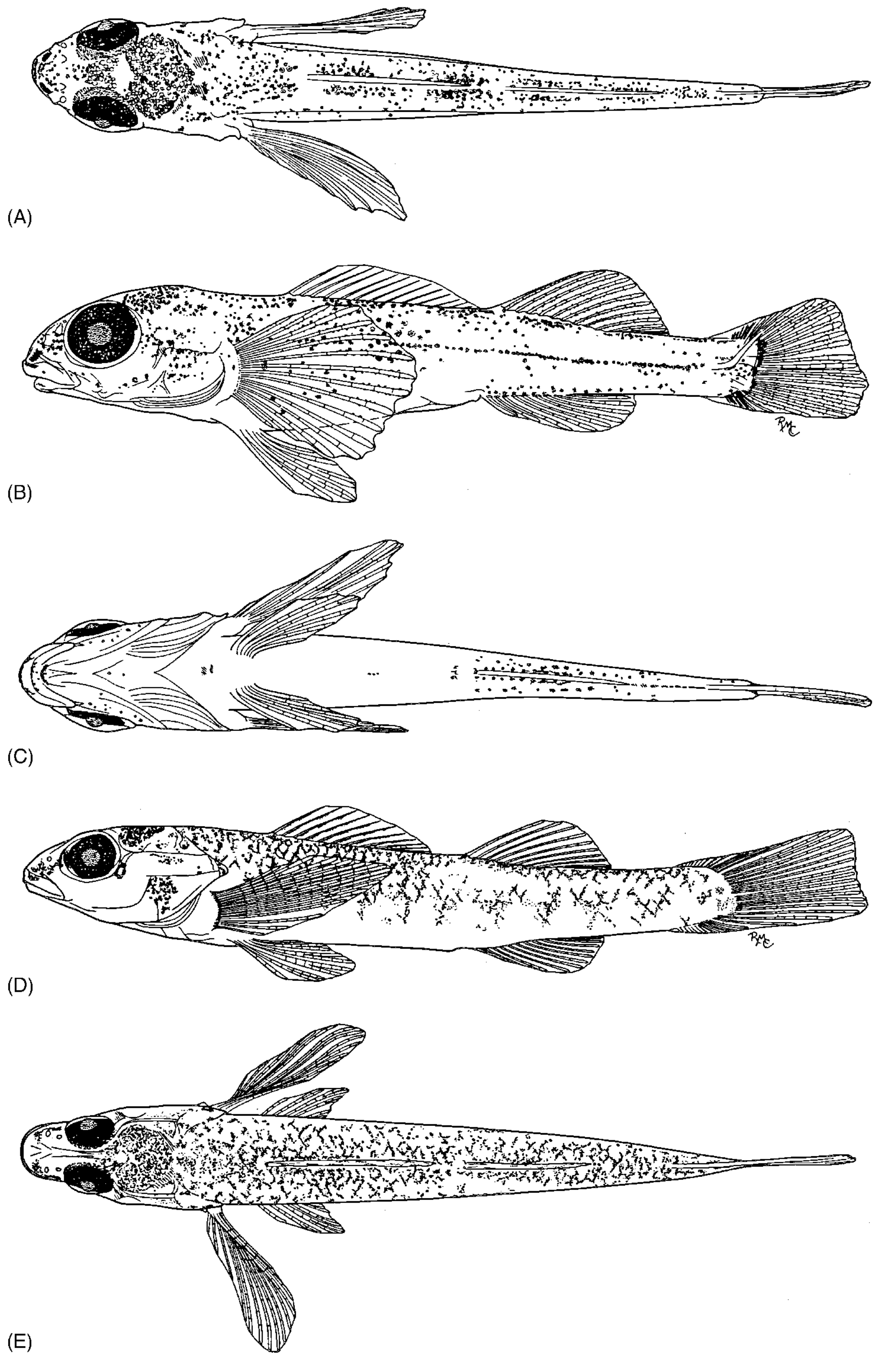

Figure 75 *Etheostoma jessiae*, blueside darter, Hinds Creek, Anderson County, TN. Early juvenile, 15.9 mm TL: (A) dorsal, (B) lateral, (C) ventral views. Juvenile, 23.5 mm TL, (D) lateral, (E) dorsal views. (A–E from reference 6, with author's permission.)

Variation

Geographic variation could not be studied since specimens were only available from Hinds Creek, TN. The species is distinct from *E. stigmaeum* based on postanal pigment of radiating melanophores at almost every mid-ventral postanal myosepta.[6] We recognize *E. jessiae* as a distinct species (T.P. Simon, unpublished data).

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 76)
Eggs. Eggs sites include riffle habitats over fine gravel or coarse sand substrates in moderate current.[6]

Yolk-sac larvae. Aquarium observations show blueside darter larvae are pelagic immediately after hatching.[6]

Post Yolk-sac Larvae. Larva become demersal at lengths greater than 9 mm, and remain in close association with the substrate. In Hinds Creek, TN, larvae and early juveniles utilize the downstream pools and near shore margins of riffles adjacent to spawning areas as nursery habitats (R. Wallus, personal observation).

Juveniles. Juveniles greater than 19 mm TL are the smallest individuals found on the margins of the riffle (R. Wallus, personal observation).

Early Growth (see Table 84)
Young attain sizes of 35 mm SL at age 1.[5]

Feeding Habits
Diet is dominated by midge larvae (58%), supplemented with microcrustaceans and mayfly nymphs.[5]

Table 84

Average calculated lengths (mm SL) of young blueside darter in Tennessee.

	Age		
State	1	2	3
Tennessee[5]	35	38–41	71 mm TL

Figure 76 Distribution of blueside darter. *E. jessiae* in the Ohio River system (shaded area).

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5. Etnier, D.A. and W.C. Starnes. 1993.
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7. Page, L.M. 1985.
8. Bailey, R.M. and W.A. Gosline. 1955.
9. Simon, T.P. et al. 1992.

Material Examined: TN: Anderson Co: Hinds Creek, at Hillvale Road, 1/2 miles SE junction I-75 and SR 61, 5.6 mi N Clinton, LRRC 436 (14); LRRC 555 (30); LRRC 556 (8); TV 2095 (42); TV 2216 (6); TV 2406 (9); TV 2462 (2).

* Original fecundity data for blueside darter from Pigeon River, Sevier County, TN. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Early life history developmental series cultured from laboratory spawned specimens are curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

STRIPETAIL DARTER

Etheostoma (Catonotus) *kennicotti* (Putnam)

Etheostoma: various mouths; *kennicotti*: named in honor of Robert Kennicott, who first caught the species in southern IL.

RANGE

Found in small direct tributaries of the Ohio River from the Cache River in southern IL, to the Tradewater River, KY; in the Green and Tennessee River systems; and in the upper Cumberland system of KY and TN.[1,2,12]

HABITAT AND MOVEMENT

Occupies shallow, slab rock pools of high-gradient streams.[1–8]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

An endemic to the study area occurring in tributaries of the Ohio River, but not occurring in the mainstream of the Ohio River proper.[1–3]

SPAWNING

Location

Eggs are attached beneath slab rocks previously selected and guarded as nesting territories by the males.[3,7,8]

Season

Spawning occurs from late March or early April until late May over the entire range of the species.[3,7,8]

Temperature

Spawning occurs from 14 to 20°C.[3]

Fecundity

The largest females produced the largest number of mature ova. Number of mature ova ranged from 24 to 130. The number of mature ova in females 30–39 mm SL was 24–49; females 39–48 mm SL had 65–130 ova.[3] Our data from Cusick Creek, Sevier County, TN, showed ovary weights that averaged 16.0% of the body weight, containing between 203 and 434 total ova averaging 1.47 mm diameter.* Females collected in late April had 50–67 ripe mature ova* (Table 85).

Sexual Maturity

Males were sexually mature at age 1, at lengths as small as 35 mm SL; females were mature at age 0+ at lengths as small as 27 mm SL.[3]

Spawning Act

Etheostoma kennicotti is an egg clusterer.[3] Males left the nest stones to court females only briefly and only when a female was near the stone. Courting consisted of a male's lateral display of his breeding coloration and spread fins, and wagging his tail near or against the female. Occasionally, the male nudged the female with his snout. When ready to spawn, the female inverted beneath the nest stone by rolling to one side. Females were observed to remain inverted for as long as an hour, during which time they rested by lowering their weight onto the substrate beneath the stone. When not resting, the female rose to the stone surface and darted over it in short, jerky movements, apparently selecting a site for egg deposition. When laying eggs, the spawning pair positioned themselves in a head-to-tail position. Trembling lasted 3–5 s, and the female moved forward slightly, depositing one or two eggs. Eggs were laid in a concentrated area but never on top of one another. Eggs added by as many as four females were observed. The presence of eggs beneath the nest stone was probably a strong stimulus for females to spawn. Nests were vigorously guarded against fishes and crayfishes.[3]

EGGS

Description

Mature ova are spherical, translucent, with a single oil globule;[1,3] demersal; adhesive; with a normal perivitelline space, and an unpigmented chorion.[8] Eggs average 2.1 mm in diameter,[3]and range from 1.9 to 2.5 mm.[7,8]

Incubation

At 19–23°C, hatching occurred after 145–150.[3]

Table 85

Fecundity data for stripetail darter from Cusick Creek, Sevier County, TN.*

		Number of Ova			
TL (mm)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
38	39.8	157	46	0	—
41	116	161	59	50	1.42
42	109	125	52	54	1.42
42	68.1	158	53	0	—
44	122	270	58	67	1.42
45	125	416	101	0	1.42
45	84.8	193	73	0	—
46	127	251	51	63	1.42
46	80.8	325	109	0	—
48	246	248	89	73	1.66

Development
Development has not been described.

YOLK-SAC LARVAE

See Figures 77 and 78

Size Range
Newly hatched at 4.1–4.7; yolk absorbed by 7–7.5 mm.[7,8]

Myomeres
Preanal 16, postanal 18–19; 34–35 total.[7,8]

Morphology
4.1–4.7 mm TL. Body laterally compressed, yolk sac large, spherical (ca. 31.9% SL); yolk orange, with a single anterior oil globule; head appears to be deflected over the yolk sac due to its robustness; eyes circular.[7,8]

6.9 mm TL. Notohord flexion occurs.[7,8]

Morphometry
See Table 86.

Fin Development
See Table 87.

4.1–4.7 mm TL. Twelve incipient rays in pectoral fins.[7,8]

5.1–5.2 mm TL. First rays formed in pectoral, spinous, and soft dorsal, simultaneously.[7,8]

6.9 mm TL. Incipient dorsal fin margin partially differentiated;[7,8] first anal fin rays formed, and incipient anal fin margin partially differentiated.[7,8]

7.5 mm TL. Incipient dorsal fin margin completely differentiated. Spinous dorsal fin origin situated over preanal myomere 6, soft dorsal origin over preanal myomeres 15–16.[7,8]

Pigmentation
See Figures 77 and 78

4.1–4.7 mm TL. Absence of pigment over majority of body; several melanophores located on gut between posterior yolk sac and anus; ventral yolk sac with a concentration of melanophores.[7]

5.1–5.2 mm TL. Melanophores dorsally on gut between yolk sac and anus; melanophores ventrally on postanal myosepta 7–13 near area of future anal fin, and scattered melanophores distributed profusely on yolk sac. Dorsally, several melanophores on cranium outlining anterior portion of otic lobe.[7,8]

6.9–7.5 mm TL. Cranium with several melanophores anterior and posterior to orbit; dorsally, melanophores outline optic lobe, with the majority forming a straight line separating the right lobe from the left; several melanophores located along the cerebellum. Laterally, pigment on ventral postanal myosepta,[7,8] 13 melanophores over differentiating anal fin. Ventrally, a concentration of melanophores

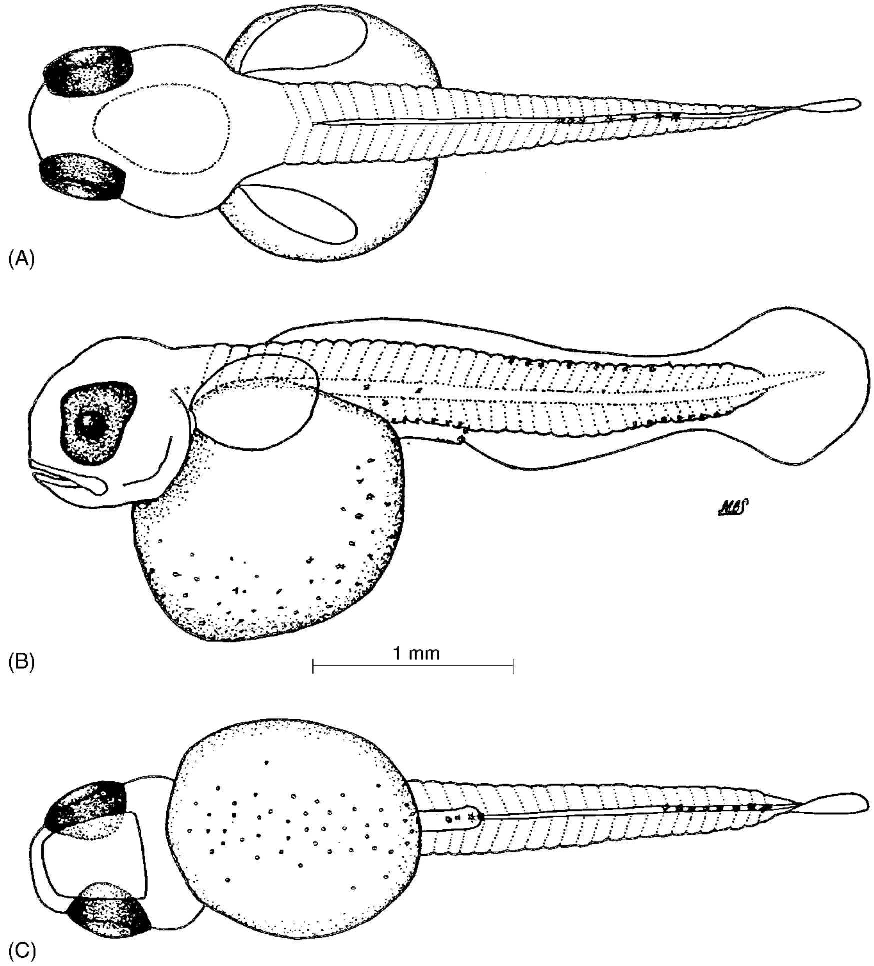

Figure 77 *Etheostoma kennicotti*, stripetail darter, Big Creek, IL; (A–C) newly hatched yolk-sac larvae, 4.3 mm TL: dorsal, lateral, ventral views. (A–C from reference 8, with author's permission).

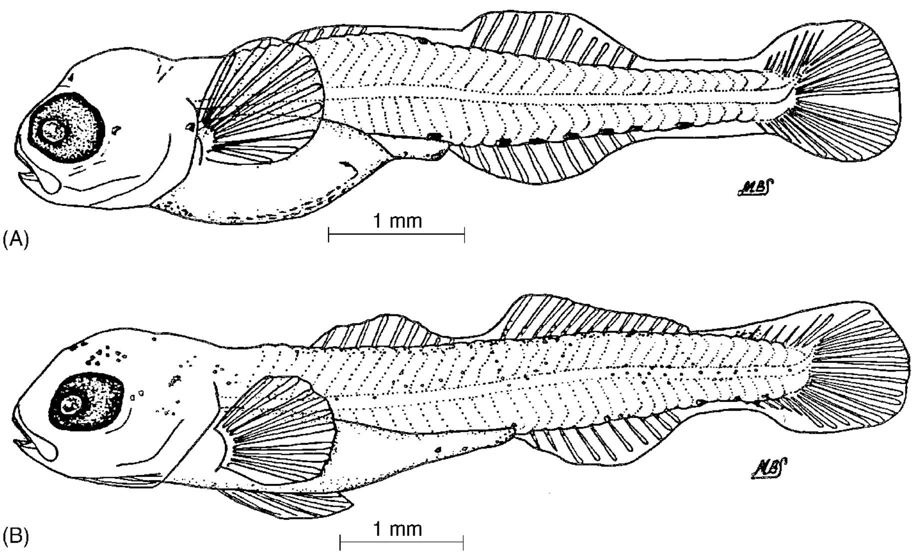

Figure 78 *Etheostoma kennicotti*, stripetail darter, Big Creek, IL; (A) Yolk-sac larva 6.9 mm TL, lateral view; (B) Post yolk-sac larva, 7.5 mm TL, lateral view. (A–B from reference 8, with author's permission.)

Table 86

Morphometric data expressed as percentage of HL and TL for young *E. kennicotti* from southern Illinois.[8]

	TL Groupings						
Length Range (mm)	**4.1–6.9**	**7.1–12.7**	**13.1–15.8**	**16.7–18.9**	**19.3–21.3**	**22.1–25.5**	**26.5–28.9**
N	**5**	**6**	**10**	**9**	**12**	**5**	**8**
Ratios/actual Measures	**(Range)**	**(Range)**	**(Range)**	**(Range)**	**(Range)**	**(Range)**	**(Range)**
As Percent HL							
SnL	8.8 ± 1.4	16.5 ± 2.8	18.6 ± 0.9	19.7 ± 0.4	19.6 ± 1.6	19.9 ± 1.0	20.1 ± 1.8
ED	47.8 ± 3.2	34.5 ± 4.8	28.9.+.1.2	27.5 ± 0.5	27.3 ± 1.0	27.1 ± 0.7	28.4 ± 0.7
As Percent TL							
HL	18.5 ± 1.5	24.7 ± 2.7	27.3 ± 0.4	26.9 ± 0.1	27.1 ± 0.4	26.1 ± 0.4	25.1 ± 0.9
Preanal	51.4 ± 2.3	50.8 ± 1.6	51.6 ± 1.2	50.7 ± 0.1	51.5 ± 0.9	51.1 ± 0.3	50.6 ± 0.7
PosAL	49.6.+.2.3	49.2 ± 1.6	48.4 ± 1.2	49.3 ± 0.1	48.5 ± 0.9	48.9 ± 0.3	49.4 ± 0.7
SL	92.3 ± 2.7	85.1 ± 1.2	83.6 ± 1.3	83.3 ± 0.5	83.9 ± 0.3	83.7 ± 0.7	84.0 ± 0.3
MAXL-Y	31.9						
GBD	23.2 ± 2.2	17.8 ± 0.0	18.0 ± 0.3	17.4 ± 0.2	17.1 ± 0.4	18.0 ± 0.9	16.4 ± 0.8
BDA	9.4 ± 1.7	12.3 ± 2.7	14.0 ± 0.4	13.6 ± 0.4	13.9 ± 0.7	14.3 ± 0.8	14.1 ± 1.4
CPD	4.9 ± 0.5	7.5 ± 1.1	8.6 ± 0.3	8.2 ± 0.3	8.3 ± 0.9	8.8 ± 0.2	7.9 ± 0.1

Table 87

Select meristic values and sizes (mm TL) at the apparent onset of development for *E. kennicotti.*

Attribute/event	*E. kennicotti*	Literature
Dorsal Fin Spines/Rays	VII –<u>VIII</u>/11–12	VI–<u>VII</u> – IX/10–<u>11–12</u>–13[1,2,4,6,9-10]
First rays formed	5.0–5.2	7.2[3]
Adult complement formed	12.1	
Anal Fin Spines/Rays	II/ 6–<u>7</u>	II/6–<u>7</u>– 9[1,2,4,10]
First rays formed	6.9	7.2[3]
Adult complement formed	7.1	
Caudal Fin Rays	xi–xii, 8 + 6–<u>7</u>, iv–xii	12–<u>14–15</u>–16[10]
First rays formed	5.1	7.2[3]
Adult complement formed	7.5	
Pectoral Fin Rays	<u>12–13</u>	11–<u>12–13–14</u>[1,2,9,10]
First rays formed	5.1	7.2[3]
Adult complement formed	6.9	
Lateral Series — Scales	34–<u>41</u>-5	38–<u>44</u>–53[1,2,4,6,9,10]
Myomere/Vertebrae	34–35/34–35	No information/32–33–<u>34</u>–35[1,2,11]
Preanal myomere	16	
Postanal myomeres	18–19	

Mean values are underscored. The number of secondary rays of the median fins are in lowercase Roman numerals.

forms a large spot at base of isthmus; scattered melanophores ventrally cover rest of yolk sac.[7,8]

POST YOLK-SAC LARVAE

See Figures 78 and 79

Size Range
Yolk absorbed by 7.5–16.7 mm TL.[7,8]

Myomeres
Preanal 16, postanal 18–19; 34–35 total.[7,8]

Morphology
7.5 mm TL. Yolk sac absorbed; no swim bladder formed; gut straight.[7,8]

12.1–12.6 mm TL. Supraorbital, infraorbital, lateral, and supratemporal head canals formed; preoperculomandibular canals begin forming.[7,8]

12.7 mm TL. Infraorbital head canals complete with eight pores extending to midorbit.[7,8]

13.1 mm TL. Scales begin to form.[7,8]

14.2–15.8 mm TL. Preoperculomandibular canal pores 10, completely formed; lateral line begins to form; scale formation complete at 15.0 mm.[7,8]

Morphometry
See Table 86.

Fin Development
See Table 87.

7.5 mm TL. First caudal fin rays formed; caudal fin rounded; anal fin margin differentiated.[7,8]

>7.5 mm TL. Pelvic fin buds formed anterior to dorsal origin succeeding complete yolk absorption.[7,8]

<12.1 mm TL. First pelvic fin rays formed.[7,8]

Pigmentation
7.5 mm TL. Preorbital and postorbital bars form; pigment on future opercle; dorsally, an increase of melanophores covering optic lobe. Dorsal body with scattered melanophores from just anterior of spinous dorsal to posterior soft dorsal. Ventrally, a large cluster of melanophores at base of isthmus, becoming site of pelvic fin bud; few melanophores on gut between pelvic fin and anus. Laterally, pigment present on preanal myomere 11–12 above gut; melanophores present on postanal myosepta 5 through 11, 13–15, and 17.[7,8]

12.1–12.7 mm TL. Extension of preorbital and suborbital bars occurs; melanophores extend from optic lobe, forming a chevron posterior to orbit. Dorsally, optic lobe covered with melanophores; pigment extends posterior, forming the first dorsal saddle;

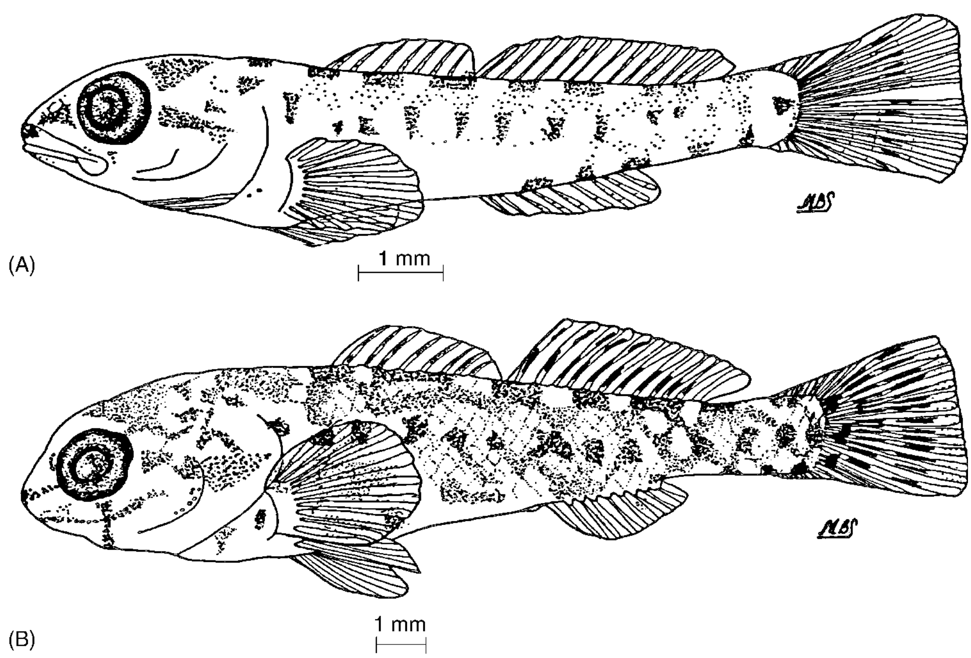

Figure 79 *Etheostoma kennicotti*, stripetail darter, Big Creek, IL; (A) Post yolk-sac larva, 12.1 mm TL, lateral view, (B) early juvenile, 21.3 mm TL, lateral view. (A–B from reference 8, with author's permission.)

7 additional saddles form. Laterally, 14 areas of concentrated melanophores form blotches. At base of caudal peduncle, a stripe forms. Ventrally, from anus to caudal fin base, are 5 areas of concentrated melanophores.[7,8]

13.1–14.4 mm TL. Melanophores form in ventral portion of opercle; preorbital, postorbital, and suborbital bars present; optic lobe formed, with melanophores extending over cerebral or olfactory lobe; suborbital bar extends ventrally, with several melanophores posterior to mandible. Dorsally, 8–9 saddles extend from nape to caudal fin. Laterally, 12–14 blothes with myomeres outlined with melanophores; prepectoral area with melanophores; distinct stripe forms near caudal peduncle base. Pigment present on pectoral, caudal, spinous, and soft dorsal, and anal fin rays. Ventrally, 5–6 rectangular melanophore blotches cluster from the anus to hypural plate.[7,8]

15.0–15.8 mm TL. Essentially the same as previous description with the exception of scales outlined with melanophores.[7]

JUVENILES

See Figure 79

Size Range
16.7[8]–20[3] mm TL or 35 mm SL.[3]

Fins
See Table 87.

Spinous dorsal VII–VIII; soft dorsal rays 11–12; pectoral rays 12–13; pelvic spines/rays I/5; primary caudal rays 8 + 6–7, secondary rays xi–xii, iv–xii.[1,2,7–9]

Morphology
17.3 mm TL. Supraorbital and supratemporal completely formed with 3 pores and 2 pores, respectively.[7]

25.5–27.5 mm TL. Infraorbital canal complete with retrogression to interrupted condition of 1 pore posterior and 4 pores anterior.[7]

Larger juveniles. No scales present on nape, cheeks, opercle, and prepectoral areas.[7]

Morphometry
See Table 86.

Pigmentation
16.7–18.3 mm TL. Pigment outlines scale edges, connecting 12–14 rectangular mid-lateral blotches to 7–8 dorsal saddles and 5–6 ventral saddles; dorsal portion of cranium with melanophores over optic lobe extending anteriorly between orbit; preorbital, postorbital, and suborbital bars well developed; opercle, interopercle, mandible, and maxillary with pigment outlining structures. Pectoral fin with melanophores on rays; two oblique stripes in spinous and five oblique stripes in soft dorsal; four vertical stripes in caudal fin; anal and pelvic fins without pigment. Distinct humeral spot present; prepectoral area with melanophores. Ventrally, melanophores concentrated at pterigiophore interdigitation with lepidotrichia of anal fin.[7,8]

TAXONOMIC DIAGNOSIS OF YOUNG STRIPETAIL DARTER

Similar species: other members members of subgenus *Catonotus;* sympatric with *E. squamiceps*

Etheostoma kennicotti hatches at 4.1–4.7 mm TL and *E. squamiceps* at 5.6–6.1 mm TL. Both species have 16 preanal myomeres and 18 or 19 postanal myomeres. *Etheostoma Kennicotti* (<13.0 mm TL) have a more spherical, larger yolk sac and a smaller head length/TL than *E. squamiceps*. *E. squamiceps* has melanophor's distributed postanally, while *E. kennicotti* has melanophores limited primarily to the yolk sac.[7]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 80)
Eggs. Eggs are laid beneath shallow, slab rock pools of high-gradient streams, where they are guarded by an attendant male.[1,–3,7–10]

Yolk-sac larvae. Remain closely associated with the substrate and are primarily demersal, remaining beneath the nest stone or burying into the gravel. The vitelline vein plexus includes a large network of branched veins that are adapted for oxygen transfer through the substrate interstitial pores.*

Post Yolk-sac Larvae. Demersal, remain in close association with the substrate.* No distinction is evident in the preferred habitat usage between larval, early juvenile, and adults.[3,7] Larval forms occupy non-slab pools to a greater extent throughout the year and are found around the margins of streams to a greater extent than adults.[3,7]

Juveniles. During September through December, juveniles are found on gravel riffles; however, the preferred habitat is slab pools.[3,7]

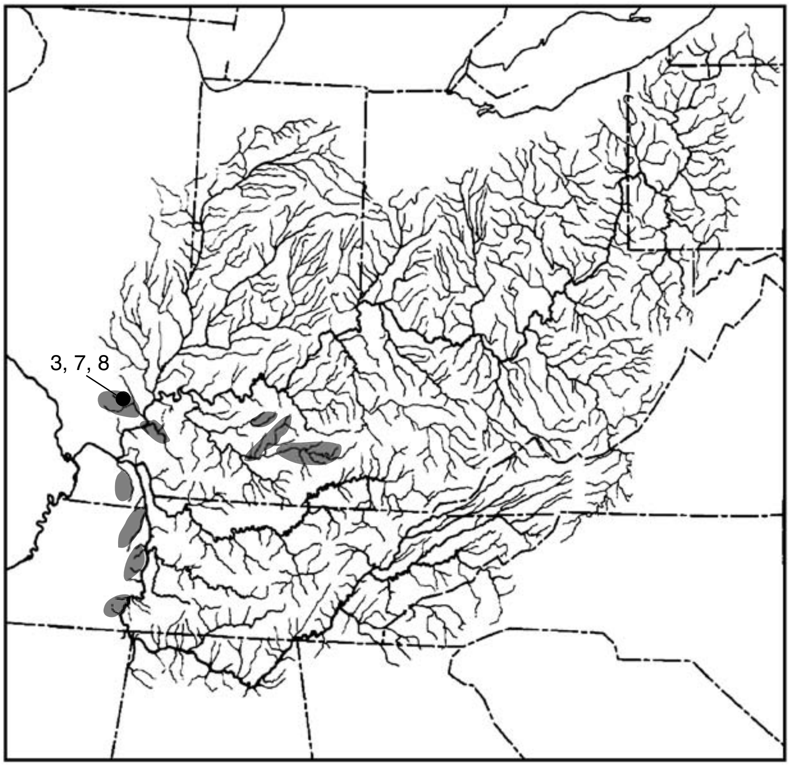

Figure 80 Distribution of stripetail darter, *E. kennicotti* from the Ohio River (shaded areas). Numbers refer to reproductive data based on the reference cited.

Early Growth (see Table 88)
By late July, larvae were 10–20 mm in Big Creek, IL.[3] *Etheostoma kennicotti* reached one half of the first year's mean growth in about 16 weeks.[8] The relationship between SL and age in months (X) is $SL = -3.11 + 33.02 \log X$ (males) and $SL = -3.37 + 31.55 \log X$ (females)[8].

Feeding Habits
Fed mainly on mayflies, copepods, chironomids, and ostracods at lengths less than 21 mm. At lengths greater than 40 mm, fed mostly on mayflies, chironomids, isopods, and amphipods.[3]

Table 88

Average calculated lengths (mm SL) of young stripetail darter from Illinois and Tennessee.

	Age		
State	**1**	**2**	**3**
Illinois[8]	24–30	38–41	43–45
Tennessee*	29–32	37–43	45–56

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Materials Examined: IL: Hardin County, Big Creek, (INHS uncatalogued).

* Original fecundity data for stripetail darter from the Cusick Creek, Sevier County, TN. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Early life history developmental series cultured from laboratory spawned specimens from Big Creek, Hardin County, IL. Specimens curated at the Center for Biodiversity, Illinois Natural History Survey, IL. Original life history observations by T.P. Simon (unpublished data).

REDBAND DARTER

Etheostoma (Oligocephalus) luteovinctum
Gilbert and Swain

Etheostoma: various mouths; *luteovinctum*: yellow-banded.

RANGE

Etheostoma luteovinctum is locally common and widespread in the Duck River system, TN. Within the Cumberland River drainage, it is common in headwaters of the Caney Fork and localized in the Stones River system, TN.[1–4]

HABITAT AND MOVEMENT

The preferred habitat of the redband darter is small streams and springs where it occurs in pools and slowly flowing limestone runs.[1–4] It occurs in streams with moderate gradient over a variety of substrates including limestone bedrock, rubble, gravel, and silt substrates.[1–4] These streams possess growths of aquatic mosses, filamentous algae, or watercress. In streams, males occupy the riffles during reproduction, but occur in pools and runs the remainder of the year.[2–4]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

The type locality for *E. luteovinctum* is Stones Creek, Davidson County, TN.[1–4] The species occurs throughout limestone streams in the Nashville Basin and in chert areas of the Barrens Plateau of the Highland Rim.[1,4]

SPAWNING

Location
Spawning occurs over gravel in shallow stream riffles.[4]

Season
Spawning season occurs from March–April.[4]

Temperature
Unknown.

Fecundity
Females (52–68 mm TL) collected in mid-April from Big Rock Creek (Duck River drainage), Marshall County, TN, had mean ovaries that were 10.9% of the body weight, containing 178.3 total ova averaging 1.11 mm diameter (Table 89).

Sexual Maturity
Adults live to reach age 2;[4] maturity is suspected to be reached by age 1 when individuals attain lengths of 50–55 mm TL.[4] Males exhibited sexually dimorphic traits during the reproductive season with an increase in brightly colored pigmentation.[4]

Spawning Act
Unknown.

EGGS

Description
Ovarian examination of females collected in mid-April showed that ovoid latent ova were 0.25–0.33 mm, early maturing ova averaged 0.66 mm, and large mature ova averaged 1.11 mm (Table 89).[*]

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Table 89

Fecundity data for redband darter from Big Rock Creek, Marshall County, TN.*

		Number of Ova			
TL (mm)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
52	100	1677	147	0	—
54	139	1159	108	95	1.11
55	227	1528	164	171	1.11
59	221	1455	207	166	1.11
59	194	1428	176	164	1.11
59	254	1797	191	193	1.11
65	188	3079	218	0	—
66	309	1848	194	216	1.11
67	283	2038	191	243	1.00
68	167	3463	240	0	—

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Spinous dorsal fin VIII–XI; soft dorsal rays 12–14; pectoral rays 12–14; anal fin rays II 6–8; pelvic fin rays I 5; caudal fin rays 14–16.[2–4]

Morphology
Total vertebrae count 36–38 including one urostylar element. Scales in the lateral series incomplete with 28–(32–40)–47 pored scales and 46–61 (50–56) total scales in the lateral range.[2–4] Gill membranes narrowly joined, frenum present. Scales present on nape, cheek, opercles, belly, and prepectoral areas. Supratemporal canal complete in adults, but sometimes interrupted in juveniles.[4]

Morphometry
Unknown.

Pigmentation
Suborbital bar prominent, and a dusky basicaudal spot may be present. Body color brown, with 7 (6–8) bold dorsal saddles and 8–9 lateral blotches. Dark margins on both dorsal fins; a dark basal band and some red spots in posterior membranes in the spinous dorsal fin. The soft dorsal fin has 3 rows of dark spots on the rays, and membranes are clear

to dusky, occasionally with some red-brown spots. Caudal fin with dark markings on rays forming 4–5 vertical bands. Other fins are generally unpigmented.[2–4]

TAXONOMIC DIAGNOSIS OF YOUNG REDBAND DARTER

Similar species: members of subgenus *Oligocephalus*.[3]

Adult. *Etheostoma spectabile* and *E. caeruleum* are most similar. The species differs from both in lacking orange branchiostegal membranes, in possessing a more scaled cheek and breast, and in having >50 scales in the lateral series. *Etheostoma caeruleum* has a complete infraorbital canal and red pigment. [4]

Larva. No early life history information exists for *E. luteovinctum.* It is not sympatric with *E. spectabile,* except possibly in the Caney Fork and upper Stones Rivers. Juveniles of the two species can be differentiated by their pigmentation. *Etheostoma luteovinctum* does not possess horizontal brown lines on the upper sides as in *E. spectabile*.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 81)
Eggs. Buried in fine gravel in slow-flowing runs and riffles.[4]

Yolk-sac larvae. Unknown.

Larvae. Unknown.

Juveniles. Unknown.

Early Growth (see Table 90)
Individuals do not exceed 2 years of age.[4] During their first year of life young darters attain 25–30 mm TL by mid-June and reach 45–50 mm TL by late July[4].

Feeding Habits
The main components of the diet include midge larvae, but other spring dwelling organisms such as isopods and amphipods may also be eaten.[4]

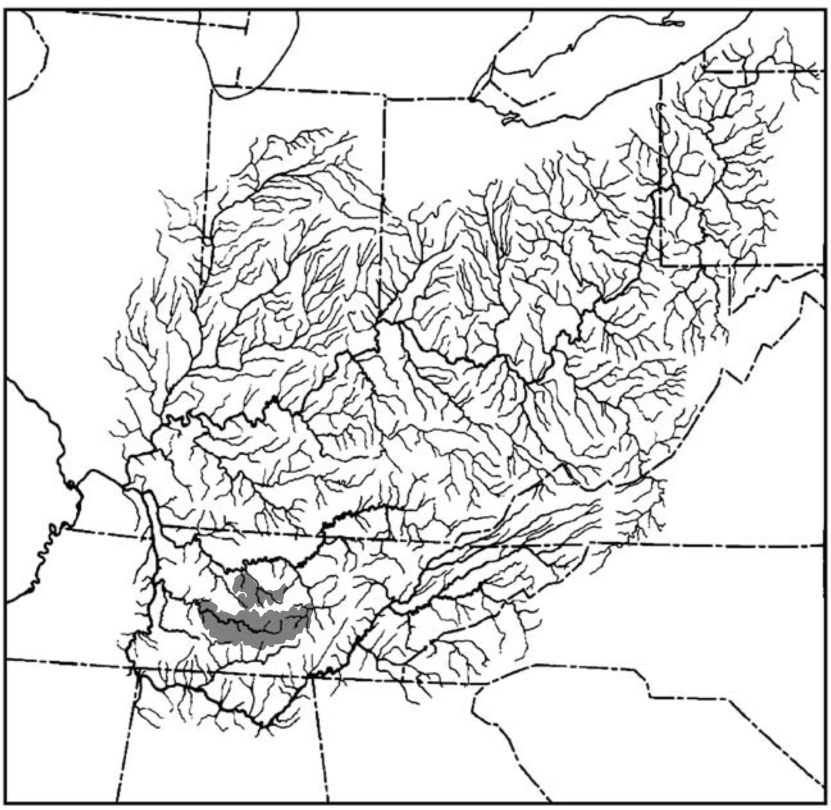

Figure 81 Distribution of redband darter, *E. luteovinctum* from the Ohio River system (shaded area).

Table 90

Average calculated lengths (mm TL) of young redband darter from Tennessee.[4]

	Age	
State	**1**	**2**
Tennessee[4]	50–55	60–70

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* Original fecundity data for redband darter from Big Rock Creek, Duck River drainage, Marshall County, TN. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe LA.

SPOTTED DARTER

Etheostoma (Nothonotus) maculatum Kirtland

Etheostoma: various mouths; *maculatum*: spotted, in reference to the red spots on the body of the males.

RANGE

Etheostoma maculatum is widely ranging in the Ohio River basin; occurs at a few sites in tributaries of the Allegheny River in northwest PA; and was formerly recorded in the Mahoning, Muskingum, and Scioto Rivers, OH. Occurs in the upper Wabash River and Blue River, IN. Records from the Licking River, KY, and lower Kanawha River, WV, that has not been matched with recent collections.[1–3,9,10]

HABITAT AND MOVEMENT

Usually inhabits the strong riffles of large streams where it is found over coarse gravel and rubble.[1,3] Taken during all months of the year, moves but slightly to deeper parts of the same riffle during the winter months.[8]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Sporadic and uncommon, occurring in the upper Green and Barren River, KY; recently discovered in North Fork Kentucky River.[3] In NY, occurs only in French Creek;[4] limited to Big Darby and Deer Creeks, Scioto basin, OH.[5] In the upper Wabash River drainage, collected from the middle Tippecanoe River,[7,11] lower White River basin,[9] and from the Blue River in Crawford, Washington, and Harrison counties, IN.[6] In PA, the species is a typical darter of the Shenango and Allegheny Rivers and French Creek.[10]

SPAWNING

Location

Localized spawning occurs in quiet areas in stream widths about 3.3 m at the head of the riffle, just before and after the water breaks in its descent over the riffle. Eggs are attached beneath flat stones at depths of 0.2–0.6 m.[8]

Season

Spawning occurs in May and early June throughout its range.[4,8]

Temperature

Spawning began at temperatures of 17°C in French Creek, PA.[8]

Fecundity (see Table 91)

A female 50 mm SL had 400 eggs; smaller females 40–45 mm SL contained ca. 200 mean mature ova.[8] Ovarian eggs mature in batches of about 65 ova.[4] Females (54–68 mm TL) collected in mid-April from Little River (Tennessee River drainage), Blount County, TN, had mean ovaries that were 10.9% of the body weight, containing 178.3 total ova averaging 1.11 mm diameter. No significant relationship was observed between increasing female size and the number of mature ova in the ovaries ($F = 6.150$, $p = 0.056$); nor with total ova ($F = 1.527$, $p = 0.252$).[*]

Sexual Maturity

Males and females were sexually mature at age 2 at lengths greater than 48 mm SL;[8] some young 32 mm SL females were mature at age 1.[8] Also reported at 30–43 mm TL.[10]

Spawning Act

Males establish territories at minimum distances of 3.6 m. A single male occupies large flat rocks. Eggs are deposited on the underside of flat stones 75–225 mm in diameter. Egg masses are square in shape, with the eggs in 4 or 5 layers and 5–10 layers opposite. Eggs are guarded exclusively by the males.[8] Reproduction occurs early in the morning when a female enters the opening of the nest stone. Courting consists mainly of a male making a lateral display followed by tail wagging, which leads the female into the cavity. A head-to-tail position is maintained while the male nudges and nipps of the caudal fin, encouraging the female to invert. Spawning occurs over an extended period of time, in 5–10 s of short vibrating bursts. A total of 3–5 eggs are laid during any single spawning event. The eggs may be layered and tend to be concentrated in the furthest portion of the cavity.* Parental care is provided by the male.*

Table 91

Fecundity data for spotted darter from Little River, Blount County, TN.*

TL (mm)	Ovary Weight (mg)	Number of Ova: Ripening Oocytes (LA)	Number of Ova: Mature Oocytes (EM, MA, LM)	Number of Ova: Ripe Eggs (MR, RE)	Egg Diameter (mm)
49	221	84	37	22	2.00
50	197	174	41	31	1.66
54	360	226	72	39	2.00
55	377	127	44	41	2.20
55	74.6	228	43	0	—
55	76.4	180	78	0	—
57	277	221	70	58	1.66
63	144	188	146	0	—
63	187	208	32	45	1.53
70	257	258	81	53	1.53

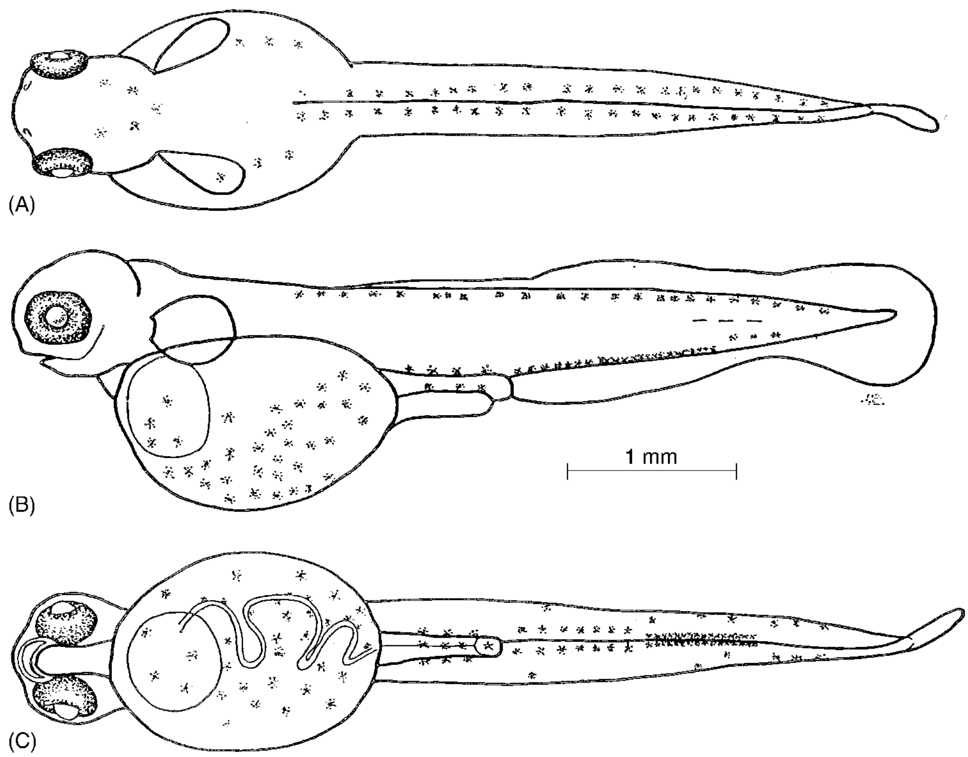

Figure 82 *Etheostoma maculatum*, spotted darter, Tippecanoe River, IN; newly hatched yolk-sac larva, 5.3 mm TL, (A) dorsal, (B) lateral (C) ventral views (A–C from reference 8, with authors' permission.)

EGGS

Description
Ovarian examination showed that ovoid latent ova ranged from 0.5 to 0.71 mm, early maturing small spherical light-yellow-colored ova ranged from 1.0 to 1.5 mm, and large mature ova ranged from 1.53 to 2.2 mm.* Mature ova are demersal, adhesive, and spherical; and possess a single oil globule, a narrow perivitelline space, and an unsculptured chorion.[8] Eggs averaged 2.0 mm in diameter.[9]

Incubation
Eggs cultured in laboratory aquaria at 22–24°C hatched after 175 h.[7]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 82

Size Range
Newly hatched at 5.0mm; yolk absorbed by 8.0 mm TL.[8,9]

Myomeres
Preanal 19, postanal 20; 39 total.[9]

Morphology
5 mm SL. Pale yellow, translucent yolk, a large (31.7% SL) spherical yolk sac. A single mid-ventral serpentine vitelline vein originates at the single anterior oil globule and proceeds mid-ventrally along the yolk sac. Head not deflected over the yolk sac; jaws developed; body robust, laterally compressed.[8]

8 mm SL. Body laterally compressed, yolk sac and oil globule greatly reduced 48 h posthatching.[*]

Morphometry
See Table 92.

Fin Development
5 mm SL. Soft dorsal fin initiation even with the anus; pectoral fin well developed; finfolds continuous.[9]

Pigmentation
5 mm SL. Melanophores distributed on the posterior cerebrum, dorsal yolk sac and gut, and ventral gut. A double row of single melanophores present on the dorsum; and numerous melanophores scattered ventrally on the yolk sac and oil globule. Paired rows of melanophores preset ventrally between the anus and postanal cluster. A concentrated cluster of melanophores occurrs mid-ventrally near postanal cluster. A concentrated cluster of melanophores occurrs mid-ventrally near postanal myomere eight and is evenly distributed posteroventrally over the next eight myomeres.[9]

8 mm SL. A few more melanophores present on the posterior part of the abdomen. Chromatophores on the underside of the yolk sac are characteristically arranged in continuous S-shaped curves.[8]

Table 92

Morphometric data expressed as percentage of SL for young *E. maculatum* from Indiana.[8,*]

	SL Groupings	
Length Range (mm)	**5.0**	**8.0**
N	**1**	**1**
As Percent TL		
SnL	1.8	2.2
PEL	7.7	8.2
OP1L	14.5	15.3
ODL	33.4	33.6
PVL	56.8	53.4
PCL	103.9	102.8
MAXL-Y	31.7	
P1L	7.6	8.1
HD	11.5	12.4
OP1D	14.4	13.6
OD1D	17.9	15.6
OD2D	9.6	9.4
BPVD	9.6	9.4
MPMD	7.9	7.8
AMPMD	4.8	5.1
MAX-YD	19.3	
BPEW	12.3	12.5
OP1W	13.2	12.8
OD1W	16.2	15.9
OD2W	6.4	6.4
BPVW	6.4	6.4
AMPMW	2.6	3.2
MAXW-Y	16.2	

POST YOLK-SAC LARVAE

Size Range
8.0 mm SL[8] to unknown length.

Myomeres
Preanal 19, postanal 20; 39 total.[8,*]

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown to 30–43 mm TL.[10]

Fins
Spinous dorsal X–XV; soft dorsal rays 10–14; pectoral rays 12–15; pelvic spines/rays I/5.[1,2]

Morphology
Total lateral line scales, 51–68; total vertebrae 37–41.[1,2,12]

Morphometry
Unknown

Pigmentation
30–43 mm TL. Body is light brownish-olive in color; sides mottled and barred with darker melanophores; traces of 4–7 vertical bands on posterior half of body; no carmine spots, sometimes very faint; horizontal lines between scale rows or vertical bands; fins spotted or largely transparent.[10]

TAXONOMIC DIAGNOSIS OF YOUNG SPOTTED DARTER

Similar species: other members of subgenus *Nothonotus*.

Etheostoma maculatum, E. vulneratum and *E. aquali* share a large (>32.0% SL), spherical yolk sac at hatching, usually more than 19 preanal myomers, dorsal pigmentation in either a single or double row and a series of mid-lateral dashes near the caudal peduncle *Etheostoma vulneratum* exhibits *E.* the largest size at hatching. *Etheostoma maculatum* is similar to *E. vulneratum* but hatches at 5.0 mm SL, significantly smaller. *Etheostoma maculatum* also differs in head length, yolk-sac length and depth, and caudal peduncle depth. Larvae of *E. aquali* can be distinguished from the former species by the cross-hatched or brushed melanophores that cover the vitelline vein.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 83)
Eggs. Eggs are deposited on the underside of flat stones in squarish clusters at the head or end of the riffles.[8] Hatching occurred by violent motions within the egg. The mouth is open as the larva emerges.[8]

Yolk-sac larvae. Larvae settled on the bottom and remained lying on their side. Occasional erratic movements were produced by rigorous jerking of the bodies. Considerable effort was required for them to reach the surface.[8]

Post yolk-sac larvae. Demersal; remain in close association with the substrate, usually on the edges of the head of the riffle within interstitial spaces.*

Juveniles. No distinction is evident between the habitat of young and adults.*

Early Growth
Juveniles were slightly less than 30 mm SL by the end of the first summer; [8] young-of-the year in OH ranged 30–43 mm in October.[10] In PA, juveniles ranged 21–28 mm in late August; and in October, ranged 22–28 mm.[8]

Feeding Habits
The majority of the spotted darter's diet consists of aquatic insects, including Dipterans, caddisflies, stoneflies, mayflies, and beetles.[8]

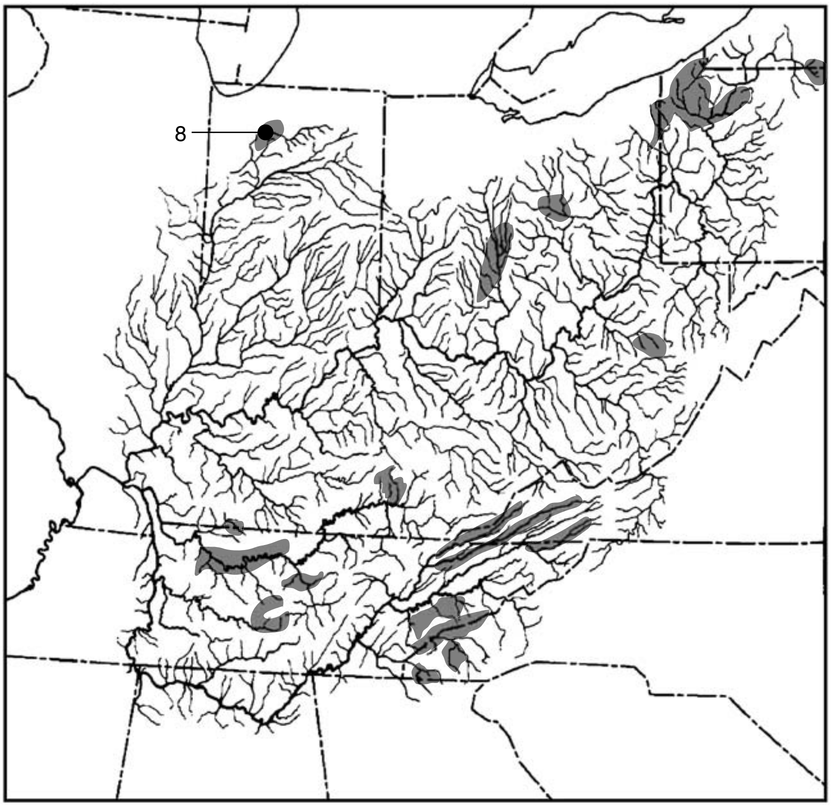

Figure 83 Distribution of spotted darter, *E. maculatum* in the Ohio River system (shaded area), and areas where early life history information has been collected (circle). Number indicates appropriate reference.

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* Simon, T.P., unpublished data.

SMALLSCALE DARTER

Etheostoma (Nothonotus) microlepidotum Raney and Zorach

Etheostoma: various mouths; *microlepidotum*: tiny scale, referring to the large number of small scales.

RANGE

Etheostoma microlepidotum occurs in large streams of the Cumberland River drainage, TN, and from Stones River downstream through Little River, KY.[4]

HABITAT AND MOVEMENT

The smallscale darter's preferred habitats are large- to medium-sized upland rivers, where it occurs locally in riffle areas with gravel and rubble substrates. Depths in these areas are 0.5 m with strong flowing currents. The smallscale darter is associated with rock boulders in the main portion of the riffle where stones are slippery due to the presence of a diatom layer.[1–6] Etnier and Starnes indicate that the species is found only in the deep, swift riffles with boulder and coarse rubble substrates with slab rock.[4]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma microlepidotum is known to occur in a few sites including the Stones, Harpeth, Red, and Little River systems. The species habitat on the Stones River has been inundated by the Percy Priest reservoir. Specimens referred to by Raney and Zorach from the Duck River are considered *E. aquali*.[4,5]

SPAWNING

Location
Smallscale darters spawn in rock crevices and alongside large horizontal slab rock. Deposition along the downstream side of slab rocks is similar to other clumping *Nothonotus* such as *E. maculatum*.[4,5]

Season
Spawning season is early April to June;[2,4] breeding occurred in aquariums from specimens collected from Red River, TN in mid-May.* Page found a nest in the East Fork Stones River, TN, in early May.[6]

Temperature
Spawning occurs at temperatures about 21°C.[6]

Fecundity
A nest stone found by Page et al. had 346 eggs attached in a loose mass to the underside of a large rock.[6]

Sexual Maturity
Males dichromatic by early April.[2] Sexual maturity occurs at age 2 for males and age 1 for females.* No nuptial tubercles were found on males; however, nuptial pigmentation included a darkened body and bright green areas on the median fins.[5]

Spawning Act
The reproductive mode of the smallscale darter is a clumper.[6] Spawning occurred in aquaria by a single pair. Courting by both sexes usually led to the female following the male, either alongside a large rock or beneath a horizontal slab rock, and spawning. Oviposition was usually a series of single adhesive eggs that were deposited in clusters like grapes.[6,*]

EGGS

Description
Unknown.

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Larger Juveniles: Spinous dorsal fin XI–XV; soft dorsal rays 11–13; pectoral rays 12–15; anal fin rays II 7–9; pelvic fin rays II 5; caudal fin rays 16 to 18.[2–4,6]

Morphology
Total vertebrae count 38–40 including one urostylar element. Branchiostegal rays six. Scales in the lateral line series complete, range from 55 to 71 scales from TN.[2–4,6]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG SMALLSCALE DARTERS

Similar species: member of subgenus *Nothonotus*. Found with *E. tippecanoe, E. rufilineatum,* and *E. camurum* on the same riffle but not in the same areas of the riffle.[2,6]

Adult. *Etheostoma microlepidotum* is similar to *E. tippecanoe* and *E. rufilineatum,* but both the *Nothonotus* species differ from *E. microlepidotum* in having an incomplete lateral line. *Etheostoma tippecanoe* has a prominent dark basicaudal bar and nape saddles, and *E. rufilineatum* has dark horizontal marks on the cheeks and opercles rather than a single suborbital bar.[2–5]

Larva. Aspects of the early life history for *E. microlepidotum* are unknown.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 84)
Eggs. Eggs are laid beneath slab rock in slightly adhesive clusters.[6]

Yolk-sac larvae. Unknown.

Post yolk-sac larvae. Unknown.

Juveniles. Juveniles are often collected from gravel riffles.[4]

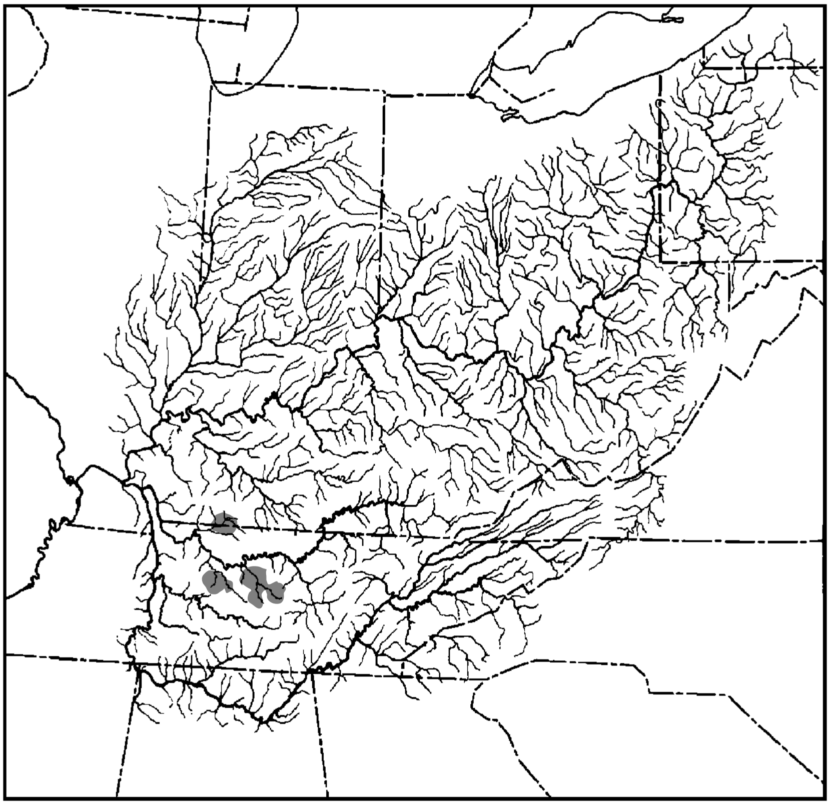

Figure 84 Distribution of smallscale darter, *E. microlepidotum* in the Ohio River system (shaded area).

Early Growth (see Table 93)
Apparently individuals live to reach 2–3 years of age.* Young smallscale darters attain lengths of 32–40 mm TL by age 1[4].

Feeding Habits
The main components of the diet are midge larvae, burrowing mayfly larvae, and oligochaete worms; large adults ingest fewer midges than do smaller fish.*

Table 93

Average calculated total length (mm TL) of young smallscale darters in Tennessee.[*,6]

State	Age 1	Age 2	Age 3
Tennessee*	32–40	50–79	93

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* Simon, T.P., unpublished data

LEAST DARTER

Etheostoma (*Boleichthys*) *microperca* Jordan and Gilbert

Etheostoma: various mouths; *microperca*: small perch, referring to the small adult size of this species when compared with other percids.

RANGE

Etheostoma microperca occurs from the northeast to the Moira River, eastern ON, throughout the Great Lakes, northwest to the Red River of the North, MN; south through northern IN, IL, and OH to Beargrass Creek, KY, disjunct populations extend into the Ozark region of MO, KS, AR, and OK.[1–3]

HABITAT AND MOVEMENT

Etheostoma microperca is found in submerged vegetation along overhanging grassy banks and among filamentous algae. The species prefers quiet waters rich in vegetation with sand or muck bottoms.[4] Moves from deeper portions of lakes and streams to shallow areas to spawn; males often arrive 1–2 weeks earlier than females.[7] Females may remain in deeper water until ready to spawn, at which time they enter the inshore spawning territory occupied by males.[8]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

The least darter is common to abundant in tributary streams occurring in OH, IN, and KY portions of the Ohio River basin.[1] In OH, the species occurs in the headwaters of the Miami and Scioto Rivers;[5] in KY, it is known from only a single specimen collected in Beargrass Creek, Jefferson County;[6] and in IN, it occurs in tributaries of the Eel, Wabash, and West Fork White River.[1]

SPAWNING

Location
Eggs are attached to leaves and twigs of aquatic macrophytes;[4,7,8] or among dense filamentous algae.[4]

Season
In the Greater Miami and Scioto Rivers, OH, spawning occurred from late April until mid-July.[4]

Temperature
Ripe adults were collected in stream temperatures ranging from 12 to 15.5°C in MI;[8] spawning temperatures ranged from 16 to 18°C.[7]

Fecundity (see Table 94)
Females 28–30 mm SL had mature ova ranging between 31 and 180.[4] Age 1 females in MI held an average of 594 eggs; age 2 females averaged 858 eggs.[12] Female *E. microperca* did not show statistically significant increasing fecundity (ANOVA F = 0.822, $p = 0.406$) with increasing length. Females between 31 and 36 mm collected between late February and early July had 25–84 large mature ova.*

Sexual Maturity
Males and females were sexually mature at age 1[4] and at 31–36 mm TL.*

Spawning Act
Males are active and constantly pursue females. Courting consists of hanging in midwater for several seconds, while vibrating their fins vigorously. The female selects the site of egg deposition and, with the male close behind, approaches the site. At the egg site, the male mounted the back of the female, the two quivered intensely for a few seconds while they curved in a loose, S-shaped manner so that the female's genital papillae were on the selected spot and 1–3 adhesive eggs were laid. The S-shaped position facilitated the close proximity of the sperm to egg. At the instant of egg laying, both the male and female had their mouths wide open. Typically, a pair would lay several eggs at one site, then move 5–15 cm from the first site and lay several more eggs. In order to lay eggs on leaves and twigs, vertical positions were required, which were maintained by rapid vibrations of the caudal and pectoral fins. The expanded pelvic fin of the male enabled him to grip the middorsum of the female. Males spawned with several females. Neither sex provided any parental care.[4]

Table 94

Fecundity data for least darter from Arkansas, Oklahoma, and Wisconsin.*

Length (mm TL)	Ovary Weight (mg)	Number of Ova: Ripening Oocytes (LA)	Number of Ova: Mature Oocytes (EM, MA, LM)	Number of Ova: Ripe Eggs (MR, RE)	Egg Diameter (mm)
31	20.3	311	83	84	0.83
32	15.5	276	82	55	0.83
33	12.2	325	105	72	0.56
33	9.9	229	67	43	0.71
34	17.9	298	111	25	1.00
34	8.7	286	116	0	0
35	25.4	332	91	82	1.00
36	8.8	240	55	39	0.71

EGGS

Description

Ovarian examination showed that ovoid latent ova were cream-colored and ranged from 0.14 to 0.17 mm, early maturing small spherical light-orange ova ranged from 0.29 to 0.41 mm, and large mature ova ranged from 0.56 to 1.0 mm.* Mature ova were heart-shaped and deeply indented (including the primary egg envelope); demersal, adhesive, with translucent yolk, single oil globule, a narrow perivitelline space, an unsculptured chorion, and unpigmented.[9] Eggs ranged from 0.3 to 0.5 mm.[9]

Incubation

Eggs incubated at 15.5°C hatched at 164 ± 13 h; at 20°C, hatching occurred in 181 ± 7 h at 22–23°C, they hatched in 144 ± 12 h, while eggs at 27°C fungused.[4] At 18°C, eggs hatched after 144–188 h.[7,8]

Development

Probably very similar to *E. proeliare.*[1] Embryonic development of the circulatory system was described in detail.[8]

YOLK-SAC LARVAE

See Figures 85 and 86

Size Range

Newly hatched at 3.0[4,8,9]; yolk absorbed by 4.5 mm.[9]

Myomeres

Preanal myomeres 15, postanal 19–20; 34–35 total.[9]

Morphology

3.0 mm TL. Body laterally compressed, yolk sac bulbous, anterior tapering posteriorly; yolk sac 25.6% TL, 27.9% SL; yolk translucent with a single anterior oil globule; head not deflected over the yolk sac; jaws well developed; eyes oblong.[9]

4.5 mm TL. Notochord flexion occurred.[9]

Morphometry

See Table 95.

Fin Development

See Table 96.

3.0 mm TL. Well-developed pectoral fin buds with nine incipient rays.[4]

3.5 mm TL. Pectoral fins large and caudal fin with an unusual shape;[4] first pectoral fin rays formed.[9]

4.0–4.5 mm TL. First dorsal and anal rays formed; complete complement of pectoral fin rays formed.[9]

Pigmentation

3.0–3.5 mm TL. Heavily pigmented; retinae black; concentration of melanophores on dorsal portion of cranium outlining the optic lobe; a profuse scattering of melanophores outlining all preanal and postanal myomeres distributed along all myosepta

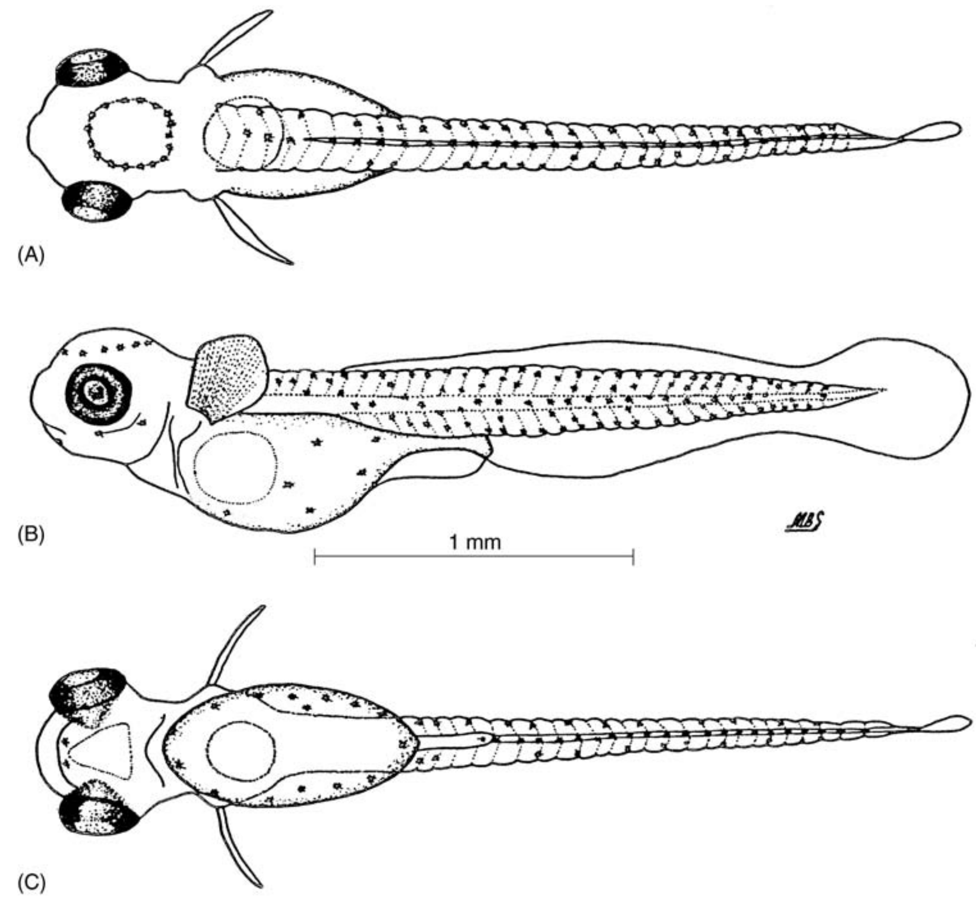

Figure 85 *Etheostoma microperca*, least darter, yolk-sac larva, 3.0 mm TL, Piscasaw River, IL: (A) dorsal, (B) lateral, and (C) ventral views. (A–C from reference 9, with author's permission.)

in epaxial and hypaxial regions. Melanophores posterior to maxillary in area of future operculum. Laterally, melanophores encircle the yolk sac, leaving the center devoid of pigment. Ventrally, a single pair of melanophores under the mandible, concentrated at anterior portion of yolk sac, less concentrated posteriorly. Melanophores at apex of every postanal myomere dorsally and ventrally.[9]

4.0 mm TL. Laterally, melanophores at apex of every myosepta with epaxial and hypaxial melanophores scattered over entire body. Melanophores at apex of every postanal myomere dorsally and ventrally.[9]

POST YOLK-SAC LARVAE

See Figures 86 and 87

Size Range
Yolk absorbed 4.5–13.2 mm.[9]

Myomeres
Preanal 15, postanal 19–20; 34–35 total myomeres.[9]

Morphology
4.5 mm TL. Yolk sac absorbed.[9]

8.2 mm TL. No swim bladder formed; gut straight.[9]

7.7–8.3 mm TL. Supraorbital and infraorbital head canals start forming; infraorbital canal complete without interruption and pore count of 10.[9]

8.9 mm TL. Scales present near caudal peduncle.[9]

12.2 mm TL. Preoperculomandibular and supratemporal canal begins forming; squamation complete.[9]

Morphometry
See Table 95.

Fin Development
5.0 mm TL. First caudal fin ray formed.[9]

6.4 mm TL. Incipient dorsal and anal fin margin partially differentiated; pelvic fin buds formed anterior to dorsal fin origin; adult complement of dorsal fin rays formed.[9]

Table 95

Morphometric data expressed as percentage of HL and TL with range of actual values in parentheses for young *E. microperca* from Illinois.[9]

	TL Groupings			
Length Range (mm)	**3.0–4.5**	**6.4–9.9**	**10.2–15.7**	**16.1–19.5**
N	**5**	**15**	**15**	**12**
Mean	**3.8**	**8.17**	**12.79**	**18.08**
Ratios/actual Measures	**(Range)**	**(Range)**	**(Range)**	**(Range)**
As Percent HL				
SnL	11.1	19.2	20.3	18.7
	(0.06–0.10)	(0.34–0.43)	(0.42–0.85)	(0.76–1.0)
ED	42.6	27.2	21.2	23.3
	(0.23–0.35)	(0.43–0.7)	(0.68–0.93)	(0.93–1.2)
As Percent TL				
HL	18.9	22.9	24.2	23.2
	(0.50–0.9)	(1.5–2.7)	(2.2–4.1)	(3.7–4.6)
Preanal	50.0	46.4	53.7	47.1
	(1.5–2.2)	(3.1–5.2)	(5.1–7.6)	(7.1–9.5)
PosAL	50.0	53.6	46.3	52.9
	(1.5–2.3)	(3.3–4.7)	(5.1–8.1)	(9.0–10.0)
SL	90.0	79.8	82.1	81.7
	(3.0–4.0)	(5.0–8.8)	(8.5–12.9)	(13.3–16.1)
TL	100	100	100	100
	(3.0–4.5)	(6.4–9.9)	(10.2–15.7)	(16.1–19.5)
BDG	12.3	15.6	15.7	16.4
	(0.40–0.56)	(0.93–1.4)	(1.3–2.6)	(2.6–3.4)
BDA	7.9	12.1	15.3	16.3
	(0.22–0.37)	(0.68–1.4)	(1.2–2.6)	(2.5–3.4)
CPD	3.8	7.9	8.3	9.8
	(0.10–0.18)	(0.43–0.76)	(0.85–1.4)	(1.4–2.0)

7.0–7.5 mm TL. Adult complement of caudal and anal fin rays formed.[9]

7.6–8.2 mm TL. Incipient dorsal and anal fin margin completely differentiated; first pelvic fin rays formed at later stages; entire finfold absorbed;[9] predorsal length 27.7 % TL, 34.0% SL.[9]

Pigmentation

4.5 mm TL. Pigmentation absent over the majority of body. Laterally, pigmentation on head posterior to orbit on future operculum. Dorsally, melanophores outlining optic lobe; ventrally, melanophores concentrated at apex of breast.[9]

6.4–8.2 mm TL. Laterally, scattered melanophores over the entire body outlining myomeres; 6–8 distinct areas forming blotches; concentration along gut. Melanophores on cranium anterior and posterior to orbit, and dorsally covering optic lobe. At the base of the differentiating anal fin a concentration of melanophores is present at ventral base. Dorsally, six rectangular saddles form. Pigment patterns were essentially unchanged for the duration of the larval period, with patterns less prominent after 7.0 mm TL.[9]

8.5–8.9 mm TL. Lateral melanophores outlining myomeres along myosepta; 7–9 blotches along midlateral; 2 half crescents present at the base of caudal peduncle. Head pigmentation with distinct preorbital and postorbital bars; suborbital bars form. Edge of suboperculum outlined; a dorsal chevron forming posterior to orbit laterally. Dorsally, melanophores are concentrated over optic lobe, and form 8–9 dorsal saddles.[9]

Table 96

Meristic counts and size (mm TL) at the apparent onset of development for *E. microperca.*

Attribute/Event	*Etheostoma microperca*[9]	Literature
Branchiostegal Rays	5,5	5–6,5–6[1–3,8,11]
Dorsal Fin Spines/Rays	IV–VIII/7–8	V–VII/9–10 [1–3,8,11]
First spines formed	4.0–4.5	
Adult complement formed	6.4	
First soft rays formed	4.0–4.5	
Adult complement formed	6.4	
Pectoral Fin Rays	10–12	13–16[1–3,8]
First rays formed	3.5	
Adult complement formed	4.5	
Pelvic Fin Spines/Rays	I/5	I/5[1–3,8]
First rays formed	8.2	
Adult complement formed	13.9	
Anal Fin Spines/Rays	I–II/5–7	I–II/5–7[1–3,8,11]
First rays formed	4.5	
Adult complement formed	7.5	
Caudal Fin Rays	vii–xvi, 4–5+5, vii–xii	11–18[1,8]
First rays formed	5.0	
Adult complement formed	7.0–7.5	
Lateral Line Scales	27–34	32–38[1,2,3,8,11]
Myomeres/Vertebrae	34–35/32–34	Unknown/31–34[1–3,8,11]
Preanal myomeres	15	
Postanal myomeres	19–20	

9.7–13.2 mm TL. A mid-lateral concentration of melanophores forming 7–9 lateral blotches; dorsal edges of scales pigmented; preorbital, postorbital, and suborbital bars chevron-shaped. Dorsally, 7–9 saddles; specks of melanophores distributed between pectoral fin rays; melanophores scattered in spinous and soft dorsal, caudal, and anal fins. Ventrally, melanophores at the base of each lepidotrichia of anal fin.[9]

JUVENILES

See Figure 87

Size Range
13.2–14.7 mm TL[9] to 28 mm TL.[4]

Fins
See Table 96.

Spinous dorsal IV–VIII; soft dorsal rays 7–8; pectoral rays 10–12; pelvic spines/rays I/5; anal spines/rays I–II/4–7; primary caudal rays 4–5 + 5, secondary rays vii–xv, vii–xii.[1–3,5,9,12]

Morphology
No information.

Morphometry
see Table 95.

Pigmentation
13.6–14.7 mm TL. Uniformly scattered pigment connecting 7–8 rectangular midlateral blotches to 7–8 dorsal saddles; scattered melanophores extend ventrally, outlining scale edges and connecting to mid-lateral blotches; dorsal section of cranium with melanophores over optic lobe; outline of scales pigmented; entire pectoral fin with scattered melanophores on membranes; three oblique stripes of clustered melanophores on the spinous and four oblique stripes on the soft dorsal (pigmented directly on rays); caudal fin with seven diagonal stripes on membrane; preorbital bar extending above maxilla; scattered melanophores on operculum, extending above maxilla

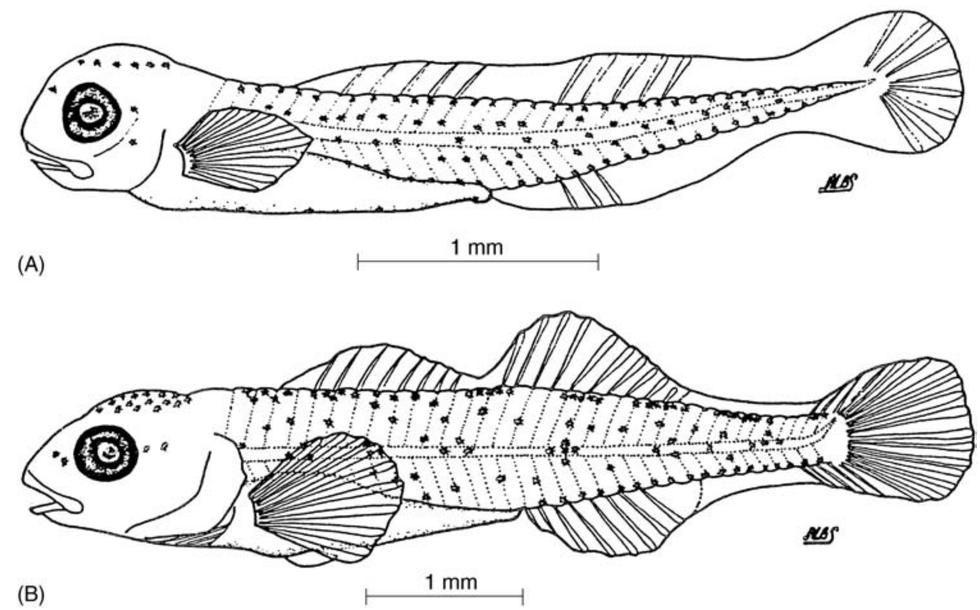

Figure 86 *Etheostoma microperca*, least darter yolk-sac larva: (A) 4.0 mm TL, unnamed tributary Iroquois River, IL: (B) post yolk-sac larvae 6.4 mm TL, Piscasaw River, IL: (A–B from reference 9, with author's permission.)

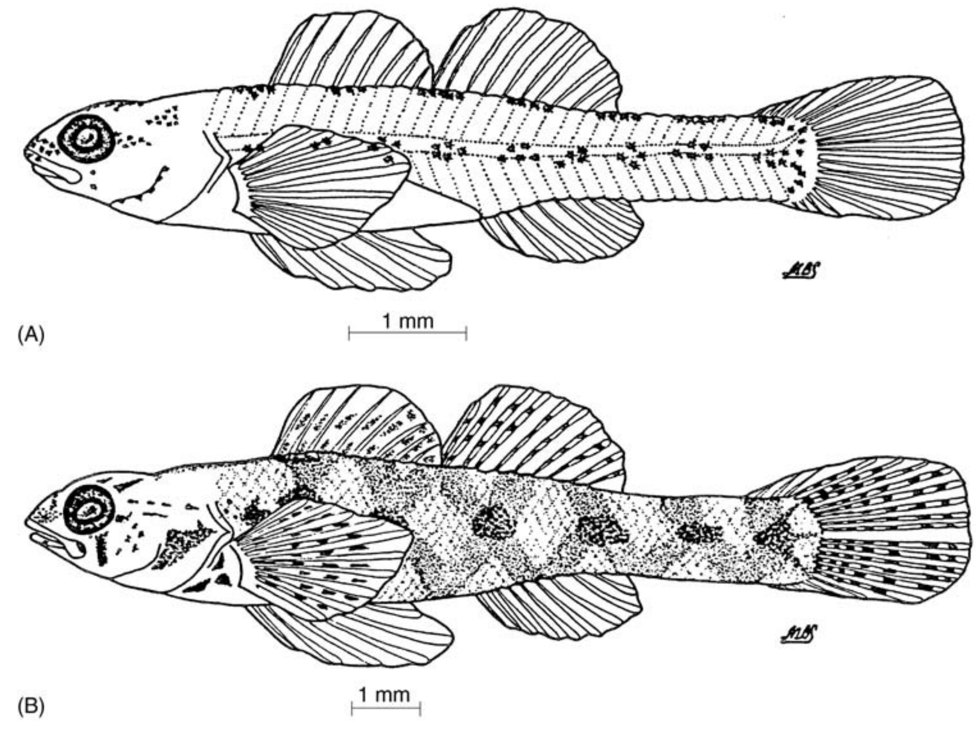

Figure 87 *Etheostoma microperca*, least darter, Piscasaw River, IL: (A) 8.2 mm TL post yolk-sac larva, and (B) 14.5 mm TL early juvenile. (A–B from reference 9, with author's permission.)

and on cheek. Ventrally, melanophores concentrated at pterigiophore interdigitation with lepidotrichia of anal fin.[9]

15–30 mm TL. Dorsally, olive-brown; sides olive-yellow; belly yellowish-white. Body mottled and speckled with browns; 3–11 vague saddles; usually 7–15 blotches along the lateral series of scales. Suborbital bars large and conspicuous. Spinous dorsal transparent, soft dorsal and caudal fin pale olive, barred with brown. Anal and pelvic fins transparent. Body pattern less contrasting.[5]

TAXONOMIC DIAGNOSIS OF YOUNG LEAST DARTER

Similar species: members of subgenus *Boleichthys.*

See *E.proeliare* diagnostic discussion.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 88)
Eggs. Eggs are attached singly to filamentous algae, and the leaves and twigs of aquatic macrophytes.[4]

Yolk-sac larvae. Within 2 days of hatching, capable of feeding on live organisms. Yolk-sac larvae remain within the leaves and foliage of aquatic macrophtyes.*

Post yolk-sac Larvae. Demersal, remain in close association with the substrate in laboratory observation.[9]

Juveniles. Found in thick growths of algae at the edge of the stream.[4]

Early Growth (see Table 97)
Etheostoma microperca attains age of 20 months.[4] At year 1, males averaged 28.4 mm and females averaged 28.1 mm.[4] *Etheostoma microperca* reached one half of the first year's mean growth in about 6–7 weeks.[4] In central WI, young attained 25–36 mm in September, and 24–26 mm in August.[12] In October, young-of-the year from OH ranged from 20 to 30 mm;[5] in IL, late June individuals were 7–13 mm SL.[4] The length–age relationship for males is SL = 11.3 + 15.09 log *X*, where *X* = age in

Table 97

Average calculated lengths (mm) of young least darter from Illinois, Wisconsin, and Indiana.[4,12]

	Age (months)	
State	**12**	**20**
Indiana* (SL)	25–27	30–33
Illinois[4] (SL)	27–28	30–32
Wisconsin[12] (TL)	35	38

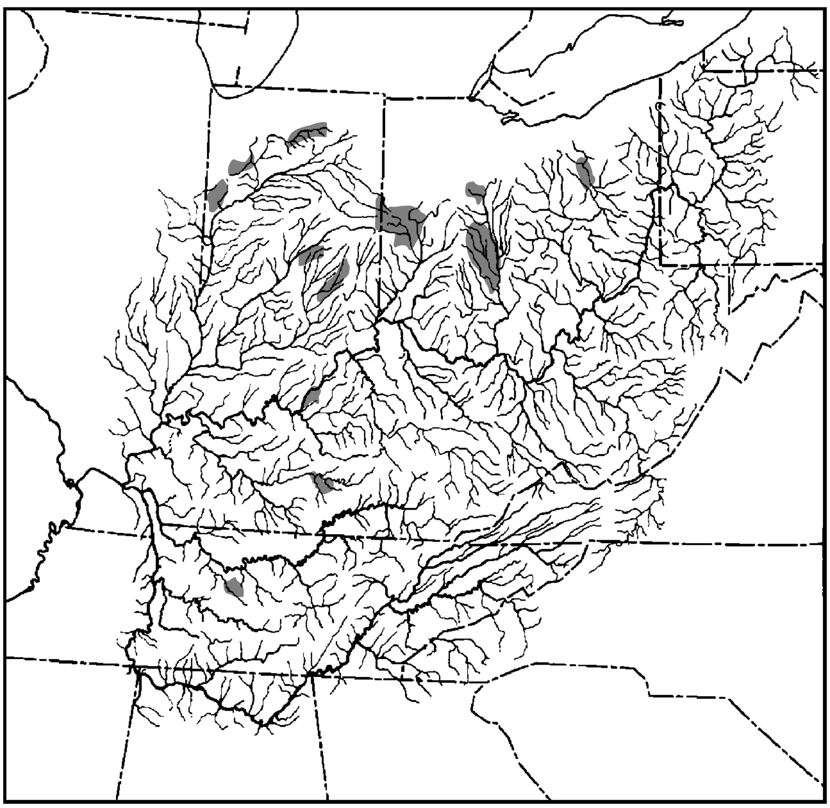

Figure 88 Distribution of least darter. *Etheostoma microperca* in the Ohio River system (shaded area).

months; females relationships are SL = 12.84 + 13.86 log *X*.[4]

Feeding Habits
Isopods, cladocerans, copepods, and chironomid larvae are important food items. Small crustaceans are important to smaller individuals.[4] Individuals found in Dinner Creek, Becker County, MN, fed mostly on midge larvae in June (72%) and July (62%), with cladocerans and copepods being more important early and late in the growing season (61%),[14] while Ottertail River populations fed consistently on midge larvae throughout the year and consumed large numbers of mayfly nymphs during July and October.[15]

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* Original fecundity data for least darter from Arkansas: Benton County: Osage Creek, 1.5 miles N Cave Springs, T 19N R 31W S 36; Feb 6, 1973; OK: Johnson Co: Blue River, 1 mile E Connerville, 27 April 1968; and WI: Portage Co: Pond at Iverson Park, Stevens Point, T 24N R 8E S 24; July 8, 1965. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Early life history developmental series cultured from laboratory spawned specimens from the Iroquois River, IL. Specimens curated at the Center for Biodiversity, Illinois Natural History Survey, Champaign, IL. Original data is from T.P. Simon, unpublished data.

LOLLYPOP DARTER

Etheostoma (*Catonotus*) *neopterum* Howell and Dingerkus

Etheostoma: various mouths; *neopterum*: new wing or fin, in reference to the uniquely modified soft dorsal fin of nuptial males.

RANGE

Etheostoma neopterum is confined to the Shoal Creek system, TN and AL.[1–3]

HABITAT AND MOVEMENT

The preferred habitat of the lollypop darter is small- to medium-sized streams. It is locally common near the margins of streams, among the tree roots beneath overhanging banks in areas with low gradient. Depths in these areas are less than 0.5 m with slow-moderate currents.[1–4]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma neopterum is confined to the Shoal Creek drainage, AL and TN.[1–3]

SPAWNING

Location
Underside of slab rocks along the middle of riffles.[1,3]

Season
Spawning occurs in mid-April.[1,3]

Temperature
Unknown.

Fecundity
A nest contained over 600 eggs attached to the underside of a slab rock. It was presumed that the eggs on the under side of the rock were contributed by several females.[1,3]

Sexual Maturity
Males were sexually mature at age 1 but did not spawn until age 2, while both age 1 and 2 females spawned.*

Spawning Act
The reproductive mode of *E. neopterum* is a clusterer.[2] Adults deposit their eggs on the underside of slab rocks where they are guarded by a single male.[1,2,6] The general description of reproduction follows that of other *Catonotus*.[1,2,6]

EGGS

Description
Unknown.

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Larger juveniles. Spinous dorsal fin VIII–XI; soft dorsal rays 10–14; pectoral rays 11–13; anal fin rays II 6–9; pelvic fin rays I 5; caudal fin rays 14–17.[1–3,5,6]

Morphology
Scales in the lateral series incomplete with 14–45 pored scales and 41–58 scales in the lateral series from TN.[1–3]

Scales present on the cheeks, opercle, nape, breast, belly, and prepectoral area.[2]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG LOLLYPOP DARTERS

Similar species: similar to other members of the *Catonous* subgenus.[3] In study zone it is sympatric with *E. crossopterum, E. squamiceps,* and *E. nigripinne.*[2]

Adult. Etheostoma neopterum can be separated from *E. crossopterum* and *E. nigripinne* by the fact that it has 11–12 soft dorsal fin rays, vs. 12–14 in the other two species. Infraorbital canals are interrupted in the other *Catonotus* species while they are complete in *E. neopterum.*[2]

Larva. Aspects of the early life history and reproductive biology for *E. neopterum* are unknown.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 89)
Eggs. Eggs are laid on the underside of slab rocks.[1–3,5–7]

Yolk-sac larvae. Unknown.

Post Yolk-sac Larvae. Unknown.

Juveniles. Unknown.

Early Growth
Largest specimen reaches 84 mm TL.[1]

Feeding Habits
Unknown.

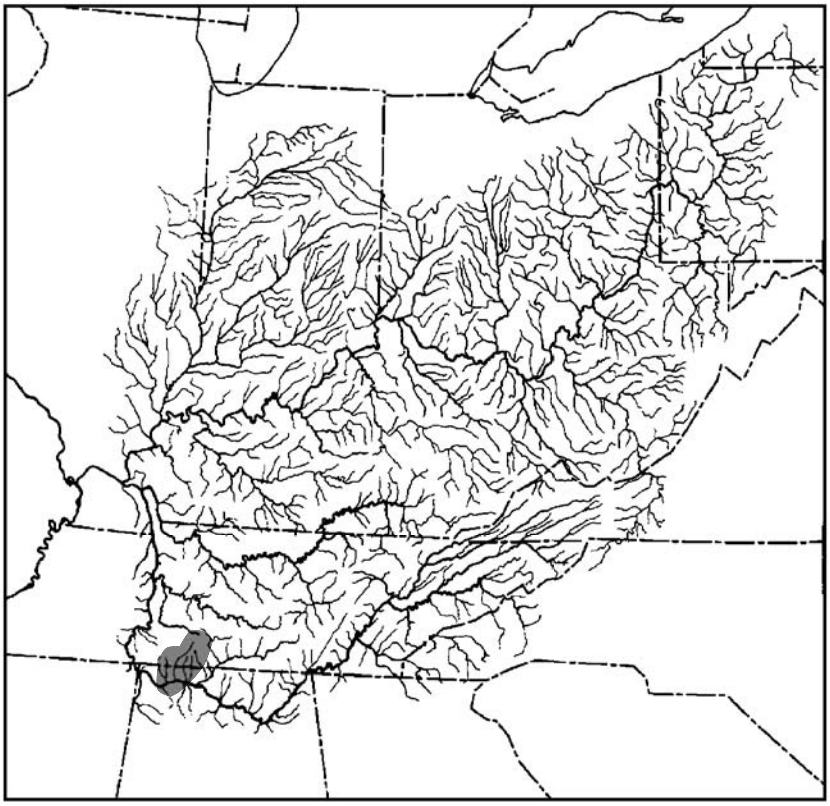

Figure 89 Distribution of lollypop darter, *E. neopterum* in the Ohio River system (shaded area).

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BLACKFIN DARTER

Etheostoma (*Catonotus*) *nigripinne* Braasch and Mayden

Etheostoma: various mouths; *nigripinne*: black fin, in reference to the black fins of breeding males.

RANGE

The blackfin darter is restricted to Highland Rim streams tributary to the Tennessee River from the Paint Rock system of northeastern AL to Decatur and Perry Counties, TN.[1,2]

HABITAT AND MOVEMENT

The preferred habitat of the blackfin darter is small upland creeks where it occurs locally in gently flowing riffles and pools with slab rock rubble substrates.[1,2]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Limited to the entire Elk River and portions of the Duck River systems, TN,[1,2] present in the Tennessee River in northern AL from the Paint Rock River west.[3,5]

SPAWNING

Location
Underside of slab rocks.[1–3]

Season
Spawning occurs in late April through May.[1–3]

Temperature
Unknown.

Fecundity
Unknown.

Sexual Maturity
Unknown.

Spawning Act
Adults deposit their eggs on the underside of slab rocks where they are guarded by a male.[3] Page and Bart indicate that the male uses egg mimics to entice females into the nest.[4]

EGGS

Description
Unknown.

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Larger juveniles. Spinous dorsal fin VIII–X; soft dorsal rays 11–15; pectoral rays 10–13; anal fin rays II 6–9; pelvic fin rays I 5; caudal fin rays 15–18.[1–3]

Morphology
Scales in the lateral series incomplete with 21–28 (10–45) scales and with 43–51 (38–51) total scales in the lateral series from TN.[2,3]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG BLACKFIN DARTERS

Similar species: Similar to other members of the *Catonotus* subgenus. Early life stages may be indistinguishable from other populations of *E. squamiceps* complex.[3]

Adult. *Etheostoma nigripinne* is similar to other Catonotus.

Larva. Aspects of the early life history for *E. nigripinne* are unknown. *Catonotus* species should differ based on myomere counts, differences in pigmentation, and yolk-sac shape.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 90)
Eggs. Eggs are laid on the underside of slab rocks.[3]

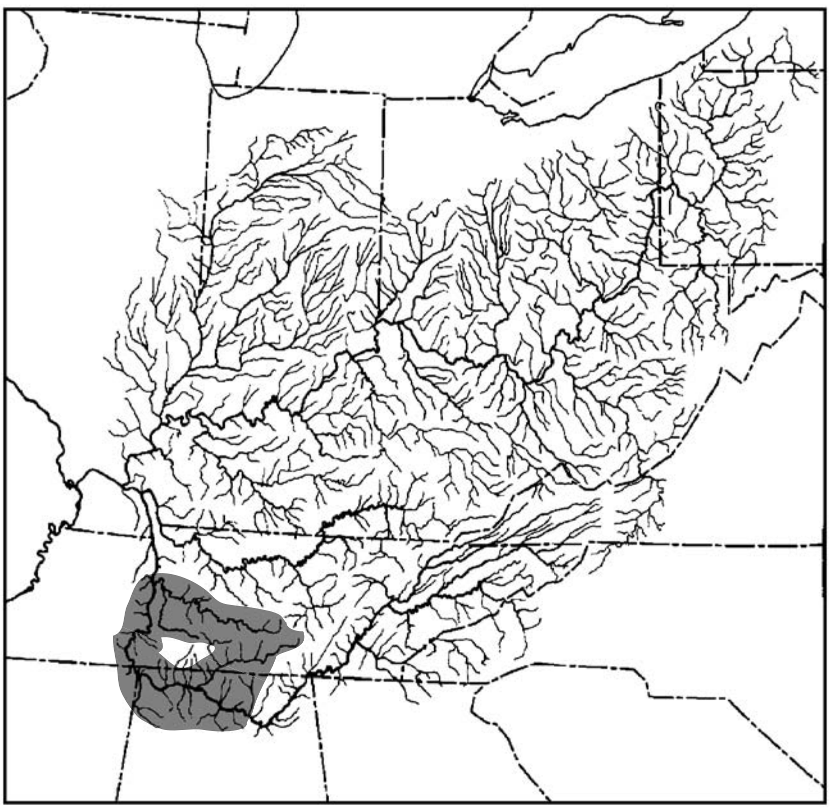

Figure 90 Distribution of blackfin darter, *E. nigripinne* in the Ohio River system (shaded area).

Yolk-sac larvae. Unknown.

Post Yolk-sac larvae. Unknown.

Juveniles. Unknown.

Early Growth
Largest specimen reaches 75 mm TL.[3]

Feeding Habits
Unknown.

LITERATURE CITED

1. Page, L.M. et al. 1992.
2. Braasch, M.E. and R.L. Mayden. 1985.
3. Etnier, D.A. and W.C. Starnes. 1993.
4. Page, L.M. and H.L. Bart. 1989.
5. Mettee, M.F. et al. 1996.

JOHNNY DARTER COMPLEX

Etheostoma (*Boleosoma*) *nigrum* Rafinesque

Etheostoma: various mouths; *nigrum*: blackened, in reference to the black head and darkened body of nuptial males.

RANGE

Etheostoma nigrum is distributed from the Hudson Bay drainage of eastern SK to as far north as the Churchill River, and from the St. Lawrence drainage to Lake Champlain; south to the Mobile basin, Gulf of Mexico, and from the York River, Appalachian Highlands, to the Platte River, WY and CO, Rocky Mountains.[1–4]

HABITAT AND MOVEMENT

Etheostoma nigrum inhabits low- to moderate-gradient, clear, small streams to large rivers and large lakes such as Lake Superior. Adults occur over many different habitat types ranging from sand, sand and gravel, unsilted gravel in runs and flowing pools below riffles, to the coarse-sifted sand and gravel of littoral Lake Superior habitats.[6]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Several forms of *E. nigrum* occur in the Ohio River drainage. Populations from the James, Roanoke, Tar-Neuse Rivers are considered *E. n. nigrum.*[5] *Etheostoma nigrum susanae* has been recently elevated to full specific status. This form is extremely rare in the upper Cumberland River; KY populations are known from locations above the Falls.[37] The only known population in TN is in Jellico Creek, Scott County;[32] it formerly occurred in Gum Creek in Scott County, but this population has been extirpated.[33] Additional records plotted in the Atlas of North American Freshwater Fishes are in error.[19] *Etheostoma nigrum* occurs in the lower Tennessee River drainage, mostly in the Coastal Plain and western and southern Highland Rim tributaries, TN and KY.[19,37] This form is the most commonly collected in northern portions of the Ohio River drainage.[34–36] An additional form that displays pleisiomorphic traits also occurs in IN, and is currently being described (T.P. Simon, and B.E. Fisher, unpublished data).

SPAWNING

Location

Egg sites include the underside of large rocks, slab limestone rocks, sticks, woody debris, submerged logs, and tin cans.[6,9–11]

Season

In Coon Creek, WI, spawning aggregates of adult males assemble during early May beneath slab rocks in the lower riffle reaches. Spawning occurs from late April until June throughout its range, with May being the peak spawning period.[6]

Temperature

Spawning temperatures ranged from 11.7 to 21.1°C.[7]

Fecundity (see Table 98)

The female johnny darter showed statistically significant increasing fecundity (ANOVA, $F = 20.563$, $p = 0.002$) with increasing length. Two 63 mm females had 173–320 large mature ova, while two 57 mm females had 0–96 large mature ova.[*] A male spawns with more than one female, and a female may spawn with 4–6 different males, depositing between 30 and 200 eggs at each spawning.[12] The number of eggs produced is a function of age and size, WI females age 1 (40–63 mm) held 169 (48–299) mature ova; age 2 females (53–69 mm) held 86–691 mature ova.[7]

Sexual Maturity

Sexual maturity is attained at age 1 at lengths between 39[*] and 63 mm.[7]

Spawning Act

Etheostoma nigrum is an egg attacher. The spawning male darkens along the dorsum and the head. Selection of a nest site includes a stationary territory approximately 25 cm in diameter usually centered around the nest site. Cleaning of the underside surface of the nest site precedes courtship. The male courts a female at the entrance to the nest site by displaying laterally erect fins. The female only

Table 98

Fecundity data for *E. nigrum* from an unnamed tributary, Wabash River, Allen County, IN.

		Number of Ova			
Length (mm TL)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
39	36.3	441	73	31	0.91
43	74.1	268	94	85	1.11
44	73.3	239	73	100	1.05
47	156	352	157	146	1.11
48	65	651	93	0	—
49	111	396	162	117	1.11
57	161	606	157	96	1.25
57	136	938	258	0	—
63	251	1130	189	173	1.25
63	280	947	152	320	1.11

enters the spawning site once it is ready to spawn. Once beneath the nest stone, adults maintain a head-to-head, inverted, horizontal orientation, with the male maintaining an inverted side-to-side position along the female. Eggs are laid one at a time and immediately fertilized by the male during a single spawning event. Eggs are usually laid in a single layer, although portions may be in double layers,[12] in an oblong compact cluster up to 13 cm in diameter. Adult males and females are polygamous. A male spawns with more than one female, and a female may spawn with 4–6 different males, depositing between 30 and 200 eggs at each spawning. Males guard the territory rather than the eggs.[9–11] Even if the nest stone and eggs are removed, the male will remain in the territory guarding the area where the nest had been.[9–11]

EGGS

Description

Ovarian examination showed that ovoid latent ova were 0.3–0.4 mm, early maturing ova averaged 0.5–0.9 mm, and large mature ova averaged 0.9–1.25 mm*. Eggs from IL, WI, and MN are spherical to slightly elliptical, mean = 2.2 mm diameter (range: 1.9–2.4 mm); transparent, demersal, and adhesive. Eggs possessed translucent clear to pale-yellow yolk (mean = 2.0 mm diameter; range: 1.7–2.2 mm); a single oil globule (mean = 0.3 mm; range: 0.2–0.3 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[6]

Incubation

Hatching occurs in 384 h at an incubation temperature of 12.8°C, in 240 h at 20°C, and in 144 h at 22.8°C.[6]

Development

Unknown.

YOLK-SAC LARVAE

See Figure 91

Size Range

Newly hatched larvae from WI, MN, and IL were 4.9; yolk is absorbed at 5.4–5.6 mm,[6] or 6 mm TL.*

Myomeres

Preanal 15 (N = 81, mean = 15.0); postanal 21 (N = 81, mean = 21.0); with 36 total. Total vertebrae count 36 (N = 3), including one urostylar element.[6]

Morphology

4.9–5.4 mm TL. Newly hatched larvae from the Mississippi River are larger than those from Lake Superior, which hatch at slightly smaller lengths between 4.3 and 5.4 mm. Body terete; snout pointed; functional jaws, upper jaw even, slightly overhanging lower jaw; yolk sac moderate (24.8% TL), tapering posteriorly; yolk translucent, pale yellow, with a single oil globule; mid-ventral vitelline vein plexus

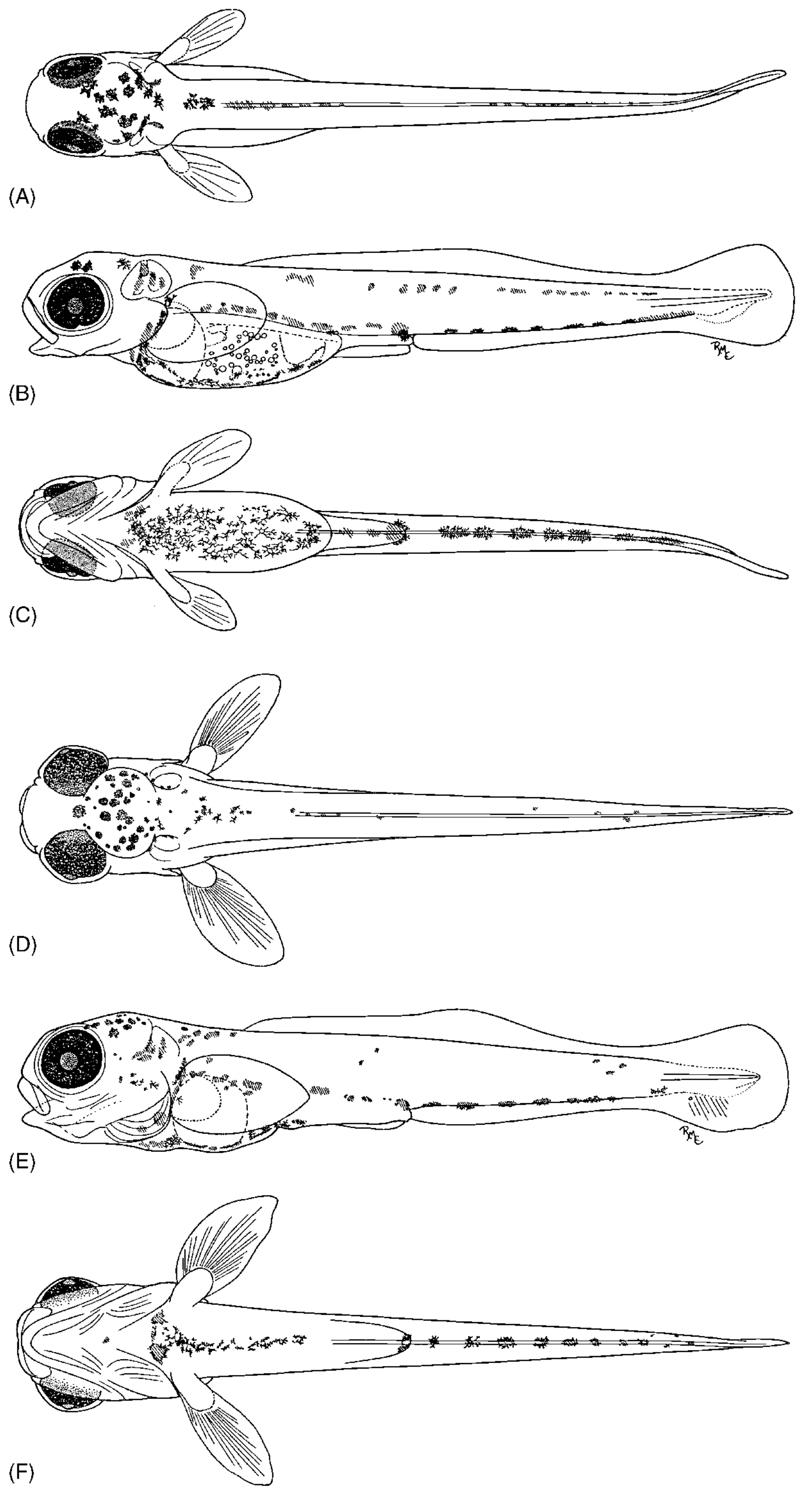

Figure 91 *Etheostoma n. nigrum*, central johnny darter, Mississippi River, Buffalo County, WI. Yolk-sac larva, 5.75 mm TL (A) dorsal, (B) lateral, (C) ventral views, Post Yolk-sac larva, 6.5 mm TL, (D) dorsal, (E) lateral, (F) ventral views. (A–F from reference 6, with author's permission.)

on yolk sac; head not deflected over the yolk sac; and eyes oval.[6]

Morphometry
See Table 99.[6]

Fin Development
See Table 100.

4.9–5.4 mm TL. Newly hatched larva with well-developed pectoral fins without incipient rays.[6]

Table 99

Morphometry of young *E. nigrum* grouped by selected intervals of total length (*N* = sample size).

	Total Length (TL) Intervals (mm)											
	4.27–5.97 (*N*=35)		6.03–7.86 (*N*=39)		8.15–9.73 (*N*=3)		13.6–13.7 (*N*=2)		14.5–17.7 (*N*=9)		18.3–23.4 (*N*=13)	
Characters	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
Length (% of TL)												
Upper jaw[a]	14.5±10.8	(0.01–0.52)	16.0±8.16	(0.02–0.66)	18.1±1.53	(0.23–0.37)	17.1±0.99	(0.50–0.53)	17.0±3.67	(0.35–0.92)	14.8±5.13	(0.35–1.10)
Snout[a]	15.9±3.85	(0.07–0.30)	17.7±3.26	(0.08–0.31)	21.2±2.34	(0.32–0.37)	22.4±1.56	(0.65–0.70)	17.6±2.44	(0.47–0.82)	23.1±3.26	(0.77–1.32)
Eye diameter[a]	42.5±5.73	(0.34–0.51)	38.5±3.50	(0.43–0.59)	40.5±3.21	(0.59–0.74)	30.6±0.14	(0.91–0.93)	29.4±3.05	(1.02–1.12)	27.6±1.92	(1.08–1.41)
Head	18.4±2.26	(0.59–1.29)	20.6±2.08	(1.13–1.79)	18.4±1.69	(1.34–1.86)	22.1±0.28	(2.97–3.05)	22.6±1.52	(2.99–4.22)	22.2±1.21	(4.05–5.08)
Predorsal	29.1±2.85	(1.12–1.92)	30.5±1.25	(1.75–2.30)	30.7±0.78	(2.43–3.03)	19.5±12.7	(1.43–3.90)	30.1±1.29	(4.34–5.72)	29.5±1.21	(5.35–6.96)
Dorsal insertion			30.8±2.09	(1.75–3.23)	46.1±2.42	(3.79–4.27)	34.2±12.7	(3.42–5.90)	46.0±1.09	(6.64–8.33)	45.2±0.88	(8.43–10.7)
D2 origin			31.1±3.39	(1.75–3.95)	48.3±1.06	(3.97–4.59)	37.1±12.6	(3.83–6.30)	48.4±1.44	(6.94–8.95)	47.0±0.72	(8.51–11.1)
D2 insertion			31.6±6.49	(1.75–3.95)	67.6±1.06	(3.97–4.59)	57.0±12.2	(3.83–6.30)	68.0±1.25	(6.94–8.95)	67.3±1.49	(8.51–11.1)
Preanal	50.3±3.07	(1.68–3.09)	51.1±1.75	(3.09–4.14)	51.5±0.76	(4.24–4.93)	50.9±0.13	(6.92–6.95)	50.1±0.80	(7.37–8.88)	50.7±1.12	(9.10–11.4)
Postanal	49.9±3.29	(1.89–3.22)	48.9±1.74	(2.84–4.40)	48.5±0.78	(3.91–4.80)	49.1±0.14	(6.65–6.73)	49.8±0.90	(7.03–9.04)	49.3±1.12	(9.15–12.1)
Standard	96.3±0.90	(4.10–5.79)	96.3±0.72	(5.76–7.72)	87.2±2.41	(7.09–8.26)	85.4±0.00	(11.6–11.7)	84.4±0.64	(12.2–15.0)	84.6±2.90	(14.5–20.0)
Yolk sac	24.8±3.78	(0.93–1.91)	20.3±5.80	(1.04–1.56)								
Fin Length (% of TL)												
Pectoral	13.5±2.94	(0.28–1.34)	16.2±2.97	(0.44–1.36)	20.0±1.63	(1.54–2.13)	17.3±0.42	(2.31–2.41)	17.5±2.64	(1.80–3.51)	16.8±2.11	(2.30–4.46)
Pelvic					7.43±2.11	(0.44–0.94)	11.3±0.42	(1.50–1.58)	14.3±1.93	(1.91–2.95)	13.5±2.39	(2.20–4.61)
Spinous dorsal			11.8	(0.93–0.93)	15.4±3.18	(1.21–1.54)	14.6±0.00	(1.99–2.00)	16.0±0.77	(2.30–2.97)	15.7±1.14	(2.61–4.02)
Soft Dorsal			20.1	(1.58–1.58)	19.2±0.40	(1.56–1.87)	19.9±0.42	(2.68–2.74)	19.6±1.12	(2.81–3.42)	20.3±1.37	(3.67–5.02)
Caudal	3.72±0.90	(0.10–0.46)	3.73±0.72	(0.14–0.39)	12.8±2.41	(0.86–1.47)	14.6±0.00	(1.99–2.00)	15.6±0.64	(2.29–2.76)	15.4±2.90	(2.60–4.74)
Body Depth (% of TL)												
Head at eyes	15.5±1.88	(0.67–1.19)	16.0±1.00	(0.91–1.16)	14.0±0.26	(1.12–1.38)	15.9±0.14	(2.15–2.17)	15.5±1.00	(2.28–2.54)	16.0±1.18	(2.70–3.97)
Head at Pl	16.6±2.75	(0.68–1.23)	14.2±3.12	(0.65–2.18)	14.4±0.35	(1.16–1.42)	19.3±2.97	(2.33–2.93)	17.3±1.05	(2.60–2.89)	17.2±0.69	(3.15–3.94)
Preanal	8.81±0.95	(0.37–0.63)	8.50±1.03	(0.42–0.82)	7.68±0.52	(0.60–0.81)	10.2±0.71	(1.32–1.47)	12.0±0.84	(1.68–2.12)	12.8±1.10	(2.16–3.21)
Mid-postanal	6.53±0.95	(0.24–0.45)	6.64±0.48	(0.37–0.62)	6.08±0.52	(0.47–0.65)	7.16±0.28	(0.94–1.01)	8.57±0.60	(1.19–1.59)	9.38±0.71	(1.61–2.29)
Caudal peduncle	3.97±0.52	(0.16–0.27)	3.98±0.52	(0.15–0.37)	5.52±0.78	(0.38–0.56)	6.35±0.57	(0.81–0.92)	6.88±0.49	(0.99–1.24)	7.02±0.56	(1.30–1.58)
Yolk Sac	9.20±3.19	(0.23–0.82)	8.73±0.85	(0.52–0.60)								
Body Width (% of HL)												
Head	78.8±15.0	(0.50–1.03)	76.9±8.78	(0.82–1.26)	75.5±5.27	(1.09–1.38)	56.7±0.85	(1.70–1.71)	54.1±5.75	(1.80–2.12)	48.3±3.77	(2.00–2.40)
Myomere Number												
Predorsal	5.14±1.24	(3.00–8.00)	4.92±0.87	(3.00–6.00)	6.00±0.00	(6.00–6.00)	5.00	(5.00–5.00)				
Soft dorsal			15.0	(15.0–15.0)	16.7±0.58	(16.0–17.0)						
Preanal	15.0±0.00	(15.0–15.0)	15.0±0.00	(15.0–15.0)	15.0±0.00	(15.0–15.0)	15.0	(15.0–15.0)				
Postanal	21.0±0.00	(21.0–21.0)	21.0±0.00	(21.0–21.0)	21.0±0.00	(21.0–21.0)	21.0	(21.0–21.0)				
Total	36.0±0.00	(36.0–36.0)	36.0±0.00	(36.0–36.0)	36.0±0.00	(36.0–36.0)	36.0	(36.0–36.0)				

[a] Proportion expressed as percent head length.

Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

Table 100

Meristic counts and size (mm TL) at the apparent onset of development for *E. nigrum nigrum*

Attribute/event	*Etheostoma nigrum nigrum*	Literature
Branchiostegal Rays	5,5[6]	5,5[2,3,13,19,20,22]
Dorsal Fin Spines/Rays	VI–X/9–12[6]	VI–X/9–15[2,3,13,19,20,22,23]
First spines formed	7.9–8.2[6]	9–10[25-27]
Adult complement formed	7.9–8.3[6]	9–10[25-27]
First soft rays formed	7.9–8.2[6]	9–10[25–27]
Adult complement formed	7.9–8.3[6]	9–10[25-27]
Pectoral Fin Rays	10–12[6]	10–14[2,3,13,19,22,23]
First rays formed	6.3[6]	9–10[25–27]
Adult complement formed	6.6–7.2[6]	9–10[25–27]
Pelvic Fin Spines/Rays	I/5[6]	I/5[2,3,13,19,22]
First rays formed	8.2–8.3[6]	9–10[25–27]
Adult complement formed	8.2–8.3[6]	9–10[25–27]
Anal Fin Spines/Rays	II/8–9[6]	I–II/6–10[2,3,13,19,20,22,23]
First rays formed	7.9–8.2[6]	9–10[25-27]
Adult complement formed	8.2–8.3[6]	9–10[25-27]
Caudal Fin Rays	vi–ix, 7–9+8–9, vi–ix[6]	13–15[19,24]
First rays formed	6.5–6.7[6]	9–10[25–27]
Adult complement formed	8.2–9.7[6]	9–10[25–27]
Lateral Line Scales	54–63[6]	50–69[2,3,13,19,20,22,23]
Myomeres/Vertebrae	36/36[6]	Unknown/36–39[2,3,19,21]
Preanal myomeres	15[6]	15[27]
Postanal myomeres	21[6]	21[27]

Pigmentation
4.9–5.4 mm TL. (newly hatched). Eyes pigmented; melanophores dorsally on the cranium covering the optic lobe. Lateral melanophores covering the otic capsule; several cutaneous melanophores at the base of the anus, forming 6–8 clusters of melanophores mid-ventrally. Ventral stellate melanophores cover the yolk sac from the anterior oil globule to the origin of the gut.[6]

POST YOLK-SAC LARVAE

See Figure 91

Size Range
5.4–6.0* mm TL to 10.1 mm TL.[6]

Myomeres
Preanal 15 (N = 81, mean = 15.0); postanal 21 (N = 81, mean = 21.0); with 36 total. Total vertebrae count 36 (N = 3), including one urostylar element.[6]

Morphology
5.4–5.6 mm TL. Digestive system functions prior to complete yolk absorption (5.6 mm); yolk absorbed (5.4–5.6 mm).[6]

5.6–6.5 mm TL. Operculum and gill arches function (5.6–6.5 mm); premaxilla and mandible form (5.8 mm).[6]

6.1–6.3 mm TL. Notochord flexion preceding caudal fin ray development.[6]

6.5–6.8 mm TL. Neuromast development occurs midlaterally from the anterior trunk posteriad (6.7 mm); snout pointed (6.8 mm).[6]

6.9–7.2 mm TL. Branchiostegal rays form.[6]

7.2–8.5 mm TL. No swim bladder forms; gut straight, without striations, portion of gut posterior to stomach short in length.[6] Upper jaw equal with lower jaw, mouth subterminal.[6]

Morphometry
See Table 99.[6]

Fin Development
See Table 100.

6.1–6.3 mm TL. Notochord flexion preceding caudal fin ray development (6.1–6.3 mm); first rays form in pectoral (6.3 mm).[6]

6.5–6.8 mm TL. Caudal fin rays form.[6]

7.9–8.2 mm TL. Dorsal and anal finfold partially differentiated (7.9 mm); spinous and soft dorsal fins simultaneously form (7.9–8.2 mm); anal fin rays form (7.9–8.2 mm); pelvic fin buds form anterior to dorsal fin origin after complete yolk absorption (8.2 mm).[6]

7.9–8.3 mm TL. Spinous dorsal fin origin situated over preanal myomere 4–6, soft dorsal origin over preanal myomere 13 (7.9–8.3 mm). Average predorsal length 31.7% SL (range: 20.9–33.4% SL), and 29.6% TL (range: 19.5–31.1% TL).[6]

8.3 mm TL. Both dorsal and anal finfolds completely differentiated (8.3 mm).[6]

8.2–8.3 mm TL. First pelvic fin ray forms.[6]

Pigmentation
5.5–6.0 mm TL. Melanophores dorsally on the cranium covering optic lobe; several dorsal melanophores on the nape, anterior future spinous dorsal and posterior future soft dorsal fin insertion. Lateral melanophores covering the otic capsule; pigment outlining the operculum; subdermal melanophores on dorsum of the gut; several cutaneous melanophores at the base of the anus, forming 6 to 8 clusters of melanophores mid-ventrally.[6]

6.1–8.2 mm TL. Concentrated melanophores dorsally over the optic lobe, extending posteriorly onto the nape and forming a cluster at the future spinous dorsal fin origin and future soft dorsal fin insertion. Lateral melanophore pigmentation similar to previous interval with the addition of several subdermal melanophores in the epaxial musculature of the caudal peduncle. Ventral melanophores form a cluster at the breast and extend posteriorly along the mid-ventral to the end of the stomach.[6]

8.5–10.1 mm TL. Preorbital and postorbital bar forming; melanophores cover the cerebellum and optic lobe, forming 4–5 dorsal saddles along the dorsum, anterior spinous dorsal fin, along the entire length of the spinous dorsal fin, mid-soft dorsal fin, and at soft dorsal fin insertion. Lateral melanophores forming nine distinct clusters along the mid-lateral line from the shoulder to the base of the caudal peduncle. Dorsally over the gut subdermal melanophores formed from the shoulder to the anus. Ventral melanophores at the anal fin; lepidiotrichia interdigitation with the pterigiophores. A dense accumulation of melanophores at the base of the caudal fin radiating into the middle of the fin.[6]

JUVENILES

See Figure 92

Size Range
10.1 mm[6] to 39–63 mm TL[7,*]

Fin Development
See Table 100.

9.6–10.7 mm TL. Complete adult fin ray counts in median fins.[6]

10.1–14.8 mm TL. Caudal fin rays with segmentation, rounded.[6]

Morphology
13.5–13.7 mm TL. Initiation of squamation across dorsum and mid-lateral line;[6]

13.5–14.5 mm TL. Squamation complete (13.6–14.5 mm); lateral line began forming (13.5–13.7 mm).[6]

15.3 mm TL. Supraorbital, infraorbital, lateral, and subtemporal head canals formed.[6]

23.4 mm TL. Infraorbital and subtemporal canal interrupted, infraorbital with six pores; lateral and supraorbital head canals complete; preoperculomandibular canal complete with 9–10 pores.[6] The nape, cheek, and breast unscaled.[2–4,6] Scales in the lateral series ranging from 43 to 59.[13]

Morphometry
See Table 99.

Pigmentation
10.1–14.5 mm TL. (early juvenile). Preorbital and postorbital bar forming; melanophores cover the cerebellum and optic lobe, forming 4–5 dorsal

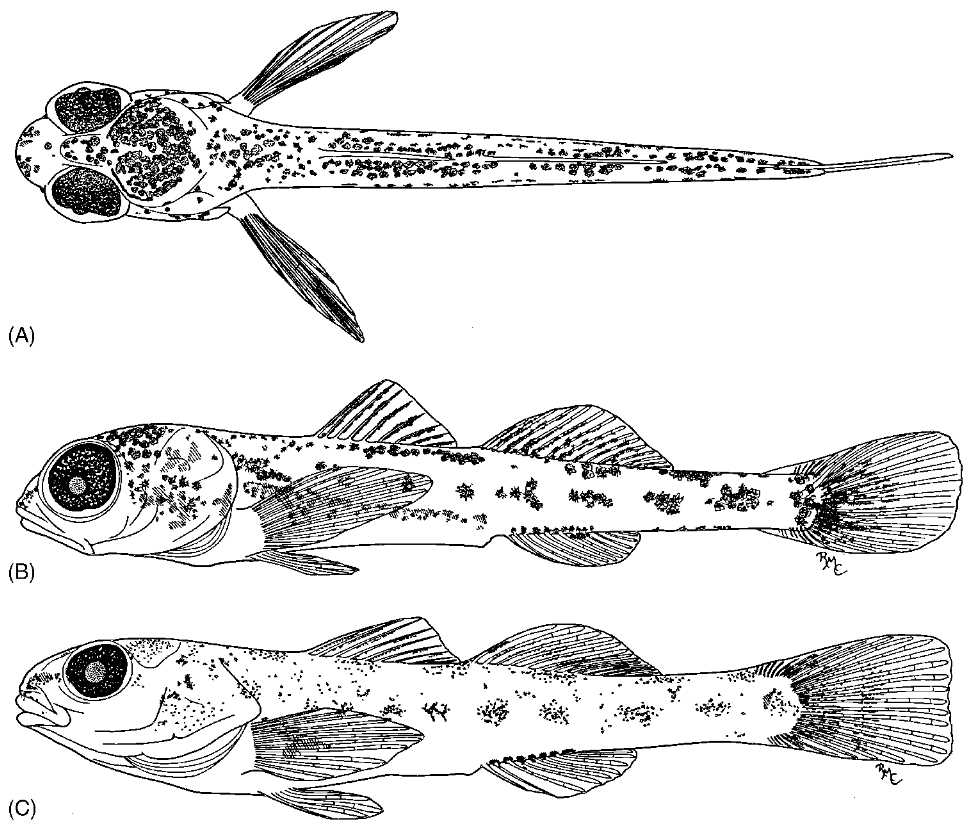

Figure 92 *Etheostoma n. nigrum*, central johnny darter, Mississippi River, Buffalo County, WI. Early juvenile, 9.7 mm TL: (A) dorsal, (B) lateral views. Juvenile, 17.0 mm TL, (C) lateral view. (A–C from reference 6, with author's permission.)

saddles along the dorsum, anterior spinous dorsal fin, along the entire length of the spinous dorsal fin, midsoft dorsal fin, and at soft dorsal fin insertion. Lateral melanophores forming nine distinct clusters along the mid-lateral line from the shoulder to the base of the caudal peduncle. Dorsally over the gut subdermal melanophores form from the shoulder to the anus. Ventral melanophores at the anal fin; lepidiotrichia interdigitation with the pterigiophores. A dense accumulation of melanophores at the base of the caudal fin radiating into the middle of the fin.[6]

15.0–23.4 mm TL. Preorbital bar formed; cranial melanophores cover the cerebellum and optic lobe; six dorsal saddles present from the nape to the caudal peduncle base. Lateral melanophores forming a chevron in the hypaxial portion of the operculum, forming ten lateral clusters from the shoulder to the caudal peduncle base; lateral clusters forming W-, X-, Y-markings. Ventral melanophores consist only of the anal fin interdigitation melanophores. Spinous dorsal fin with a proximal and medial stripe; soft dorsal fin with medial melanophores stripe; and caudal fin with 2–3 vertical stripes. The pectoral, pelvic, and anal fins are unpigmented.[6]

TAXONOMIC DIAGNOSIS OF YOUNG JOHNNY DARTER

Similar species: members of subgenus *Boleosoma* and *Vallantia.*

Adult. The *E. nigrum* group consists of three nominal subspecies, *E. n. eulepis, E. n. nigrum,* and *E. n. susanae*.[5] The subspecies *E. n. eulepis* is characterized by the more extensive squamation of the nape, cheek, and breast.[14] Lagler and Bailey[4] indicated a genetic basis for the inheritance of observed scalation in laboratory spawned individuals. Adult *E.n. eulepis* are larger than *E. n. nigrum,* and also possess melanophore markings on the cheek, which are absent in subspecies *E. n. nigrum* (T.P. Simon, unpublished data). Subspecies *E. n. susanae* is confined to the Cumberland River above Cumberland Falls.[15] *Etheostoma susanae* is distinguished from *E. n. nigrum* based on the absence of the scales on thetop of cranium, opercle and midbelly being scaleles; preoperculomandibular canal always interrupted near mandible articulation, and an interrupted preorbital stripe.[3,15]

Larva. The two studied subspecies of *E. nigrum* can be differentiated by the presence of dorsal pigmentation on the head, large size at hatching, and more extensive lateral pigmentation in *E. n. nigrum*. Mid-ventral postanal pigmentation in *E. n. eulepis* usually consists of 4–6 clusters, while in *E. n. nigrum* the clusters number 6–8.[6]

Variation

Geographic variation shows no deviation in meristic or myomere expression in the Great Lakes and Mississippi River drainage populations.[6] Slight differences in size at hatching are observed between the eastern and western populations of the Mississippi River. The Iowa River, IA, and Fox River, IL, populations hatch at 4.7–5.0 mm and 4.9–5.4 mm, respectively. Significant differences in hatching size are observed between Lake Superior and Mississippi River populations. Lake Superior specimens hatch at smaller length intervals, 4.3–5.4 mm and Mississippi River populations hatch at 4.9–5.4 mm, respectively. No differences in pigmentation or morphometric expression were observed.[6]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 93)

Eggs. Egg sites include the underside of large rocks, slab limestone rocks, sticks, woody debris, submerged logs, and tin cans.[6,7,9–11]

Yolk-sac larvae. Aquarium observations show that johnny darter larvae are demersal immediately after hatching.[6] In the Middle Fork Drakes Creek, KY, yolk-sac larvae are collected from vegetated shoreline and algal-covered rocks, over gravel substrates, and within root structures along bank habitat.[16]

Post Yolk-sac Larvae. Larva remain in close association with the substrate.[6] Larvae from the St. Louis River estuary of Lake Superior, MN , are collected from late May until early August. Peak densities average 37/100 m^3 in mid-June, with larvae primarily in bottom larval tows at temperatures between 11.7 and 21.1°C (T.P. Simon, unpublished data). In tributaries of the Mississippi River, WI, MN, and IL, larvae and early juveniles utilize silted sand and gravel littoral areas downstream of pools and near shore margins of riffles adjacent to spawning areas as nursery habitats.[6] Sampling during May, in the middle Ohio River, ORM 572, McAlpine Pool main channel habitats, revealed densities of 0.9/100 m^3 johnny darter larvae, collected at 17.2°C in bottom plankton net samples.[17]

Juveniles. Juvenile stages of development remain associated with the substrate.[6] Juveniles greater than 18 mm TL are the smallest individuals found along the margins of run habitat.[6]

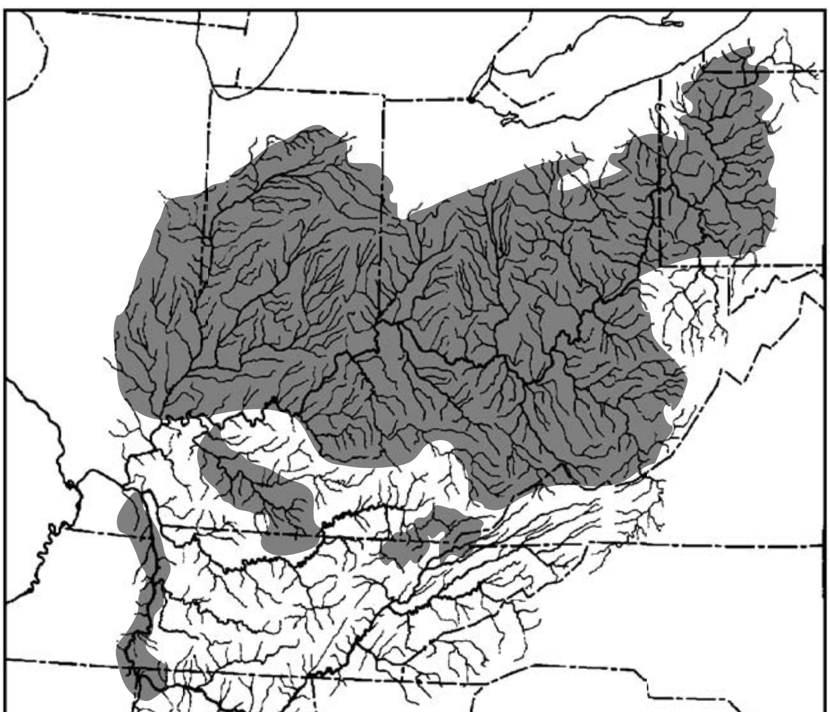

Figure 93 Distribution of johnny darter, *E. nigrum*, in the Ohio River system (shaded areas).

Early Growth (see Table 101)
Young-of-the-year johnny darters reach lengths of 18 mm by September in IN (T.P. Simon, unpublished data). Specimens from TN reach lengths of 29–38 mm at the end of the first year of growth.[19] The length–weight relationship is log $W = -12.9211 + 3.2972 \log L$, where weight is in g- and total length is in mm.[7]

Feeding Habits
Early juveniles consumed equal portions of chironomid, blackfly larvae, *Hyallela* and entomostracans.[18] Juveniles (15 mm) fed on entomostracans and minute midge larvae.[28] Adult diets include 50% chironomids, and black fly larvae, with *Hyallela* and entomostracans making up the remainder. Feeding occurs primarily during the day;[30] sight is the primary sense used to capture prey.[31]

Table 101

Average calculated lengths (mm TL) of young johnny darter from Tennessee and Wisconsin.

	Age		
State	**1**	**2**	**3**
Tennessee[19]	29–38	43–51	60+
Wisconsin[7]	32–67	37–77	68

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Material Examined: *E. n. nigrum*. MN: Fillmore Co.: Root River, near Mystery Caves, LRRC 914 (5); St. Louis Co.: St. Louis River, M.L. Hibbard Station, Duluth, T 49N R 14W S 8, LRRC 617 (3); LRRC 618 (2); LRRC 619 (4); LRRC 620 (3); LRRC 621 (1); LRRC 622 (1). WI: Buffalo Co.: Mississippi River, Pool 5, Alma, Alma Twp., T 21N R 13W S 11/14. LRRC 915 (4); LRRC 916 (1); LRRC 917 (2); LRRC 918 (5); LRRC 919 (7); LRRC 920 (2). Vernon Co.: Coon Creek, at SR 162 bridge, 2.5 miles SW Coon Valley, T 14N R 6W S 24. LRRC 921 (5); LRRC 922 (5); LRRC 923 (3); LRRC 924 (2); LRRC 925 (5); LRRC 926 (5); LRRC 927 (5); LRRC 928 (5); LRRC 929 (3); LRRC 930 (5). Mississippi River, Pool 9, downstream Genoa, T 13N R 7W S 29. LRRC 931 (3). Mississippi River, Thief Island, Pool 9, at Genoa Power Station, T 13N R 7W S 29. LRRC 932 (1); LRRC 933 (1); LRRC 934 (1). LaCrosse Co.: Mississippi River, 1.5 miles SW LaCrosse, Pool 8, Shelby Twp., T 15N R 8W S 7, LRRC 935 (1); Mississippi River, Pool 7, 1.3 miles NW LaCrosse, Campbell Twp., T 16N R 8W S 25/26, LRRC 936 (1). Monroe Co.: LaCrosse River, Sparta, Sparta Twp., T 17N R 4W S 23, LRRC 937 (5). Black River, Richmond Bay-Catgut slough, 1.0 miles S Onalaska, Onalaska Twp., T 16N R 7W S 5, LRRC 938 (1). IL: Ogle Co.: Rock River, Byron, Byron Twp., T 25N R 11E S 32, LRRC 939 (1).

* Original fecundity data for johnny darter from an unnamed creek Wabash River, Allen County, IN. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Early life history developmental series cultured from laboratory spawned specimens curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

BARCHEEK DARTER

Etheostoma (Catonotus) obeyense Kirsch

Etheostoma: various mouths; *obeyense*: of the Obey River.

RANGE

Etheostoma obeyense is restricted but locally common in the Nashville Basin tributaries to the middle Cumberland River and lower Caney Fork River, KY and TN.[1–6]

HABITAT AND MOVEMENT

The preferred habitat of the barcheek darter is moderate to sluggish flowing pools in small- to medium-sized creeks.[1–6] In larger systems, such as the Little South Fork, KY, the species occurs in headwater. The preferred substrates are slab limestone rubble or small flat stones scattered over bedrock or sand and gravel.[4–6] Sometimes the species occurs in sandy areas with detritus.[5]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma obeyense is extremely localized, occurring in streams tributary to the Cumberland River and lower Caney Fork in DeKalb, Putnam, Smith, and Wilson Counties, TN.[1–5] The species has been locally common and sometimes abundant from the Obey River to the Big South Fork.[2,3,5]

SPAWNING

Location
Underside of slab rocks,[9,10] similar to other *Catonotus*.

Season
Spawning occurs from late April to June;[5,6,9,10] breeding occurs in April and May in KY.[2]

Temperature
Unknown.

Fecundity (see Table 102)
Females produced about 33–158 ova per year.[5,6,9,10] Nests had single-layered clusters ranging from 22 to 622 eggs on the underside of a stone.[9–10] Our data show that females (40–56 mm TL) collected in mid-April from Marrow Bone Creek, Cumberland County, KY, had ovaries that were 18.3% of the body weight, and contained 374.9 total ova averaging 0.719 mm diameter.*

Sexual Maturity
Adults live to age 3,[5–6] however, maturity is reached at age 1 for females and age 2 for males.[6,9] Male tuberculation was absent. Females may develop traces of yellow on the body, cheek bar, and appropriate fins, but are not colorful. The female genital papilla has an oval pad with radiating grooves. Males exhibited sexually dimorphic traits during the reproductive season with the pectoral and pelvic fins darkening, as does the head and breast region; small fleshy swellings occur on the tips of dorsal spines and the genital papilla is a small trianglar flap.[2] Sexually mature by 38 mm TL in KY (Table 102).

Spawning Act
Etheostoma obeyense is a clusterer.[6,9] Adults deposit their eggs on the underside of slab rocks, where they are guarded by a male.[6] Males court females by erecting fins, intensifying their color, and by wagging tail their. When a female enters a nest, she assumes a belly-up position. The male joins her, pressing alongside and spawning occurs with 2–5 eggs deposited during each encounter.[6,9] A nest may contain as many as 622 eggs from several different females.[5,9,10]

EGGS

Description
Eggs from Fishing Creek, KY, are spherical, mean = 2.2 mm diameter (range: 2.0–2.7 mm); translucent; demersal; and adhesive. Eggs possess translucent, amber yolk (mean = 2.1 mm diameter; range: 1.9–2.6 mm); a single oil globule (mean = 0.5 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[*,10]

Incubation
Unknown.

Table 102

Fecundity data for barcheek darter from Marrow Bone Creek, Cumberland County, KY.*

			Number of Ova			
Date	TL (mm)	GSI	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
12 April	56	14.7	435	67	89	1.42
	56	14.3	281	81	95	1.53
	54	24.7	356	92	89	1.66
	53	13.9	270	51	67	1.53
	49	21.9	285	109	59	1.66
	45	25.7	268	85	78	1.66
	44	20.3	148	58	42	1.66
	41	19.5	130	55	31	1.66
	40	13.3	110	41	42	1.33
	38	14.8	91	59	59	1.2

Development
Unknown.

YOLK-SAC LARVAE

Size Range
KY populations from Fish Creek hatch between 6 and 7 mm TL[10] and yolk absorbed at unknown lengths.

Myomeres
Preanal 16, postanal 22 or 23, with total 38 or 39[10].

Morphology
6–7 mm TL (newly hatched). Body terete; nout blunt; with functional jaws, upper jaw even, slightly extending past lower jaw; well-developed pectoral fins with incipient rays; yolk sac large (36.6% TL), spherical; yolk translucent, clear to pale yellow, with a single oil globule; complex vitelline vein network mid-ventrally on yolk sac; head not deflected over the yolk sac; and eyes oval.[10,*]

8 mm TL. Digestive system functions and complete yolk absorption.[10]

Morphometry
Unknown.

Fin Development
See Table 103.

6–7 mm TL. Well-developed pectoral fins with incipient rays.[10]

Pigmentation
6–7 mm TL (newly hatched). Eyes pigmented; melanophores dorsally over anterior and posterior cerebellum and nape; melanophores distributed laterally, dorsally over the gut posterior to the yolk sac; ventral pigmentation consists of mid-ventral scattered stellate melanophores surrounding the vitelline vein on the yolk sac, and punctate melanophores along every mid-ventral postanal myosepta.[10]

POST YAC-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Table 103

Meristic counts and size (mm TL) at the apparent onset of development for *E. obeyense.*

Attribute/Event	*Etheostoma obeyense*	Literature
Branchiostegal Rays	6,6	6,6[2,3,5–8,12]
Dorsal Fin Spines/Rays	VIII–X/12–14	VIII–X/12-15[2,3,5–8,12]
First spines formed	8.4–9.0	
Adult complement formed	9.3–9.8	
First soft rays formed	6.7–7.2	
Adult complement formed	8.5–9.0	
Pectoral Fin Rays	12	11–14[2,3]
First rays formed	8.4	
Adult complement formed	8.4	
Pelvic Fin Spines/Rays	I/5	I/5[2,3,5–8,12]
First rays formed	8.5–9.6	
Adult complement formed	8.5–9.6	
Anal Fin Spines/Rays	II/7–10	II/7–10[2,3,5–8,12]
First rays formed	7.7–8.4	
Adult complement formed	8.4–9.0	
Caudal Fin Rays	vii–xi, 9+8, viii–xi	15–18[5]
First rays formed	6.4–7.2	
Adult complement formed	8.4–9.0	
Lateral Line Scales	47–53	39–56 [2,3,5–8,12]
Myomeres/Vertebrae	38–39/37	Unknown/36–37[2,3,5,12]
Preanal myomeres	16	
Postanal myomeres	22–23	

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown to sexually mature as small as 38 mm TL.*

Fin Development
Larger juveniles. Spinous dorsal fin VIII–X; soft dorsal rays 12–15; pectoral rays 11–14; anal fin rays II 7–10; pelvic fin rays I 5; caudal fin rays 15–18.[1–3]

Morphology
Vertebrae 36–37. [2,5–8] Scales in the lateral series incomplete with 10–26 pored scales and 39–56 total scales in the lateral series from TN. [2–5]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG BARCHEEK DARTERS

Similar species: similar to other members of the *Catonotus* subgenus.

Adult. *Etheostoma obeyense* is similar to and sympatric with *E. kennicotti, E. flabellare, E. percnurum,* and *E. virgatum*.[2,3–5] The barcheek darter can be differentiated from *E. percnurum* and *E. kennicotti* by the dark blotch at the anterior base of the spinous dorsal fin and the pale bar on the cheek, which the other species do not possess. *Etheostoma flabellare* differs from *E. obeyense* by the broad connection of the gill membranes, lacking the oblique pale bar on the cheek, and in the areas of sympatry, possesses rows of horizontal lines along the sides.

Larva. *Etheostoma obeyense* can be separated from other *Catonotus* species based on differences in size at hatching, myomere counts, and differences in pigmentation. *Etheostoma obeyense* has higher preanal myomere counts than *E. flabellare* and fewer postanal myomeres than *E. percnurum* and *E. kennicotti*. *Etheostoma obeyense* hatches at the largest size of any other *Catonotus,* and has more pigmentation than the other species.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 94)
Eggs. Eggs are laid on the underside of slab rocks.[2–6]

Yolk-sac larvae. Yolk-sac larvae remain buried in interstitial pore spaces beneath the slab rock nests.*

Post yolk-sac Larvae. Larvae are benthic and would rarely be collected in drift samples. The precocious fin ray development is consistent with greater parental investment.[11]

Juveniles. Juveniles were found in the gently flowing pools and riffle edges among slab rocks.[9,10]

Early Growth
Specimen reaches 32–42 mm SL at age 1.[5,10] (Table 104).

Feeding Habits
The diet is dominated by midge larvae and mayfly nymphs; young feed heavily on microcrustaceans, including copepods.[5,9,10]

Table 104

Average calculated lengths (mm SL) of young barcheek darter in Tennessee.

State	Age 1	Age 2	Age 3
Tennessee[5–10]	32–42	42–60	60–85

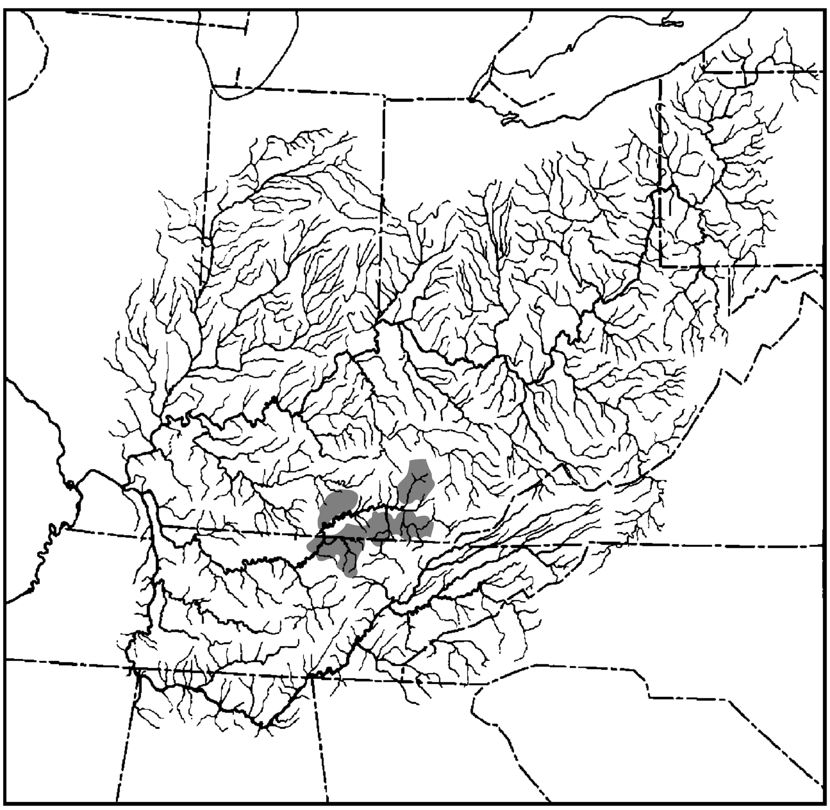

Figure 94 Distribution of barcheek darter, *E. obeyense* in the Ohio River system (shaded area).

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* Original fecundity data for barcheek darter from Marrow Bone Creek, Cumberland County, KY. Specimens curated at Northeast Louisiana University, Museum of Zoology, Monroe. Original observations of early life ecology by T.P. Simon, unpublished data.

DIRTY DARTER

Etheostoma (*Catonotus*) *olivaceum* Braasch and Page

Etheostoma: various mouths; *olivaceum*: refers to the olive color of nonbreeding individuals, common name referred by D.A. Etnier, referring to its drab color and indistinct mottling on the sides.

RANGE

Etheostoma olivaceum occurs in direct tributaries of the Cumberland River in Trousdale and Smith Counties, and more abundantly in small tributaries of the lower Caney Fork system in central TN.[1–4]

HABITAT AND MOVEMENT

Etheostoma olivaceum inhabits small streams with an abundance of large rocks or bedrock. It occurs in streams 1–2 m wide. Females and young are found in pools, while large males are often found in riffles.[1–4] Occurs in streams with mean width of 3.7 m, depth of 0.2 m, gradient of 7.6 m/km, and water velocity of 0.2 m/s.[8] Found in spring-fed streams that ranged from 3 to 13 m wide with a depth range from 5 to 25 cm.[5]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma olivaceum is endemic to small tributaries of the lower Caney Fork River, and tributaries of the Cumberland River in Cannon, DeKalb, Putnam, Smith, Trousdale, and Wilson Counties, TN.[5] It occurs in the Nashville Basin physiographic province or the boundary region between the Nashville Basin and eastern Highland Rim. Downstream of Center Hill Dam it was found in Snow Creek, Mulherrin Creek, Hickman Creek, Smith Fork Creek, Rock Spring Branch, and Big Indian Creek. It was also collected from three tributaries of Center Hill Reservoir in Delkalb and Putnam Counties: Mine Lick Creek, Fall Creek, and Pine Creek. In the Cumberland River drainage, it was collected from Dixon Creek, Peyton Creek, Hogan Creek, Smith and Trousdale Counties, TN.[5]

SPAWNING

Location

Spawning occurs on the underside of trash (tin can), on pieces of tile, and on slab rocks.[7]

Season

Etheostoma olivaceum selected cavities under slab rocks and defended them during March and April in Brush Creek, TN.[7] Spawning possibly extends until May.[7]

Temperature

Spawning occurred in Brush Creek, TN, when water temperatures ranged from 17 to 19°C.[7]

Fecundity (see Table 105)

The female dirty darter showed no significant relationship between increasing fecundity (ANOVA, $F = 3.350$, $p = 0.105$) and increasing length in either Mine Lick Creek[7] or Brush Creek,[6] TN samples. Two 66 mm females had 215–283 large mature ova, while several 57 mm females had 35–74 large mature ova (T.P. Simon, unpublished data).[7] Small ova appeared in early October, yellow ova in early February, and orange ova in March.[6]

Sexual Maturity

Females 36 mm contained mature ova and were sexually mature,[6] while males less than 43 mm failed to have breeding colors and enlarged testes and probably did not spawn.[7]

Spawning Act

Etheostoma olivaceum is a nest cluster. Eggs were found on the underside of stone, a tin can, and a piece of tile in Brush Creek. A single spawning attempt was witnessed from aquarium observation and was identical to *E. squamiceps*. The female only briefly inverted to deposit eggs, unlike all other *Catonotus* species in which the female remains inverted for the duration of egglaying, which may last for hours. Trash was used as a nesting site although most nests were on stones. Eggs were packed tightly in a concentrated area, but were not laid on top of others. In a single instance, two nests were found beneath the same stone when lifted from the stream. The margins of the nests were only 15 cm apart, and presumably when the stone was partially embedded in the stream bed, the two guarding males were hidden from each other. Counts and estimates of the number of eggs in 19 nests averaged 486 (range: 107–1500). Males of *E. olivaceum* remain beneath their nest stones after spawning, and guard the eggs until hatching.[6]

Table 105

Fecundity data for *E. olivaceum* from Mine Lick Creek, Putnam County, TN.[7]

Length (mm TL)	Ovary Weight (mg)	Number of Ova: Ripening Oocytes (LA)	Number of Ova: Mature Oocytes (EM, MA, LM)	Number of Ova: Ripe Eggs (MR, RE)	Egg Diameter (mm)
43	5.4	95	35	28	1.42
52	9.4	142	69	0	—
57	269	145	65	51	2.00
57	186	117	49	35	1.81
57	226	174	77	74	1.66
60	232	158	60	64	1.81
62	245	126	67	70	1.66
65	248	160	56	85	1.53
66	424	112	84	87	1.81
66	247	104	51	60	1.81

EGGS

Description
Ovarian examination showed that ovoid latent ova were 0.5–0.66 mm, early maturing ova were deeply indented similar to *E. proeliare* and averaged 0.83–1.33 mm, and large mature ova averaged 1.42–2.0 mm.[7] Eggs from Brush Creek, TN, are spherical, mean = 2.0 mm diameter (range: 1.9–2.2 mm); transparent, demersal, and adhesive. Eggs possessed translucent clear to pale-yellow yolk (mean = 1.8 mm diameter; range: 1.7–1.9 mm); a single oil globule (mean = 0.2 mm; range: 0.18–0.24 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[7]

Incubation
Hatching occurs after 216 h at an incubation temperature of 22°C.[7]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 95

Size Range
6.6–6.8; yolk absorbed by 7.2 mm.[7]

Myomeres
Preanal 16 (N = 5), postanal 23 (N = 5), with 39 total. Total vertebrae count 38 (N = 3), including one urostylar element.[7]

Morphology
6.6–6.8 mm TL. Newly hatched larvae possess a terete body; snout blunt; functional jaws, with upper jaw even, to slightly overhanging lower jaw; yolk sac moderate (24.8% of TL), oval and robust, but not spherical; yolk translucent, pale yellow, with a single oil globule; mid-ventral vitelline vein plexus on yolk sac; head not deflected over the yolk sac; and eyes spherical.[7]

Morphometry
See Table 106.[7]

Fin Development (see Table 107)
6.6–6.8 mm TL. Newly hatched larva with well-developed pectoral fins with incipient rays.[7]

7.0–7.2 mm TL. Digestive system functions prior to complete yolk absorption.

Pigmentation
6.6–6.8 mm TL. Newly hatched larvae with pigmented eyes; and melanophores dorsally on the cranium cover the optic lobe and extend along the nape to the anterior dorsal finfold. Melanophores extend along the opercle, and outline the dorsum of

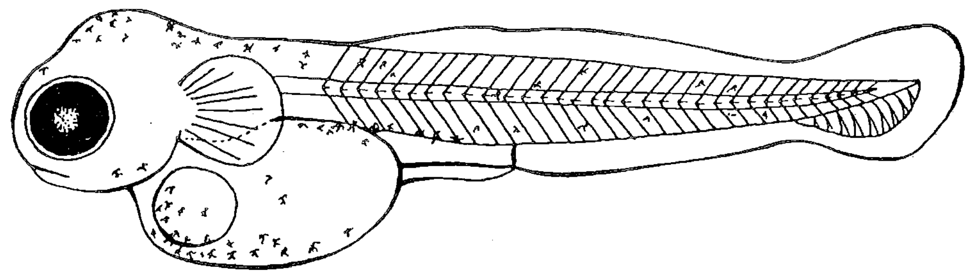

Figure 95 *Etheostoma olivaceum*, dirty darter, Brush Creek, Smith County, TN, 6.8 mm TL, lateral view. (From reference 7, with permission.)

Table 106

Morphometric data expressed as percentage of HL and TL for young *E. olivaceum* from Tennessee.[7] Mean and standard deviation in parentheses.

	TL Groupings				
Length Range (mm)	**6.6–7.4**	**7.9–12.6**	**15.0–19.8**	**20.0–25.5**	**25.9–26.4**
N	**8**	**5**	**22**	**21**	**6**
(Mean ± SD)					
As Percent HL					
SnL	12.5 ± 1.2	18.2 ± 2.1	19.9 ± 2.1	19.6 ± 2.2	20.2 ± 2.1
ED	50.04 ± 3.6	46.4 ± 2.5	32.9 ± 1.1	28.2 ± 1.2	27.5 ± 0.9
As Percent TL					
HL	18.6 ± 0.9	25.1 ± 1.8	24.8 ± 1.2	24.8 ± 1.3	24.7 ± 0.9
Preanal	53.5 ± 1.7	50.0 ± 2.5	49.7 ± 2.6	49.2 ± 1.7	48.7 ± 0.8
PosAL	46.5 ± 1.3	50.0 ± 2.5	50.3 ± 2.6	50.8 ± 1.7	51.3 ± 0.8
SL	94.8 ± 2.3	84.2 ± 1.2	84.6 ± 1.7	83.3 ± 1.9	84.6 ± 1.5
BPED	19.8 ± 1.3	15.1 ± 0.7	14.2 ± 0.6	13.8 ± 1.0	13.7 ± 0.3
GBD	24.4 ± 3.6	19.8 ± 1.2	17.3 ± 0.9	16.6 ± 0.9	15.8 ± 0.3
BDA	9.9 ± 1.2	11.7 ± 0.9	12.6 ± 0.7	12.9 ± 0.9	12.9 ± 0.2
CPD	4.7 ± 0.5	6.8 ± 0.7	7.4 ± 0.7	7.8 ± 0.6	7.1 ± 0.6
YSL	27.9 ± 0.8				
YSD	16.3 ± 1.0				

the yolk sac and gut, extending along the midlateral along the notochord. Ventral melanophores scatter along the distal third of the yolk sac and extend into the central half of the yolk sac.[7]

POST YOLK-SAC LARVAE

Size Range
7.3–10.2 mm TL.[7]

Myomeres
Preanal 16 (N = 3), postanal 23 (N = 3), with 39 total. Total vertebrae count 38 (N = 3), including one urostylar element.[7]

Morphology
7.3 mm TL. Yolk absorbed.[7]

7.5 mm TL. Operculum and gill arches function; premaxilla and mandible form.[7]

7.3–7.8 mm TL. Notochord flexion precedes caudal fin ray development (7.3–7.8 mm);[7] branchiostegal rays form (7.4–7.8 mm).[7]

7.9–8.3 mm TL. No swim bladder forms; gut straight, without striations, portion of gut posterior to stomach is short in length.[7]

8.5 mm TL. Upper jaw equal with lower jaw, mouth terminal.[7]

Table 107

Meristic counts and size (mm TL) at the apparent onset of development for *E. olivaceum.*

Attribute/event	*Etheostoma olivaceum*	Literature
Branchiostegal Rays	6,6[7]	6,6[2–4,10]
Dorsal Fin Spines/Rays	IX–X/12–13[7]	VIII–X/11–14[2–4,10]
First spines formed	7.9-8.2[7]	
Adult complement formed	9.6–10.7[7]	
First soft rays formed	7.9–8.2[7]	
Adult complement formed	9.6–10.7[7]	
Pectoral Fin Rays	12[7]	11–13[2–4,10]
First rays formed	6.6–6.8[7]	
Adult complement formed	9.6–10.7[7]	
Pelvic Fin Spines/Rays	I/5[7]	I/5[2–4,10]
First rays formed	8.2–8.3[7]	
Adult complement formed	9.6–10.7[7]	
Anal Fin Spines/Rays	II/7–8[7]	II/6-8[2–4,10]
First rays formed	7.9–8.2[7]	
Adult complement formed	9.6–10.7[7]	
Caudal Fin Rays	viii–xi, 8–9+8–9, ix–x[7]	15–18[2,3,10]
First rays formed	7.3–8.4[7]	
Adult complement formed	10.1–14.1[7]	
Lateral Line Scales	44–53[7]	44–58[2–4,10]
Myomeres/Vertebrae	39/37–39[7]	Unknown/37–39[2–4]
Preanal myomeres	16[7]	
Postanal myomeres	23[7]	

Morphometry
See Table 106.[7]

Fin Development
See Table 107.

7.3–7.8 mm TL. Notochord flexion precedes caudal fin ray development (7.3–7.8 mm); first rays form in pectoral (7.3 mm)[6].

7.3–8.0 mm TL. Caudal fin rays form.[7]

7.9–8.2 mm TL. Dorsal and anal finfold partially differentiated (7.9 mm); spinous and soft dorsal fins simultaneously form (7.9–8.2 mm); anal fin rays form (7.9–8.2 mm); pelvic fin buds form anterior to dorsal fin origin after complete yolk absorption (8.2 mm).[7]

7.9–8.3 mm TL. Spinous dorsal fin origin situated over preanal myomere 4 and soft dorsal origin over preanal myomere 15 (7.9–8.3 mm). Average predorsal length 31.7% of SL (range: 20.9–33.4% SL), and 29.6% of TL (range: 19.5–31.1% TL).[7]

8.3 mm TL. Both dorsal and anal finfolds completely differentiated (8.3 mm).[7]

8.2–8.3 mm TL. First pelvic fin ray forms.[7]

Pigmentation
7.2–8.2 mm TL. Melanophores present dorsally over the optic lobe, extending posteriorly onto the nape and forming a cluster at the future spinous dorsal fin origin and future soft dorsal fin insertion. Lateral melanophore pigmentation similar to previous interval. Ventral melanophores form a cluster at the breast and extend posteriorly along the mid-ventral to the end of the stomach.[7]

8.5–10.1 mm TL. Preorbital and postorbital bars form; melanophores cover the cerebellum and optic lobe. Lateral melanophores form distinct clusters along the mid-lateral from the shoulder to the base of the caudal peduncle. Dorsally over the gut subdermal melanophores form from the shoulder to the anus. Ventral melanophores at the anal fin; lepidiotrichia interdigitation with the pterigiophores. A dense accumulation of melanophores at the base of the caudal fin radiates into the middle of the fin.[7]

JUVENILES

Size Range
10.1[7] mm TL to 35–45 mm SL.[6]

Fin Development
Branchiostegal rays 6,6;[7,10] dorsal spines/rays VIII–(IX)–X/11–(12–13)–14;[7,10] pectoral fin rays 11–(12)–13;[7,10] anal spines/rays II/7–8;[7,10] pelvic fin spines/rays I/5;[7,10] caudal fin rays 16–(17)–18.[7,10]

9.6–10.7 mm TL. Complete adult fin ray counts in median fins.[7]

10.1–14.8 mm TL. Caudal fin rays with segmentation rounded.[7]

Morphology
13.5–13.7 mm TL. Initiation of squamation across dorsum and mid-laterally.[7]

13.5–14.5 mm TL. Squamation complete.[6,7]

15–15.3 mm TL. Lateral line began form (15 mm).[6,7] Supraorbital, infraorbital, lateral, and subtemporal head canals form (15.3 mm).[7]

>20 mm TL. Lateral line incomplete, extends to the dorsal fin origin; squamation complete; infraorbital complete.[6]

23.4 mm TL. Infraorbital and subtemporal canal interrupted, infraorbital with six pores; lateral and supraorbital head canals complete; preoperculomandibular canal complete with 9–10 pores.[7] Scales present on the nape, belly, and prepectoral area; cheeks and opercles naked; and breast variably scaled.[2–4,6] Scales in the lateral series range from 43 to 59.[7]

Morphometry
See Table 106.

Pigmentation
10.1–14.5 mm TL. (*early juvenile*). Preorbital and postorbital bars form; melanophores cover the cerebellum and optic lobe, forming 4–5 dorsal saddles along the dorsum, anterior spinous dorsal fin, along entire length of the spinous dorsal fin, midsoft dorsal fin, and at soft dorsal fin insertion. Lateral melanophores form nine distinct clusters along the mid-lateral from the shoulder to the base of the caudal peduncle, while dorsally over the gut, subdermal melanophores form from the shoulder to the anus. Ventral melanophores at the anal fin; lepidiotrichia interdigitation with the pterigiophores. A dense accumulation of melanophores at the base of the caudal fin radiates into the middle of the fin.[7]

15.0–23.4 mm TL. (*juvenile*). Preorbital bar forms; cranial melanophores cover the cerebellum and optic lobe; eight dorsal saddles are present from the nape to the caudal peduncle base and join the lateral melanophores connecting to just below mid-lateral. Body mottled and dark. Ventral light along mid-ventral. Spinous dorsal fin with a proximal and medial stripe; soft dorsal fin with medial scattered melanophores; and caudal fin with five vertical stripes. The pectoral, pelvic, and anal fins are unpigmented.[7]

<20 mm TL. Juveniles had prominent round spots along the mid-lateral and distinct dorsal blotches.[4]

>20 mm TL. Specimens mottled and essentially identical to adults.[4]

TAXONOMIC DIAGNOSIS OF YOUNG DIRTY DARTER

Similar species: members of subgenus *Catanotus*.

Adult. *Etheostoma olivaceum* is distinguished from all other members of the subgenus, with the exception of *E. neopterum*, by an uninterrupted infraorbital canal with eight infraorbital pores, 10 preoperculomandibular pores, 13 or more pored lateral line scales, scales present on nape and prepectoral area, scales absent on cheek and opercle, distinct black vertical bands on caudal fin, branchiostegal membranes slightly connected, no dark suborbital bar, usually 9 dorsal spines, 12–13 dorsal rays, and 7–8 anal rays. It differs from *E. neopterum* by the absence of scales on the opercle. It is separated from the barcheek darters (*E. virgatum, E. obeyense, E. babouri, E. smithi,* and *E. striatulum*) by the lack of the bar pattern on the cheek, lack of red and blue pigments, and modally 7–8 anal rays. It differs from *E. flabellare* and *E. kennicotti* and the barcheeks by the presence of scales on the nape and prepectoral area. It differs from *E. squamiceps* by the absence of scales on cheeks and opercles, absence of a dark suborbital bar, seven scales above the lateral line modally, and 12 pectoral rays and 12 dorsal rays modally.

Larvae. Larvae possess smaller yolk sacs that are less round and more oval than other members of *Catonotus*. Dorsal pigmentation extending from the cerebellum to just posterior to the dorsal finfold origin is diagnostic.

Variation. Juveniles showed significant variation in the ratio of eye diameter to head length. No geographic variation was found.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 96)
Eggs. Eggs are guarded by an attendant male beneath the nest stone until hatching.[6]

Yolk-sac larvae. Newly hatched larvae are benthic, remaining beneath the nest stone until yolk absorption is nearly complete or hiding in the interstitial spaces of the substrate.[7]

Post Yolk-sac Larvae. Larvae are benthic and remain hidden in interstitial spaces.[7]

Juveniles. Juveniles were found over gravel or smooth bedrock in slow, shallow water;[5] in slab rock pools along the margins of the stream; and occasionally in riffles or bedrock pools.[6]

Early Growth (see Table 108)
Half of the first year's mean growth was reached in about 10 weeks, which is less than other species of *Catonotus.*[6] Young ranging from 15 to 28 mm were collected on June 18.[6] Maximum age is 2.5 years.[6]

Feeding Habits
The main diet is constituted by aquatic insects and small crustaceans.[6] Chironomid larve are consumed by all age classes; but small individuals feed heavily on microcrustaceans.[6] Mayflies are ingested by all size classes greater than 21 mm.[6]

Table 108

Average calculated lengths (mm TL) of young dirty darter in Tennessee.

	Age		
State	1	2	3
Tennessee[6]	41.8–48.5	47–53	64.8

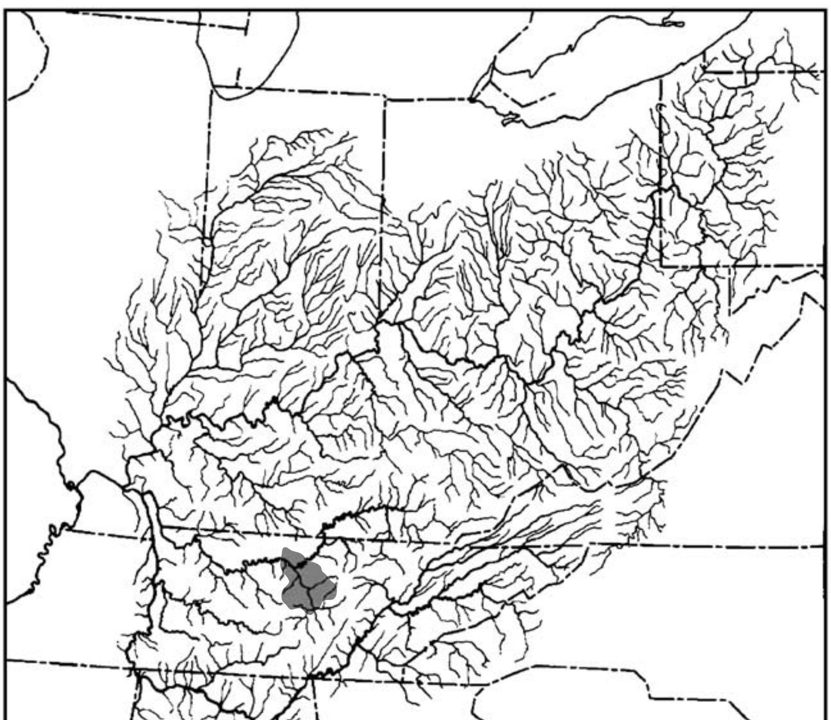

Figure 96 Distribution of dirty darter, *E. olivaceum* in the Ohio River system (shaded area).

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* Original fecundity data from Mine Lick Creek, Putnam Co., TN, curated by Northeast Louisiana University, Museum of Zoology, Monroe.

GUARDIAN DARTER

Etheostoma (*Catonotus*) *oophylax* Ceas and Page

Etheostoma: various mouths; *oophylax*: egg guarder.

RANGE

Etheostoma oophylax is limited to tributaries of the lower Tennessee River from Perry County, TN, downstream into KY.[1,2]

HABITAT AND MOVEMENT

The preferred habitat of the crown darter is small to medium upland rivers, where it occurs locally in areas of bedrock or gravel substrate in riffles or margins of riffles. Depths in these areas are 0.5–1 m, with slow-sluggish currents.[1,2]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma oophylax is limited to tributaries of the lower Tenesee River from Perry County, TN, downstream into KY.[1–3]

SPAWNING

Location
Underside of slab rocks.[3,4]

Season
Spawning occurs in mid-April.[3,4]

Temperature
Unknown.

Fecundity (See Table 109).
A nest contained 600 eggs attached to the underside of a slab rock. It was presumed that the double layer of eggs underneath the rock was contributed by several females, and was a result of limited preferred habitat.[3,4] Our observations from an unnamed creek, Calloway County, KY, suggests that females between 44 and 66 mm TL possessed between 234 and 580 ova.*

Sexual Maturity
Females mature by 44 mm TL in KY (Table 109).*

Spawning Act
Adults deposit their eggs on the underside of slab rocks where they are guarded by a male.[3]

EGGS

Description
Eggs from an unnamed creek, Calloway Co., Kentucky, are spherical, mean = 2.2 mm diameter (range: 2.0–2.5 mm); translucent; demersal; and adhesive. Eggs possess translucent, amber to orange yolk (mean = 2.2 mm diameter; range: 1.9–2.4 mm); a single oil globule (mean = 0.5 mm); a narrow perivitelline space (mean = 0.3 mm); and an unsculptured and unpigmented chorion.*

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Table 109

Fecundity data for guardian darter from an unnamed creek, Calloway County, KY.*

			Number of Ova			
Date	TL	GSI	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
March 4	66	8.8	296	158	126	1.25
	55	5.6	284	112	69	1.00
	55	4.2	230	82	35	1.00
	52	4.4	212	98	43	1.20
	52	4.9	195	89	46	1.00
	52	4.9	196	83	25	1.11
	50	4.4	178	74	48	1.00
	49	4.5	180	76	42	1.00
	48	3.6	156	61	30	0.95
	44	4.9	155	54	25	1.00

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown to 44 mm TL in KY (Table 109).*

Fin Development
Larger juveniles. Spinous dorsal fin 8–11; soft dorsal rays 10–14; pectoral rays 11–13; anal fin rays II 6–9; pelvic fin rays I 5; caudal fin rays 16–18.[1–3]

Morphology
Scales in the lateral series incomplete with 40–55 scales in the lateral series from TN.[2,3]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG GUARDIAN DARTER

Similar species: similar to other members of the *Catonous* subgenus of the *E. squamiceps* complex. Early life stages may be indistinguishable from other populations.[3] In study area it is sympatric with *E. flabellare.*[3]

Adult. *Etheostoma oophylax* is similar to *E. flabellare.* Both of the *Catonotus* species differ based on myomere counts, and differences in pigmentation.

Larva. Aspects of the early life history and reproductive biology for *E. oophylax* are unknown.

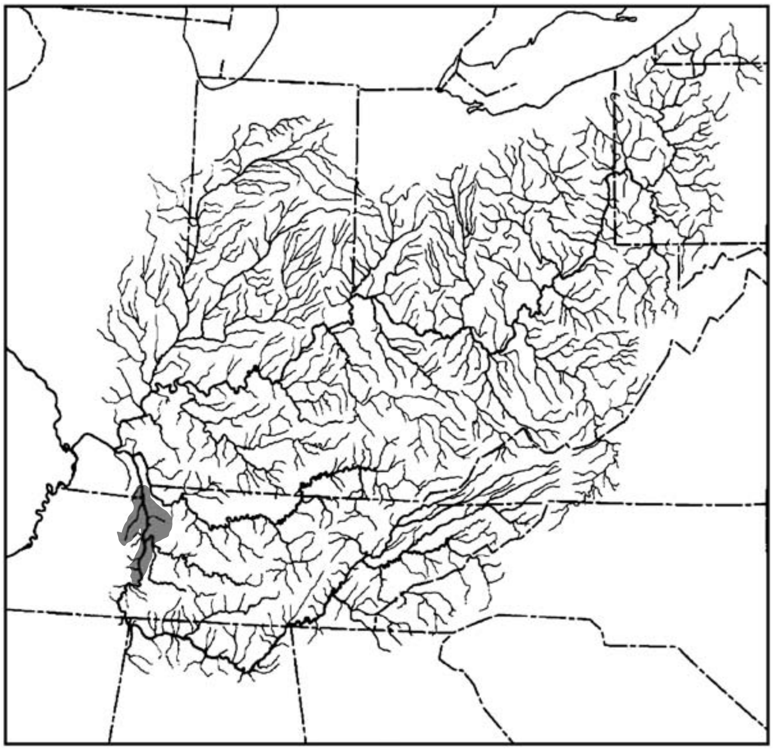

Figure 97 Distribution of guardian darter, *E. oophylax* in the Ohio River system (shaded area).

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 97)
Eggs. Eggs are laid on the underside of slab rocks.[3]

Yolk-sac larvae. Unknown.

Post Yolk-sac Larvae. Unknown.

Juveniles. Unknown.

Early Growth
Largest specimen reaches 84 mm TL.[3]

Feeding Habits
Unknown.

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* Original fecundity data for guardian darter from an unnamed creek, Calloway County, KY. Specimens curated at Northeast Lousiana University Museum of Zoology, Monroe. These specimens are curated as lollypop darter.

GOLDSTRIPE DARTER

Etheostoma (*Fuscatelum*) *parvipinne* Gilbert and Swain

Etheostoma: various mouths; *parvipinne*: short, or small fin.

RANGE

Etheostoma parvipinne is wide-ranging, but not abundant, occurring from Gates Creek, a tributary of the Red River, southeastern OK, south through eastern TX, north to southeastern MO, and east to Gulf Coastal drainages and southwestern GA.[1–3,8,9] It also occurs from the Savannah River, GA, to Brazos River, TX, and north in the Mississippi Embayment to southwestern KY and southeastern MO.[8]

HABITAT AND MOVEMENT

Etheostoma parvipinne inhabits spring-fed streams,[7–10] and occurs in a variety of habitats ranging from quiet water over a rubble bottom to moderate current over sand and gravel beds near restricted beds of filamentous algae.[7] It is also found in spring outflows that have an abundance of aquatic vegetation,[10] shallow, spring-fed streams (0.6–2.6 m wide), or spring branches of low to moderate gradient with sandy bottoms and lacking rooted vegetation because of heavy tree canopy. Specimens were most frequently collected in sand substrates, where fallen twigs, decaying leaves, and other detritus formed protected areas in long, shallow pools having slight to moderate current.[6]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma parvipinne is restricted to areas below the Fall Line, showing fidelity to the Coastal Plain. It occurs on the east side of the lower Tennessee River in a small area of Coastal Plain north of Pickwick Dam, TN.[8] and is also found in Colbert County, AL.[9] It is known from four localities in western KY, including Terrapin and Powell Creeks, Graves County, and Sugar Creek and Billie Branch, Calloway County, KY.[11] *Etheostoma parvipinne* also occurs in the Bear Creek drainage of northeastern MS.[13]

SPAWNING

Location
Spawning adults were collected from root masses, aquatic vegetation, and woody debris snags in swift chutes of Coastal Plain streams.[9]

Season
Spawning occurs from mid-March through June in AL,[9] while in MS and TN[4,8] it occurs during March and April, probably extending into May.

Temperature
Unknown.

Fecundity (see Table 110)
The female goldstripe darter did not show statistically significant increasing fecundity with increasing length.*,[4] A 48 mm SL female had 6 large mature ova and 68 maturing ova, while a 55 mm SL female had 63 mature ova and 3 ripe ova.[4] A male spawns with more than one female, and a female may spawn with multiple males, depositing 1–3 eggs at each spawning.[4]

Sexual Maturity
Males with were 49–57 mm SL and females with 43–55 mm SL were sexually mature.[4] Males were sexually dimorphic during spawning, and their body coloration changed from uniform olive–brown, or olive–brown with dark blotches to brown with a series of black vertical bars. The black teardrop darkened to become uniform black and the eye became an intense red. The pelvic and anal fins darkened to become uniform black rather than dusky, and the dorsal fin, including the dorsal spot, became intense black.[4] Males had small breeding tubercles on the distal portions of the anal fin rays.[8]

Spawning Act
Etheostoma parvipinne is an egg attacher.[4] Aquarium observations were based on the behavior of ten individuals collected from Lafayette County, MS. Males were aggressive but not territorial during spawning interactions with other males. Courtship behavior included males performing stationary

Table 110

Fecundity data for *E. parvipinne* from an unnamed spring, Lafayette County, MS[4] and Owens Creek, Union Parish, LA.[*]

Length (mm SL)	Ovary Weight (mg)	Number of Ova: Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
48[4]	—	—	68	6	0.76
55[4]	—	—	63	3	1.00
43[*]	175	1282	496	156	1.00
52[*]	132	1045	452	397	0.71
51[*]	31	1113	255	0	—
45[*]	54.9	1288	326	239	0.71

and lateral displays with erect dorsal fins. No elaborate courting displays were observed between males and females. Males chased females as they moved around the aquarium, positioning themselves on various sustrates. Females paused, and their head and body vibrated before they moved onto a spawning substrate. During spawning, a male mounted the back of a female with his caudal peduncle curved downward and to the side of hers as she positioned herself on a spawning substrate; then, the pair vibrated and an egg was released. Eggs were singly attached to the spawning substrate. Eggs were attached to plant stems (46%), plant roots above the substrate (31%), gravel substrate at the base of plants (15%), or within or on top of rock cavity (8%). Eggs were not buried in the gravel. Not all mountings resulted in the deposition of an egg. Spawning was promiscuous, with both males and females spawning with more than one partner. No parental care was provided.[4]

EGGS

Description
Ovarian examination showed that latent eggs were 0.3 mm in diameter, early mature ova were 0.50–0.66 mm in diameter, and ripe ova were 0.71–1.0 mm in diameter.* Eggs from MS were spherical, mean = 1.0 mm diameter (range: 0.85–1.1 mm); translucent, demersal, and adhesive.[4] Eggs from LA possessed orange yolk.*

Incubation
Hatching occured after 192 h at an incubation temperature of 20°C.[4]

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Newly hatched larvae are heavily pigmented.[4]

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown to 43–51 mm SL.*

Fin Development
Branchiostegal rays 6,6,[8] dorsal fin spinous/soft rays VIII–(IX–X)/9–(10)–12;[5,6,8,9,12] pectoral rays 13–(14–16)–17;[8] anal spines/rays I–(II)/7–(8)–9;[5,6,8,9,12] pelvic spines/rays I/5;[5,6,8,9,12] caudal fin 14–(16)–18.[12]

Richards[12] found that 67% of the specimens measured had two anal spines, while Etnier and Starnes[8] found that 67% of TN specimens had a single anal spine.

Morphology
Lateral line scales 49–57;[5,6,12] vertebrae 36–38;[8] infraorbital canals complete with 8–10 pores.[5,6,12] Frenum present, nape, cheeks, opercles, breast, belly, and prepectoral area scaled, with nape scales deeply embedded. Supratemporal canals broadly interrupted; infraorbital canal complete.[8]

Morphometry
Unknown.

Pigmentation
Juveniles are relatively drab in coloration and lack exceptionally bright colors. Base color is gray or yellowish; anterior half of the lateral line (and often the nape) is conspicuously depigmented with yellow tones; may possess seven or eight dorsal saddles and 12 or more mid-lateral blotches. Other body mottling is present. Dorsal, pectoral, and caudal fin rays, and often the membranes, are speckled with dark brown pigment. A distinct basicaudal spot is present at the midbody.[8]

TAXONOMIC DIAGNOSIS OF YOUNG GOLDSTRIPE DARTER

Similar species: *Etheostoma swaini*, *E. crossopterum*, and *E. neopterum.*

Etheostoma parvipinne juveniles are similar to *E. swaini* and may be mistaken for the latter due to their monochromatic pigmentation. *Etheostoma swaini* has separate gill membranes, a complete or narrowly interrupted supratemporal canal, a naked breast, and always two anal spines. *Etheostoma tuscumbia* is found in the area near Pickwick Reservoir, and can be separated from *E. parvipinne,* but has separate gill membranes, with only about half of the scales pored in the lateral series, and scales on top of the head extending to the interorbital areas Two members of subgenus *Catonotus* (*E. crossopterum* and *E. neopterum)* are potentially sympatric but differ in having a higher number of soft dorsal rays than dorsal spines.[8]

Variation. Little variation was found in most characters with the exception of the anal fin spines.[5,6,8,9,12]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (see Figure 98)
Eggs. Spawning habitats include root masses, aquatic vegetation, and woody debris snags in swift chutes of Coastal Plain streams.[9]

Yolk-sac larvae. Presumably occur in aquatic vegetation and remain in pool habitats of springs.

Post Yolk-sac Larvae. Unknown.

Juveniles. Unknown.

Early Growth (see Table 111)
The lifespan is 2–3 years.[9] Larvae are 20 mm in length during mid-April in TN.[8]

Feeding Habits
Diet of *E. parvipinne* includes midges, mayflies, blackflies, beetles, and microcrustaceans.[9] Diet in TN includes a variety of arthropods such as midge larvae, dipteran pupae, caddisfly larvae, dytiscid beetles larvae, and small crayfish.[8]

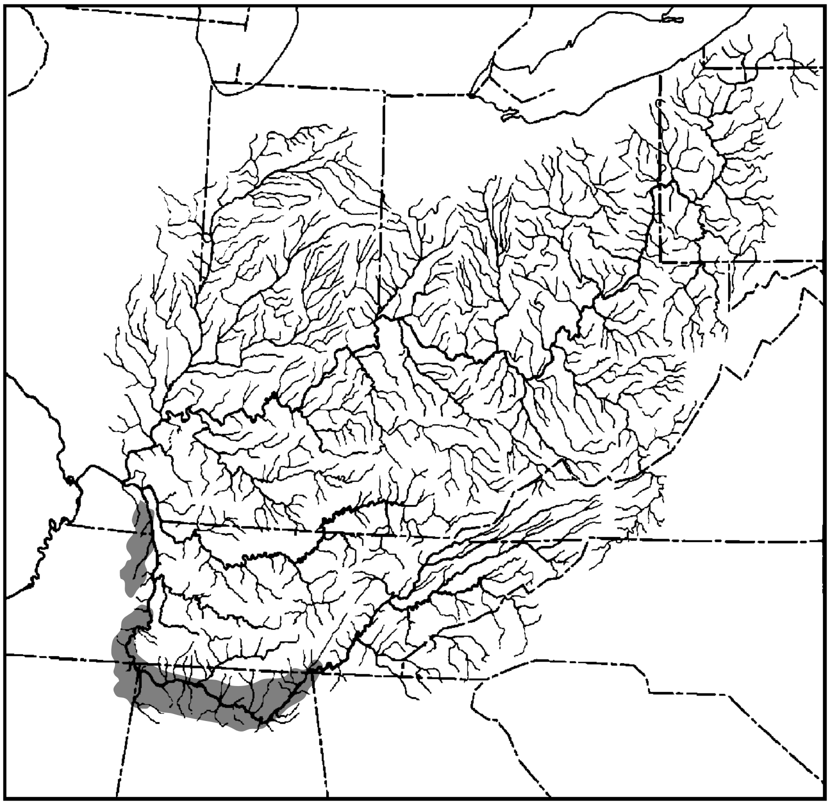

Figure 98 Distribution of goldstripe darter, *E. parvipinne* in the Ohio River system (shaded areas).

Table 111

Average calculated length (mm TL) of young goldstripe darter in Tennessee.

	Age		
State	**1**	**2**	**3**
Tennessee [8]	32–38	45–50	55–65 (75)

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DUSKYTAIL DARTER

Etheostoma (*Catonotus*) *percnurum* Jenkins

Etheostoma: various mouths; *percnurum*: duskytail, referring to the reduced barring on the caudal fin.

RANGE

Etheostoma percnurum is endemic to the upper Tennessee and middle Cumberland drainages.[1–3] The type locality is Copper Creek, which is just below the mouth of Obeys Creek, Scott County, VA.[3]

HABITAT AND MOVEMENT

Etheostoma percnurum inhabits clear, warm, moderate gradient, intermontane large creeks to moderately large rivers,[3,4] with streams that range between 10 and 80 m in width.[4] It occurs in gently flowing pools, generally in the vicinity of riffles, with substrates composed of large rocks over bedrock or sand and gravel, at depths of 0.3–1.2 m;[3] siltation in these habitats is minimal.[3,4] Habitats range from slack water and detritus to slightly silted stones and bedrock.[4] A concentration of breeding adults occupied a moderate-velocity run.[4] Males establish territories beneath large rocks in the same pools that they inhabit during the rest of the year.[3,5–8]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma percnurum possesses the most fragmented range of any species in the *E. flabellare* species group.[4] Six relict populations are known including Copper Creek, VA, and five populations in TN.[4] Populations from TN include Citico Creek, Monroe County; Abrams Creek, Blount County; the Little River, Blount County; the South Fork Holston River, Sullivan County; and the Big South Fork Cumberland River, Scott County.[3,4] Populations in Abrams Creek and South Fork Holston River, TN, are extirpated.[3,4] A single individual was collected from the Clinch River at Speers Ferry, VA.[4]

SPAWNING

Location

Spawning occurs beneath slab rocks, where the female attaches adhesive eggs to the underside of the rock. Adult males guard the eggs and fan the eggs with pectoral and spinous dorsal fin knobs. Egg slabs are usually found in shallow pools or in moderate-velocity runs of large rubble and boulders.[3–8]

Season

In TN and VA, spawning begins in late April and continues through June,[3,4] while aquarium spawning occurs in early April.[5]

Temperature

Spawning occurs at temperatures between 17.5 and 24°C,[3,5,6] while aquarium spawning occurs between 13 and 24°C.[5]

Fecundity

Females averaged 26 (9–44) mature eggs, which was essentially the same as the number of eggs laid per spawning act. A female captured in April and held in an aquarium produced six clutches of 7–40 eggs during a single spawning season. Nest contained a mean of 79 (23–200) eggs.[5,6]

Sexual Maturity

Males and females were sexually mature at age 1, but only males larger than 39 mm SL guarded nests. Females as small as 28 mm SL were gravid.[5,6,8] In VA, the smallest mature male was 35 mm SL, and the smallest mature female was 26 mm.[4] The largest immature fish was a 38 mm male and a 26 mm female.[4]

Spawning Act

Etheostoma percnurum is an egg-clusterer[7,8] and a fractional spawner.[4] Adults from the Little River, TN, were captured and held in aquaria.[5,6,8] Males cleaned the nest sites of silt and debris and emerged from the nest to court females. Courtship consisted of the male erecting his fins, wagging his tail, and nipping. This behavior continued until the female entered the nest. Shortly after entering the nest, the female inverted and pressed her abdomen against the underside of the rock, and vibrated prior to egg deposition, which probably signaled the male to invert, head-to-tail, and fertilize the egg. The female remained inverted throughout the spawning session, which lasted for up to 5 h or more. Males resumed an upright position after each egg was fertilized. Eggs are laid in a single layer. Both sexes are polygamous and males spawned with multiple females.[3–8] The nest is aggressively guarded by the male. Parental care is provided by the attending male.[1–8]

EGGS

Description
Fertilized eggs were translucent and spherical and averaged 2.8 mm in diameter from wild nests (range: 2.6–3.3 mm; N = 35; SD = 0.2 mm), and 2.9 mm from aquarium nests (range: 2.6–3.3 mm; N = 25; SD = 0.1 mm).[7] The chorion was clear, adhesive, and flattened at the point of attachment to the nest stone. The yolk was translucent and a large translucent oil globule, surrounded by several smaller ones, imparted an amber color to the egg.[7]

Incubation
Eggs incubated at 18–27°C and hatched after 264–336 h.[3]

Development
The morula was round and measured 0.8–0.9 mm in diameter; the yolk was 2.2–2.3 mm in diameter, with a single large oil globule 0.6–0.7 mm in diameter; and the perivitelline space ranged from 0.1 to 0.4 mm (5 h old embryos).[5,7] The blastoderm of the early embryo covered 67% of the yolk, the embryonic axis was formed, and the germ ring was visible (26 h old embryo).[5,7] In the tail-bud stage, the optic vesicles began to form, and 9 somites were visible (ca. 28–47 h embryo).[5,7] In early tail-free embryos, dorsal and ventral finfolds were developing; auditory vesicles were visible; lenses were forming in the unpigmented eyes; about 30 somites were discernible; the heart was beating clearly; and the embryo occasionally twitched.[5,7] Melanophores were widely scattered over the yolk membrane and were concentrated mostly on the vent and body-yolk juncture (50 h embryos).[5,7] By the late tail-free stage, the head was highly elevated; the eyes were grayish-black; and the pectoral fin buds were present.[5,7] Melanophores were more concentrated over the yolk membrane and had developed ventrally along the body to the tail (72–96 h embryos).[5,7] In late embryos, the eyes were pigmented black; the newly formed mouth opened and closed; opercles moved; and the well-developed pectoral fin buds fluttered.[5,7] A highly branched vitelline plexus covered the anterior-ventral portion of the yolk sac, very similar to that described by Paine for embryos of *E. flabellare*. Melanophores were present on the yolk sac, dorsally and ventrally along the bases of the finfolds, mid-laterally toward the tail, and on top of the head.[5,7] Late embryos wiggled frequently and vigorously, and the chorion was soft and delicate (>125 h embryos).[5,7] Eggs hatched in 264–336 h (11–14 days) at 18–27°C.[5,7]

YOLK-SAC LARVAE

See Figures 99 and 100

Size Range
Etheostoma percnurum newly hatched, Little River, TN, 4.5–5.4 mm;[7] 5.2[3]; yolk absorbed by 9.3 mm.[7]

Myomeres
Preanal 15, postanal 19–21 (mean = 19.9, N = 20); with total 34–36.[7]

Morphology
4.5–5.4 mm TL. Newly hatched larva with a robust, spherical yolk sac, 47.9% of TL, and yolk translucent, containing a single oil globule (0.7 mm diameter).[7] Vitelline vein forms a plexus on mid-ventral yolk sac; head not deflected over the yolk sac; jaws developed; eye diameter spherical.[7]

5.8 mm TL. Notochord flexion occurs.[7]

6.2 mm TL. Branchiostegal rays form.[7]

8.1 mm TL. No swim bladder forms; gut straight.[7]

Morphometry
See Table 112.

Predorsal length 32.3% of TL (range: 29.0 to 44.2% TL); 38.3% of SL (range: 31.2 to 53.3% SL).[7]

Fin Development
See Table 113.

4.5–5.4 mm TL. Newly hatched larva with well-developed pectoral buds with six incipient rays.[7]

5.8 mm TL. First pectoral rays form. Median fin rays in the spinous and soft dorsal, anal, and caudal fins form simultaneously.[7]

6.2 mm TL. Caudal fin round.[7]

7.4 mm TL. Incipient anal fin margin partially differentiated.[7]

7.5 mm TL. Incipient dorsal fin margin partially differentiated. Spinous dorsal fin origin situated over

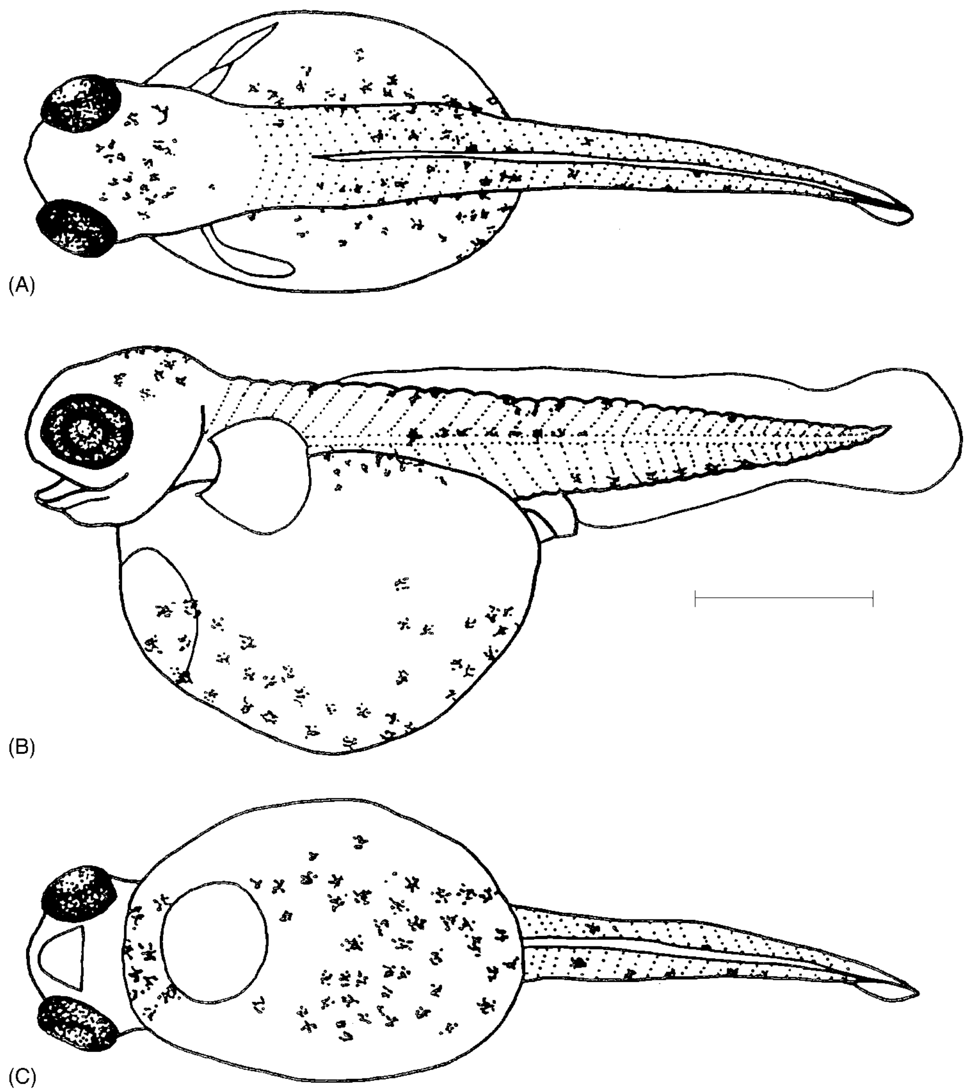

Figure 99 *Etheostoma percnurum*, duskytail darter, yolk-sac (newly hatched) larvae, Little River, TN. 5.1 mm TL, (A) dorsal, (B) lateral, and (C) ventral views. (A–C from reference 7, with authors' permission.)

preanal myomere 3–4, soft dorsal origin situated over postanal myomere 16.[7]

7.8 mm TL. Incipient anal fin margin completely differentiated.[7]

8.1 mm TL. Entire finfold absorbed.[7]

>8.1 mm TL. Pelvic fin buds form anterior to spinous dorsal fin origin.[7]

Pigmentation

4.9–5.7 mm TL. Newly hatched larvae; body translucent; amber oil globule flattened, located anteriorly in yolk sac; highly branched vitelline plexus (red in life) over oil globule and anterior–ventral portion of yolk sac; melanophores on yolk sac; most melanophores on yolk sac concentrated ventrally, posterior-laterally, and at body–yolk juncture; prominent path of melanophores on top of head; melanophores irregularly distributed along dorsum, mid-laterally along myosepta, and ventrally toward the tail.[7]

6.1–6.2 mm TL. Melanophores develop anteriorly on top of head toward snout.[7]

7.4–8.3 mm TL. Body straw-colored, less translucent; dense patch of stellate melanophores on top of cranium; orbital bar of melanophores develop from opercle to snout; melanophores concentrated medially along dorsum and mid-laterally along horizontal septum; melanophores beginning to develop on

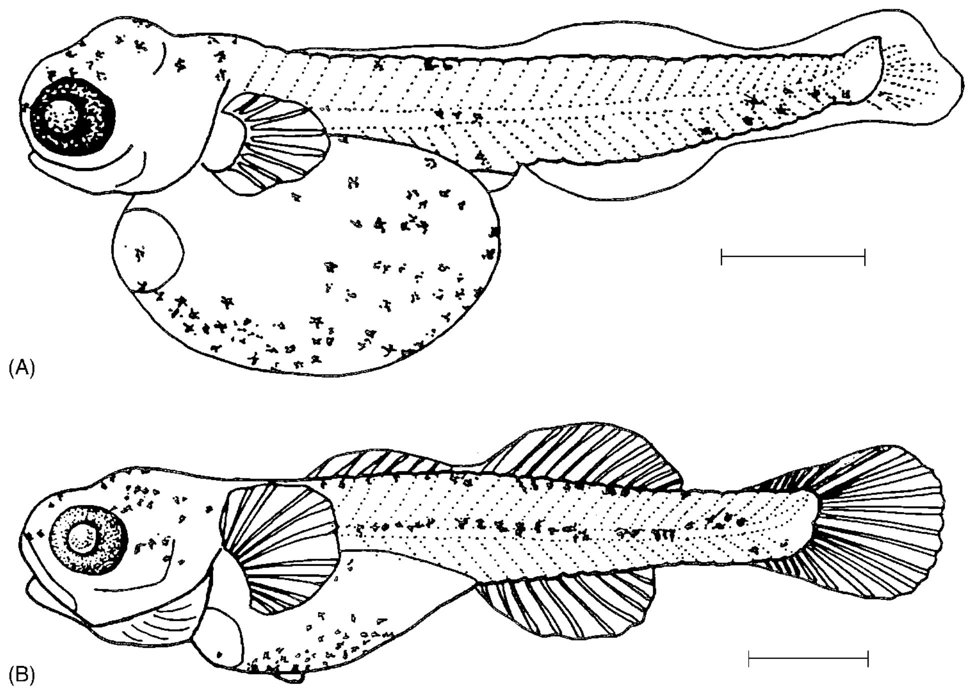

Figure 100 *Etheostoma percnurum*, duskytail darter, Little River, TN; (A) yolk-sac larva, 6.9 mm TL, lateral view, (B) yolk-sac larva, 8.2 mm TL, lateral view. (A–B from reference 7, with author's permission.)

Table 112

Morphometric data expressed as percentage of HL and TL for young *E. percnurum* from Little River, TN.[7]

	TL Groupings		
Length Range (mm)	**4.5–6.2**	**7.1–11.8**	**12.3–15.5**
N	**6**	**16**	**3**
Mean	**5.19**	**9.3**	**13.8**
As Percent HL			
SnL	9.5 ± 1.5	15.0 ± 2.4	17.8 ± 0.1
ED	41.1 ± 5.2	37.6 ± 4.1	30.8 ± 5.1
As Percent TL			
HL	21.4 ± 2.0	23.2 ± 2.3	26.6 ± 0.1
Preanal	56.8 ± 4.6	50.3 ± 1.7	52.4 ± 1.6
PosAL	43.2 ± 5.1	49.7 ± 1.9	47.6 ± 1.4
SL	96.3 ± 0.4	86.3 ± 2.7	82.8 ± 0.9
BDG	37.3 ± 7.0	21.4 ± 3.7	17.0 ± 1.1
BDA	9.7 ± 1.3	12.3 ± 4.0	11.6 ± 1.1
CPD	4.3 ± 0.9	7.0 ± 0.5	6.8 ± 1.3

soft dorsal, caudal, and anal fin rays; subcutaneous melanophores dorsally on gut.[7]

POST YOLK-SAC LARVAE

See Figure 101

Size Range
9.3 to 15.5 mm TL.[7]

Myomeres
Preanal 15, postanal 19–21; 34–36 total myomeres.[7]

Morphology
9.3 mm TL. Yolk completely absorbed.[7]

Table 113

Meristic counts and size (mm TL) at the apparent onset of development for *E. percnurum*.[7]

Attribute/event	*Etheostoma percnurum*	Literature
Branchiostegal Rays	5,5[7]	5,5[3,4]
Dorsal Fin Spines/Rays	VI–(VII)–VIII/12–13[7]	IX–XII/10–12[3,4]
First spines formed	5.8[7]	
Adult complement formed	6.1[7]	
First soft rays formed	5.8[7]	
Adult complement formed	7.4[7]	
Pectoral Fin Rays	12–(13)–14[7]	13–15[3,4]
First rays formed	5.8[7]	
Adult complement formed	6.1–6.2[7]	
Pelvic Fin Spines/Rays	I/5[7]	I/5[3,4]
First rays formed	8.8–9.2[7]	
Adult complement formed	8.8–9.2[7]	
Anal Fin Spines/Rays	II/(7–8)–9[7]	II/6–8[3,4]
First rays formed	5.8[7]	
Adult complement formed	7.4[7]	
Caudal Fin Rays	xi–xvi, 8+8–9, xi–xv[7]	15–18[3,4]
First rays formed	5.8[7]	
Adult complement formed	7.5[7]	
Lateral Line Scales	38–(40–45)–48[7]	42–58[3,4]
Myomeres/Vertebrae	(34)–36/33–(34)–35[7]	Unknown/38–40[3,4]
Preanal myomeres	15[7]	
Postanal myomeres	19–21[7]	

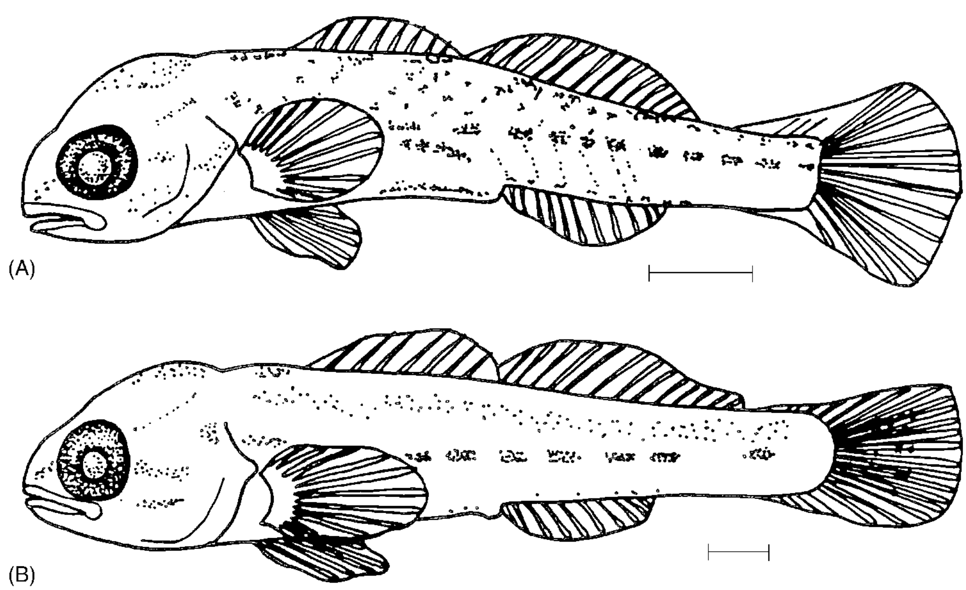

Figure 101 *Etheostoma percnurum*, duskytail darter, Little River, TN, (A) Post yolk-sac larva 9.5 mm TL, lateral view, (B) early juvenile 15.5 mm TL, lateral view. (A–B from reference 7, with author's permission.)

15.5 mm TL. Scale formation initiated at base of caudal peduncle.[7]

Morphometry
See Table 112.

Fin Development
See Table 113

9.3 mm TL. First pelvic fin rays form.[7]

Pigmentation
9.2–9.8 mm TL. Pre- and post-orbital bars distinct; melanophores form indistinct blotches dorsally (7–8) and mid-laterally; light scattering of melanophores on soft dorsal, caudal, and anal rays, and to a lesser extent on spinous dorsal fin; subcutaneous melanophores on back of head and opercles; iridescent gold pigment in eyes.[7]

10.1–15.5 mm TL. Body opaque, straw-colored, heavily pigmented with melanophores; melanophores on top of head concentrated and confluent; dorsal and lateral blotches wider, diffuse, with indistinct dorso-lateral connections between them; soft dorsal, anal, and caudal fin rays line with melanophores; few melanophores on pectoral and pelvic fin rays, spinous dorsal fin, beneath the head, breast, and belly; gold iridescence in eyes more pronounced.[7]

JUVENILES

See Figure 101

Size Range
15.5[7] mm TL to usually 39 mm SL,[3,4] as small as 26–35 mm SL.[4]

Fins
Branchiostegal rays 6,6;[3,4,6] dorsal spines/rays VI–(VII)–VIII/ 10–(11–12)–13;[3,4,6] pectoral rays 12-14;[3,4,6] pelvic spines/rays I/5;[3,4,6] anal fin spines/rays II/6–(7–8);[3,4,6] caudal rays 15–(17–18)–19.[3,4,6]

Morphology
See Table 112.

18 mm SL. Squamation nearly complete. Scales absent from the cheeks, opercles, nape breast, prepectoral area, and middle of the abdomen; infraorbital and supratemporal canals interrupted; vertebrae 33–(34)–35.[3,4,6,7]

Pigmentation
18 mm SL. Pigmentation nearly complete; body straw-colored, 12 lateral vertical brown bars connected dorso-laterally to 6–7 irregular brow dorsal saddles, dark humeral spot, and cheeks speckled with melanophores.[7]

TAXONOMIC DIAGNOSIS OF YOUNG DUSKYTAIL DARTER

Similar species: members of subgenus *Catonotus*.

Etheostoma percnurum is sympatric with *E. flabellare*. *Etheostoma percnurum* larvae are more precocious and develop incipient rays in the pectoral fins and complete rays in the median fins and complete rays in the median fins earlier than *E. flabellare*; however, squamation begins later at lengths >15 mm TL. These two taxa can be separated from other *Catonotus* members (i.e., *E. kennicotti* and *E. squamiceps*) based on myomere number, pigmentation, and fin ray development relative to size. *Etheostoma kennicotti* has melanophores scattered across the yolk sac similar to *E. flabellare*, while it differs in possessing a dorsal and ventral cluster posterior to the anus. The other three taxa can be separated based on yolk sac diameter, eye shape, and ontogenetic development of fin rays. *Etheostoma percnurum* has a spherical eye shape, while both subspecies of *E. flabellare* have an oval eye shape. Significant differences exist in development of fin rays. The development of fin rays is more precocious in *E. f. lineolatum*, occurring at smaller length intervals for all but the formation of the first pelvic fin rays. Yolks sac diameter is greatest in *E. percnurum* (48% of TL) followed by *E. f. lineolatum* (42% TL) and *E. f. flabellare* (31% of TL), while the yolk sac is absorbed at smaller length intervals in *E. f. lineolatum* and at similar sizes for *E. f. flabellare* and *E. percnurum*. *Etheostoma squamiceps* can be separated from *E. f. lineolatum* because the former possesses 16 preanal and 18–19 postanal myomeres. *Etheostoma smithi* has myomere counts similar to *E. f. lineolatum*, but differs in yolk sac diameter, pigmentation, and formation of the rays. Yolk-sac diameter is smaller (33.5%) than *E. f. lineolatum*, pigmentation is restricted to the nape; ventral yolk sac and mid-ventral postanal myosepta; and fin ray formation occurs later than in *E. f. lineolatum*.[7]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 102)
Eggs. Eggs are attached to the underside of slab rocks in shallow riffles and the edges of runs, and are guarded by the paternal males.[3,4,6,7]

Yolk-sac larvae. Yolk-sac larvae remain in close association with the guarded nest, inhabiting the interstitial spaces of the nest until post-yolk absorption. Yolk-sac larvae possess extensive vitelline vein

Figure 102 Distribution of duskytail darter, *E. percnurum* in the Ohio River system (shaded area) and areas where early life history information has been collected (circle). Number indicates appropriate reference.

networks, which is consistent with a subterranean, benthic life style.[7]

Post Yolk-sac Larvae. Larvae are demersal and remain in close association with the substrate along the edges of riffles in extremely shallow, interstitial pore spaces. Larvae are seldom found among root-mats, aquatic macrophytes, and submerged roots.[7]

Juveniles. No distinction is evident between the habitat of young juveniles and adults.[3,4,6,7]

Early Growth (see Table 114)

Males were larger than females after 6 months and averaged 40.4 mm SL. Life span is slightly more than 2 years.

Table 114

Average calculated lengths (mm SL) of young duskytail darters in Tennessee and Virginia.

	Age	
State	**1**	**2**
Tennessee[4]	34.7–40.4	48–55
Virginia[5]	26–38	35–47

Feeding Habits

Diet is primarily midge larvae, mayfly nymphs (mostly heptagenids), and microcrustaceans.[5,6]

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Material Examined: TN: Little River series studied by S.R. Layman (UT, uncatalogued).

CYPRESS DARTER

Etheostoma (*Boleichthys*) *proeliare* (Hay)

Etheostoma: various mouths; *proeliare*: battle, in reference to the species being first collected from the Tuscumbia River close to the battlefield at Corinth, MS.

RANGE

Etheostoma proeliare occurs along the Gulf Coast from the Choctowhatchee River, FL, to the San Jacinto River, TX. It occupies the Mississippi Embayment and the Mobile River system below the Fall Line. At the extreme of its range it extends into southern IL and adjacent portions of KY and MO. In AR and OK, particularly in the Arkansas River, it extends northwest of the Fall Line.[1–3]

HABITAT AND MOVEMENT

Etheostoma proeliare is restricted to lowland creeks, oxbow lakes, and wetlands of the floodplains of the Ohio, lower Tennessee, and Cumberland Rivers. It is associated with lead-laden and vegetated water bodies in sluggish current, pools, or the shorelines of lakes.[4] Greatest concentrations were in accumulations of leaves and sticks on the bottom of streams and, secondarily, in filamentous algae. The presence of leaves and vegetation is more important than pools and riffles.[3]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma proeliare is sporadic and rare in creeks, streams, sloughs, and lakes that border the lower Ohio River, lower Cumberland River drainage, Livingston County, and lower Tennessee River, KY. Three of the five records from the lower Tennessee were prior to impoundment.[4] In IL, *E. proeliare* occurs in the Cache River and other direct tributaries to the lower Ohio River.[5]

SPAWNING

Location

Eggs are attached to leaves, the underside of rocks, dead twigs, and exposed tree roots.[6]

Season

In IL, from March to June; [6] in tributaries to the Tennessee River, MS and TN from March to May,[6] and from mid-March until early June.[8]

Temperature

Stream temperatures at the time of capture of ripe adults ranged from 9.5 to 16°C.[6]

Fecundity (see Table 115)

Females 28–30 mm had mature ova ranging between 28 and 116.[6] Females (35–44 mm TL) collected in early April had mean ovaries that were 11.7% of the body weight, containing 106.8 total ova averaging 0.94 mm diameter. Female *E. proeliare* showed statistically significant increasing fecundity (ANOVA, $F = 63.077$, $p > 0.0001$) with increasing length*. Females between 35 and 44 mm collected in early April had 6 to 137 large mature ova.*

Sexual Maturity

Males and females were sexually mature at age 1 at lengths between 22.5 and 30 mm SL.[6]

Spawning Act

Courting consisted mainly of a male and female darting about the aquarium with the female leading the male closely behind her. At times the male mounted the female, clasping her upper sides with his large pelvic fins, and, while mounted, occasionally rubbed his chin on the top of her head and cheeks. The female selected the site for egg deposition, and with the male close behind her, elevated to the site. The male mounted the back of the female; the two bodies vibrated together for a few seconds and were curved in such a way that the female's genital papilla was placed on the selected spot where 1–3 eggs were laid. At the instant that the eggs were laid, the female's mouth was wide open; the male's mouth was always closed. Eggs were laid as high as 13 cm above the substrate. After spawning, the pair separated and rested for as long as a minute before they resumed at a site 5–15 cm from the first. Vertical and inverted positions and also rapid vibrations of the caudal and pectoral fins were observed. The male maintained his position

Table 115

Fecundity data for *E. proeliare* from Bayou Bartholomew (Ouchita River drainage), LA*.

Length (mm TL)	Ovary Weight (mg)	Number of Ova: Ripening Oocytes (LA)	Number of Ova: Mature Oocytes (EM, MA, LM)	Number of Ova: Ripe Eggs (MR, RE)	Egg Diameter (mm)
44	94.6	857	184	137	0.95
41	75.1	704	198	123	0.91
39	58.5	659	153	121	0.91
36	56.5	631	121	90	0.95
40	90.4	890	203	132	0.95
40	57.0	738	232	0	—
41	65.1	797	150	128	0.91
40	73.8	689	186	133	0.91
39	68.5	807	132	91	1.00
35	33.3	668	117	6	1.00

by means of the expanded male pelvic fins on the middorsum of the female. Females may spawn with more than a single male, although this was not observed in laboratory aquaria. No parental care was provided by either sex.[6]

EGGS

Description

Ovarian examination showed that ovoid latent ova were 0.25 mm, early maturing small spherical ova ranged between 0.50 and 0.77 mm, and large mature ova averaged 0.91–1.0 mm.* Mature ova are deeply indented, including the primary egg envelope. Mature ova are demersal, adhesive, with translucent yolk; a single oil globule; a narrow perivitelline space; and an unsculptured chorion.[8] Eggs ranged from 0.5 to 1.1 mm;[6] and from 0.8 to 1.1 mm.[8]

Incubation

At 10°C, eggs developed but failed to hatch, while eggs incubated at 15°C hatched at 300 ± 9 h; at 20°C hatching was observed at 211 ± 23 h and at 22–23°C hatching occurred at 131 ± 9 h.[6,8] At 26–28°C hatching occurred after 129–130 h.[7]

Development

Development was described, specifically describing the indentation of the egg envelope.[7]

YOLK-SAC LARVAE

See Figure 103

Size Range

Newly hatched at 3.2–3.5[6–8]; yolk absorbed by 4.2 mm.[8]

Myomeres

Preanal 15, postanal 19–20; 34–35 total.[8]

Morphology

3.2–3.5 mm TL. Body laterally compressed, yolk sac bulbous, anterior tapering posteriorly; single anterior oil globule; head not deflected over the yolk sac; jaws well developed; eyes oblong.[8]

Morphometry

See Table 116.

Fin Development

See Table 117

3.2–3.5 mm TL. Well-developed pectoral fin buds with nine incipient rays.[8]

4.2 mm TL. First pectoral rays formed; first dorsal fin rays formed.[8]

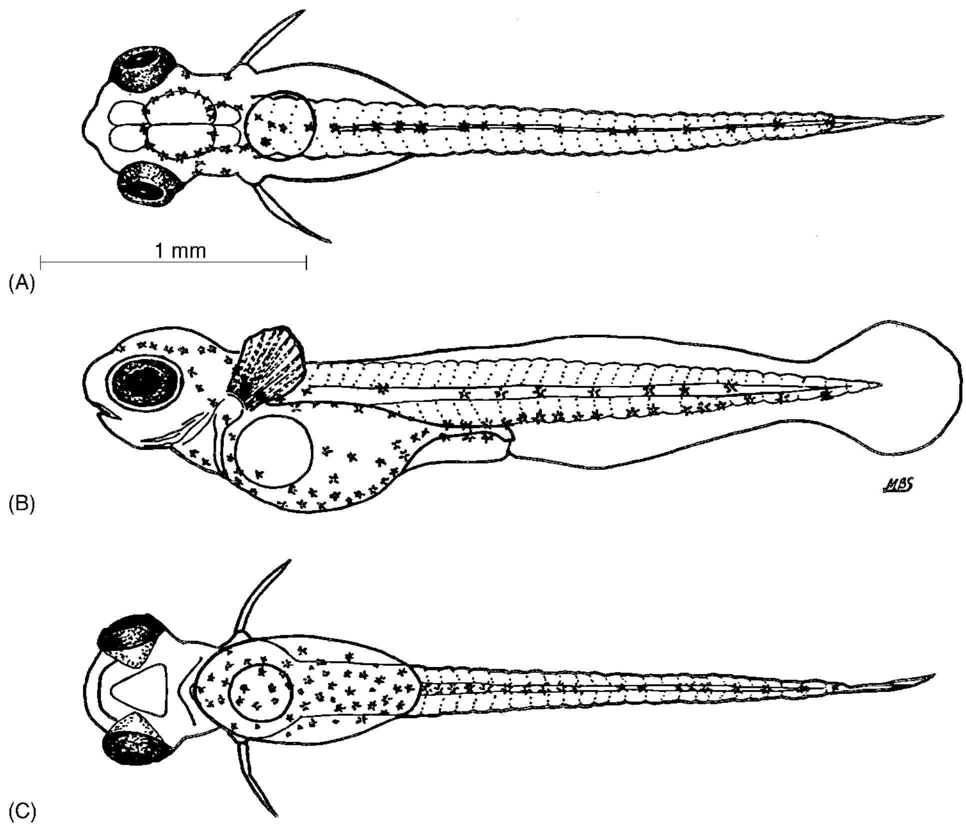

Figure 103 *Etheostoma proeliare*, cypress darter, Max Creek, IL; (A–C) yolk-sac (newly hatched) larvae, 3.3 mm TL, (A) dorsal, (B) lateral, and (C) ventral views. (A–C from reference 8, with author's permission.)

Pigmentation

3.2–3.5 mm TL. Moderately pigmented; retinae black; concentration of melanophores on dorsal portion of cranium outlining the optic lobe and tapering into a point around the cerebellum; a single row of melanophores dorsally from the occiput to the tip of the caudal peduncle; two oblique parallel series of melanophores extend laterally from the posterior portion of the orbit into the anterior and posterior sections of the yolk sac. A mid-lateral stripe consisting of a single melanophore at the anterior apex of preanal myomere 2–12 alternates every fifth myoseptum and every third myoseptum from the anus to postanal myomere 14. Melanophores were observed around anus ventrally and over the yolk sac dorsally; ventrally, a single melanophore at anterior margins of pectoral myomere 1–6, 8–9, and 11–13, then alternating thereafter.[8]

4.2 mm TL. Dense occipital pigmentation; dorsally, a single row of melanophores from the nape to the end of the caudal fin. A single diagonal line of melanophores extending from the orbit through the cleithra; dense dermal and subdermal pigment on the ventral portion of the yolk sac; pigment little to entirely absent dorsally on gut; pigment outlining dorsally and ventrally the anus from the stomach posteriad. Mid-lateral stripe of single melanophores at posterior part of myosepta from preanal myomeres 8–13, and located every other myosepta on postanal myosepta 1–9. Ventrally, melanophores located on postanal myomeres 5–14 and at tip of the caudal peduncle.[8]

POST YOLK-SAC LARVAE

See Figures 104–106

Size Range

>4.2 mm TL to <13.5 mm TL.[8]

Myomeres

Preanal 15, postanal 19–20; 34–35 total.[8]

Morphology

4.2 mm TL. Yolk sac absorbed; notochord flexion occurred.[8]

8.9 mm TL. No swim bladder formed; gut straight.[8]

9.9–10.8 mm TL. Supraorbital and infraorbital head canals start to form, and are completely formed by

Table 116

Morphometric data expressed as percentage of HL and TL for young *E. proeliare* from Illinois and Louisiana.[8]

	TL Groupings				
Length Range (mm)	**3.2–4.2**	**5.2–9.9**	**10.0–15.6**	**16.0–19.4**	**20.2–23.5**
N	**11**	**29**	**29**	**22**	**25**
Mean	**3.38**	**7.13**	**12.5**	**17.86**	**21.08**
Ratios/actual Measures	**(Range)**	**(Range)**	**(Range)**	**(Range)**	**(Range)**
As Percent HL					
SnL	15.0	18.2	18.2	23.0	0.88
	(0.06–0.16)	(0.15–0.44)	(0.38–0.66)	(0.6–0.88)	(0.72–1.0)
ED	40.4	36.5	26.7	32.7	17.7
	(0.2–0.3)	(0.37–0.7)	(0.6–1.1)	(1.0–1.2)	(1.1–1.4)
As Percent TL					
HL	15.4	19.0	23.7	19.2	23.5
	(0.46–0.75)	(0.9–2.7)	(2.3–3.8)	(3.8–4.8)	(4.0–5.7)
Preanal	48.2	46.8	53.1	46.6	46.2
	(1.5–2.0)	(2.5–4.6)	(4.7–7.6)	(7.4–9.3)	(9.0–10.6)
PosAL	51.8	53.2	46.9	53.4	53.8
	(1.7–2.2)	(2.7–5.3)	(5.3–8.0)	(8.6–10.1)	(11.2–12.9)
SL	96.7	89.6	83.2	85.1	82.1
	(3.0–4.0)	(5.0–8.8)	(8.5–12.9)	(13.3–16.1)	(16.4–19.3)
TL	100	100	100	100	100
	(3.2–4.2)	(5.2–9.9)	(10.0–15.6)	(16.0–19.4)	(20.2–23.5)
BDG	17.8	15.6	15.0	16.0	15.3
	(0.56–0.7)	(0.79–1.7)	(1.4–2.5)	(2.5–3.0)	(3.0–3.6)
BDA	7.4	9.2	14.3	12.6	12.6
	(0.2–0.3)	(0.38–1.1)	(1.4–2.5)	(1.8–2.4)	(2.2–3.2)
CPD	3.8	5.3	7.5	7.8	7.5
	(0.12–0.16)	(0.2–0.7)	(0.6–1.1)	(1.1–1.5)	(1.3–1.8)

10.9 mm; infraorbital canal complete without interruption and pore count of 10.[8]

12.1 mm TL. Preoperculomandibular and supratemporal canal begins to form.[8]

12.7 mm TL. Scales start to form on operculum.[8]

Morphometry
See Table 116.

Fin Development
See Table 117.

>4.2–5.4 mm TL. First dorsal rays formed.[8]

5.4–6.5 mm TL. First caudal fin ray formed; first anal fin ray formed.[8]

7.9–9.0 mm TL. Caudal fin truncate.[8] Pelvic buds formed anterior to dorsal fin origin; first pelvic fin rays formed at 8.14 mm; incipient dorsal and anal fin margin partially differentiated.[8] (8.3–8.8 mm)

Pigmentation
6.4–8.5 mm TL. Oblique line separated into several melanophores posterior to orbit and several others on cleithra. Melanophores dorsally forming eight distinct areas of concentration (less apparent forming a straight line from 6.4 to 7.1 mm). Subdermal pigment concentrated ventrally under stomach; several melanophores ventrally forming a straight row between cleithra and center of stomach. Melanophores located posterior to caudal peduncle near differentiating caudal fin.[8]

9.9 mm TL. Melanophores dorsally concentrated over cerebrum, optic lobe, and cerebellum; suborbital tear

Table 117

Meristic counts and size (mm TL) at the apparent onset of development for *E. proeliare.*

Attribute/event	*Etheostoma proeliare*	Literature
Branchiostegal Rays	5,5[8]	5,5[1–3]
Dorsal Fin Spines/Rays	VII–(VIII)/9–10[8]	VII–(VIII)–IX/8–(11)–13[1,2,5,7,13]
First spines formed	4.2[8]	
Adult complement formed	8.9[8]	
First soft rays formed	4.2[8]	
Adult complement formed	8.9[8]	
Pectoral Fin Rays	9–10[8]	8–(10) 13[1–3]
First rays formed	3.8[8]	
Adult complement formed	4.2[8]	
Pelvic Fin Spines/Rays	I/5[8]	I/5[1–3]
First rays formed	8.4[8]	
Adult complement formed	8.9[8]	
Anal Fin Spines/Rays	I/ 5–6[8]	I–II/4–7[1,2,5,7,13]
First rays formed	6.3[8]	
Adult complement formed	>9.9[8]	
Caudal Fin Rays	viii–xiv, 4–5+5, viii–xii[8]	9–(10–11)–12[3,11]
First rays formed	5.4[8]	
Adult complement formed	7.7[8]	
Lateral Line Scales	32–39[8]	32–(35–36)–38[1–3,5,7,10,13]
Myomeres/Vertebrae	(34)-35/35–36[8]	Unknown/32–(35–36)–38[1,2,5,7,9]
Preanal myomeres	15[8]	
Postanal myomeres	(19)–20[8]	

drop formed as well as preorbital and postorbital bars; melanophores forming a half circle on ventral portion of opercle. A single mid-lateral stripe of melanophores from anterior margin of pectoral fin posterior to caudal peduncle forming 11 lateral blotches; ventral melanophores concentrated in a single row from the articulation of the pectoral fin posterior to anus. Specks of melanophores at distal half of pectoral fins; two oblique rows of melanophores forming stripes on the spinous and soft dorsal fins; two diagonal rows of melanophores forming stripes on caudal fin.[8]

10.2–11.8 mm TL. Preorbital, postorbital, and suborbital bars chevron-shaped; melanophores extending obliquely and ventrally from the midpoint of the orbit on opercle. A mid-lateral concentration of melanophores forms 9–11 lateral blotches; dorsally 8–9 saddles; several clusters of ventral melanophores on breast and further posterior, with a single line of pigment inbetween; posteriorly a single line of melanophores ventrally from the anus to caudal peduncle expands into a small cluster at the tip. Specks of melanophores scattered between pectoral fin rays; spinous and soft dorsal fin rays each with two oblique stripes; caudal fin with four diagonal stripes.[8]

JUVENILES

See Figure 106

Size Range

13.5–14.2 mm TL to 22.5–29.2 mm TL.[8]

Fins

Spinous dorsal VI–IX; soft dorsal rays 4–7; pectoral rays 9–10; pelvic spines/rays I/5; primary caudal rays 4–5 + 5, secondary rays viii–xiv, viii–xii.[3,8–11]

Morphology

No information.

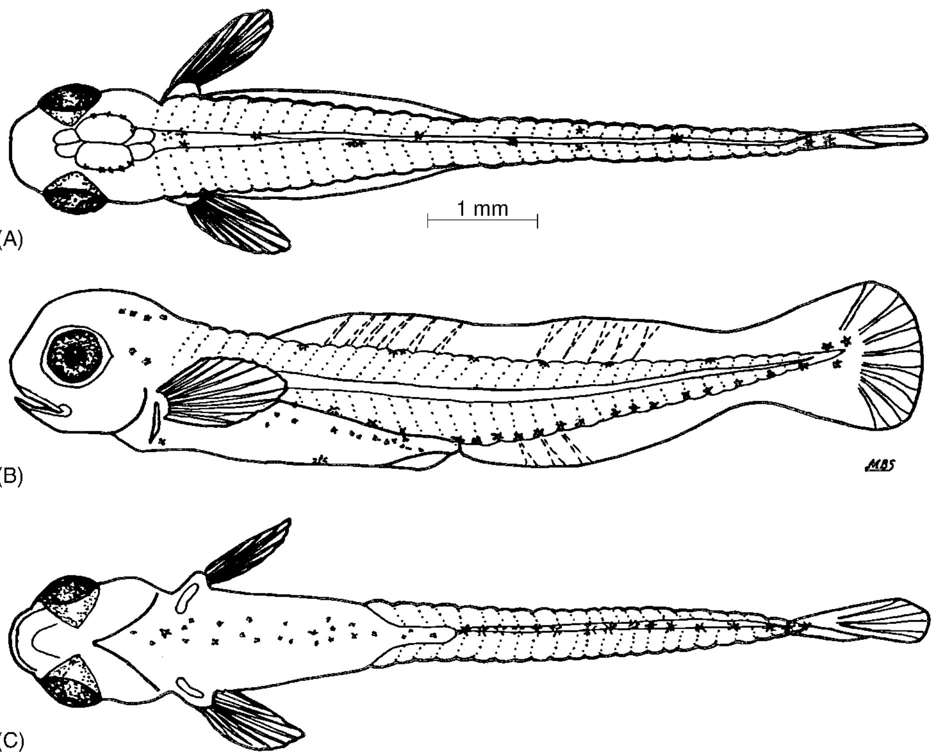

Figure 104 *Etheostoma proeliare*, cypress darter Max Creek, IL; post yolk-sac larva 6.5 mm TL; (A) dorsal, (B) lateral, and (C) ventral view. (A–C from reference 8, with author's permission.)

Morphometry
See Table 116.

Pigmentation
13.5–14.2 mm TL. Preorbital bar extending to tip of snout; dorsal section of cranium well pigmented; scattered pigment connecting 9–11 rectangular midlateral blotches to 8–9 dorsal saddles; scattered melanophores extending ventrally connecting lateral blotches; a vertical stripe at the posterior margin of the caudal peduncle bisecting the last rectangular blotch; outline of scales pigmented; melanophores ventrally at pterigiophores with lepidotrichia of anal fin only. Entire pectoral fin with scattered melanophores on membranes; 3 oblique stripes of clustered melanophores on the spinous and soft dorsal (pigmented directly on the ray), anal fin with a single stripe; caudal fin with 4 diagonal stripes on membrane.[8]

TAXONOMIC DIAGNOSIS OF YOUNG CYPRESS DARTER

Similar species: similar to other *Boleichthys*.

Cypress darters hatch at small lengths and possess the fewest postanal myomeres (19–20) of any darter. A halo of melanophores encircles the cranium and an oblique stripe runs from the anus along the midlateral to the caudal peduncle. The yolk sac is heavily pigmented.*

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 107)
Eggs. Eggs are attached to dead leaves, twigs, and the sides and undersides of large rocks.[6–8]

Yolk-sac larvae. Yolk-sac larvae remain in close association with filamentous algae and aquatic macrophytes after hatching.[6]

Post Yolk-sac Larvae. Larvae are demersal, remain in close association with the substrate, aquatic macrophytes, and submerged roots.[6]

Juveniles. No distinction is evident between the habitat of young and adults.[6]

Early Growth (see Table 118)
June young-of-the year ranged from 9 to 19 mm;[6] *E. proeliare* reached one half of the first year's

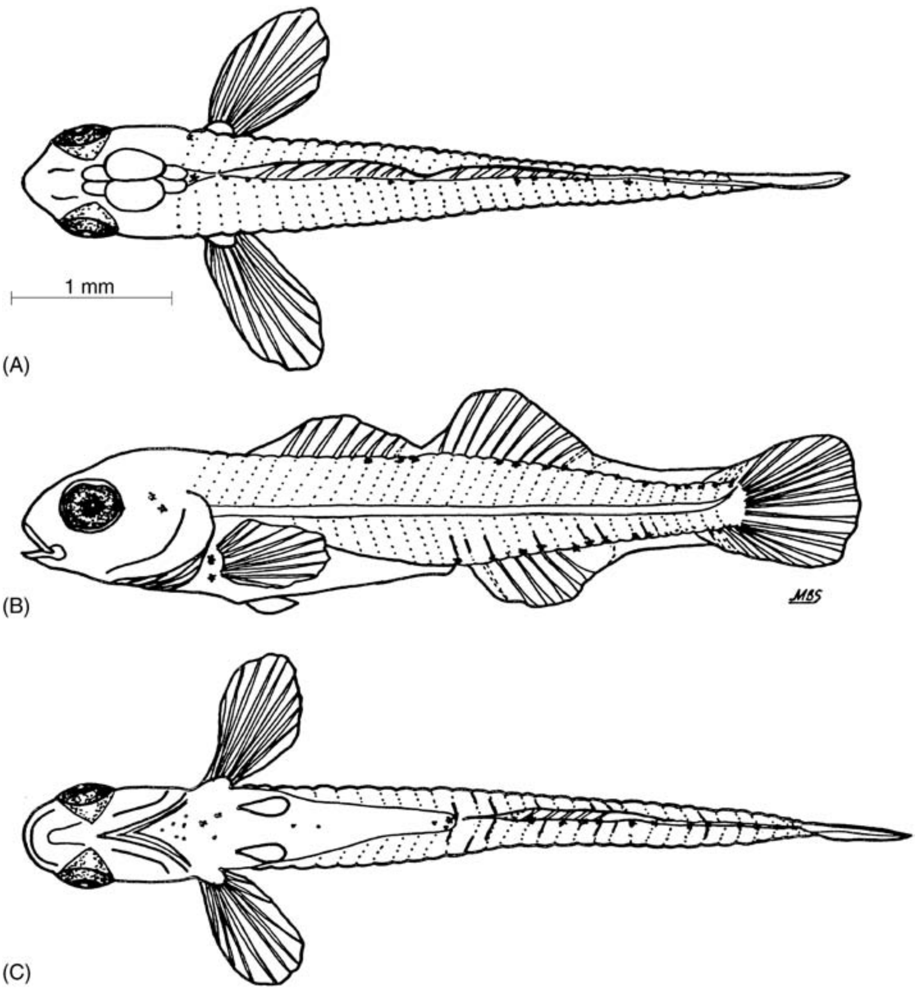

Figure 105 *Etheostoma proeliare*, cypress darter, lower Mississippi River, LA post yolk-sac larva, 8.3 mm TL, (A) dorsal, (B) lateral, and (C) ventral view. (A–C from reference 8, with author's permission.)

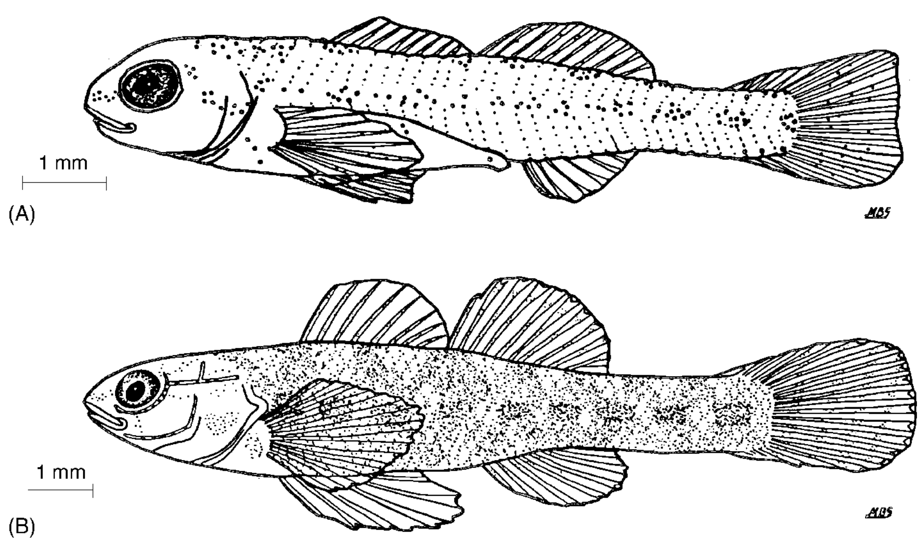

Figure 106 *Etheostoma proeliare*, cypress darter, Max Creek, IL, (A) post yolk-sac larva, 9.9 mm TL, lateral view, (B) early juvenile, 13.5 mm TL, lateral view. (A–B from reference 8, with author's permission.)

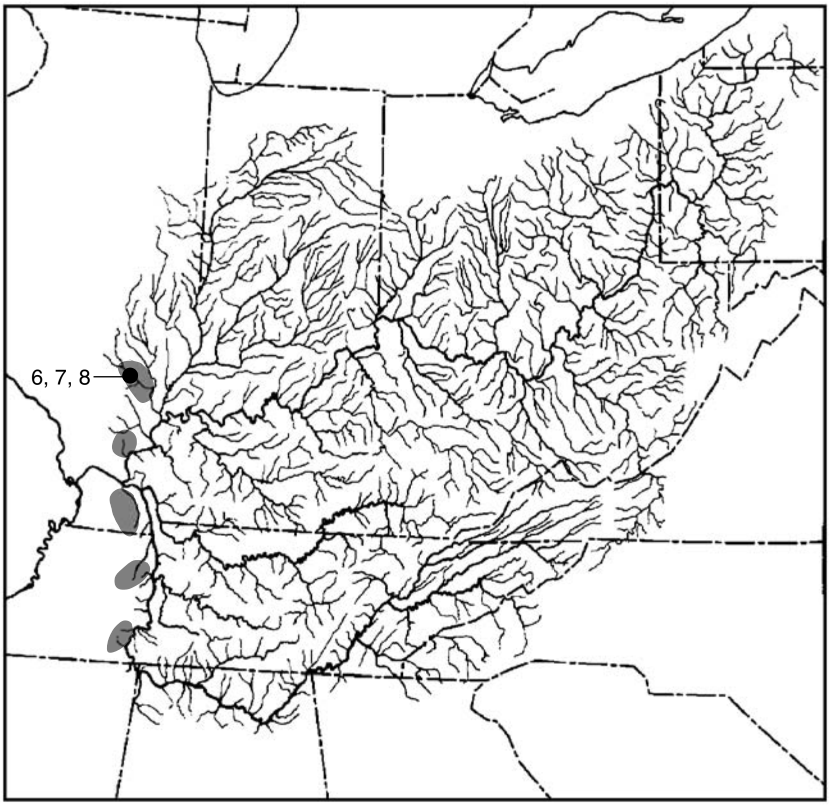

Figure 107 Distribution of cypress darter, *Etheostoma proeliare,* in the Ohio River system, (shaded area) and areas where early life history information has been collected (circle). Numbers indicate appropriate reference.

Table 118

Average calculated lengths (mm SL) of young cypress darter in Illinois and Tennessee.[6,12]

State	Age (months) 6	12	18
Illinois[6]	26–27	29–31	31–34
Tennessee[12]	—	35	39.6

mean growth in about 8 weeks.[6] The relationship between SL and age in months (X) for males is SL = 10.8 + 18.08 log X and for females SL = 11.7 + 17.08 log X.[6]

Feeding Habits
Chironomid larvae are an important food item as are small crustaceans, especially copepods and cladocerans.[6]

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* Original fecundity data for cypress darter from Bayou Bartholomew (Ouchita River drainage), LA. Specimens curated at Northeast Louisiana University, Museum of Zoology, Monroe. Early life history developmental series cultured from laboratory spawned specimens from Max Creek, Johnson County, IL. Specimens curated at the Center for Biodiversity, Illinois Natural History Survey, Champaign, IL.

EGG-MIMIC DARTER

Etheostoma (*Catonotus*) *pseudovulatum* Page and Ceas

Etheostoma: various mouths; *pseudovulatum*: provided with false eggs.

RANGE

Etheostoma pseudovulatum is limited to the lower Duck River system, TN.[1–3]

HABITAT AND MOVEMENT

The preferred habitat of the egg-mimic darter is small upland creeks where it occurs beneath overhanging banks in areas of low gradient. Preferred habitats have dense mats of exposed tree roots.[1,2]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma pseudovulatum is limited to Piney River, Little Piney Creek, and Beaverdam Creek of Hickman and Dickson Counties, TN.[1,2]

SPAWNING

Location
Underside of slab rocks.[1–3]

Season
Spawning occurs in late April through May.[1,2]

Temperature
Unknown.

Fecundity
Unknown.

Sexual Maturity
Unknown.

Spawning Act
Adults deposit their eggs on the underside of slab rocks where they are guarded by a male.[3]

EGGS

Description
Unknown.

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Larger juveniles: Spinous dorsal fin 8–11; soft dorsal rays 10–14; pectoral rays 11–13; anal fin rays II 6–9; pelvic fin rays I 5; caudal fin rays 14–17.[1–3]

Morphology
Scales in the lateral series incomplete with 14–45 pored scales and 41–58 total scales in the lateral series from TN.[1–3]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG EGG-MIMIC DARTER

Similar species: members of the *Catonotus* subgenus of the *E. squamiceps* complex. Early life stages may be indistinguishable from other populations.[3] In the study area it is sympatric with *E. flabellare.*[3]

Adult. *E. pseudovulatum* is similar to *E. flabellare.*[3]

Larva. Aspects of the early life history and reproductive biology for *E. pseudovulatum* are unknown.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 108)
Eggs. Eggs are laid on the underside of slab rocks.[3]

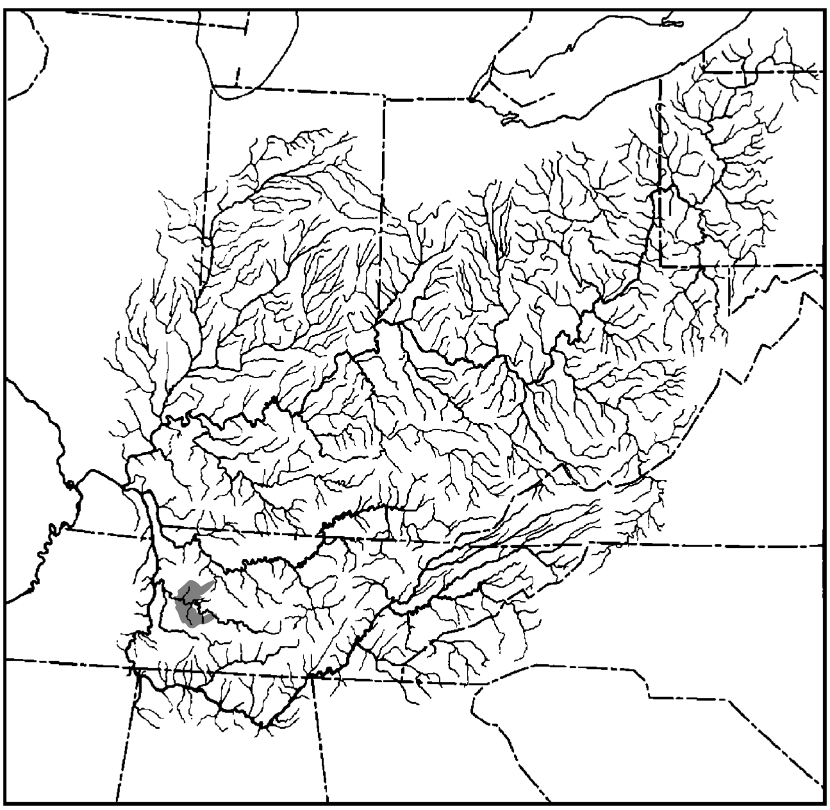

Figure 108 Distribution of egg-mimic darter, *Etheostoma pseudovulatum* in the Ohio River system (shaded area).

Yolk-sac larvae. Unknown.

Post Yolk-sac Larvae. Unknown.

Juveniles. Unknown.

Early Growth
Largest specimen reaches 84 mm TL.[3]

Feeding Habits
Unknown.

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FIREBELLY DARTER

Etheostoma (*Ulocentra*) *pyrrhogaster* Bailey and Etnier

Etheostoma: strain mouth; *pyrrhogaster*: flame-colored belly or stomach, in reference to the bright reddish-orange undersurface, lower side, and anal fin, especially in nuptial males.

RANGE

Etheostoma pyrrhogaster is found in the Obion and Forked Deer River basins.

HABITAT AND MOVEMENT

The firebelly darter inhabits low-gradient, clear to slightly turbid, small- to medium-sized streams. Adults occur over silt, sand, and fine gravel substrates lacking rocks, boulders, and swift current.[2]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Note: Although this species is not recorded from the Ohio River drainage, we include a discussion of its early life history for comparison with those *Ulocentra* found in the drainage. The firebelly darter is a species of special concern in TN due to pervasive stream channelization projects. It has a more limited distribution in KY.[2]

SPAWNING

Location
Ripe females are collected from emergent vegetation, tree roots, and brush piles.[4] Egg sites include tree roots, slight depressions on the vertical sides of rocks, and less often, horizontal tops of the rocks in flowing pool habitats in slight current.[7] Spawning pairs from the Obion River are observed to prefer exposed tree roots in deep (1.0 m) flowing pool habitats.[5]

Season
Spawning continues from March–May or June in KY;[4] and from April to May in TN populations.[2]

Temperature
Spawning in Terrapin Creek, Graves County, KY, occurs when temperatures reach 11–20°C.[4,6]

Fecundity
Age 1 females longer than 27 mm SL contained a mean of 28.4 large ova per female.[4,6] Age 2 and 3 females contained a mean of 14 large ova per female. These values are considered to be underestimations of fecundity because of the likelihood of egg recruitment during the spawning season.[4,6]

Sexual Maturity
All males and females attaining age 1 were sexually mature;[2,4] age 1 females longer than 27 mm SL are sexually mature.[1]

Spawning Act
Etheostoma pyrrhogaster is an egg-attacher. Spawning was observed in darters obtained from Terrapin Creek, Graves County, KY.[4,6] Supplemented observations have been made on spawning pairs maintained in laboratory aquaria from the Obion River, TN.[5] Egg sites include tree roots, slight depressions on the vertical sides of rocks and less often, on horizontal tops of rocks in flowing pool habitats in slight current.[7] Prior to spawning, the female swims slowly over the substrate examining the sides of rocks for places to deposit eggs. A male usually follows closely behind, defending the female from other males. When the female is ready to spawn she orients herself vertically and is mounted by the male. The male body movements resemble an S-shape, with the caudal peduncle of the male wrapped around that of the female. Adults maintain a head-to-head orientation with vents juxtaposed and pressed against the rock surface. Eggs are laid individually on the vertical surface of the rock, generally 3–5 during a single spawning event. The pair is observed to switch positions on the rock, depositing eggs on different sections of the same and different rocks. Each adult is promiscuous, spawning with multiple partners on different rocks.[4,6] The female, when left unattended, spawns with any male available.[4] This sometimes occurs when a dominant male is defending the moving territory by chasing away other males. No

cleaning of the rock surface or parental care is provided before or after the eggs are laid. Eggs are most frequently laid over sand and gravel at the aquarium wall interface.[4,6] Spawning pairs from the Obion River are observed to prefer exposed tree roots in deep (1.0 m) flowing pool habitats.[5]

EGGS

Description
Eggs from Terrapin Creek, Graves Co., KY, are spherical, mean = 1.6 mm diameter (range: 1.4–1.7 mm); translucent; demersal; and adhesive. Eggs possess translucent, pale-yellow yolk (mean = 1.5 mm diameter; range: 1.3–1.6 mm); a single oil globule (mean = 0.5 mm); a moderate perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[5]

Incubation
Hatching occurs after 146–190 h at an incubation temperature of 22–28°C.[4,6]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 109

Size Range
3.5[4]–4.2[4,5]; yolk absorbed by 4.5 mm.[5]

Myomeres
Preanal 15 (5) or 16 (6)(N = 11, mean = 15.5); postanal 22 (9) or 23 (2)(N = 11, mean = 22.2); with total 37 (4), 38 (6), or 39 (1)(N = 11, mean = 37.7).[5]

Morphology
3.5–4.2 mm TL. Newly hatched larva with a terete body; snout blunt; functional jaws, upper jaw even, to slightly extending past lower jaw; yolk sac moderate (22.6% TL), oval to tapered posteriorly; yolk translucent, pale yellow, with a single oil globule; single serpentine vitelline vein mid-ventrally on yolk sac; head not deflected over the yolk sac; and eyes oval.[5] No swim bladder forms; gut straight, without striations, portion of gut posterior to stomach normal in length (3.5–4.2 mm).[5]

>4.2 mm TL. Due to limited study material, ontogenetic development cannot be continued past lengths greater than 4.5 mm; The premaxilla and mandible form, notochord flexes, yolk absorption occurs, branchiostegal rays form, dorsal and anal finfolds differentiate, and fin rays form occur at lengths greater than 4.5 mm TL.[5]

Morphometry
See Table 119.[5]

Average predorsal length 30.7% SL (range: 29.1–31.4% SL), and 29.6% TL (range: 28.0–30.2% TL).[5]

Fin Development
See Table 120.

3.5–4.2 mm. Well-developed pectoral fins without incipient rays;[5] spinous dorsal fin origin situated over preanal myomere 3–6, soft dorsal origin over preanal myomere 16–19 (3.5–4.2 mm).[5]

Pigmentation
3.5–4.2 mm TL. Newly hatched larva with pigmented eyes; melanophores dorsally outlining the optic lobe and over posterior cerebellum or nape; dorsal melanophores distributed posteriorly anterior to dorsal finfold insertion; laterally, dorsally over the gut from the pectoral fin tip to the anus; several melanophores on the caudal finfold above the notochord terminus; ventral pigmentation consists of a mid-ventral series of numerous scattered stellate melanophores forming a band around the vitelline vein on the yolk sac; punctate melanophores ventrally outline the gut; and paired punctate melanophores along almost every mid-ventral postanal myosepta.[5]

4.2–4.5 mm TL. Similar to previous length interval with exception of mid-lateral stripe forming from the pectoral fin tip to the anus.[5]

POST YOLK-SAC LARVAE

Size Range
4.5 mm TL[5] to unknown lengths.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

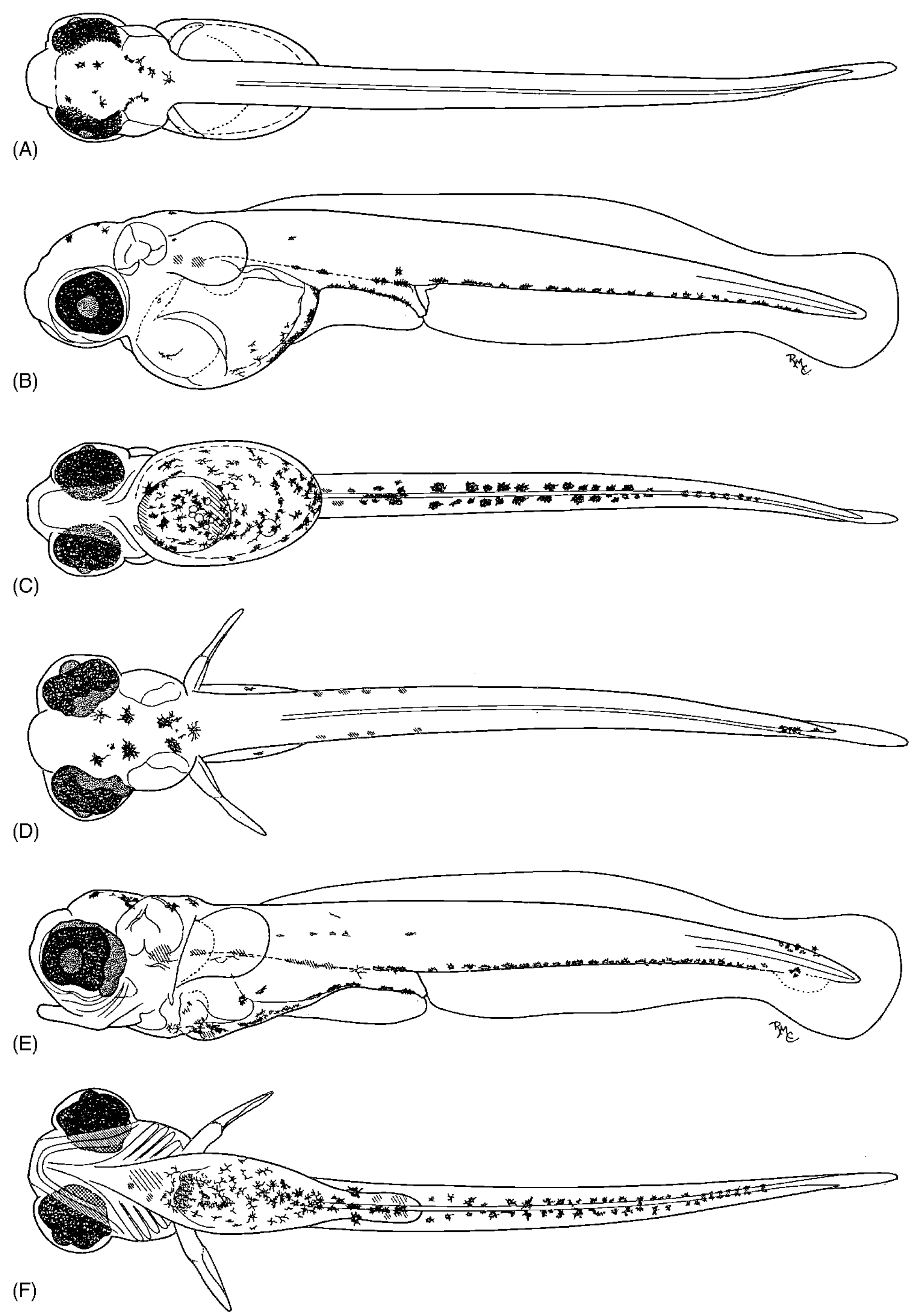

Figure 109 *Etheostoma pyrrhogaster*, firebelly darter, Terrapin Creek, Graves County, KY. Yolk-sac larva, 4.1 mm TL: (A) dorsal, (B) lateral, (C) ventral views; Yolk-sac larva, 4.4 mm TL: (D) dorsal, (E) lateral, (F) ventral views. (A–F from reference 5, with author's permission.)

JUVENILES

Size Range
Unknown to 27 mm SL.[1,2,4]

Fin Development
Branchiostegal rays 5–6,5–6;[1-3,5,6] dorsal fin spines/rays IX–(X–XI)–XII/(11–12)–13,[1-3,5,6] pectoral fin rays 13–15;[1-3,5,6] pelvic fin spines/rays I/5;[1-3,5,6] anal fin spines/rays II/(7–8)–9;[1-3,5,6] caudal fin rays viii–x, 8+8, viii–xi[5] or 15 to 17.[1,2,6]

Morphology
Early juvenile. Infraorbital, lateral, and supratemporal head canals not interrupted; preoperculomandibular canal complete with 9–10 pores, supratemporal pores 3, infraorbital pores 6–8 (usually 7), supraorbital

Table 119

Morphometry of *E. pyrrhogaster* larvae grouped by selected intervals of total length (N = sample size).[5]

	Total Length (TL) Intervals (mm)	
	3.50–4.23 (N = 11)	
Characters	**Mean ± SD**	**Range**
Length (% of TL)		
Upper Jaw[a]	21.4 ± 5.47	(0.12–0.28)
Snout[a]	12.6 ± 3.09	(0.08–0.13)
Eye diameter[a]	47.5 ± 3.53	(0.31–0.44)
Head	20.9 ± 2.05	(0.68–0.90)
Predorsal	29.6 ± 3.16	(0.98–1.28)
Dorsal insertion		
D2 origin		
D2 insertion		
Preanal	48.9 ± 1.96	(1.79–2.11)
Postanal	51.1 ± 1.96	(1.64–2.22)
Standard	96.2 ± 1.49	(3.30–4.16)
Yolk Sac	22.6 ± 2.10	(0.72–1.00)
Fin Length (% of TL)		
Pectoral	9.08 ± 1.30	(0.29–0.47)
Pelvic		
Spinous dorsal		
Soft dorsal		
Caudal	3.78 ± 1.49	(0.07–0.24)
Body Depth (% of TL)		
Head at Eyes	17.0 ± 1.81	(0.54–0.73)
Head at P1	19.9 ± 4.87	(0.52–0.98)
Preanal	8.31 ± 1.04	(0.28–0.38)
Mid–postanal	6.11 ± 0.61	(0.21–0.27)
Caudal peduncle	3.19 ± 0.38	(0.10–0.16)
Yolk sac	14.4 ± 3.57	(0.34–0.72)
Body Width (% of HL)		
Head	81.0 ± 5.55	(0.56–0.72)
Myomere Number		
Predorsal	3.36 ± 0.51	(3.00–4.00)
Soft dorsal		
Preanal	15.5 ± 0.52	(15.0–16.0)
Postanal	22.3 ± 0.47	(22.0–23.0)
Total	37.8±0.60	(37.0–39.0)

[a] Proportion expressed as percent head length.

Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

canal pores 4, coronal pore single (Bailey and Etnier, 1988). Cheek, opercle, nape, and belly are completely scaled; breast squamation usually with anterior half-naked and posterior half-covered with embedded or weakly exposed scales.[1,2]

Scales in the lateral series ranging from 36 to 46 (41 to 43[5])(usually fewer than 43) in the Obion and Forked Deer River systems.[1,2] Total vertebrae count 38 (4) or 39 (11)(N = 15, mean = 38.7).[2]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG FIREBELLY DARTER

Similar species: members of subgenus *Ulocentra.*

Adult. Firebelly darters should not be collected from the Ohio River drainage. *Etheostoma pyrrhogaster* can be differentiated from the other members of the *E. duryi* species group by the continuous broad red band in the anal fin and in both dorsal fins of males; possesses vomerine teeth; lacks a premaxillary frenum; branchiostegal rays 5; infraorbital pores 7; lateral line scales 36–46 (usually fewer than 43); and usually 10–13 scales around the caudal peduncle[2,3,8].

Larva. *Etheostoma pyrrhogaster* is similar to other *Ulocentra* members of the *E. duryi* species group in pigmentation, development, and myomere counts. The species has overlapping, low preanal (15–17) myomere counts, and low postanal (22–23) myomere counts similar to species *E. zonistium*. The species is distinguished from *E. zonistium* by hatching at smaller lengths, possessing more yolk-sac pigmentation, and slightly more epaxial pigmentation laterally and ventrally on the postanal myosepta.[5]

Variation
Intraspecific variation of *E. pyrrhogaster* is similar between population series from TN and KY.[5] The species differs from *E. duryi* species group in pigmentation and ontogenetic events. *Etheostoma pyrrhogaster* pigmentation is similar to other members of the species group, consisting of paired melanophores dorsally and few melanophores ventrally on the yolk sac.[5] Melanophores do not become clustered posteriorly at larger

Table 120

Meristic counts and size (mm TL) at the apparent onset of development for *E. pyrrhogaster*.

Attribute/event	*Etheostoma pyrrhogaster*[5]	Literature
Branchiostegal Rays	5,5[5]	5–6,5–6[1–3,6]
Dorsal Fin Spines/Rays	X–XI/11–12[5]	IX–XII/11–13[1–3,6]
First spines formed	>4.2[5]	
Adult complement formed	>4.2[5]	
First soft rays formed	>4.2[5]	
Adult complement formed	>4.2[5]	
Pectoral Fin Rays	13–14[5]	13–15[1–3,6]
First rays formed	>4.2[5]	
Adult complement formed	>4.2[5]	
Pelvic Fin Spines/Rays	I/5[5]	I/5[1–3,6]
First rays formed	>4.2[5]	
Adult complement formed	>4.2[5]	
Anal Fin Spines/Rays	II/7–8[5]	II/7–9[1–3,6]
First rays formed	>4.2[5]	
Adult complement formed	>4.2[5]	
Caudal Fin Rays	viii–x, 8+8, viii–xi[5]	15–17[1,2,6]
First rays formed	>4.2[5]	
Adult complement formed	>4.2[5]	
Lateral Line Scales	41–43[5]	36–46[1–3,6]
Myomeres/Vertebrae	37–39/38–39 [5]	Unknown/38–39[1–3,6]
Preanal myomeres	15–16[5]	15[4,6]
Postanal myomeres	22–23[5]	21[4,6]

length intervals.[5] Dorsal pigmentation extends only to the dorsal finfold origin in yolk-sac larvae. This species hatches at the smallest lengths known for subgenus *Ulocentra,* rivaling even *E. zonistium.*[5]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 110)

Eggs. Egg sites include tree roots, slight depressions on the vertical sides of rocks, and less often, horizontal tops of rocks in flowing pool habitats in slight current.[7] Spawning pairs from the Obion River are observed to prefer exposed tree roots in deep (1.0 m) flowing pool habitats.[5]

Yolk-sac larvae. Aquarium observations indicate that firebelly darter larvae are epibenthic immediately after hatching.[5] They become demersal only at greater lengths, where they remain in close association with the substrate.[5]

Post Yolk-sac Larvae. Firebelly darter larvae from Obion River, TN, were collected in equal numbers from pool areas behind tree roots and other structures that acts as obstructions in flowing habitat during mid-March.[5] All length intervals were collected in epibenthic dipnet samples from the near shore habitats usually associated with tree roots or rubble.[5]

Juveniles. Early juveniles utilize the downstream pools and backwater areas adjacent to spawning pools as nursery habitats.[5]

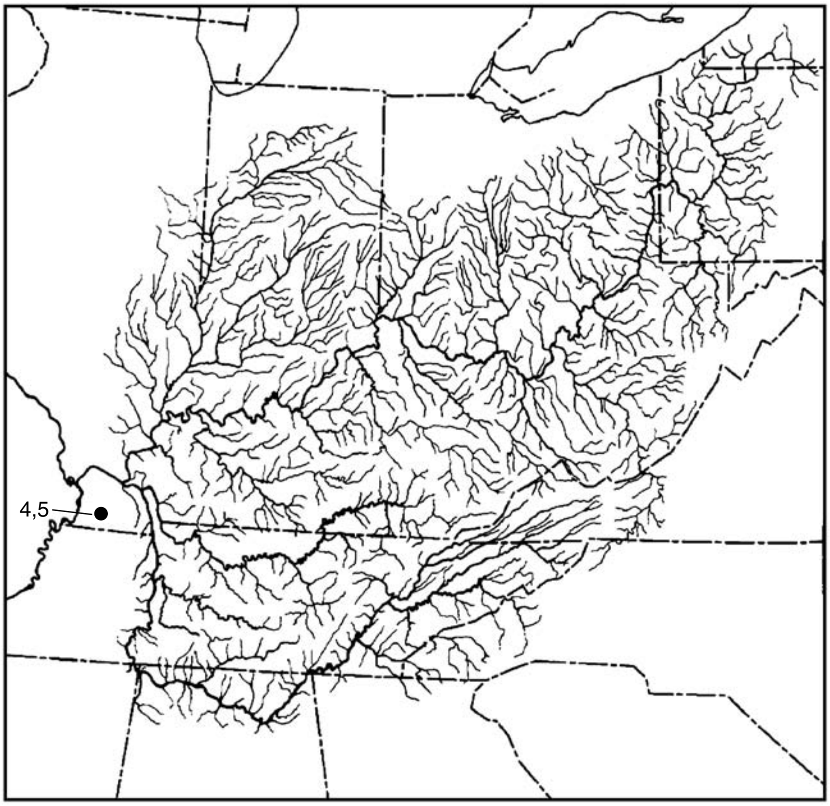

Figure 110 Location of early life history studies for firebelly darter, *E. pyrrhogaster* in the Upper Obion River system (Mississippi River drainage). Numbers represent appropriate references.

Early Growth
Firebelly darters reach 20 mm SL by mid-September, and reach maturity at age 1 when fish are between 35 mm SL in TN, while females average 32 mm and males 36 mm in Terrapin Creek, KY.[4,6]

Feeding Habits
Diet primarily comprises chironomid midge larvae.[1,4]

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Material Examined: KY: Graves Co.: Terrapin Creek, Obion River drainage, just N Tennessee Hwy 69 bridge at the TN–KY border, SIUC uncatalogued (4); SIUC uncatalogued (1); SIUC uncatalogued (1); SIUC uncatalogued (3). Beaver Slough, 0.5 miles S Bell City, SIUC uncatalogued (2).

KENTUCKY SNUBNOSE DARTER

Etheostoma (*Ulocentra*) *rafinesquei* Burr and Page

Etheostoma: various mouths; *rafinesquei*: named after the pioneer ichthyologist, Constantine S. Rafinesque.

RANGE

Etheostoma rafinesquei occurs throughout the upper Green and lower Barren River drainages, KY.[1–4] The species is most common in tributaries of the Nolin River and Little Barren River and in Russell, Brush, Pitman, and Goose Creeks. This species occurs in tributaries of the Gasper River, and is most common in headwaters, especially Wiggington Creek. Except for one upstream locality, *E. rafinesquei* is not known in the main channel of the Green River.[3]

HABITAT AND MOVEMENT

The Kentucky snubnose darter inhabits moderate-gradient, clear, small- to moderate-sized streams. Adults prefer unsilted rock or gravel substrates in flowing pools, and in the spring they are associated with riffle margins and aquatic macrophytes.[3,4]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma rafinesquei is endemic to the upper Green and lower Barren Rivers where it is occasional and uncommon.[4]

SPAWNING

Location
Egg sites include the vertical sides and horizontal tops of rocks in riffle and flowing pool habitats in slight to moderate current.[5–8]

Season
Males in spawning color were found from mid-March until late May in moderate current on riffles.[3] Kentucky snubnose darter peak spawning occurs during mid-April in Middle Pitman Creek, KY.[8] Spawning throughout its range occurs from late March until mid-May.[6–8]

Temperature
Spawning activity initiates in Middle Pitman Creek, KY, when temperatures reach 20°C, and terminates when temperatures are consistently over 20°C.[8]

Fecundity
Etheostoma rafinesquei has clutch size correlated with stream temperature and interclutch interval is inversely correlated with temperature.[8]

Sexual Maturity
Males and females are sexually mature at age 1. Females longer than 32 mm are involved in spawning.[9]

Spawning Act
Etheostoma rafinesquei is an egg attacher. Field and laboratory observations showed that males established dominance hierarchies and maintained floating territories.[5,6] A single male follows a single female to the egg site and mounts the female as their bodies are pressed against the vertical sides of large inclined stones. Adults maintain a head-to-head orientation with vents juxtaposed. Eggs are laid individually on the vertical surface of the rock, generally 3–5 during a single spawning event as the pair ascends steep rocks as much as 30 cm off the bottom.[5,6] The pair is observed to switch positions on the rock, depositing eggs on different sections of the same and different rocks (Weddle, G., personal communication). Spawning preference is for vertical substrates (68% of total spawn), inclined surfaces (27%), and least preferred are horizontal surfaces (>5%).[7] Eggs are also attached to a pore on an individual piece of gravel, but are not buried in the gravel.[7] *Etheostoma rafinesquei* also is reported to invert while spawning.[7] Since only a single pair of adults were maintained in the aquarium and field trials it cannot be determined if the pair would have switched spawning partners as noted by Page and Mayden in their observations of *E. atripinne* and *E. etnieri*.[9] Spawning duration may be as long as 2 months before reproduction is discontinued.[9] No cleaning of the rock surface or parental care is provided before or after the eggs are laid.[9] Spawning occurs approximately every 1.5–2.6 days for approximately 2 months.[9]

EGGS

Description
Eggs from Middle Pitman Creek, Taylor Co., KY, are spherical, mean = 1.2 mm in diameter (range: 1.0–1.3 mm); translucent; demersal; and adhesive.[9] Eggs possess translucent, pale-yellow yolk (mean = 1.0 mm diameter; range: 0.9–1.1 mm); a single oil globule (mean = 0.5 mm); a moderate perivitelline space (mean = 0.15 mm); and an unsculptured and unpigmented chorion.[9]

Incubation
Hatching occurs after 144–168 h at an incubation temperature of 20°C (G. Weddle, personal communication).[9]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 111

Size Range
3.6–4.6 mm TL; yolk absorbed by 4.9–5.2 mm TL.[9]

Myomeres
Preanal 16 (49), 17 (36), 18 (4), or 19 (1)(*N* = 90, mean = 16.5); postanal 22 (39), 23 (36), or 24 (15)(*N* = 90, mean = 22.7); with total 38 (11), 39 (48), 40 (27), or 41 (4)(*N* = 90, mean = 39.3).[9]

Morphology
3.6–4.6 mm TL. Newly hatched larvae with terete body; snout blunt; with functional jaws, upper jaw even to slightly extending past lower jaw; yolk sac small (26.2% TL), oval to tapered posteriorly; yolk translucent pale yellow, with a single oil globule; single serpentine vitelline vein mid-ventrally on yolk sac; head not deflected over the yolk sac; and eyes oval.[9]

4.3–5.2 mm TL. Premaxilla and mandible form.[9]

Morphometry
See Table 121.[9]

Fin Development
See Table 122.

3.6–4.6 mm TL. Well-developed pectoral fins without incipient rays.[9]

Pigmentation
3.6–4.6 mm TL. Newly hatched larvae with pigmented eyes; melanophores dorsally over posterior cerebellum and nape; laterally, melanophores distributed dorsally and ventrally around the gut posterior to the yolk sac. Ventral pigmentation consists of a midventral band of stellate melanophores surrounding the vitelline vein on the yolk sac, and punctate melanophores along every midventral postanal myosepta forming a continuous stripe.[9]

4.8–4.9 mm TL. Additional punctate melanophores dorsally on optic lobe, otherwise similar to previous length interval.[9]

POST YOLK-SAC LARVAE

See Figures 111 and 112

Size Range
4.9–11.7 mm TL.[9]

Myomeres
Preanal 16 (49), 17 (36), 18 (4), or 19 (1) (*N* = 90, mean = 16.5), postanal 22 (39), 23 (36), or 24 (15)(*N* = 90, mean = 22.7); with total 38 (11), 39 (48), 40 (27), or 41 (4)(*N* = 90, mean = 39.3).[9]

Morphology
4.9–5.2 mm TL. Yolk absorbed.[9]

5.9–6.3 mm TL. Digestive system functions preceeding complete yolk absorption.[9]

6.3–7.6 mm TL. Operculum and gill arches function (7.0–7.6 mm).[9]

7.3–9.6 mm TL. Branchiostegal rays form.[9]

7.4–11.7 mm TL. No swim bladder forms; gut straight, without striations, portion of gut posterior to stomach normal in length.[9]

9.2–10.5 mm TL. Neuromast development occurs midlaterally from the anterior trunk posteriad (9.4 mm).[9]

Morphometry
See Table 121.[9]

Fin Development
See Table 122.[9]

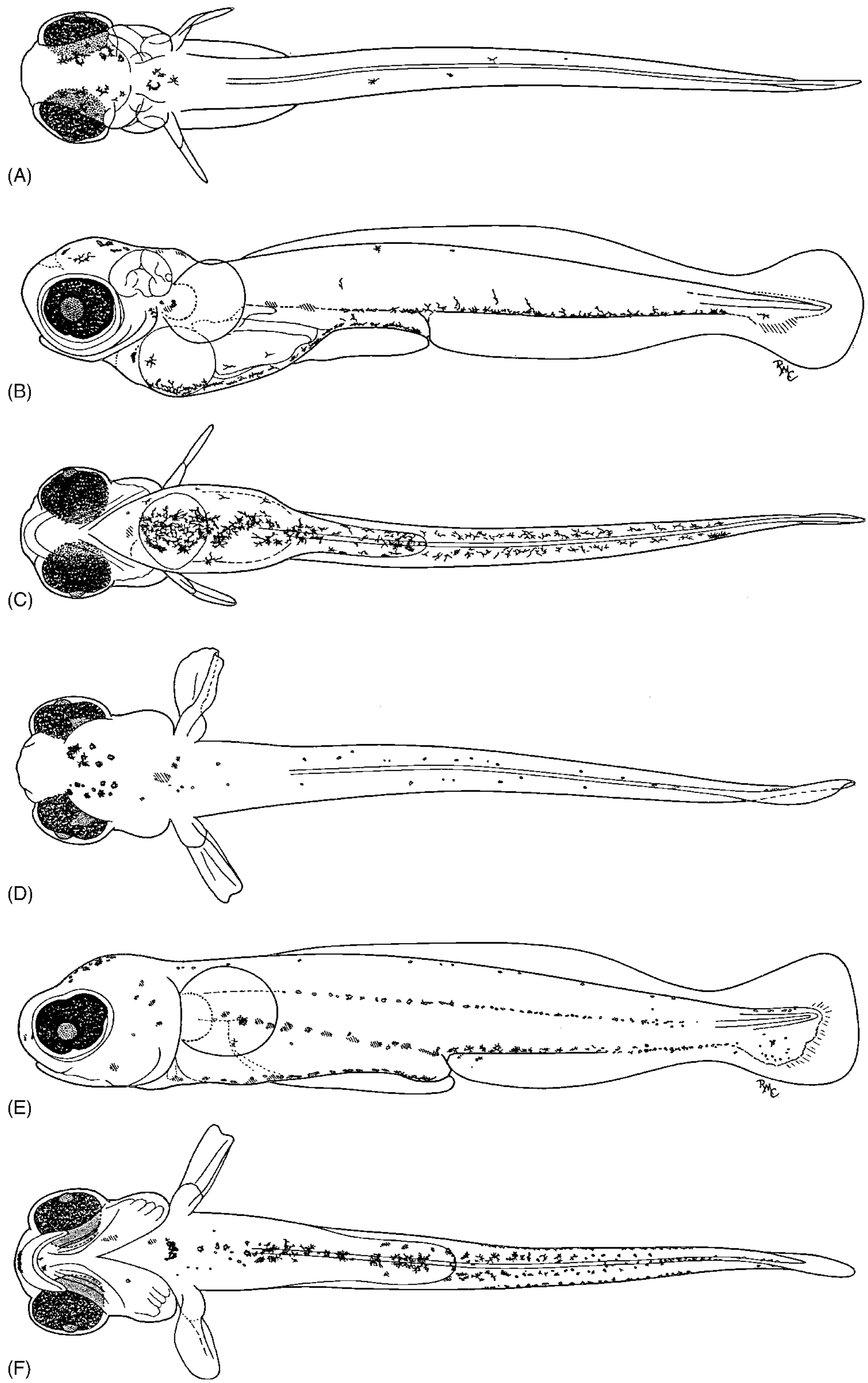

Figure 111 *Etheostoma rafinesquei*, Kentucky snubnose darter, Middle Pitman Creek, Taylor County, KY. Yolk sac larva, 4.5 mm TL: (A) dorsal, (B) lateral, (C) ventral views; post yolk-sac larva, 7.1 mm TL, (D) dorsal, (E) lateral, (F) ventral views. (A–F from reference 9, with author's permission.)

6.3–7.6 mm TL. First rays form in caudal fin (6.4–6.6 mm); pectoral fin rays form (6.3–7.6 mm); anal and soft dorsal fin rays form (7.0–7.6 mm).[9] Notochord flexion occurs simultaneously or shortly after caudal fin ray development (7.1–7.6 mm);[9]

7.3–9.6 mm TL. Branchiostegal rays form.[9]

7.6–8.3 mm TL. Pelvic fin buds form anterior to dorsal fin originate after complete yolk absorption.[9]

Table 121

Morphometry of young *E. rafinesquei* grouped by selected intervals of total length (*N* = sample size).[9]

	Total Length (TL) Intervals (mm)											
	3.62–4.88 (*N*=14)		5.01–6.99 (*N*=44)		7.02–8.99 (*N*=35)		9.11–10.9 (*N*=36)		11.1–12.9 (*N*=26)		13.1–16.4 (*N*=17)	
Characters	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
Length (% of TL)												
Upper jaw [a]	30.3 ± 4.13	(0.20–0.32)	28.7 ± 6.59	(0.16–0.81)	27.8 ± 5.08	(0.25–0.64)	25.3 ± 3.55	(0.39–0.66)	24.5 ± 3.09	(0.48–0.77)	27.3 ± 4.45	(0.58–1.04)
Snout [a]	16.4 ± 2.02	(0.10–0.15)	14.7 ± 3.67	(0.08–0.34)	15.1 ± 5.14	(0.10–0.62)	18.2 ± 2.20	(0.22–0.50)	18.0 ± 1.76	(0.36–0.56)	18.9 ± 2.40	(0.41–0.62)
Eye diameter[a]	47.0 ± 3.24	(0.29–0.46)	41.9 ± 4.28	(0.36–0.58)	39.6 ± 5.76	(0.22–0.77)	35.2 ± 1.93	(0.62–0.80)	33.6 ± 2.16	(0.75–0.98)	33.2 ± 1.64	(0.80–1.10)
Head	18.4 ± 1.37	(0.67–0.92)	19.6 ± 1.59	(0.86–1.44)	19.9 ± 1.09	(1.33–1.86)	20.4 ± 1.14	(1.70–2.30)	21.6 ± 1.46	(2.26–2.98)	21.2 ± 1.24	(2.58–3.34)
Predorsal	28.7 ± 4.64	(0.86–1.40)	29.8 ± 3.54	(0.82–2.57)	28.5 ± 1.80	(1.84–2.61)	27.2 ± 1.09	(2.40–3.00)	27.6 ± 1.26	(2.90–3.64)	27.2 ± 0.88	(3.42–4.48)
Dorsal insertion							34.3 ± 9.14	(2.40–5.16)	32.7 ± 8.42	(3.00–6.04)	38.9 ± 8.71	(3.60–7.12)
D2 origin							36.8 ± 12.3	(2.40–5.66)	34.1 ± 10.7	(3.00–6.68)	42.2 ± 11.2	(3.60–8.48)
D2 insertion							44.4 ± 21.9	(2.40–5.66)	39.6 ± 19.9	(3.00–6.68)	55.0 ± 20.9	(3.60–8.48)
Preanal	49.8 ± 1.53	(1.82–2.52)	49.5 ± 3.10	(2.18–3.62)	51.5 ± 1.14	(3.46–4.58)	50.8 ± 0.93	(4.59–5.62)	49.9 ± 1.29	(5.32–6.40)	48.8 ± 2.14	(6.38–8.14)
Postanal	50.2 ± 1.54	(1.80–2.60)	49.7 ± 1.84	(2.38–3.48)	48.6 ± 1.16	(3.32–4.43)	49.2 ± 0.93	(4.39–5.54)	50.8 ± 1.81	(5.58–6.64)	51.1 ± 2.15	(6.44–9.34)
Standard	96.2 ± 0.90	(3.50–4.74)	95.6 ± 2.63	(4.45–6.74)	95.3 ± 1.76	(6.75–8.14)	88.9 ± 2.48	(7.95–9.76)	86.4 ± 2.76	(9.42–11.1)	84.9 ± 1.20	(11.0–13.8)
Yolk sac	26.2 ± 3.26	(0.92–1.48)	23.5	(1.32–1.32)								
Fin Length (% of TL)												
Pectoral	9.15 ± 1.28	(0.28–0.56)	10.8 ± 1.74	(0.40–0.88)	11.3 ± 1.11	(0.70–1.02)	14.9 ± 3.66	(1.06–2.68)	14.4 ± 3.19	(1.22–2.24)	17.0 ± 3.89	(1.28–3.14)
Pelvic					1.50 ± 1.35	(0.01–0.24)	5.20 ± 1.64	(0.14–0.88)	8.77 ± 2.75	(0.34–1.44)	11.7 ± 4.96	(0.37–2.72)
Spinous dorsal							18.2 ± 2.23	(1.22–2.26)	19.2 ± 1.19	(2.18–2.54)	18.1 ± 2.32	(2.00–3.06)
Soft dorsal							19.5 ± 0.94	(1.75–2.24)	20.6 ± 0.73	(2.34–2.74)	19.8 ± 1.21	(2.56–3.40)
Caudal	3.80 ± 0.90	(0.12–0.26)	4.39 ± 2.63	(0.12–1.16)	4.73 ± 1.76	(0.10–0.85)	11.1 ± 2.48	(0.10–1.45)	13.6 ± 2.76	(0.62–2.12)	15.1 ± 1.20	(1.71–2.53)
Body Depth (% of TL)												
Head at eyes	16.6 ± 2.80	(0.58–1.17)	15.6 ± 0.94	(0.72–1.16)	15.7 ± 0.59	(1.04–1.36)	14.9 ± 0.62	(1.28–1.62)	14.4 ± 0.82	(1.49–1.89)	14.2 ± 0.93	(1.81–2.27)
Head at P1	22.9 ± 3.78	(0.79–1.14)	15.0 ± 0.80	(0.71–1.10)	15.3 ± 0.73	(1.00–1.32)	15.2 ± 0.85	(1.30–1.74)	17.2 ± 3.85	(1.57–3.22)	15.8 ± 1.20	(1.89–2.49)
Preanal	8.68 ± 2.93	(0.22–0.79)	10.3 ± 1.27	(0.35–0.80)	11.4 ± 0.71	(0.72–1.12)	12.8 ± 0.94	(1.00–1.47)	13.8 ± 0.66	(1.48–1.80)	13.1 ± 0.94	(1.60–2.06)
Mid-postanal	6.50 ± 2.44	(0.15–0.62)	7.34 ± 0.93	(0.24–0.62)	8.37 ± 0.64	(0.52–0.82)	8.82 ± 0.47	(0.74–0.97)	9.07 ± 0.42	(0.98–1.22)	8.81 ± 0.70	(1.10–1.38)
Caudal peduncle	2.93 ± 1.36	(0.09–0.37)	1.81 ± 2.34	(0.13–0.37)	2.74 ± 2.47	(0.28–0.57)	3.55 ± 3.70	(0.56–0.82)	2.29 ± 5.52	(0.82–1.00)	4.51 ± 2.65	(0.90–1.02)
Yolk sac	14.4 ± 4.73	(0.40–1.00)	5.70	(0.32–0.32)								
Body Width (% of HL)												
Head	83.2 ± 15.4	(0.58–1.10)	73.4±8.76	(0.70–1.02)	70.0 ± 4.00	(0.96–1.22)	66.4 ± 5.43	(1.16–1.46)	59.2 ± 3.73	(1.26–1.74)	65.9 ± 20.8	(1.44–3.88)
Myomere Number												
Predorsal	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)	3.96 ± 0.20	(3.00–4.00)	4.00 ± 0.00	(4.00–4.00)
Soft dorsal	16.0	(16.0–16.0)	16.0 ± 0.00	(16.0–16.0)	15.8 ± 0.73	(15.0–17.0)	16.4 ± 0.91	(16.0–19.0)	17.2 ± 0.69	(16.0–20.0)	17.3 ± 0.60	(17.0–19.0)
Preanal	16.1 ± 0.27	(16.0–17.0)	16.2 ± 0.39	(16.0–17.0)	16.3 ± 0.46	(16.0–17.0)	16.6 ± 0.60	(16.0–18.0)	16.4 ± 0.70	(16.0–19.0)	16.6 ± 0.87	(16.0–19.0)
Postanal	23.9 ± 0.37	(23.0–24.0)	23.2 ± 0.62	(22.0–24.0)	22.9 ± 0.55	(22.0–24.0)	22.8 ± 0.78	(22.0–24.0)	22.9 ± 0.63	(22.0–24.0)	22.8 ± 0.67	(22.0–24.0)
Total	39.9 ± 0.27	(39.0–40.0)	39.4 ± 0.58	(38.0–40.0)	39.1 ± 0.50	(38.0–40.0)	39.4 ± 0.68	(38.0–41.0)	39.3 ± 0.69	(38.0–41.0)	39.5 ± 0.94	(38.0–41.0)

[a] Proportion expressed as percent head length.

Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

Table 122

Meristic counts and size (mm TL) at the apparent onset of development for *E. rafinesquei*.[9]

Attribute/event	*Etheostoma rafinesquei*	Literature
Branchiostegal Rays	5,5[9]	5,5[1,3]
Dorsal Fin Spines/Rays	X–XII/10–13[9]	X–XIII/10–12[1,3]
First spines formed	8.4–8.9[9]	12–15[11]
Adult complement formed	9.2–9.8[9]	12–15[11]
First soft rays formed	7.7–8.2[9]	8.5[11]
Adult complement formed	7.7–9.1[9]	12–15[11]
Pectoral Fin Rays	13–15[9]	13–15[1,3]
First rays formed	7.4–9.3[9]	10–12[11]
Adult complement formed	7.4–9.3[9]	12–15[11]
Pelvic Fin Spines/Rays	I/5[9]	I/5[1,3]
First rays formed	9.1–9.3[9]	12–15[11]
Adult complement formed	9.1–9.3[9]	12–15[11]
Anal Fin Spines/Rays	II/7–8[9]	II/6–8[1,3]
First rays formed	7.6–8.2[9]	8.5[11]
Adult complement formed	9.1–9.4[9]	12–15[11]
Caudal Fin Rays	viii–x, 8–9+7–8, viii–ix[9]	11–16[3]
First rays formed	6.8–7.5[9]	10–12[11]
Adult complement formed	9.1–10.4[9]	12–15[11]
Lateral Line Scales	42–49[9]	37–56[1,3]
Myomeres/Vertebrae	38–41/38–39 [9]	Unknown/38–41[1,3,12]
Preanal myomeres	16–19[9]	
Postanal myomeres	22–24[9]	

8.2–9.2 mm TL. Dorsal and anal finfold partially differentiated.[9]

7.1–9.3 mm TL. Spinous dorsal fin origin situated over preanal myomere 3–4, soft dorsal originate over preanal myomere 15–19.[9]

9.2–10.5 mm TL. Spinous dorsal rays form (9.2–10.5 mm).[9]

10.5–10.9 mm TL. First pelvic fin ray form.[9]

9.2–12.7 mm TL. Complete adult fin ray counts in median fins.[9]

10.1–11.7 mm TL. Both finfolds are completely differentiated.[9]

Pigmentation

4.9–6.6 mm TL. Additional punctate melanophores dorsally on optic lobe, otherwise similar to previous length interval.[9]

6.8–8.8 mm TL. Dorsum of cranium with several large melanophore clusters on cerebellum; dorsum of body with patches of melanophores at nape, posterior dorsal finfold origin, at developing soft dorsal rays, and at the caudal peduncle. Several melanophores anterior to eye, forming preorbital bar; several melanophores posterior to eye on operculum; laterally, a series of melanophores from the pectoral fin tip to the anus; a mid-lateral stripe of single melanophores from the pectoral fin to the caudal peduncle base along the notochord. A series of melanophores occurs mid-ventrally from the breast to midstomach; a cluster of mid-ventral postanal melanophores begin at anal fin insertion and continue toward caudal peduncle; a series of melanophores at each mid-ventral postanal myosepta.[9]

8.9–9.7 mm TL. Cranial clusters of melanophores on the tip of the snout and chin, posterior to eye on the cheek, and dorsum of the cerebellum; second cluster of ventral melanophores forming over the developing anal fin.[9]

9.8–11.7 mm TL. Heavily pigmented; distinct preorbital bar; chin pigmentation outlines mandible; melanophores scattered on cheek and ventral half of opercle; dorsum with a series of melanophores forming large rectangular clusters from the nape to the soft dorsal fin insertion; melanophores dorsally forming a continuous line of pigment from the anal fin tip to the caudal peduncle base. A series of melanophores extend from midpectoral fin to the hypural plate; a series of large clustered melanophores form a series of cutaneous and subdermal stripes over the gut; three large clustered melanophores present over the anus. Ventral melanophores form a single mid-ventral row from the breast to the anus; mid-ventral melanophores densely distributed over the entire anal fin forming two rows over last six postanal myosepta.[9]

JUVENILES

See Figure 112

Size Range
11.7–32 mm TL.[9]

Fin Development
See Table 122

13.2 mm TL. Caudal fin slightly emarginate (13.2 mm).[9]

Morphology
12.2–13.2 mm TL. Upper jaw equal with lower jaw becoming subterminal (12.2–13.2 mm).[9]

14.2–16.1 mm TL. Infraorbital and supraorbital canals form.[9]

16.4 mm TL. Lateral, subtemporal and preoperculomandibular head canals form.[9]

18.0 mm TL. Initiation of squamation and lateral line begin to form.[9]

Early juveniles. Infraorbital, lateral, and supratemporal head canals not interrupted, preoperculomandibular canal complete with 9 pores, infraorbital pores 7–9.[3,9] Cheek scales variable, usually embedded; opercle, nape, and belly are completely scaled; breast naked to partially scaled.[1,3,9] Total vertebrae count 38–39 (N = 3, mean = 38.7), including one urostylar element. Scales in the lateral series range from 37 to 42 throughout the range.[3,9]

Morphometry
See Table 121.[9]

12.2–13.2 mm TL. Average predorsal length 30.8% SL (range: 28.5–36.3% SL), and 28.3% TL (range: 26.1–33.3% TL).

Pigmentation
12.1–13.5 mm TL. Well-defined preorbital and postorbital bar; anterior outline of cerebellum and entire optic lobe covered with melanophores; eight distinct saddles forming from the nape to the caudal peduncle. Lateral pigmentation consists of a distinct, continuous, mid-lateral stripe from the shoulder to the caudal fin base; a series of melanophores present over the gut; a vertical series of melanophores present along caudal fin base, forming a medial stripe in the spinous dorsal fin; proximally and medially in the soft dorsal fin; and proximally along the anal fin. The ventrum of the chin possesses melanophores along the edge; continues from the breast to the anus mid-ventrally; and forms three clusters from the anus, around the anal fin, and along the caudal peduncle.[9]

14.4–19.0 mm TL. Preorbital bar well developed but postorbital bar weakly formed, consisting of only a chevron-shaped cluster of melanophores on the operculum; dorsum of cranium with two distinct lines of melanophores outlining the cerebellum and covering the optic lobe; dorsum with eight saddles of accumulated melanophores. Lateral melanophores form a series of mid-lateral clusters along the midline from the shoulder to the caudal peduncle; a series of horizonal hypaxial melanophores extends from the anus to the hypural plate. Ventral melanophores are present between the pelvic fin on the breast, and at the lepidiotrichia interdigitation with the pterigiophores of the anal fin. Medial stripe of melanophores in the spinous and soft dorsal fins; dense melanophores along the vertical base of the caudal fin and scattered throughout the membranes. No pigmentation apparent in the pectoral, anal, or pelvic fins.[9]

TAXONOMIC DIAGNOSIS OF YOUNG KENTUCKY SNUBNOSE DARTERS

Similar species: members of subgenus *Ulocentra.*

Adult. Etheostoma rafinesquei is a member of the *simoterum* species group of the darter subgenus *Ulocentra*. *Etheostoma rafinesquei* can be differentiated from other members of the *E. simoterum* species group

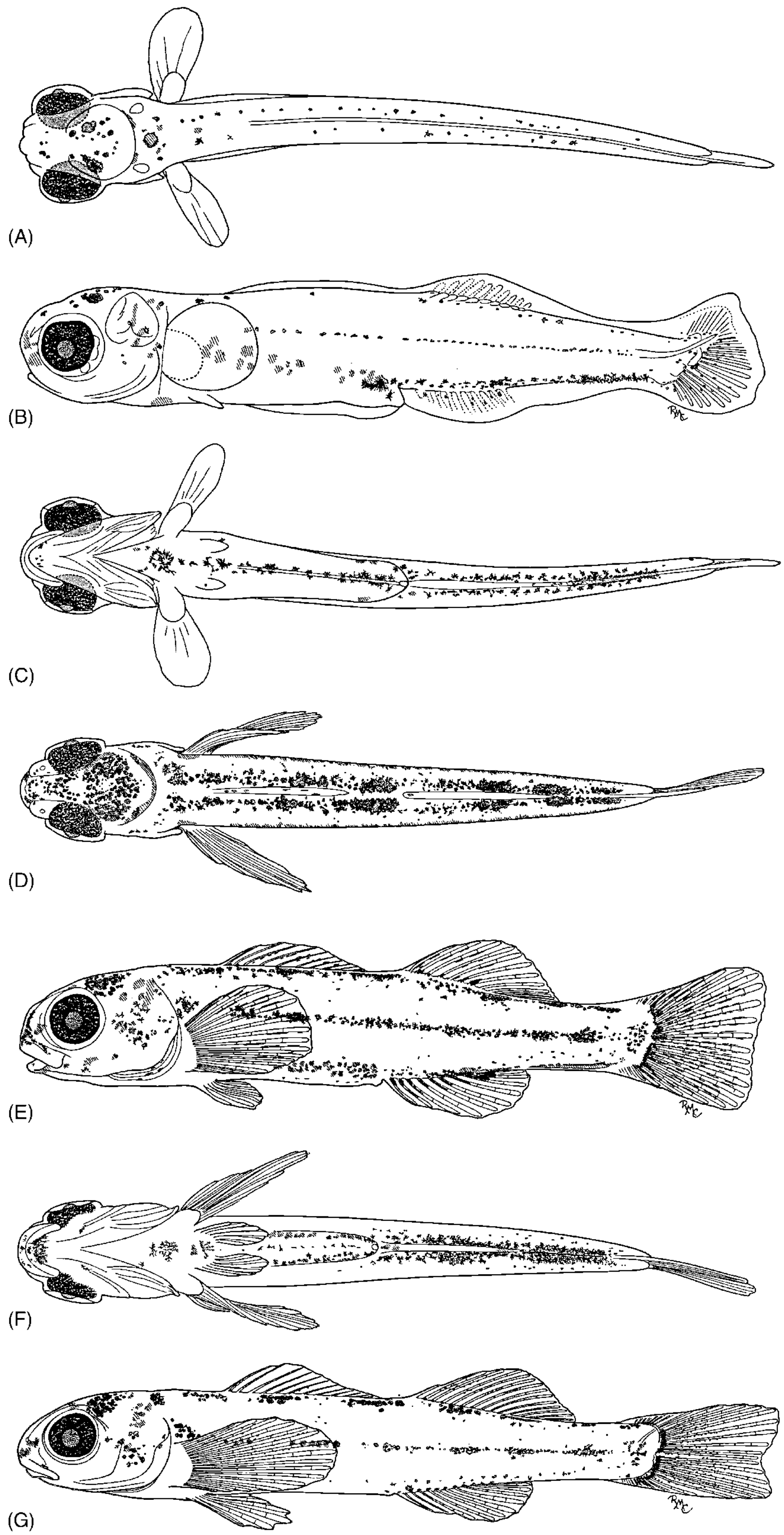

Figure 112 *Etheostoma rafinesquei*, Kentucky snubnose darter, Middle Pitman Creek, Taylor County, KY. Post yolk-sac larva, 9.0 mm TL: (A) dorsal, (B) lateral, (C) ventral views; early juvenile, 13.5 mm TL, (D) dorsal, (E) lateral, (F) ventral views. Juvenile, 18.1 mm TL, (G) lateral view. (A–G from reference 9, with author's permission.)

based on low lateral line and traverse scale counts. *Etheostoma rafinesquei* has 37–42 lateral line scales and 10–12 traverse scales; 7–10 dark bars that are 5–6 scale rows high; and a dorsum with 7–9 saddles. *Etheostoma rafinesquei* occurs throughout the upper Green River and its tributaries at least as far downstream as Nolin River, KY.[1,3,4,10]

Larva. *Etheostoma rafinesquei* is very similar to species *E. barrenense*; however, it differs in subtle pigmentation and myomere counts.[9] Both species have overlapping, moderate preanal (16–19) myomere counts, while *E. rafinesquei* has higher postanal (22–24) myomere counts.[9]

Variation
Etheostoma rafinesquei differs from *E. barrenense* based on ontogenetic events and pigmentation. Yolk-sac larvae, although similarly pigmented as other *Ulocentra* species, hatch at smaller length intervals than other sympatric species.[9] At lengths greater than 6 mm, larvae develop a mid-lateral stripe that persists until larger length intervals.[9] Although *E. rafinesquei* is most similar to *E. barrenense*, the two are allopatric.[9]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 113)
Eggs: Egg sites include the vertical sides and horizontal tops of rocks in riffle and flowing pool habitats in slight to moderate current.[5–8]

Yolk-sac larvae. Aquarium observations indicate that Kentucky snubnose darter larvae are epibenthic immediately after hatching.[9]

Post yolk-sac larvae. All length intervals less than 13 mm are collected in epibenthic dipnet samples from the near shore habitats usually associated with tree roots or rubble.[9] Kentucky snubnose darters become demersal only at lengths greater than 13 mm, at which time they remain in close association with the substrate.[9] Kentucky snubnose darter larvae from Middle Pitman Creek are collected in equal numbers from eddy areas adjacent to riffles and from behind tree roots.[9] These and other structures act as obstructions in flowing pool habitats

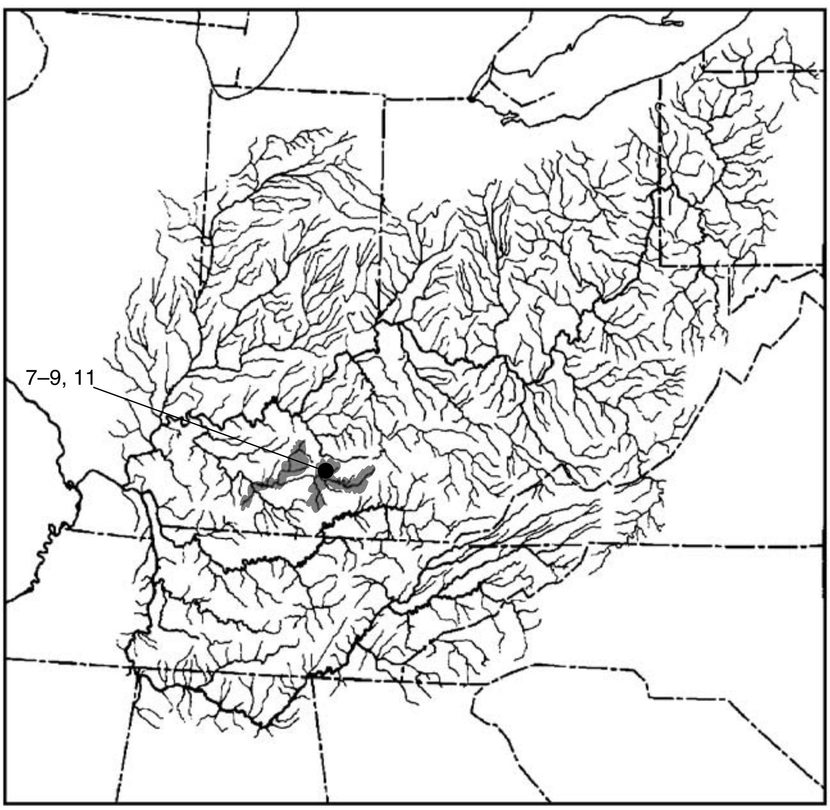

Figure 113 Distribution of Kentucky snubnose darter, *E. rafinesquei* in the Ohio River system (shaded area), and areas where early life history information has been collected (circle). Numbers indicate appropriate references.

from late April to late May (G. Weddle, personal communication).

Juveniles. In Middle Pitman Creek, downstream pools and backwater areas adjacent to spawning riffles serve as nursery habitats.[9] Juveniles 19 mm TL were found on downstream rootwads and root mats.[9]

Early Growth
No information

Feeding Habits
Larva and early juveniles feed on mayflies and midge larvae.[9]

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Material Examined: KY: Taylor Co.: Middle Pitman Creek, at Salem Church Road, 3.3 miles NW Campbellsville, SIUC uncatalogued (3); SIUC uncatalogued (3); SIUC uncatalogued (6); SIUC uncatalogued (28); SIUC uncatalogued (22); SIUC uncatalogued (6); SIUC uncatalogued (1); SIUC uncatalogued (65); SIUC uncatalogued (26).

REDLINE DARTER

Etheostoma (*Nothonotus*) *rufilineatum* (Cope)

Etheostoma: various mouths; *rufilineatum*: redline.

RANGE

Etheostoma rufilineatum is restricted to the Tennessee and Cumberland River systems. It is common in the eastern TN portion of the Tennessee River, but is rare in western streams tributary to the lower Tennessee River.[1,7] *Etheostoma rufilineatum* occurs throughout the Cumberland River drainage below Cumberland Falls.[2–7]

HABITAT AND MOVEMENT

Etheostoma rufilineatum usually inhabits riffle areas of a variety of stream sizes ranging from medium to large creeks and streams to moderate-sized rivers. Occurs in moderate current, over clean gravel substrates, at depths of 25–50 cm.[2] In KY, prefers long riffles with slow to moderate current over clean sand, gravel, and rubble substrates.[2–4] The species moves slightly into deeper portions of the same riffle during the winter months.[*,7]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma rufilineatum is common in the Tennessee and Cumberland River systems.[1–7] In the TN portion of the Cumberland River system it is restricted to the area west of the Big South Fork,[1,3–5] but occurs throughout the Cumberland River system below Cumberland Falls.[2,7]

SPAWNING

Location
Eggs were spawned in riffles or run habitats with swift current in sand and gravel.[8] Eggs were buried beside or between cobble,[8] and deposited in small clusters.[4] Spawning adults were collected from rubble riffles at water depths ranging from 0.7 to 1.0 m in the Pigeon River, Cocke Co., TN and from gravel shoals at depths of 0.5–1.0 m in the Little River, Blount Co., TN.

Season
Spawning in the Little River, TN, occurs from late May to early August.[8] Spawning occurs earlier in Hinds Creek, Anderson Co., TN, from early April until late July.* Peak spawning in Hinds Creek occurred during mid-July.* Spawning in the North Fork Holston River, occurred from mid-May until mid-August.[9]

Temperature
Spawning began at temperatures ranging from 15 to 17 C;* field observations from Hinds Creek found daytime water temperatures during spawning periods to range from 12.4 to 24.4°C.*

Fecundity (see Table 123)
Three size classes of ova existed, but no correlation was observed between numbers of mature ova (class I) and adjusted body weight and between mature ova and standard length.[9] Ovarian eggs mature in batches of about 5–8 ova.* In Hinds Creek, TN, clutch size ranged from 13 to 132 mature oocytes and averaged 98.4. Larger females produced larger clutches (r = 0.01; $p < 0.01$).* Ovaries represented 12.6% of the total body weight. Female *E. rufilineatum* did not show statistically significant increasing fecundity (ANOVA, $F = 6.653$, $p > 0.031$) with increasing length. Females between 49 and 71 mm collected during early April had 31–84 large mature ova.*

Sexual Maturity
Males and females were sexually mature at age 1.[*,8,9] Females and males matured at lengths greater than 42 mm TL from the North Fork Holston River, VA.[8,9]

Spawning Act
Etheostoma ruflineatum is an egg clumper. The redline darter is polygamous, exhibiting male polygyny and female polyandry. Males establish territories around cobble or large gravel. Males first begin to exhibit spawning colors in December, but ripe males appear on the spawning riffles only in March. Courting consists mainly of an intensely colored male making lateral displays, which leads the female into the spawning territory. The male exhibits brilliant

Table 123

Fecundity data for redline darter from the Little River, Tennessee River drainage, Blount Co., TN.*

		Number of Ova			
Length (mm TL)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM,MA,LM)	Ripe Eggs (MR,RE)	Egg Diameter (mm)
49	144	340	66	31	1.66
50	192	424	56	49	1.66
51	209	394	89	42	1.81
53	192	528	103	59	1.54
56	246	552	133	35	1.81
57	290	447	96	64	1.81
60	284	592	130	69	1.54
63	406	744	145	84	1.66
64	283	763	192	71	1.54
65	307	795	208	38	1.66
71	579	912	278	83	1.66

red pigmentation on the sides and fins. The female, when ready to spawn, approaches the guarded territory, The male is territorial, guarding an area around a rock, even when removed. Females bury themselves between two cobble or boulder rocks during egg laying. A single male mounts the female and the eggs are attached to the sides of the large rocks or attached below the substrate on the rocks. The female arches her body and deposits 5–8 eggs in a small cluster. The male is usually positioned laterally alongside the female. He raises his head, arches his caudal peduncle, pressing his genital papilla downward, quivers, and extrudes milt for a few seconds. Egg masses are clustered together, but not in a grape-like adhesive cluster as in other *Nothonotus*.* Spawning territories are guarded exclusively by the males.[8]

EGGS

Description
Ovarian examination showed that ovoid cream-colored latent ova ranged from 0.4 to 0.5 mm, early maturing small spherical orange-colored ova ranged between 0.83 and 0.95 mm, and large mature, orange ova ranged between 1.54 and 1.81 mm (T.P. Simon, unpublished data).* Mature ova are demersal, adhesive, transparent, and spherical, and possess a single, large oil globule, a narrow perivitelline space, and an unsculptured chorion.* Hinds Creek, TN eggs averaged 2.0 mm in diameter. Eggs were transparent and possessed a pale yellow yolk.*

Incubation
Eggs cultured in laboratory aquaria at 15–17°C hatched after 408 h;* and those cultured at 14.5–16.2°C hatched in 336–406 h.*

Development
Ova development began in late February;[9] stage I oocytes are disk-shaped when in side female ovaries.*

YOLK-SAC LARVAE

See Figure 114

Size Range
Newly hatched at 6.2–6.9 mm TL; yolk absorbed by 8.5 mm TL in TN.*[,18]

Myomeres
Predorsal 6; preanal 19 (5), 20 (13), or 21(1) (mean = 19.8; *N* = 19), postanal 16 (1), 18 (1), 19 (9), 20 (7), or 21 (1) (mean = 19.3; *N* = 19); total 37(1), 38(2), 39(12), 40(3), or 41(1).*[,18]

Morphology
6.2–6.8 mm TL. Pale yellow, translucent yolk, moderate (32.8% TL) oval yolk sac. Cranium not enlarged anteriorly, extending beyond the snout; eyes ovoid;

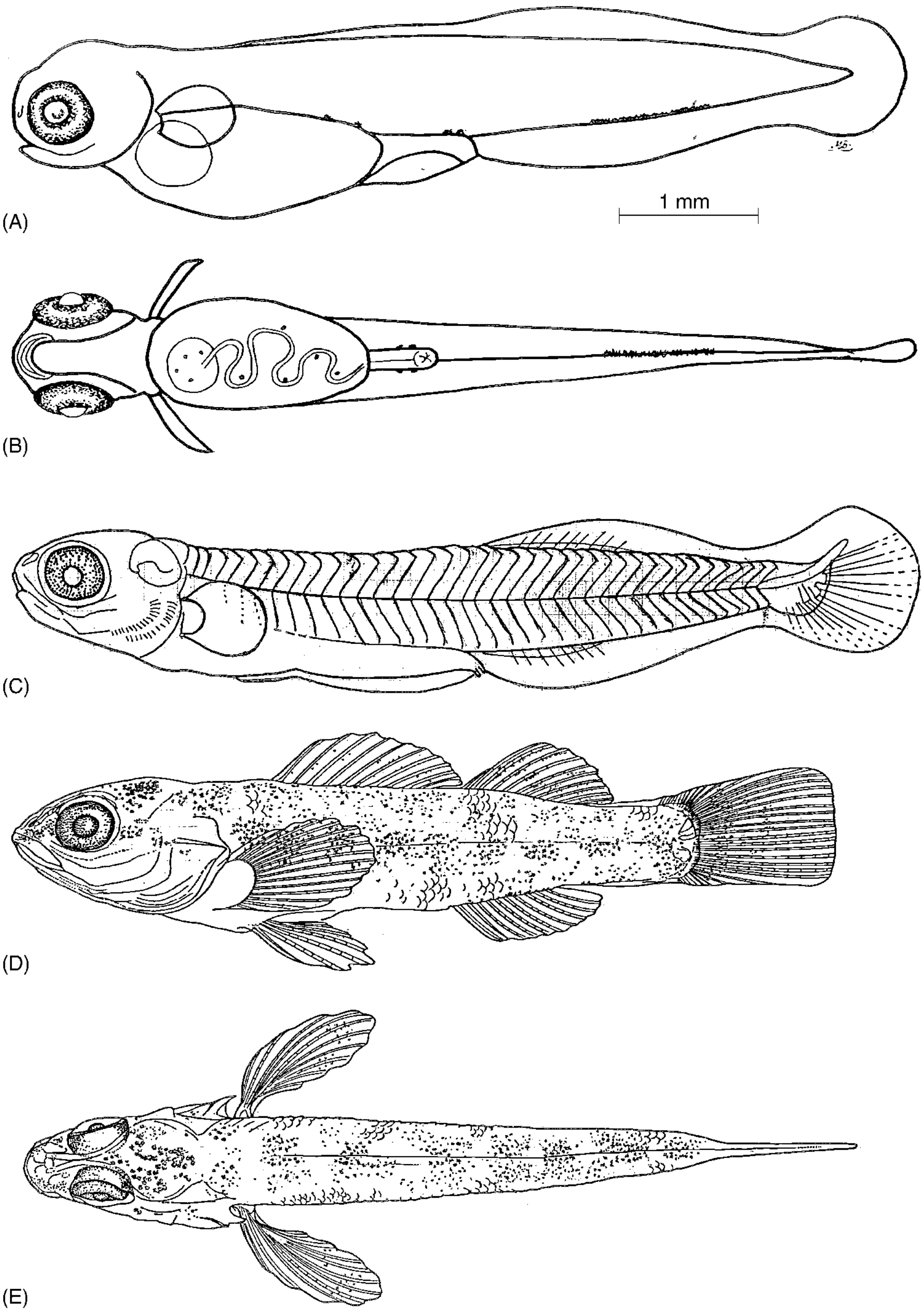

Figure 114 *Etheostoma rufilineatum*, redline darter, Hinds Creek, TN: (A,B) yolk-sac larva, 7.0 mm TL, lateral and ventral view; (C) post yolk-sac larva, 10.8 mm TL, lateral view; (D–E) early juvenile, 16.3 mm TL, lateral and dorsal view. (A–B from reference 18, with author's permission; C–E original drawings.)

a single mid-ventral serpentine vitelline vein originates at the single anterior oil globule and proceeds mid-ventrally along the yolk sac. Head not deflected over the yolk sac; jaws not well developed.*[,18]

6.9–8.5 mm TL. Body laterally compressed, head small with stomodeum becoming functional jaws.*[,18]

Morphometry
See Table 124.

Fin Development
6.2–6.8 mm TL. Incipient median finfolds complete; pectoral fins well developed. No incipient fin rays in any median of paired fin.*[,18]

Table 124

Morphometric data expressed as percentage of HL and TL for young *E. rufilineatum* from TN.*[,18]

	TL Groupings		
Length Range (mm)	**6.2–8.5**	**9.0–11.8**	**12.4–16.3**
N	**19**	**13**	**6**
Mean	**7.46**	**10.29**	**13.45**
(Range of Actual Measures)	**(Range)**	**(Range)**	**(Range)**
As Percent HL			
SnL	9.3	16.9	17.2
	(0.07–0.19)	(0.31–0.44)	(0.48–0.75)
ED	52.6	41.3	36.1
	(0.56–0.77)	(0.75–1.02)	(0.99–1.5)
As Percent TL			
HL	16.7	20.1	23.1
	(0.96–1.55)	(1.67–2.69)	(2.75–4.25)
HD	11.9	14.1	13.7
	(0.75–1.19)	(1.16–1.73)	(1.67–2.25)
Preanal	52.7	54.9	53.9
	(3.25–4.75)	(4.9–6.5)	(6.7–8.63)
PosAL	47.3	45.1	46.1
	(2.95–3.8)	(4.15–5.3)	(5.7–7.64)
SL	97.3	91.0	86.0
	(6.0–8.2)	(8.2–10.45)	(10.7–13.73)
BDA	9.9	9.2	14.0
	(0.54–0.95)	(1.02–1.67)	(1.67–2.25)
MAXL-Y	39.7		
	(2.36–2.72)		

6.9–8.5 mm TL. Yolk sac diminishing; gut straightening and becomes functional by the end of the length interval.*[,18]

Pigmentation

6.2–8.5 mm TL. Early yolk sac stages heavily pigmented. No melanophores dorsally; lateral melanophores along the edge of the yolk sac, dorsally over the gut, ventrally along the anus, and along the hypaxial myosepta from postanal myomere 2–11. Ventral melanophores outline the median portion of the yolk sac outlining the serpentine vitelline vein. Ventral cluster of melanophores diagnostic of subgenus *Nothonotus* over future anal fin.*

POST YOLK-SAC LARVAE

See Figure 114

Size Range

>8.55–13.4 mm TL.*

Myomeres

Predorsal 5–6; preanal 19(5), 20(10), or 21(2) (mean = 19.8; *N* = 17); postanal 16(9), 17(5), 18(2), or 19(1) (mean = 16.7; *N* = 17); total 35(1), 36(8), 37(6), or 38(2). *

Morphology

8.55–9.9 mm TL. Digestive system functional; snout becoming slightly pointed.*

10.0–13.4 mm TL. Snout becoming more pointed.*

Morphometry

See Table 124.

Fin Development

See Table 125.

Table 125

Meristic counts and size (mm TL) at the apparent onset of development for *E. rufilineatum.*[*]

Attribute/event	*Etheostoma rufilineatum*[*]	Literature
Branchiostegal Rays	6,6	6,6 [3,4,7]
Dorsal Fin Spines/Rays	VIII–XI/11–13	VIII–XIV/10–14[3,4,7]
First spines formed	10.0	
Adult complement formed	12.0	
First soft rays formed	9.0	
Adult complement formed	10.0	
Pectoral Fin Rays	13–14	11–16[3,4]
First rays formed	9.9	
Adult complement formed	13.4	
Pelvic Fin Spines/Rays	I/5	I/5[3,4]
First rays formed	11.8	
Adult complement formed	13.4	
Anal Fin Spines/Rays	II/7–9	II/6–9[3,4,7]
First rays formed	9.0	
Adult complement formed	10.0	
Caudal Fin Rays	vii–xi, 8–11+7–11, viii–xi	14–18[7]
First rays formed	8.5	
Adult complement formed	10.0	
Lateral Line Scales	48–55	35–53 [3,4,7]
Myomeres/Vertebrae	36–41/36–38	Unknown/36–40[3,4,7]
Preanal myomeres	19–21	
Postanal myomeres	16–21	

8.5 mm TL. First rays form in the caudal fin. Pectoral and spinous dorsal fins without fin rays; no pelvic fin bud; median finfolds not differentiated.*

9.0–9.6 mm TL. Finfolds continuous (9.0 mm TL); soft dorsal and anal fin spine and rays first form by 9.4 mm TL; pelvic bud formed by 9.6 mm TL.*

9.9–10.0 mm TL. Pectoral fin rays form (9.9 mm TL); dorsal spines first form (10.0 mm TL); adult complement of caudal, anal, and soft dorsal fin rays complete (10.0 mm TL).*

11.8–12.0 mm TL. Pelvic fin rays form, median finfolds partially differentiated by 11.8 mm TL. Adult complement of spines form in spinous dorsal fin.*

13.4 mm TL. Adult complement of pectoral and pelvic fin spines and rays form; pelvic finfold differentiated.*

Pigmentation

8.6–9.9 mm TL. Similar to previous length interval with only slight pigment changes. Mid-ventral postanal pigment intensified slightly and a few postanal melanophores along the lateral line.*

10.0–13.4 mm TL. Melanophores form in small groups aligned with the posterior half of the second dorsal fin by 10.5 mm TL; 5–6 patches of melanophores spread evenly and extend from the anterior margin of the spinous dorsal fin to the posterior margin of the second dorsal fin by 12.5 mm TL; a few melanophores occur over the hind brain.*

JUVENILES

See Figure 114

Size Range

>13.5* to 42 mm TL.[9]

Fins
Spinous dorsal IX–(XI–XII)–XIV; soft dorsal rays 10–(12)–14; pectoral rays 11–(13–14)–16; pelvic spines/rays I/5; anal spines/rays II/6–(8)–9.*[,2–4,7]

Morphology
16.4 mm TL. Squamation over most of the body; opercle spine formed. Branchiostegal membranes separate or narrowly connected; snout moderately pointed; nape, cheek, and breast and prepectoral area unscaled; opercle and belly scaled. Lateral line scales complete, 43–58; total vertebrae 36–(38)–40.*[,2–4,7,10]

Pigmentation
13.4 mm TL. Dorsal melanophores scattered over the cerebellum, forming six dorsal saddles across mid-dorsum of the back. Five lateral blotches forming along mid-lateral along the lateral line.

16.4 mm TL. Dorsal melanophores forming preorbital bars; scattered melanophores over cerebrum, nape, and opercles; eight dorsal saddles formed anterior spinous dorsal origin, midspinous dorsal fin, spinous dorsal insertion, soft dorsal origin, midsoft dorsal, soft dorsal insertion, and caudal peduncle base. Melanophores laterally forming pre- and postorbital bars extending posteriorly from interopercle onto opercle; nine mid-lateral blotches along lateral line from anterior pectoral fin base, mid-pectoral fin, just anterior distal edge of pectoral fin, posterior distal edge of pectoral fin, anterior soft dorsal fin origin, posterior origin of soft dorsal fin, midsoft dorsal fin, soft dorsal fin insertion, and hypural plate. Melanophores scattered on distal edge of pectoral fin, forming a mid-spinous dorsal fin stripe, two stripes on the midsoft dorsal fin and distal edge of soft dorsal fin, and along the proximal edge of caudal fin. A second caudal fin stripe is formed in the center of the caudal fin. The pelvic and anal fins are without pigmentation.*

TAXONOMIC DIAGNOSIS OF YOUNG REDLINE DARTER

Similar species: *Etheostoma rufilineatum* is similar to *E. blennioides* and *E. zonale*.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 115)
Eggs. Eggs are adhesive, attached to the sides of large rocks, and are often attached to the sides of rocks beneath the substrate of large cobble or rubble.[6–8]

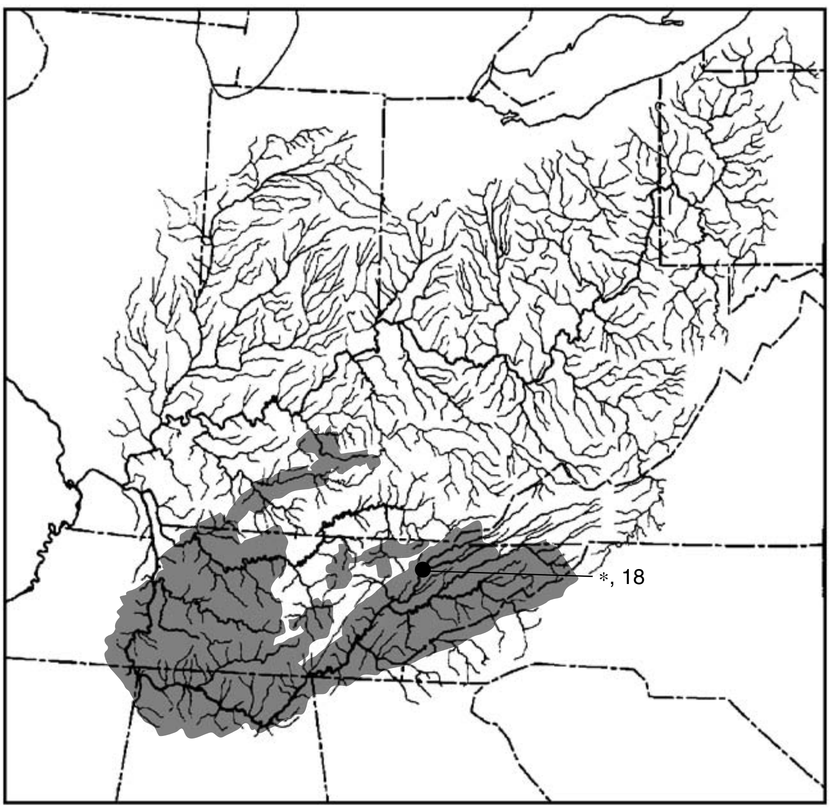

Figure 115 Distribution of redline darter, *E. rufilineatum* in the Ohio River system (shaded area) and areas where early life history information has been collected (circle). Number indicates appropriate reference and asterisk indicates original data.

Yolk-sac larvae. Yolk-sac larvae are pelagic at hatching. They are active swimmers and do not appear to be sensitive to light.* Yolk-sac larvae collected in drift nets from Hinds Creek averaged 0.017 fish/min between early April and mid-May* and were present in the drift from Hinds Creek from late April until mid-July.*

Post Yolk-sac larvae. Larvae are demersal, occurring along the slower moving portions of riffles along edges.*[,11] Larvae collected from drift samples using plankton nets from Hinds Creek from mid-May until early June averaged 0.016 fish/min (range: 0.013–0.017 fish/min).* Larvae were present in the Hinds Creek drift from mid-May until late August.*

Juveniles. Usually in gentle to moderate currents along the margins of riffles. In Hinds Creek, juveniles occurred in shallow (0.08–0.15 m), in slower riffle areas.*

Early Growth (see Table 126)
Almost a fifth (20.2%) of total growth is achieved within the first month of life. A series of larvae cultured from Hinds Creek tripled in size within the first month of life. A clutch of eggs fertilized on May 1 from the Pigeon River, TN, attained 12.5 mm TL by June 9. Specimens from Hinds Creek had full squamation by 16.4 mm TL.* In VA, age 1 specimens ranged between 41.9 and 43.6 mm TL.[9] Redline darters grew at a decreasing rate and males grew faster than females.[9,11] Estimated annual survival for males and females was 0.44 and 0.33, respectively[9].

Feeding Habits
Redline darters are primarily insectivores and invertivores,[9,11] feeding on truefly larvae (midges), other insects, and invertebrates.[8,9,13–17] The majority of the redline darter's diet consists of dipterans (67–87% of total diet) and aquatic insects.[9] The smallest darters consumed chironomid and ephemeroptera larvae in the greatest numbers and, to a lesser extent, caddisflies and microcrustaceans.[7,9,11]

Table 126

Average calculated lengths (mm TL) of young redline darters in Virginia and Tennessee.[8,11]

State	Age 1	2	3	4
Tennessee[8]	33–42	46–53	74	
Virginia [11]	36	51–69	60	67

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Material Examined: TN: Hinds Creek. (TV uncatalogued, reference collection).

* Original fecundity data for orangefin darter from Little River, Tennessee River drainage, Blount Co., TN.* Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Early life history and observations developmental series cultured by TVA from field and laboratory spawned specimens from Hinds Creek, TN. Specimens curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

ARROW DARTER

Etheostoma (*Litocara*) *sagitta* (Jordan and Swain)

Etheostoma: various mouths; *sagitta*: an arrow.

RANGE

Etheostoma sagitta is endemic to the upper Cumberland and upper Kentucky River systems of KY and TN.[1–3] Subspecies *E. s. sagitta* is endemic to the Cumberland River system of southeast KY and northeast TN, while *E. s. spilotum* is endemic to the upper Kentucky River system.[2–4]

HABITAT AND MOVEMENT

The arrow darter inhabits the moderate-to high-gradient, clear, small streams and moderate rivers. Adults prefer the upland unsilted gravel, cobble and boulder as slab substrates in riffles, and flowing pools below riffles (T.P. Simon, pers. observ.). Kuehne and Bailey[4] noted that *E. s. spilotum* is found in streams so small that they are periodically reduced to intermittent pools. In Stinking Creek, upper Cumberland River drainage, TN spawning aggregates of adults assemble between mid-February and mid-March on riffles (R. Wallus, personal communication).

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Most localities where *E. sagitta* are known are above Cumberland Falls. Capture by the Kentucky River of a former tributary of the Cumberland River appears to have been the dispersal route by which the arrow darter entered the Kentucky system.[4]

SPAWNING

Location
Spawning occurs beneath or near rocks where males have fanned out a depression in the substrate. The males are territorial, defending the depression,[8] or males may defend a moving territory.[7]

Season
Bailey[5] and Kuehne and Barbour[2] reported spawning occurring in March and April throughout its range, with April probably being the peak spawning period.[3] Reproduction in Stinking Creek, TN, occurred during a single week in April.[7]

Temperature
Spawning temperatures ranged from 15.5 to 16°C.[6,7]

Fecundity (see Table 127)
Ten females (58–69 mm TL) collected in early- to mid-April from Stinking Creek, Cambell Co., TN, had ovaries that were 13.5% of the body weight, containing 1404.1 total ova averaging 0.18 mm diameter.* Lowe[8] reported that females had 67–265 mature eggs.

Sexual Maturity
Adults may live to reach age 3;[2,3] however, maturity is suspected to be at age 1.[7] An adult male (65.3 mm TL) from TN had testes that were 1.07% of the body weight on 11 April.* Male tuberculation was absent from June to January. Male tuberculation was at maximum development between February and May.* All females 58–69 mm TL were sexually mature, 22% of 52–58 mm TL females were mature, while none of the females less than 50 mm TL were sexually mature. Males less than 58 mm TL were all immature, while 62–71 mm TL, 35% of all males 58–66 mm TL, and all males larger than 71 mm TL were mature.* Males exhibited sexually dimorphic traits during the reproductive season with an increase in brightly colored pigmentation and extension of the genital papillae from the cloacal pad. Females had distended abdomens and flattened and triangular genital papillae with a few dark spots.[2]

Spawning Act
The reproductive mode of *E. sagitta* is a burier.[6] A territorial male defends a moving territory and pursues a female and mounts her. Adults maintain a head-to-head orientation, with the male retaining a serpentine position along the female with their vents juxtaposed.[6,7] Eggs are laid individually in fine gravel substrates, generally 3–5 during a single

Table 127

Fecundity data for arrow darter from Stinking Creek, Cambell County, TN.*

Date	TL (mm)	GSI	Number of Ova: Ripening Oocytes (LA)	Number of Ova: Mature Oocytes (EM, MA, LM)	Number of Ova: Ripe Eggs (MR, RE)	Egg Diameter (mm)
April 9	69	13.3	1442	189	134	1.33
	69	10.2	1373	165	84	1.33
	68	11.5	1701	183	57	1.43
	65	11.5	1249	147	62	1.33
	64	13.6	1328	209	86	1.33
April 11	64	3.5	830	173	189	1.53
	62	18.2	912	123	86	1.53
	61	17.6	948	112	98	1.66
	60	18.4	918	159	96	1.53
	58	17.3	818	94	76	1.53

spawning event.[6,7] The sex ratio was 1:1.1 males to females based on specimens examined during the reproductive period in Stinking Creek, TN.[7] Lowe[8] reported observations of captive reproduction in an artificial raceway. Spawning occurs beneath or near rocks where males fan out a depression in the substrate. The males are territorial defending the depression. Initial courtship includes rapid dashes, fin flaring, nudging, and quivering motions by the male followed by similar responses by the female. The female partially buries herself in the substrate and is mounted by the male. The male is thought to defend the nest site at least until the eggs hatch.[8]

EGGS

Description
Eggs from TN are spherical, average 1.6 mm in diameter (range: 1.5–1.8 mm), transparent, demersal, and nonadhesive. Eggs possess translucent, clear to pale-yellow yolk (mean = 1.6 mm in diameter; range: 1.5–1.7mm); a single oil globule (mean = 0.3 mm; range: 0.2–0.4 mm); a large perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[7]

Incubation
Hatching occurred after 240–253 h at an incubation temperature of 15.5–16°C.[7]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 116

Size Range
TN populations from Stinking Creek hatch between 4.6 and 5.8 mm; and yolk is absorbed by 6.0 mm TL.[7]

Myomeres
Preanal 17–18 (N = 17, mean = 17.9); postanal 22–23 (N = 17, mean = 22.1); with mean of 40 total.[7]

Morphology
4.6–5.8 mm TL. Newly hatched fish have a laterally compressed body; round snout; functional jaws, upper jaw even, to slightly overhanging lower jaw; yolk sac moderate (28.4% TL), rectangular; yolk translucent clear to pale yellow, with a single oil globule; single mid-ventral vitelline vein on yolk sac; head not deflected over the yolk sac; and eyes oval.[7]

5.8–6.0 mm TL. Digestive system functions immediately before complete yolk absorption.[7]

Morphometry
See Table 128.[7]

Fin Development
See Table 129.

4.6–5.8 mm TL. Well-developed pectoral fins without incipient rays.[7]

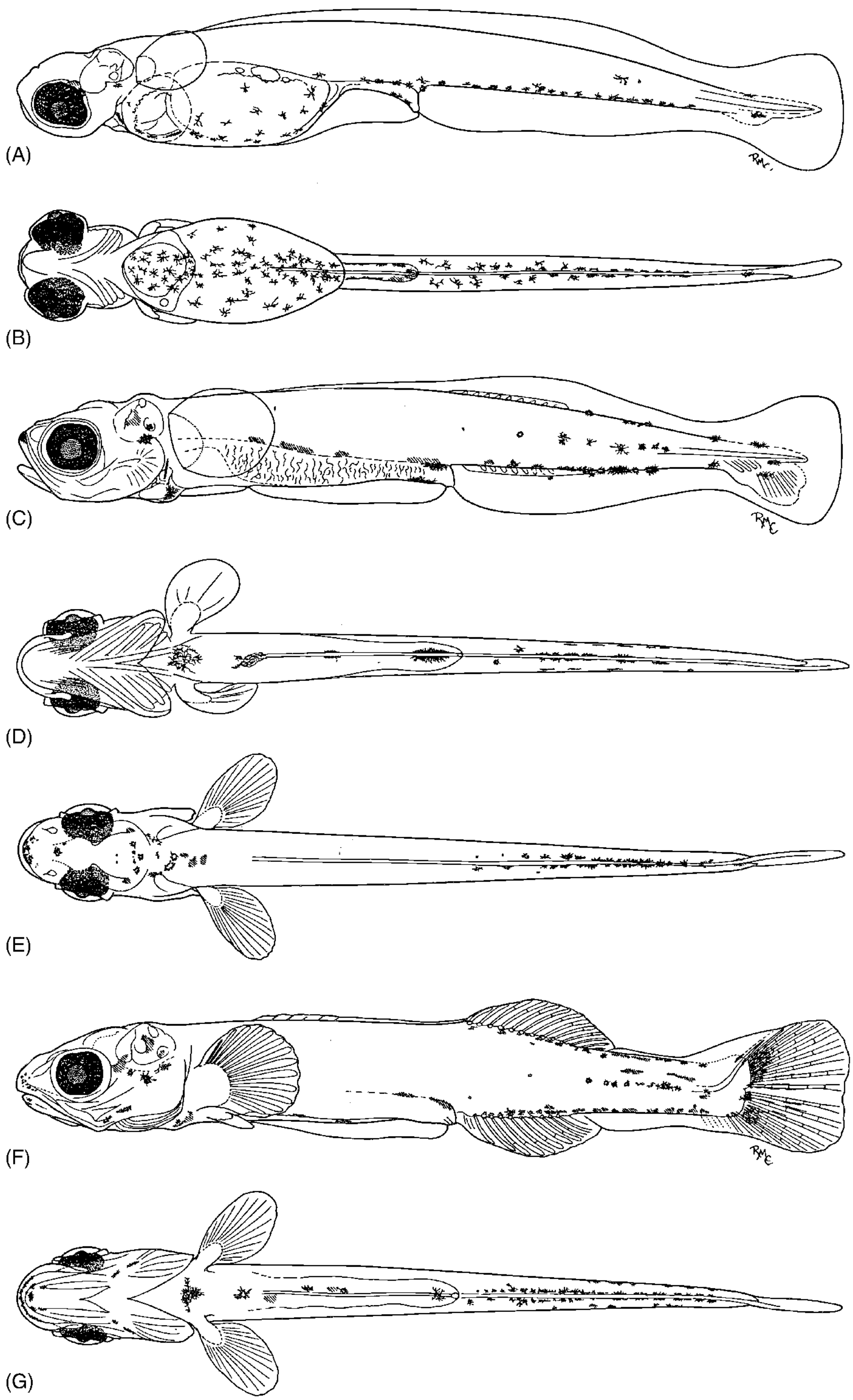

Figure 116 *Etheostoma sagitta*, arrow darter, Stinking Creek, Campbell County, TN. Yolk sac larva, 5.75 mm TL: (A) lateral, (B) ventral views; post yolk-sac larvae, 9.13 mm TL, (C) lateral, (D) ventral views; post yolk-sac larvae, 13.35 mm TL, (E) dorsal, (F) lateral, (G) ventral views. (A–G from reference 7, with author's permission.)

Pigmentation

4.6–5.8 mm TL. Newly hatched, eyes pigmented; no pigmentation dorsally on cranium, nape, or back; laterally, few melanophores distributed dorsally over the gut and immediately posterior to the anus, and along the mid-ventral postanal myosepta; several melanophores along mid-lateral near base of future anal fin insertion; and diagonally opposed melanophores near the tip of the notochord. Ventral stellate melanophores scattered on the distal half of the yolk

Table 128

Morphometry of young *E. sagitta* grouped by selected intervals of total length (N = sample size).[7]

	Total Length (TL) Intervals (mm)											
	4.62–5.94(N=4)		6.01–7.38 (N=8)		8.75–10.9 (N=2)		12.7–14.8 (N=3)		15.6–17.7 (N=8)		19.0–26.1 (N=5)	
Characters	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
Length (% of TL)												
Upper jaw[a]	18.8 ± 5.45	(0.12–0.36)	21.6 ± 5.69	(0.16–0.38)	24.2 ± 4.38	(0.45–0.46)	31.3 ± 4.06	(0.71–1.14)	41.6 ± 6.60	(1.27–2.07)	32.4 ± 1.97	(1.39–2.16)
Snout a	12.3 ± 1.99	(0.08–0.20)	14.8 ± 1.53	(0.12–0.22)	18.4 ± 1.13	(0.29–0.42)	22.3 ± 0.79	(0.57–0.71)	22.2 ± 1.55	(0.71–0.95)	22.1 ± 0.92	(0.99–1.33)
Eye diameter[a]	39.3 ± 5.84	(0.25–0.48)	37.7 ± 1.41	(0.38–0.48)	34.0 ± 3.39	(0.60–0.69)	29.5 ± 1.05	(0.80–0.92)	29.1 ± 1.48	(1.00–1.20)	27.3 ± 1.74	(1.22–1.56)
Head	17.7 ± 3.29	(0.76–1.34)	18.5 ± 1.33	(1.00–1.28)	19.4 ± 0.71	(1.65–2.18)	21.0 ± 1.15	(2.62–3.23)	23.2 ± 1.23	(3.42–4.25)	24.3 ± 0.70	(4.50–6.34)
Predorsal	26.6 ± 1.38	(1.24–1.68)	27.7 ± 3.33	(1.54–2.00)	29.0 ± 1.41	(2.63–3.06)	28.2 ± 0.70	(3.64–4.13)	29.4 ± 1.67	(4.01–5.39)	30.5 ± 0.55	(5.70–8.00)
Dorsal insertion							41.0 ± 11.0	(3.64–7.21)	46.1 ± 1.33	(6.82–8.29)	47.3 ± 1.28	(8.70–12.7)
D2 origin							43.8 ± 13.2	(3.64–7.64)	51.8 ± 1.75	(7.53–9.49)	52.3 ± 1.26	(9.62–13.6)
D2 Insertion							57.4 ± 25.1	(3.64–7.64)	71.6 ± 1.87	(7.53–9.49)	71.3 ± 1.46	(9.62–13.6)
Preanal	50.5 ± 1.63	(2.28–3.12)	50.0 ± 2.22	(2.88–3.81)	53.5 ± 0.66	(4.72–5.80)	52.3 ± 2.46	(6.80–7.82)	53.2 ± 1.00	(8.16–9.15)	53.2 ± 1.15	(9.98–13.6)
Postanal	49.0 ± 1.47	(2.24–3.00)	50.0 ± 2.22	(3.00–3.57)	46.5 ± 0.71	(4.03–5.14)	47.7 ± 2.43	(5.92–7.46)	46.8 ± 1.01	(7.21–8.50)	46.8 ± 1.12	(8.53–12.4)
Standard	95.6 ± 1.99	(4.29–5.72)	95.6 ± 1.35	(5.82–7.13)	94.8 ± 2.26	(8.44–10.2)	85.9 ± 3.91	(11.2–12.7)	85.8 ± 1.11	(13.2–14.9)	84.9 ± 1.03	(16.1–21.8)
Yolk sac	28.4 ± 2.04	(1.42–1.63)	24.3 ± 3.11	(1.59–1.63)								
Fin Length (% of TL)												
Pectoral	7.34 ± 1.52	(0.24–0.51)	9.01 ± 0.77	(0.50–0.66)	11.2 ± 0.71	(0.93–1.28)	12.6 ± 1.35	(1.44–2.03)	14.6 ± 1.39	(2.06–2.74)	17.2 ± 1.35	(3.01–5.00)
Pelvic					2.74	(0.30–0.30)	6.56 ± 1.61	(0.60–1.14)	9.39 ± 1.15	(1.26–2.03)	12.5 ± 1.82	(2.06–3.92)
Spinous dorsal							19.3 ± 2.69	(2.57–3.08)	16.7 ± 0.72	(2.49–2.90)	16.8 ± 0.90	(3.00–4.74)
Soft dorsal							20.4 ± 1.84	(2.82–3.14)	19.8 ± 0.98	(3.05–3.39)	18.9 ± 0.93	(3.45–5.14)
Caudal	4.38 ± 1.99	(0.16–0.33)	4.38 ± 1.35	(0.19–0.43)	5.15 ± 2.26	(0.31–0.74)	14.1 ± 3.91	(1.48–2.74)	14.2 ± 1.11	(1.91–2.74)	15.1 ± 1.03	(2.71–4.31)
Body Depth (% of TL)												
Head at Eyes	14.3 ± 1.61	(0.72–0.94)	13.8 ± 1.48	(0.82–1.00)	13.9 ± 0.28	(1.20–1.54)	12.4 ± 0.79	(1.66–1.85)	12.8 ± 0.39	(1.94–2.19)	12.4 ± 0.60	(2.31–2.98)
Head at P1	17.3 ± 5.57	(0.75–1.16)	11.8 ± 1.05	(0.71–0.82)	12.4 ± 0.71	(1.04–1.41)	13.1 ± 0.66	(1.66–2.00)	13.9 ± 0.40	(2.13–2.37)	17.4 ± 7.44	(2.68–5.82)
Preanal	8.33 ± 0.86	(0.44–0.48)	7.30 ± 0.65	(0.42–0.58)	10.3 ± 0.71	(0.86–1.18)	12.0 ± 0.72	(1.44–1.85)	12.3 ± 0.54	(1.85–2.16)	12.4 ± 0.64	(2.22–3.45)
Mid–postanal	6.53 ± 0.81	(0.34–0.40)	5.61 ± 0.32	(0.34–0.44)	7.18 ± 1.13	(0.56–0.87)	8.05 ± 0.25	(1.03–1.20)	8.55 ± 0.32	(1.29–1.51)	8.51 ± 0.34	(1.57–2.35)
Caudal peduncle	2.88 ± 0.18	(0.14–0.18)	2.67 ± 0.28	(0.16–0.20)	3.98 ± 2.40	(0.20–0.62)	6.54 ± 0.62	(0.74–1.02)	7.14 ± 0.46	(1.05–1.23)	7.43 ± 0.70	(1.34–2.24)
Yolk Sac	13.9 ± 3.02	(0.69–0.80)	9.98	(0.60–0.60)								
Body Width (% of HL)												
Head	75.1 ± 9.18	(0.64–0.84)	67.1 ± 4.04	(0.74–0.89)	66.3 ± 5.66	(1.16–1.36)	59.5 ± 2.00	(1.62–1.88)	52.1 ± 4.28	(1.64–2.13)	48.1 ± 3.20	(2.19–2.77)
Myomere Number												
Predorsal	5.75 ± 0.55	(5.00–6.00)	5.75 ± 0.51	(5.00–6.00)	6.00 ± 0.00	(6.00–6.00)	5.00 ± 0.00	(5.00–5.00)	5.13 ± 0.35	(5.00–6.00)	5.00 ± 0.00	(5.00–5.00)
Soft dorsal					18.0	(18.0–18.0)	17.7 ± 0.58	(17.0–18.0)	17.9 ± 0.35	(17.0–18.0)	18.0 ± 0.00	(18.0–18.0)
Preanal	18.0 ± 0.00	(18.0–18.0)	17.9 ± 0.35	(17.0–18.0)	18.0 ± 0.00	(18.0–18.0)	18.0 ± 0.00	(18.0–18.0)	18.1 ± 0.35	(18.0–19.0)	18.0 ± 0.00	(18.0–18.0)
Postanal	22.0 ± 0.00	(22.0–22.0)	22.1 ± 0.35	(22.0–23.0)	22.0 ± 0.00	(22.0–22.0)	21.7 ± 0.58	(21.0–22.0)	22.0 ± 0.00	(22.0–22.0)	22.0 ± 0.00	(22.0–22.0)
Total	40.0 ± 0.00	(40.0–40.0)	40.0 ± 0.00	(40.0–40.0)	40.0 ± 0.00	(40.0–40.0)	39.7±0.58	(39.0–40.0)	40.1 ± 0.35	(40.0–41.0)	40.0 ± 0.00	(40.0–40.0)

[a] Proportion expressed as percent head length.

Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

Table 129

Meristic counts and size (mm TL) at the apparent onset of development for *E. sagitta*.[7]

Attribute/event	*Etheostoma sagitta*[7]	Literature
Branchiostegal Rays	6,6	6,6[2,3,10–13]
Dorsal Fin Spines/Rays	IX–XI/12–15	IX–XI/12–15[2,3,5,10–13,]
First spines formed	12.7	
Adult complement formed	12.7	
First soft rays formed	10.9	
Adult complement formed	10.9	
Pectoral Fin Rays	16	14–16[2–5,10,13]
First rays formed	12.7	
Adult complement formed	12.7	
Pelvic Fin Spines/Rays	I/5	I/5[2,3,5,10,13]
First rays formed	14.8	
Adult complement formed	14.8	
Anal Fin Spines/Rays	II/9–12	II/9–12[2–5,10,11,13]
First rays formed	10.9	
Adult complement formed	10.9	
Caudal Fin Rays	ix–xi, 9+8, viii–x	17[5,10]
First rays formed	8.8	
Adult complement formed	12.7	
Lateral Line Scales	56–69	50–69[2–5,10,11,13]
Myomeres/Vertebrae	40/39–40	Unknown/39–40[2,3,10,12]
Preanal myomeres	17–18	
Postanal myomeres	22–23	

sac; melanophores outline gut ventrally and laterally; and form a double row along the anal finfold.[7]

POST YOLK-SAC LARVAE

See Figure 116

Size Range

6.0–6.3 mm TL to 14.8 mm TL.[7]

Myomeres

Preanal 17–18 (N = 17, mean = 17.9); postanal 22–23 (N = 17, mean = 22.1); with mean of 40 total.[7]

Morphology

6.0–6.3 mm TL. yolk absorbed.[7]

6.7–7.4 mm TL. Operculum and gill arches function and teeth form in both jaws. Premaxilla and mandible form.[7]

8.7–8.8 mm TL. Snout pointed. No swim bladder forms; gut straight, without striations, portion of gut posterior to stomach elongate in length.[7]

8.8–10.9 mm TL. Neuromast development occurs mid-laterally from the anterior trunk posteriad. Upper jaw equal with lower jaw, mouth terminal.[7]

Morphometry

See Table 128.[7]

Fin Development

See Table 130.[7]

8.8 mm TL. First rays form in caudal fin and branchiostegal rays.[7]

10.9–12.7 mm TL. Anal and soft dorsal fin rays form and notochord flexion precedes caudal fin ray develop . Pelvic fin buds form anterior to dorsal fin origin after complete yolk absorption. Spinous

Table 130

Average calculated length (TL mm) of young arrow darters in Kentucky[9,10] and Tennessee.

State	Age 1	2	3
Kentucky[9]	37–66	55–82	74+
Tennessee[10]	50	65	

dorsal rays form by 12.7 mm; dorsal and anal finfold partially differentiated between 10.9 and 12.7 mm and pectoral fin rays form by 12.7 mm. Spinous dorsal fin origin situated over preanal myomere 5–6, soft dorsal origin over preanal myomere 18.[7]

Pigmentation

6.0–8.0 mm TL. Yolk-sac melanophores concentrate on mid-ventral breast, and become subdermal.[7]

8.7–10.9 mm TL. Cranial melanophores on posterior tip of the snout and on posterior edge of otic capsule clusters forming; from the posterior soft dorsal fin insertion to the notochord several melanophore; lateral subdermal melanophores extend from the posterior edge of pectoral fin to the anus, and are distributed mid-laterally from the future midanal fin to the caudal peduncle. Double rows of postanal melanophores combine mid-ventrally to form a single row; additional ventral melanophore pigmentation is present in the hypaxial section of the hypural plate of the developing caudal fin.[7]

12.7–14.8 mm TL. Dorsal cranial pigmentation outlines the edge of the mandible, along the anterior and posterior edges of the optic lobe, and extends onto the nape; dorsal melanophores clutter from the origin of the soft dorsal fin to the caudal fin base. Lateral melanophores found beneath the otic capsule and on the posterior margin of the mandibular hinge. Melanophores concentrate mid-laterally forming a single stripe and along the vertical edge of the caudal peduncle base radiating into the caudal fin. Ventrally, melanophores edge the tip of the maxillae and branchiostegal ray origin mid-ventrally forming a series of melanophore clusters from the breast to the anus, and postanally forming a single row of melanophores from the anus to caudal peduncle.[7]

JUVENILES

See Figure 117

Size Range

14.8[7] mm to 50 mm TL[8]; or 58–71 mm TL.*

Fin Development

Branchiostegal rays 6,6; spinous/soft dorsal rays IX–XI/ 12–15; pectoral rays 13–16; anal fin spines/rays II/9–12; pelvic spine/rays I/5; caudal fin rays 15–18.[2,3,7,10]

14.8 mm TL. Complete adult fin ray counts in median fins; caudal fin rays with segmentation, truncate to slightly emarginate.[7] First pelvic fin ray forms by 14.8 mm. Dorsal and anal finfolds are completely differentiated.[7]

Morphology

Total vertebrae count 40 (N = 2), including one urostylar element. Scales in the lateral series ranging from 52[2,3,7,10] to 69 (Stinking Creek, TN).*

14.8 mm TL. Supraorbital, infraorbital, lateral, and subtemporal head canals form.[7]

14.8–16.3 mm TL. Lateral line begins to form [7]

>16.3 mm TL. Initiation of squamation across dorsum and mid-laterally.[7]

26.1 mm TL. Infraorbital, lateral, and supratemporal head canals complete, preoperculomandibular canal complete with 10 pores, infraorbital pores 6; squamation complete;[7] cheek naked, opercle and breast unscaled, nape is fully scaled.[2,3]

Morphometry

See Table 128.[7]

14.8 mm TL. Average predorsal length 25.7% SL (range: 23.8–26.5% SL) and 28.7% TL (range: 26.6–30.7% TL).

Pigmentation

15.6–17.7 mm TL. Preorbital and postorbital bars developed; melanophores on mandible and along the posterior edge of the hypaxial opercule. Cranial melanophores concentrated over the cerebellum and optic lobes. Dorsum with 8–9 clusters of melanophores concentrated on the nape, anterior spinous dorsal fin, mid-spinous dorsal fin, just anterior to the spinous dorsal fin insertion, between the spinous and soft dorsal fins, posterior to the soft dorsal fin origin, midsoft dorsal fin, posterior soft dorsal fin insertion, and at the base of the caudal peduncle.

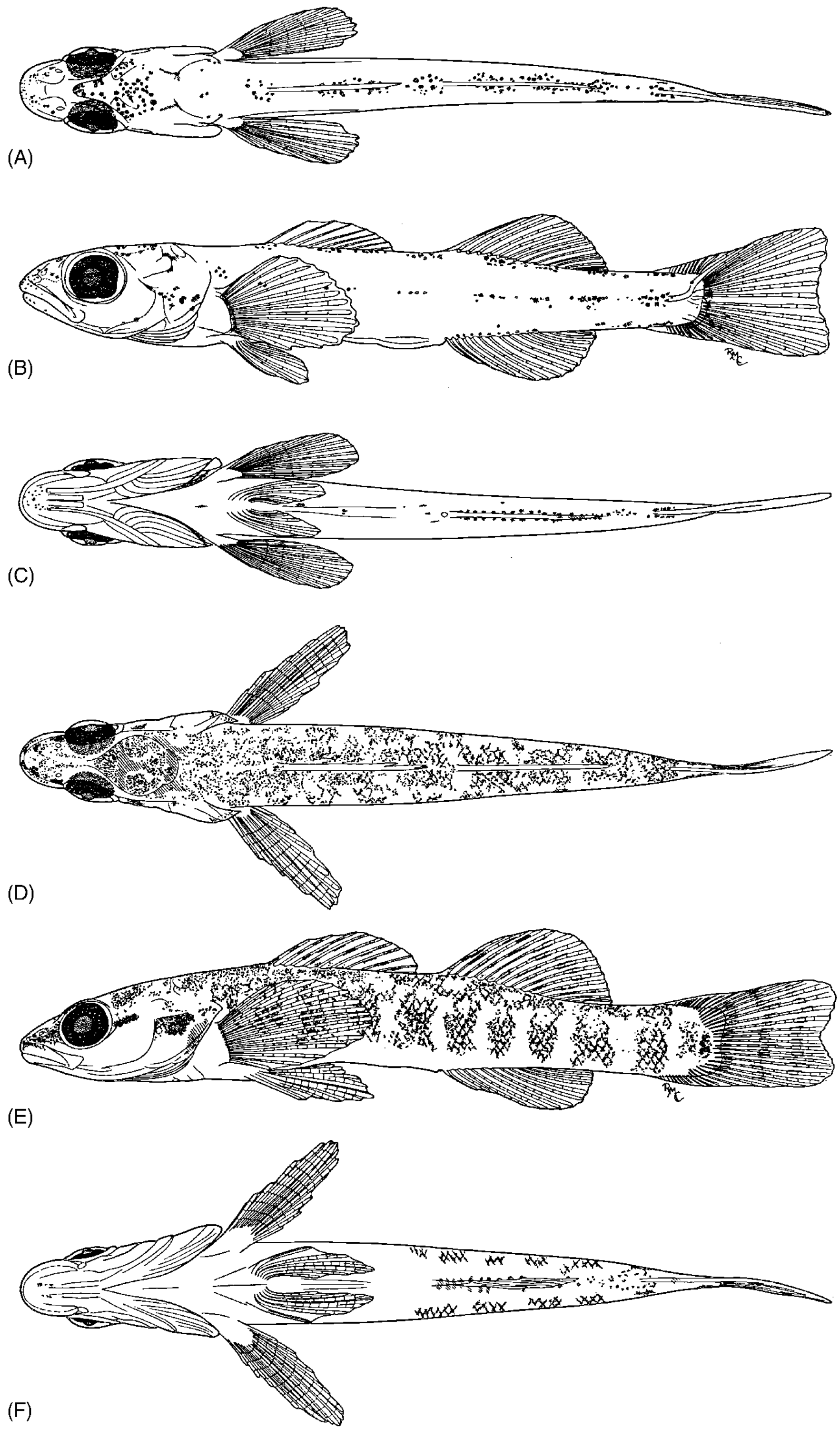

Figure 117 *Etheostoma sagitta*, arrow darter, Stinking Creek, Campbell County, TN. Early juvenile, 17.7 mm TL: (A) dorsal, (B) lateral, (C) ventral views; juvenile, 27.5 mm TL, (D) dorsal, (E) lateral, (F) ventral views. (A–F from reference 7, with author's permission.)

Mid-lateral series of melanophores grouped into 10 single clusters and a vertical stripe occurs at the base of the caudal fin. Ventral melanophores outline the anal fin lepidiotrichia and occur at the base of the caudal peduncle.[7]

19.6–26.1 mm TL. Edge of mandible with discrete, broken lines of pigment outlining structure, dorsal cranial pigmented formed, vermiculate pattern along nape extending posteriorly along dorsum. Laterally, preorbital and postorbital bars are well formed, 10–12 deep U-shaped clusters along midlateral conspicuous, a central cluster of melanophores present at caudal peduncle base. Ventrally, a few melanophores are present on chin, and surrounding anal fin, lepidiotrichia interdigitates with pterigiophores. Spinous and soft dorsal fins with two oblique melanophore stripes; caudal fin with 3–4 vertical bands of melanophores. No pigmentation apparent in the pectoral, anal, and pelvic fins.[7]

TAXONOMIC DIAGNOSIS OF YOUNG ARROW DARTERS

Similar species: members of genus *Percina*.[7] The arrow darter is a member of the subgenus *Litocara*.[7]

Adult. The *E. sagitta* group consists of two taxonomically recognizable subspecies,[4,7] *E. sagitta* and *E. s. spilotum*. The subspecies *E. s. sagitta* is characterized by the presence of 60 lateral line scales or more, 7 or fewer are unpored. Subspecies *E. s. spilotum* has fewer than 59 lateral line scales of which 8 or more are unpored.[4]

Larva. The subgenus characterization is based on information gathered for *E. sagitta*. The species *E. sagitta* is similar in body morphology to members of the genus *Percina*. A single synapomorphy is the possession of fewer preanal myomeres than *Percina*. The species possesses functional jaws, 17–18 preanal myomeres, moderate size, and a rectangular yolk sac that distinguishes it from other subgenera in *Etheostoma*. Geographic variation of the arrow darter was not examined since specimens are only available from Stinking Creek, TN. Sister taxa are unavailable for intrasubgeneric comparison; however, the species can be separated from other known members of the subgenus *Etheostoma* by the fewer preanal myomeres (<19) and more slender body depth.[7]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 118)
Eggs. Egg sites include riffle habitats over fine gravel substrates 45–50 mm deep, in moderate current.[7]

Yolk-sac larvae. Aquarium observations indicate arrow darter larvae are pelagic immediately after hatching.[7]

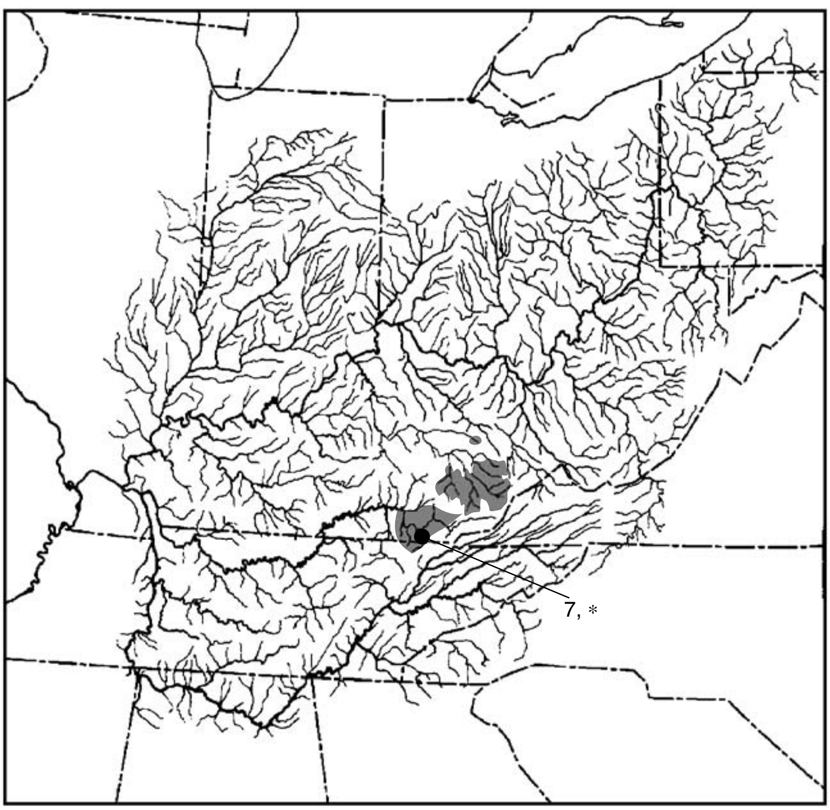

Figure 118 Distribution of arrow darter, *Etheostoma sagitta* in the Ohio River system (shaded area) and areas where early life history information has been collected (circle). Number indicates appropriate reference. Asterisk indicates original data.

Post Yolk-sac larvae. Larvae become demersal at lengths greater than 15 mm and remain in close association with the substrate. In Stinking Creek, TN, larvae and early juveniles utilize the downstream pools and near shore margins of riffles adjacent to spawning areas as nursery habitats.[7]

Juveniles. Juveniles, greater than 26 mm TL, are the smallest individuals found on the margins of the riffle.[7]

Early Growth (see Table 130)
Lowe[8] and Lotrich[9] reported arrow darters reach about 50 mm TL the first year of life. By mid-June some larvae exceeded 20 mm SL[10] .

Feeding Habits
The diet of arrow darters includes a large percentage of mayfly nymphs, blackfly, and midge larvae, and lesser numbers of caddisfly, stonefly, and beetle larvae. Juveniles feed on microcrustaceans and dipteran larvae.[2,3,8–10]

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Material Examined: TN: Cambell County: Stinking Fork (TVA reference collection).

* Original fecundity data for arrow darter from Stinking Creek, Cambell County, TN. Specimens are curated at Northeast Lousiana University, Museum of Zoology, Monroe. Original early life history and developmental series from specimens cultured by TVA and curated at Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

BLOODFIN DARTER

Etheostoma (*Nothonotus*) *sanguifluum* (Cope)

Etheostoma: various mouths; *sanguifluum:* blood flowing.

RANGE

Etheostoma sanguifluum is restricted to the Cumberland River drainage,[1–6] from the Rockcastle River, KY, downstream throughout the Caney Fork in middle TN.[4]

HABITAT AND MOVEMENT

Etheostoma sanguifluum inhabits upland streams and rivers where it is associated with rapid currents of riffles over substrates of boulders, cobbles, and pebbles.[1–6] It prefers shallow riffles with depths of 9–30 cm often associated with gravels and large stones.[5]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma sanguifluum is restricted to the middle Cumberland River where it is generally distributed, and is common in the Rockcastle River, Big and Little South Fork Rivers, and Buck Creek.[1–6]

SPAWNING

Location
Spawning and nest-building occur in the interstitial spaces between the substrate and overlying rocks.[6]

Season
Spawning possibly occurs during mid-April* until early June in TN.[5]

Temperature
Unknown.

Fecundity
Unknown.

Sexual Maturity
Sexual maturity is attained at age 1, when individuals attain lengths between 35 and 45 mm TL.[4]

Spawning Act
Etheostoma sanguifluum is an egg clumper.* Spawning behavior based on aquarium observations shows that the spawning act is similar to *E. vulneratum.* Large territorial males guard areas around a nest stone, located in swift, shallow water. Males establish poorly defined territories and defend themselves against intruding males. Females selected the spawning site and initiate spawning.* Courtship includes male following the female, who swims close to the bottom in short bursts. The female wedges herself between the substrate and the overlying rock. The male lies on top of her and the pair vibrate vigorously for 3–5 s. Intermittent resting breaks in spawning occur for 2–3 min before another spawning episode.* The female remains more or less stationary during the spawning act, producing a partially buried, grape-like mass of eggs. The female swims forward a few centimeters between each spawning act.* Males may protect the spawning site for several hours after spawning, but are never observed to protect the same site in the successive days.*

EGGS

Description
Eggs of *E. sanguifluum* are demersal, adhesive, and spherical, averaging 2.8 mm in diameter (range = 2.6–3.0 mm) yolks are unpigmented; possessing a single oil globule, a narrow perivitelline space, and a sculptured and unpigmented chorion.*

Incubation
Eggs incubated at 22–24°C hatched in 158–224 h.*

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown to 35–45 mm TL.[4]

Fin Development
Larger Juveniles. Spinous dorsal fin XII–XIV; soft dorsal rays 11–14; pectoral rays 13–15; anal fin spines/rays II/7–9; pelvic fin rays I/5; caudal fin rays 16–17.[2–5]

Morphology
Total vertebrae count 38–40 including one urostylar element. Scales in the lateral series complete with 50–67 (53–61) pored scales in the lateral range.[2–5] Gill membranes narrowly joined, frenum present. Scales absent from the nape, breast, and prepectoral area; opercle and belly scaled, cheeks with a few scales at postorbital spot. Supratemporal and infraorbital head canals complete.[4,5]

Morphometry
Unknown.

Pigmentation
Dorsum dusky; saddles indistinct, a large stripe from snout to spinous dorsal fin may be present. Lateral blotches are indistinct and vary in number. At least posterior third of the body has dark horizontal bands. Red spots develop on the body encircled with dark rings. Lower side and belly dusky, narrow humeral bar partly hidden behind pectoral fin.[4]

TAXONOMIC DIAGNOSIS OF YOUNG BLOODFIN DARTER

Similar species: members of subgenus *Nothonotus*.

Etheostoma sanguifluum is a member of the egg-clumper group along with *E. maculatum, E. aquali, E. camurum, E. chlorobranchium,* and *E. vulneratum.*[7–9] These species possess more than 19 preanal myomeres, large (>32.0% SL) spherical yolk sacs, and dorsal pigmentation in either a single or a double row, and a series of mid-lateral dashes near the caudal peduncle. Within this group, *E. vulneratum* exhibits the largest egg diameter and size at hatching. While *E. maculatum* is most similar to *E. vulneratum,* it hatches at 5.0 mm SL. Larvae of *E. aquali* can be distinguished from the other species based on the cross-hatched or brushed melanophores that cover the vitelline vein.[7]

Variation
Unknown.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 119)
Eggs. Eggs are clumped in the interface spaces between the stones and the substrate in shallow riffles.*

Yolk-sac larvae. Unknown.

Post yolk-sac larvae. Unknown.

Juveniles. Unknown.

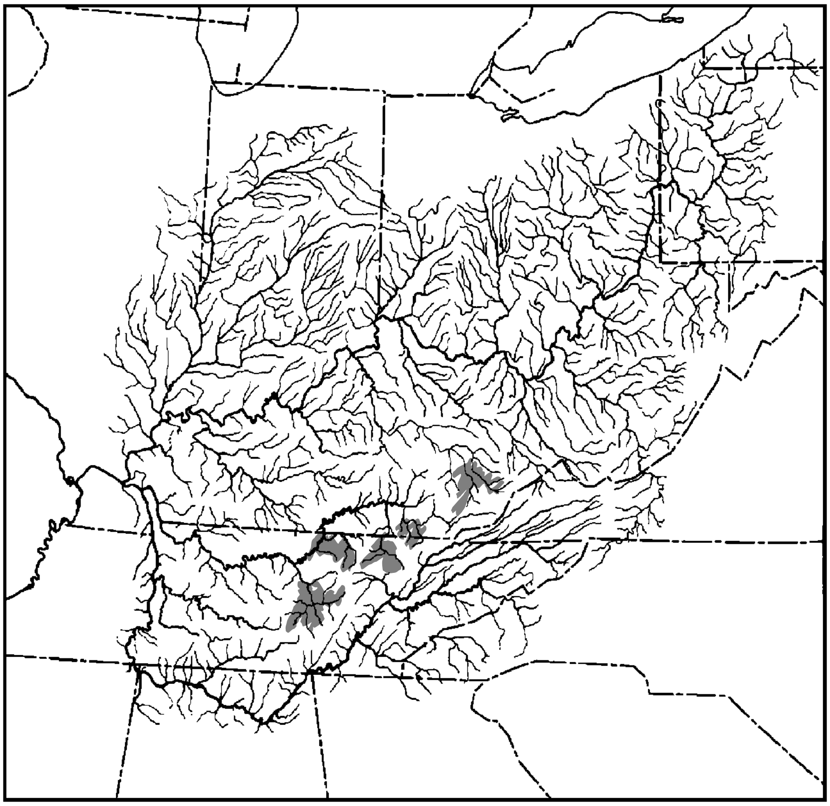

Figure 119 Distribution of bloodfin darter, *Etheostoma sanguifluum* in the Ohio River system (shaded areas).

Early Growth
Young-of-the-year specimens attained lengths of 35–45 mm in the following spring.[4] Maximum longevity may be 4–5 years.[4]

Feeding Habits
Not reported but presumably the diet includes immature aquatic insects.

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* T.P. Simon, unpublished data.

TENNESSEE SNUBNOSE DARTER

Etheostoma (*Ulocentra*) *simoterum* (Cope)

Etheostoma: various mouths; *simoterum*: snubnosed.

RANGE

Etheostoma simoterum occurs throughout the middle and upper Tennessee River from TN, MS, AL, GA, and VA.[1–6] The species is absent from montane areas of NC and reaches its downstream limit in the Tennessee River drainage at the mouth of the Duck River.[4] It has been suggested that its absence from Bear Creek, AL, is probably a collection artifact.[4] Recent collections from the Bluestone River, a tributary to the New River, Tazewell County, and the Big Sandy River, Dickenson County, VA, suggest an accidental introduction into the upper Ohio River drainage.[5]

HABITAT AND MOVEMENT

The Tennessee snubnose darter inhabits moderate-gradient, clear, small streams to moderate-sized rivers. Adults prefer unsilted gravel substrates or bedrock strewn with rubble in moderate current[2,4] (T.P. Simon, personal observation).

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma simoterum is common in the lower Blue Ridge of the upper Tennessee throughout all upland physiographic provinces. It is absent from the Coastal Plain and in the Cumberland drainage.[8,*,7]

SPAWNING

Location
Egg sites include the vertical sides and horizontal tops of rocks in riffles and flowing pool habitats, in slight to moderate current.[7] Spawning occurs on algae-covered boulders in slow currents along the margin of the stream.[11]

Season
In the Nolinchucky River, Greene County, TN, males in spawning color were collected during mid-February from riffles in moderate current.[7] Tennessee snubnose darter's peak spawning occurs from April through early May in TN.[8] Spawning throughout its range occurs from late March until early June.[2]

Temperature
Spawning activity initiates in Hinds Creek, TN, when temperatures reach 12–17.2°C.[7]

Fecundity (see Table 131)
Female snubnose darter show statistically significant increasing fecundity (ANOVA, $F = 6.342$, $p = 0.036$) with increasing length. Two 47 mm females had 60–78 large mature ova, while several 44 mm females had 60–62 large mature ova.

Sexual Maturity
Tennessee snubnose darter survives to spawn 2 years, with age 1 fish averaging 35–42 mm SL at first reproduction.[8]

Spawning Act
Etheostoma simoterum is an egg attacher.[7] During aquarium observations, a single male follows a single female to the egg site and in a complex series of movements intertwines her body and presses against the vertical sides of slab rocks.[7] The male body movements resemble an S-shape, with the caudal peduncle of the male wrapped around that of the female. Adults maintain a head-to-head orientation with vents juxtaposed. Eggs are laid one at a time on the vertical surface of the rock, generally 3–5 during a single spawning event. The pair is observed to switch positions on the rock depositing eggs on different sections of the same and different rocks. Since only a single pair of adults was maintained in the aquarium it could not be determined if the pair would have switched spawning partners as noted by Page and Mayden regarding observations on *E. atripinne*.[13] Spawning may consist of as many as 30 such episodes before the male and female discontinue reproduction. No cleaning of the rock surface or parental care is provided before or after

Table 131

Fecundity data for *E. simoterum* from Little River, Blount County, TN.

		Number of Ova			
Length (mm TL)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
40	58.2	558	107	53	1.00
41	87.3	718	116	58	1.11
41	76.9	702	91	48	1.25
42	104	728	124	72	1.18
44	123	985	137	61	1.25
44	112	705	142	60	1.11
44	126	797	121	82	1.11
46	98.7	697	128	64	1.11
47	109	774	153	78	1.11
47	113	930	159	60	1.11

the eggs are laid. Spawning occurs approximately every 3–4 days for approximately a month.[7]

EGGS

Description
Examination of ovaries shows that ovoid latent ova are 0.4 mm, early maturing ova averaged 0.7– 0.8 mm, and large mature ova average 1.0–1.25 mm. Eggs from Hinds Creek, Anderson Co., TN, are spherical, mean = 1.2 mm in diameter (range = 1.0–1.4 mm); translucent; demersal; and adhesive. Eggs possess translucent, pale yellow yolk (mean = 1.1 mm in diameter; range = 0.9–1.3 mm); a single oil globule (mean = 0.26 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[7]

Incubation
Hatching occurs after 144–168 h at an incubation temperature of 20°C.[7]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 120

Size Range
4.3–4.7 mm TL; yolk absorbed by 6.3 mm.[7]

Myomeres
Clinch River drainage, preanal 15 (12), 16 (51), 17 (21), or 18 (12)(*N* = 96, mean = 16.3); postanal 21 (3), 22 (37), 23 (53), or 24 (3)(*N* = 96, mean = 22.6); with total 37 (4), 38 (14), 39 (67), or 40 (11)(*N* = 96, mean = 38.9).[7] French Broad River drainage, preanal 16 (13), 17 (4), or 18 (3)(*N* = 20, mean = 16.5); postanal 22 (8) or 23 (12)(*N* = 20, mean = 22.6); total 38 (3), 39 (12), or 40 (5)(*N* = 20, mean = 39.1).[7] Nolichucky River drainage, preanal 16 (15), 17 (25), or 18 (2)(*N* = 42, mean = 16.7); postanal 21 (1), 22 (35), or 23 (5)(*N* = 42, mean = 21.6); with total 38 (12), 39 (25), or 40 (5)(*N* = 42, mean = 38.8).[7]

Morphology
4.3–4.7 mm TL. Newly hatched larvae with terete body; snout blunt; with functional jaws, upper jaw even, to slightly extended past lower jaw; yolk sac small (22.0% TL), oval to tapered posteriorly; yolk translucent clear to pale yellow, with a single oil globule; single serpentine vitelline vein midventrally on yolk sac; head not deflected over the yolk sac; eyes spherical.[7]

6.1–6.3 mm TL. Digestive system functions prior to complete yolk absorption.[7]

6.3–6.5 mm TL. Premaxilla and mandible form.[7]

Morphometry
See Table 132.

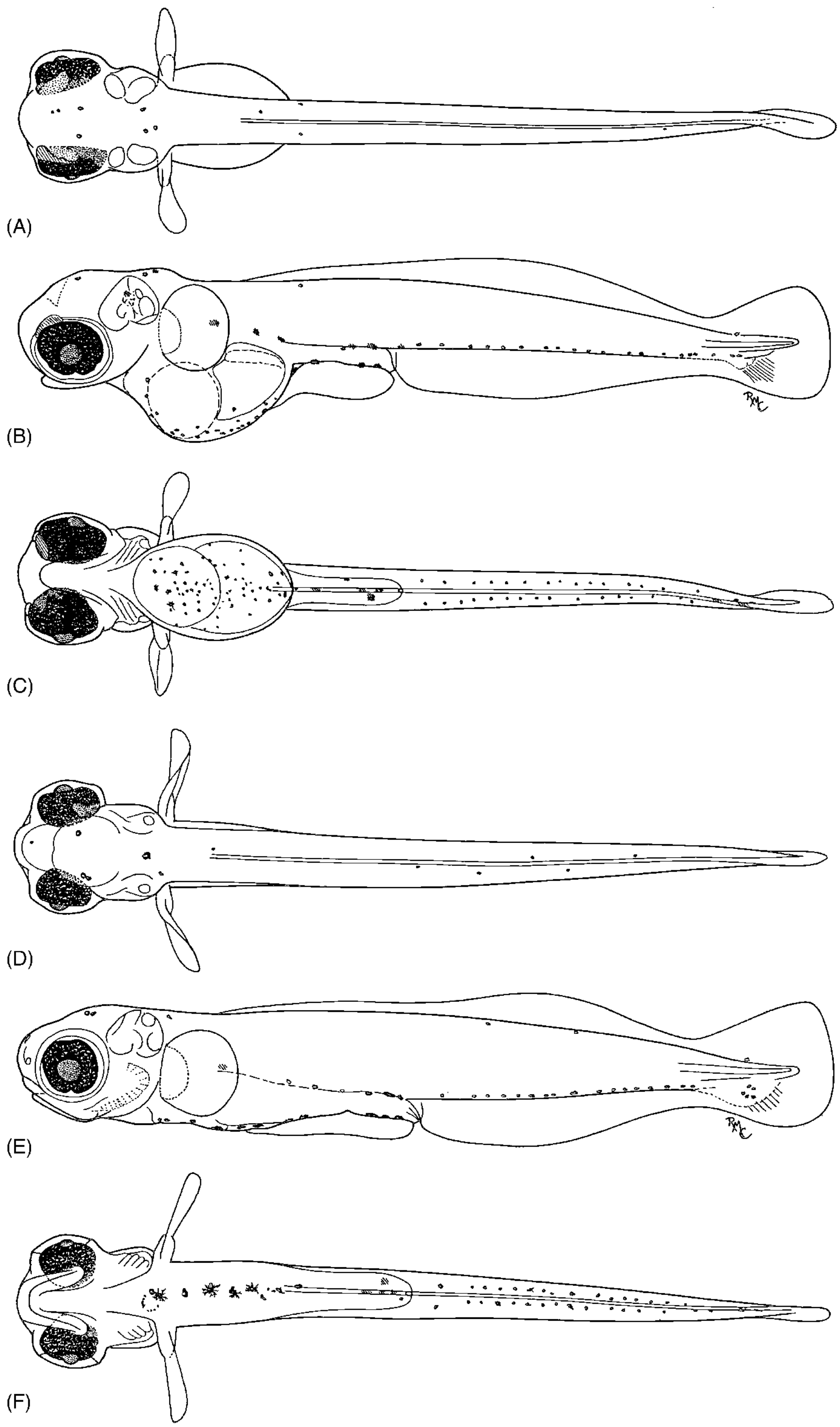

Figure 120 *Etheostoma simoterum*, Tennessee snubnose darter, Nolichucky River, Greene County, TN. Yolk-sac larva, 5.0 mm TL: (A) dorsal, (B) lateral, (C) ventral views; post yolk-sac larva, 7.5 mm TL, (D) dorsal, (E) lateral, (F) ventral views. (A–F from reference 7, with author's permission.)

Fin Development
See Table 133.

4.3–4.7 mm TL. Newly hatched larva with well-developed pectoral fins without incipient rays.[7]

Pigmentation
4.3–4.7 mm TL. Newly hatched larva with pigmented eyes; melanophores present dorsally over posterior cerebellum or nape; melanophores distributed laterally, dorsally over the gut posterior to the yolk sac.

Table 132

Morphometry of young *E. simoterum* grouped by selected intervals of total length (N = sample size).[7]

	Total Length (TL) Intervals (mm)											
	4.31–5.82 (N = 31)		6.01–7.73 (N = 43)		8.08–9.93 (N = 32)		10.2–13.0 (N = 41)		13.0–15.5 (N = 16)		16.5–20.7 (N = 6)	
Characters	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
Length (% of TL)												
Upper jaw[a]	25.7 ± 3.63	(0.20–0.36)	26.7 ± 6.27	(0.24–0.62)	26.9 ± 4.80	(0.31–0.66)	27.9 ± 3.14	(0.54–0.93)	27.2 ± 3.31	(0.70–1.02)	24.4 ± 2.75	(0.90–1.06)
Snout[a]	13.9 ± 3.65	(0.08–0.22)	15.2 ± 2.30	(0.12–0.27)	17.5 ± 4.60	(0.22–0.64)	19.2 ± 2.08	(0.33–0.72)	17.9 ± 1.69	(0.46–0.71)	18.6 ± 1.16	(0.63–0.82)
Eye diameter[a]	46.2 ± 3.77	(0.39–0.47)	40.6 ± 3.75	(0.47–0.71)	38.0 ± 1.93	(0.60–0.77)	34.1 ± 1.19	(0.72–0.94)	32.0 ± 1.31	(0.92–1.14)	31.3 ± 1.38	(1.14–1.36)
Head	18.6 ± 1.00	(0.74–1.13)	19.3 ± 1.23	(0.90–1.68)	19.8 ± 1.09	(1.51–2.12)	21.4 ± 1.03	(2.01–2.86)	22.2 ± 1.04	(2.70–3.64)	22.1 ± 1.29	(3.43–4.46)
Predorsal	28.5 ± 1.99	(1.11–1.76)	28.9 ± 1.46	(1.72–2.36)	27.3 ± 2.77	(1.44–3.02)	28.7 ± 1.28	(2.80–3.80)	28.4 ± 1.18	(3.64–4.60)	26.3 ± 4.10	(3.22–5.52)
Dorsal insertion					28.0 ± 10.8	(0.00–4.78)	42.3 ± 9.34	(2.80–6.44)	45.9 ± 7.45	(3.96–7.96)	46.4 ± 5.34	(6.40–9.82)
D2 origin					28.3 ± 11.3	(0.00–5.03)	44.6 ± 10.9	(2.80–7.00)	48.3 ± 8.48	(3.96–8.52)	49.2 ± 5.28	(6.88–10.4)
D2 insertion					37.0 ± 19.3	(0.00–5.03)	59.3 ± 20.2	(2.80–7.00)	67.3 ± 16.0	(3.96–8.52)	74.3 ± 11.3	(6.88–10.4)
Preanal	48.2 ± 1.36	(2.10–2.94)	50.5 ± 1.72	(2.92–4.09)	51.6 ± 1.76	(3.98–5.40)	52.3 ± 1.63	(5.17–6.72)	50.6 ± 1.22	(6.50–7.84)	49.4 ± 0.79	(8.20–10.0)
Postanal	51.8 ± 1.35	(2.10–2.90)	49.5 ± 1.72	(2.90–3.77)	48.4 ± 1.76	(3.96–4.89)	47.4 ± 1.70	(4.71–6.47)	49.8 ± 1.00	(6.53–7.77)	50.6 ± 0.80	(8.25–10.7)
Standard	96.2 ± 0.81	(4.15–5.56)	95.8 ± 0.86	(5.75–7.40)	91.2 ± 3.36	(7.09–8.88)	88.0 ± 3.36	(8.84–11.6)	85.3 ± 1.49	(11.2–13.4)	85.2 ± 1.75	(13.8–17.5)
Yolk sac	22.0 ± 1.92	(0.84–1.24)										
Fin Length (% of TL)												
Pectoral	8.22 ± 1.04	(0.32–0.56)	10.6 ± 1.27	(0.50–1.00)	12.4 ± 1.68	(0.72–1.42)	17.8 ± 2.45	(1.26–2.94)	20.9 ± 2.33	(2.40–3.84)	21.0 ± 1.59	(3.28–4.20)
Pelvic			3.40	(0.26–0.26)	4.48 ± 2.40	(0.01–0.78)	10.2 ± 2.53	(0.58–1.85)	14.6 ± 2.51	(1.44–2.71)	16.0 ± 0.85	(2.56–3.39)
Spinous dorsal					19.4 ± 2.20	(1.66–2.14)	19.8 ± 1.29	(2.00–2.70)	20.0±1.44	(2.44–3.36)	20.2 ± 1.40	(3.18–4.30)
Soft dorsal					21.4 ± 2.02	(1.74–2.40)	20.8 ± 1.04	(1.94–2.90)	21.7 ± 2.47	(2.71–3.98)	25.2 ± 9.06	(3.48–9.00)
Caudal	3.76 ± 0.81	(0.11–0.28)	4.20 ± 0.86	(0.16–0.52)	8.80 ± 3.36	(0.32–1.60)	12.0 ± 3.36	(0.32–2.00)	14.7 ± 1.49	(1.76–2.75)	14.8 ± 1.75	(2.23–3.33)
Body Depth (% of TL)												
Head at eyes	14.6 ± 1.03	(0.59–0.82)	15.3 ± 0.74	(0.90–1.20)	15.2 ± 1.07	(1.18–1.67)	15.1 ± 0.50	(1.42–2.08)	15.3 ± 0.73	(1.96–2.40)	15.0 ± 1.18	(2.42–2.96)
Head at P1	18.4 ± 3.03	(0.70–1.27)	14.7 ± 1.14	(0.84–1.21)	15.2 ± 1.02	(1.10–1.65)	18.0 ± 3.53	(1.55–3.54)	17.8 ± 0.57	(2.28–2.92)	17.9 ± 0.59	(3.00–3.63)
Preanal	8.21 ± 0.67	(0.30–0.48)	10.3 ± 1.22	(0.56–1.14)	12.6 ± 0.93	(0.90–1.36)	13.7 ± 0.91	(1.32–2.21)	13.8 ± 0.61	(1.82–2.18)	14.0 ± 0.74	(2.20–2.98)
Mid-postanal	5.90 ± 0.53	(0.23–0.36)	6.99 ± 0.84	(0.28–0.62)	8.48 ± 0.66	(0.52–0.93)	8.80 ± 0.30	(0.88–1.22)	8.94 ± 0.28	(1.18–1.38)	9.27 ± 0.44	(1.48–1.94)
Caudal peduncle	2.92 ± 0.35	(0.10–0.18)	3.18 ± 1.11	(0.17–0.44)	6.40 ± 1.07	(0.34–0.82)	5.31 ± 2.01	(0.68–1.00)	5.49 ± 1.93	(0.92–1.20)	7.52 ± 0.61	(1.12–1.62)
Yolk sac	12.1 ± 2.40	(0.31–0.78)										
Body Width (% of HL)												
Head	73.2 ± 7.53	(0.42–0.80)	70.3 ± 6.03	(0.72–1.16)	68.2 ± 4.03	(1.00–1.44)	65.0 ± 2.01	(1.30–1.84)	62.2 ± 5.39	(1.61–2.26)	62.8 ± 5.05	(2.16–2.90)
Myomere Number												
Predorsal	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)	4.05 ± 0.22	(4.00–5.00)	4.00 ± 0.00	(4.00–4.00)	4.00 ± 0.00	(4.00–4.00)
Soft dorsal	17.0 ± 0.00	(17.0–17.0)	17.0 ± 0.00	(17.0–17.0)	17.2 ± 0.37	(17.0–18.0)	17.3 ± 0.48	(17.0–18.0)	17.0 ± 0.00	(17.0–17.0)	17.0 ± 0.00	(17.0–17.0)
Preanal	15.6 ± 0.49	(15.0–16.0)	16.2 ± 0.47	(16.0–18.0)	16.7 ± 0.58	(16.0–18.0)	17.0 ± 0.67	(16.0–18.0)	17.1 ± 0.67	(16.0–18.0)		
Postanal	22.8 ± 0.58	(22.0–24.0)	22.8 ± 0.48	(22.0–24.0)	22.3 ± 0.48	(22.0–23.0)	21.9 ± 0.49	(21.0–23.0)	21.9 ± 0.52	(21.0–23.0)		
Total	38.5 ± 0.72	(37.0–40.0)	39.0 ± 0.51	(38.0–40.0)	39.1 ± 0.57	(38.0–40.0)	39.0 ± 0.50	(38.0–40.0)	39.0 ± 0.43	(38.0–40.0)		

[a] Proportion expressed as percent head length.

Note: Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

Table 133

Meristic counts and size (mm TL) at the apparent onset of development for *E. simoterum*.[7]

Attribute/event	*Etheostoma simoterum*[7]	Literature
Branchiostegal Rays	5,5[7]	5,5[2,3,8]
Dorsal Fin Spines/Rays	IX–XI/10–12[7]	IX–XII/10–12[2,3,8]
First spines formed	8.4–8.9[7]	
Adult complement formed	9.1–9.4[7]	
First soft rays formed	7.7–8.2[7]	
Adult complement formed	8.6–9.0[7]	
Pectoral Fin Rays	13–15[7]	13–15[2,3]
First rays formed	7.4–9.3[7]	
Adult complement formed	8.6–9.3[7]	
Pelvic Fin Spines/Rays	I/5[7]	I/5[2,3]
First rays formed	9.1–9.3[7]	
Adult complement formed	9.1–9.3[7]	
Anal Fin Spines/Rays	II/7–8[7]	II/6–8[2,3,8]
First rays formed	7.6–8.2[7]	
Adult complement formed	8.7[7]	
Caudal Fin Rays	vii–xiii, 7–8 + 7, viii–xi[7]	15–18[8]
First rays formed	6.8–7.5[7]	
Adult complement formed	8.7–9.2[7]	
Lateral Line Scales	49–53[7]	42–58[2,3,8]
Myomeres/Vertebrae	37–40/38–40[7]	Unknown/38–40[2,3,8,9]
Preanal myomeres	15–18[7]	
Postanal myomeres	21–24[7]	

Ventral pigmentation consists of mid-ventral stripes of stellate melanophores surrounding the vitelline vein on the yolk sac, and punctate melanophores are found along every mid-ventral postanal myosepta.[7]

5.0–6.7 mm TL. Cranium with distinct melanophores over the optic lobe extending posteriorly onto the nape to approximately the spinous dorsal fin origin. Lateral melanophores present over the gut.[7]

POST YOLK-SAC LARVAE

See Figures 120 and 121

Size Range
6.3–6.7 to 10.2–12 mm.[7,*]

Myomeres
Clinch River drainage, preanal 15 (12), 16 (51), 17 (21), or 18 (12)(*N* = 96, mean = 16.3); postanal 21 (3), 22 (37), 23 (53), or 24 (3)(*N* = 96, mean = 22.6); with total 37 (4), 38 (14), 39 (67), or 40 (11)(*N* = 96, mean = 38.9).[7] French Broad River drainage, preanal 16 (13), 17 (4), or 18 (3)(*N* = 20, mean = 16.5); postanal 22 (8) or 23 (12)(*N* = 20, mean = 22.6), total 38 (3), 39 (12), or 40 (5)(*N* = 20, mean = 39.1).[7] Nolichucky River drainage, preanal 16 (15), 17 (25), or 18 (2)(*N* = 42, mean = 16.7); postanal 21 (1), 22 (35), or 23 (5)(*N* = 42, mean = 21.6); with total 38 (12), 39 (25), or 40 (5)(*N* = 42, mean = 38.8).[7]

Morphology
6.3–6.7 mm TL. Yolk absorbed.[7]

6.8 mm TL. Operculum and gill arches function.[7]

7.5–8.6 mm TL. Neuromast development occurs midlaterally from the anterior trunk posteriad.[7]

7.5–9.6 mm TL. Branchiostegal rays form.[7]

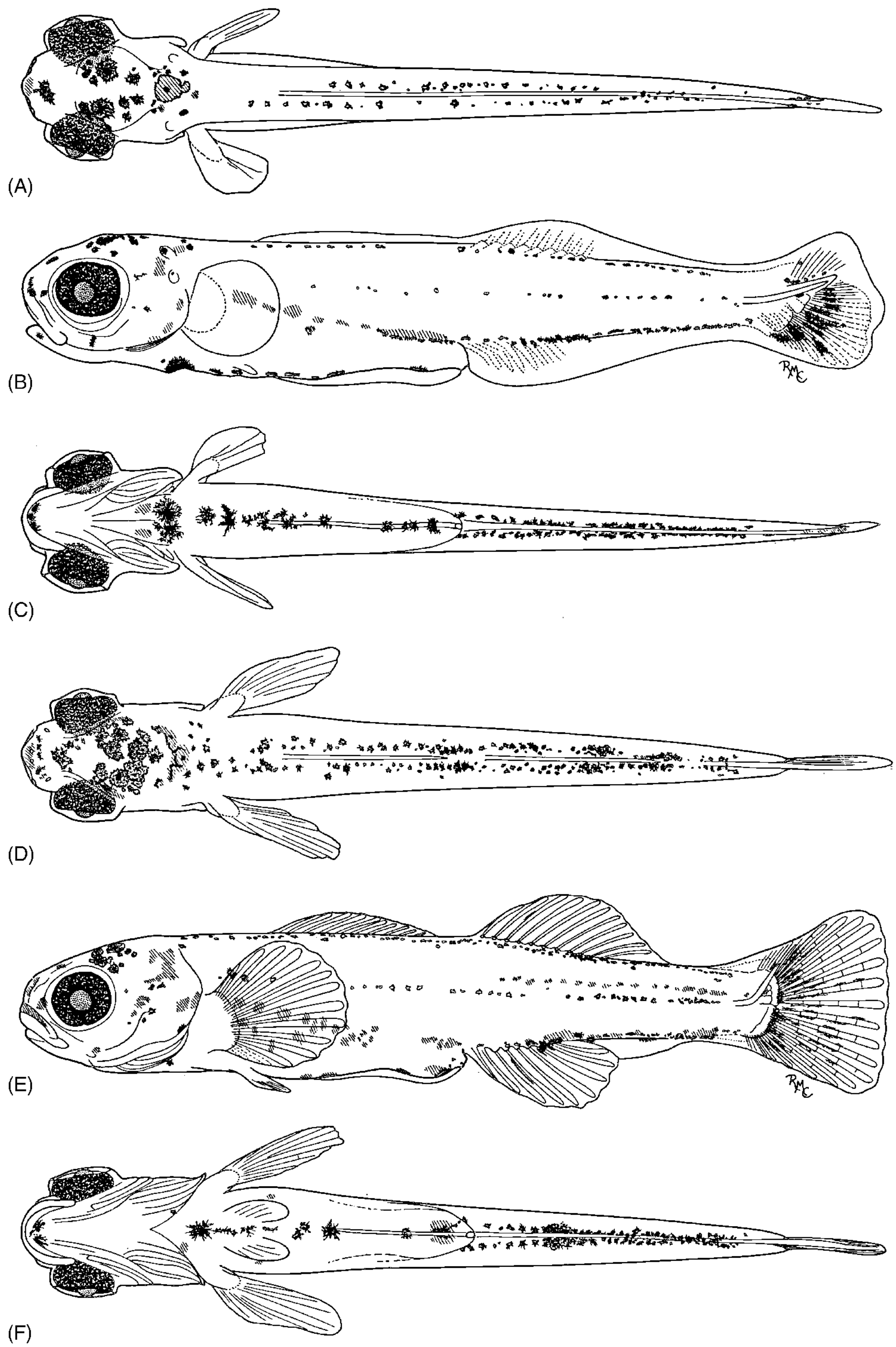

Figure 121 *Etheostoma simoterum*, Tennessee snubnose darter, French Broad River, Sevier County, TN. Post yolk-sac larva, 9.1 mm TL: (A) dorsal, (B) lateral, (C) ventral views; post yolk-sac larvae, 11.9 mm TL, (D) dorsal, (E) lateral, (F) ventral views. (A–F from reference 7, with author's permission.)

7.4–10.2 mm TL. No swim bladder forms; gut straight, without striations, portion of gut posterior to stomach normal in length.[7]

Morphometry
See Table 132.[7]

Fin Development
See Table 133.

6.8–7.5 mm TL. First rays form in caudal fin.[7]

7.4–9.3 mm TL. Pectoral fin rays form.[7]

7.6–8.2 mm TL. Anal fin ray forms.[7]

7.3–8.1 mm TL. Notochord flexion proceed caudal fin ray development.[7]

7.7–8.2 mm TL. Soft dorsal fin rays form.[7]

7.5–9.6 mm TL. Branchiostegal rays form.[7]

8.2–8.6 mm TL. Pelvic fin buds form anterior to dorsal fin origin after complete yolk absorption.[7]

8.4–8.9 mm TL. Spinous dorsal fin rays form.[7]

9.0–9.3 mm TL. Dorsal and anal finfold partially differentiated (9.0–9.3 mm); first pelvic fin ray forms (9.1–9.3 mm); complete adult fin ray counts in median fins (9.2 mm).[7]

9.6–10.2 mm TL. Both finfolds completely differentiated.[7]

9.3–10.4 mm TL. Spinous dorsal fin origin situated over preanal myomere 4–5 and soft dorsal origin over preanal myomere 17–18.[7]

Pigmentation
6.8–8.8 mm TL. Dorsum of cranium with several large melanophores clustering on cerebellum; several melanophores found on dorsum even on the soft dorsal fin. Lateral series of melanophores present from the tip of the pectoral fin to the anus; and at the base of the hypural plate above and below the notochord. Ventral pigmentation includes a single series of melanophores present mid-ventrally from the breast to the anus; two clusters of mid-ventral postanal melanophores begin at postanal myomere three and extend to the caudal peduncle base.[7]

8.9–9.7 mm TL. Macromelanophores accumulate near the snout and over the optic lobe; two pairs of melanophores extend from the spinous dorsal fin origin to the caudal peduncle base. Lateral pigmentation includes a precursor of the preorbital and postorbital bars; subdermal pigment appears over the gut, becoming cutaneous near the anus; a single mid-lateral series of melanophores is present from the tip of the pectoral fin to the caudal peduncle; a large dense accumulation of melanophores found in the epaxial and hypaxial sections of the caudal fin. Ventrally, the mandible tip is outlined; a single series of melanophores extends from the breast to the anus, forming a double row from the anus to the caudal peduncle.[7]

9.8–11.9 mm TL. Melanophores on the snout outlines the maxillary and the otic capsule; pigmentation on dorsum begins to form eight distinct clusters. Melanophores present in the subdermal layer over the gut and in the epaxial muscle from the anus to the caudal fin base; extend into the anal fin near its insertion; and radiate into the caudal fin from the caudal fin base to the medial portion of the fin.[7]

JUVENILES

See Figure 122

Size Range
12.0 mm TL* to 35–42 mm TL.[7,*]

Fin Development
Branchiostegal rays 5,5;[2,3,7,8] dorsal fin spines/rays (IX–XI)–XII/10–12;[2,3,7,8] pectoral fin rays 13–15;[2,3,7] pelvic fin spines/rays I/5;[2,3,7] anal fin spines/rays II/6–(7–8);[2,3,7,8] caudal fin rays vii–xiii, 7-8+7, viii–xi[7] or 15–18[8]; lateral line scales 42–(49–53)[7]–58.[2,3,8]

Total vertebrae count 38–40 (N = 3, mean = 39.0), including one urostylar element. Scales in the lateral series range from 49 to 53 in the Clinch and French Broad River drainages, 42–58 throughout range.[7]

13.0 mm. Caudal fin slightly emarginate (13.0 mm).[7]

Morphology
11.3–12.6 mm TL. Upper jaw equal with lower jaw, becoming subterminal (11.3–12.6 mm); infraorbital and supraorbital canals form (11.7 mm); lateral, subtemporal and preoperculomandibular head canals form (12.6 mm).[7]

13.0 mm TL. Infraorbital, lateral, and supratemporal head canals not interrupted, preoperculomandibular canal complete with 8–10 pores; infraorbital pores 7–9.[3]

15.2 mm TL. Initiation of squamation.[7]

15.5–17.2 mm TL. Squamation complete.[7]

18.0 mm TL. Lateral line begins to form.[7]

Early juvenile. Cheek scales, usually embedded; cheek, opercle, nape, and belly are completely scaled; breast naked.[2,5,8]

Morphometry
See Table 132.[7]

11.3–12.6 mm TL. Average predorsal length 29.9% SL (range = 25.9–32.2% SL), and 28.3% TL (range = 24.5–30.4% TL).[7]

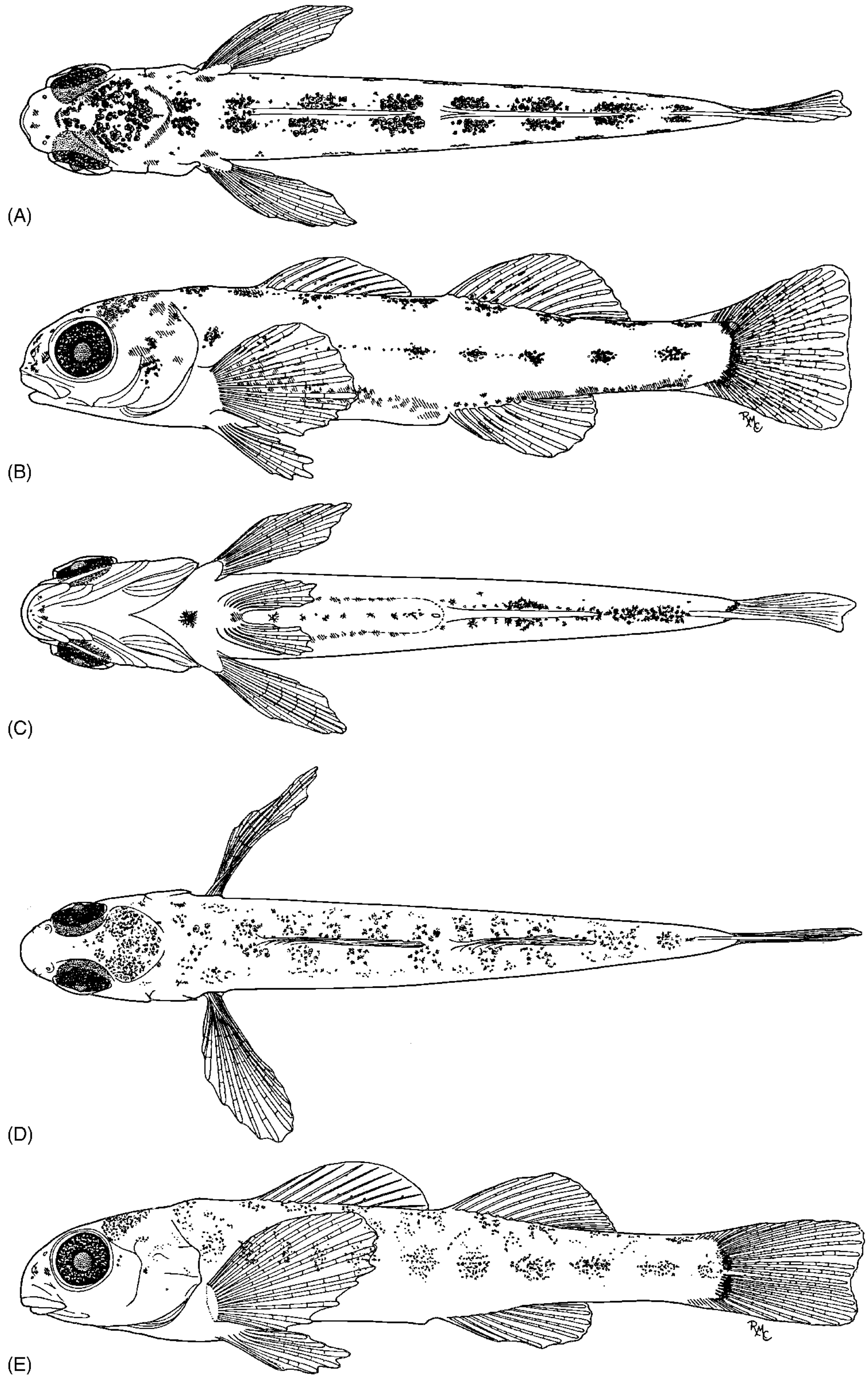

Figure 122 *Etheostoma simoterum*, Tennessee snubnose darter, Hinds Creek, Anderson County, TN. Juvenile, 14.6 mm TL: (A) dorsal, (B) lateral, (C) ventral views; juvenile, 19.8 mm TL, (D) dorsal, (E) lateral views. (A–E from reference 7, with author's permission.)

Pigmentation

12.1–15.5 mm TL. Similar to previous interval with the exception of the dorsal saddles becoming more distinct, form eight saddles. Mid-lateral clusters of melanophores form seven discrete blotches. Ventral melanophore clusters accumulate from the middle of the anal fin and near the insertion to the caudal peduncle.[7]

*16.5–20.7 mm TL.** Dorsum of cranium with optic lobe covered with stellate melanophores; 8–10 dorsal saddles formed. Lateral pigmentation includes the presence of 10–11 mid-lateral blotches; and a dense vertical accumulation of melanophores at the caudal fin base. Melanophores scattered proximally in the spinous and soft dorsal fins; and along the membranes in the caudal fin. The pectoral, anal, and pelvic fins are unpigmented.[7]

TAXONOMIC DIAGNOSIS OF YOUNG TENNESSEE SNUBNOSE DARTER

Similar species: members of subgenus *Ulocentra*.

Adult. The *E. simoterum* group may consist of the nominal form, as well as *E. atripinne* from the Cumberland River drainage. Burr and Warren (1986) suggest that Etnier (1980) had combined the two forms with recommendation of subspecies recognition. Etnier (1980) had only recommended further study of these two forms. Each form was recognized as distinct species for the purpose of description and phylogenetic analysis.

Etheostoma simoterum can be differentiated from *E. atripinne* based on modes of 48–53 lateral line scales and eight dorsal saddles. *Etheostoma simoterum* has modes of 39–43 lateral line scales and 12–18 scales around the caudal peduncle. *Etheostoma simoterum* occurs throughout the middle and upper Tennessee River system in TN, MS, AL, GA, and VA, while *E. atripinne* occurs in the middle Cumberland River, KY and TN, and the Duck River, west-central.[2,3]

Larva. E. simoterum is virtually identical to species *E. atripinne* in pigmentation and myomere counts. Both species have overlapping, low preanal (15–17) myomere counts. However *E. simoterum* has higher postanal (22–24) myomere counts.[7]

Variation
The three populations of *E. simoterum* exhibit no intraspecific variation in myomere counts, ontogenetic events, or body proportions.[7]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 123)
Eggs. Egg sites include the vertical sides and horizontal tops of rocks in riffles and flowing pool habitats, in slight to moderate current.[7]

Figure 123 Distribution of Tennessee snubnose darter, *Etheostoma simoterum* in the Ohio River system (shaded area).

Yolk-sac larvae. Aquarium observations show that Tennessee snubnose darter larvae are epi-benthic immediately after hatching.[7]

Post yolk-sac larvae. Larvae become demersal at lengths >13 mm when they remain in close association with the substrate. Tennessee snubnose darter larvae from Hinds Creek, a tributary of the Clinch River, downstream of the Norris Dam, are collected in equal numbers from eddy areas adjacent to riffles, from behind tree roots and other structures over sand in water 0.3–0.5 m depth, and in flowing pool habitat from late April to late July.[7]

Juveniles. In the French Broad River, downstream of Douglas Lake, larvae and early juveniles utilize the downstream pools and backwater areas adjacent to spawning riffles as nursery habitats. All length intervals, <13 mm, are collected in epi-benthic dipnet samples from the near-shore habitats usually associated with tree roots or rubble. Juveniles, >25 mm TL are the smallest individuals found on the margins of the riffle and flowing pool habitat in Hinds Creek.[7]

Early Growth (See Table 134.)
Age 1 fish average about 35 mm SL (females) and 42 mm SL (males).[8] Maximum age is between 18 and 24 months;[10] and maximum size is 70–72 mm SL.[12] Growth increases by threefold from the highest elevation to the lowest elevation.[12]

Feeding Habits
Food of young and adults is primarily midge larvae, supplemented by mayfly nymphs, caddisfly larvae, and micocrustaceans;[8] small numbers of amphipods and fingernail clams, microcrustaceans, water mites, and snails.[5]

Table 134

Average calculated lengths (mm SL) of young Tennessee snubnose darters in Tennessee and Virginia.[5,8]

State	Age 1	Age 2	Age 3
Tennessee[8]	35–42	48–55	64–76
Virginia[5]			70–72

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Material Examined: TN: Anderson Co.: Hinds Creek, at Hillvale Road, 1/2 mi SE junct I-75 and SR 61, 5.6 miles N Clinton, TV 1150 (3); TV 1167 (4); TV 1208 (4); TV 1209 (16); TV 1225 (27); TV HC001 reference collection (4); TV HC001 reference collection (5); TV reference collection (2); TV reference collection (3); TV reference collection (5); TV reference collection (4); TV reference collection (3); TV reference collection (3); TV reference collection (4); TV reference collection (1); TV reference collection (3); TV reference collection (3); TV reference collection (1); TV reference collection (1); TV reference collection (1); TV reference collection (1); TV reference collection (1); TV reference collection (2); TV reference collection (3); TV reference collection (2). Knox Co.: French Broad River, below Douglas Dam, 4 miles SE junct. US 40/SR 66, LRRC 664 (23). Greene Co.: Nolichucky River, downstream from Hale bridge on Hwy 340, LRRC 821 (52).

* Original fecundity data for Tennessee snubnose darter from Little River, Tennessee River drainage. Blount County, TN. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Early life history developmental series cultured from field and laboratory spawned specimens from Nolichucky River, Greene County, TN; French Broad River, Sevier County, TN; and Hinds Creek, Anderson County, TN. Specimens curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

SLABROCK DARTER

Etheostoma (*Catonotus*) *smithi* Page and Braasch

Etheostoma, various mouths; *smithi*, named in honor of Philip W. Smith, prominent IL zoologist.

RANGE

Etheostoma smithi is sporadic in tributaries of the lower Cumberland River basin, from the mouth of the river in KY upstream to Caney Fork, TN. Also, occurs in the lower Tennessee River below the Duck River, TN.[1–3,10]

HABITAT AND MOVEMENT

Etheostoma smithi inhabits the shallow, slab-rock pools in the headwaters and upper reaches of streams.[4] Limited mobility occurs during the year with the majority of adults remaining in slab pools.[4] Habitats also include the gravel bottom pools in the Duck River, and variable habitat is usually pools with either sand, gravel, or bedrock substrates in the lower Cumberland River.[3]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma smithi is common in tributaries to the Cumberland River in the Nashville basin, from the mouth of the Caney Fork River downstream to Nashville.[5,6] In the Tennessee River, it occurs in eastern tributaries downstream from the mouth of Duck River, and rarely in tributaries to lower Duck River.[5]

SPAWNING

Location
Spawning occurs beneath slab rocks, which are selected by the females and is guarded by the males as nesting territories. The species is considered to be a guarding, egg-clumping speleophil (B.2.5) following Balon,[8] or as a clusterer following Page.[1] The female attaches the adhesive eggs to the underside of the rock. Adult males guard the eggs until hatching and pick off fungused eggs and gently massage and fan the eggs with pectoral and spinous dorsal fin knobs.[4] Egg slabs are usually in the margins and slower portions of the rivers and stream riffles and runs.[1–4,7]

Season
Spawning occurs from late April to mid-June in Ferguson Creek, KY;[3,4] peak reproduction occurs during May.[4]

Temperature
Peak spawning occurs between 15 and 20°C in KY.[4]

Fecundity
The largest females produce the greatest number of ova. The largest females ovaries are 24.3% of the body weight, and average 15.2%. Several 28 mm SL females possess between 17 and 33 mature ova, while a 43 mm SL female has 69 mature ova.[4] Nest stones from Ferguson Creek, KY, average 328 eggs and range between 175 and 600 eggs. Spawning occurs with the same or multiple males.[4]

Sexual Maturity
Males and females are sexually mature at age 1; females attain sexual maturity at 30 mm SL and males at 35 mm SL.[3,4]

Spawning Act
Etheostoma smithi is an egg clusterer. Males court females by lateral displays, with the median fins held erect and tail wagging. When a female joins a male beneath the nest stone, the male becomes extremely active, continuously courting the female, and occasionally nudging her with his snout. When spawning occurs the female inverts and presses her genital papillae against the nest stone. The male is positioned head-to-tail or head-to-head. Both tremble as sperm and eggs are released. The female lays 1–2 eggs in a concentrated area on the underside of the stone, but never on top of one another. Females only spawn in the nests of successful males. As many as four females singly spawn with the same male. The male vigorously guards the nest stone against potential egg predators. The male brushes the eggs with erect dorsal fins and removes dead eggs. The female does not assist in guarding the nest.[4]

EGGS

Description
Eggs are spherical, averaging 2.2 mm in diameter (range = 1.9–2.4 mm), demersal, and adhesive. Eggs contain translucent yellow yolk, a single oil globule, a narrow perivitelline space, an unsculptured chorion, and are unpigmented.[1,4,7–9]

Incubation
Eggs incubated at 13°C hatched in 29.5–30.5 days, while eggs at 21°C hatched in 12.5–13.5 days.[4,7]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 124

Size Range
Newly hatched at 6.1 mm TL; yolk absorbed by 7.4–7.6 mm TL.[7]

Myomeres
Preanal 15, postanal 19–21; total 34–36; predorsal 4.[7]

Morphology
6.1 mm TL. Newly hatched larvae with a terrate body; eye oval; large, spherical yolk sac, (31.4% SL, 33.5% L), with a single oil globule, and a distinct vitelline vein network; head not deflected over the yolk sac.[7]

7.0 mm TL. Notochord flexion preceeds complete yolk absorption.[7]

Morphometry
See Table 135.

Fin Development
6.1 mm TL. Well-developed pectoral fins with nine incipient rays, caudal fin with seven incipient rays. Dorsal and anal finfolds complete without evidence of fin rays.[7]

7.0 mm TL. Incipient dorsal and anal finfolds partially differentiated; spinous and soft dorsal fins, and anal fin rays form; pelvic buds form anterior to dorsal fin origin preceding complete yolk absorption.[7]

Pigmentation
6.1 mm TL. Retinae black; body pigmentation, sparce limited to melanophores on posterior cerebellum, mid-ventral yolk sac, anus, and postanal myomeres found in five clusters.[7]

7.0 mm TL. Throat pigmentation evident, extending into isthmus.[7]

POST YOLK-SAC LARVAE

See Figure 125

Size Range
7.4 to 10.3 mm TL.[7]

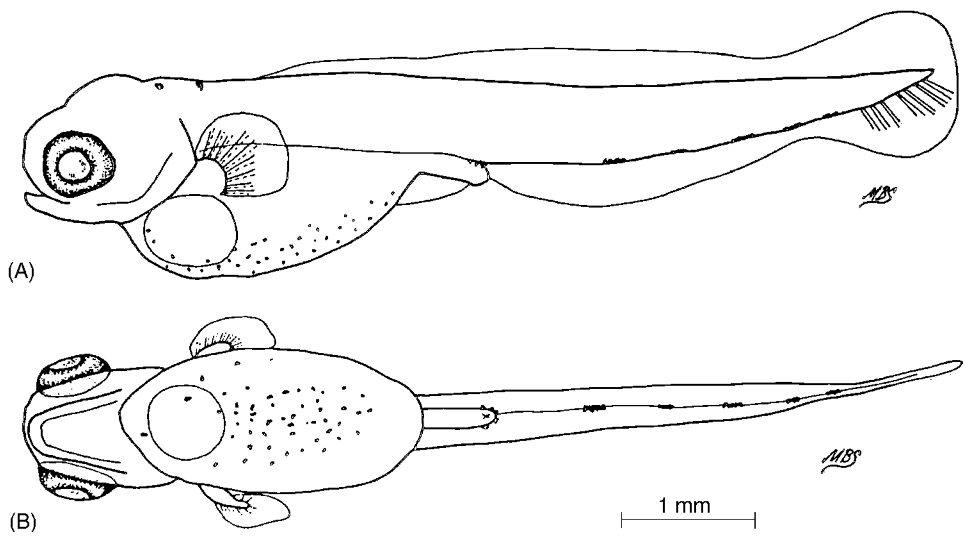

Figure 124 *Etheostoma smithi*, slabrock darter yolk-sac (newly hatched) larva, 6.1 mm TL, Ferguson Creek, KY (A) lateral, (B) ventral views. (A–B from reference 7, with author's permission.)

Table 135

Morphometric data expressed as percentage of HL and TL for young *E. smithi* from Kentucky.[7]

	TL Groupings					
Length Range (mm)	**6.1–7.4**	**7.6–12.6**	**13.0–16.0**	**16.1–19.8**	**20.0–25.5**	**25.9–26.4**
***N* Mean ± SD**	**3**	**10**	**34**	**28**	**26**	**3**
As Percent HL						
SnL	12.6 ± 1.3	18.5 ± 2.0	19.5 ± 1.5	19.9 ± 2.1	19.6 ± 2.0	20.2 ± 2.0
ED	39.04 ± 4.2	30.3 ± 2.5	27.9 ± 1.3	27.9±1.1	26.2 ± 1.1	26.5 ± 0.8
As Percent TL						
HL	19.8 ± 0.9	25.4 ± 2.0	25.7 ± 1.5	25.0 ± 1.3	25.8 ± 1.1	24.8 ± 0.7
Preanal	50.4 ± 1.9	50.0 ± 2.5	50.9 ± 2.8	49.7 ± 2.6	49.2 ± 1.7	48.7 ± 0.8
PosAL	49.6 ± 1.9	50.0 ± 2.5	49.1 ± 2.8	50.3 ± 2.6	50.8 ± 1.7	51.3 ± 0.8
SL	92.1 ± 3.5	84.2 ± 2.1	86.0 ± 2.1	84.6 ± 1.6	83.3 ± 1.4	84.6 ± 1.6
BPED	16.0 ± 1.1	15.1 ± 0.5	15.0 ± 0.8	14.2 ± 0.8	13.8 ± 1.1	13.7 ± 0.2
GBD	17.5 ± 4.6	16.8 ± 1.1	17.4 ± 1.0	17.1 ± 0.8	17.0 ± 0.9	15.9 ± 0.3
BDA	10.2 ± 1.3	11.9 ± 0.9	12.4 ± 1.1	12.9 ± 0.7	13.2 ± 0.9	12.5 ± 0.2
CPD	4.4 ± 0.6	6.8 ± 0.8	7.2 ± 0.5	7.4 ± 0.4	7.8 ± 0.5	7.1 ± 0.5

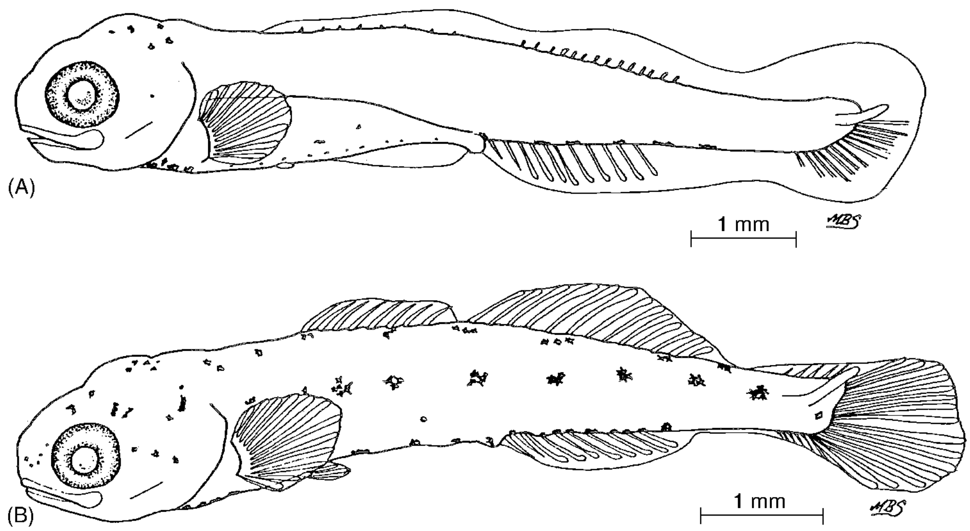

Figure 125 *Etheostoma smithi*, slabrock darter post yolk-sac larva, Ferguson Creek, KY: (A) 7.4 mm TL, (B) 10.3 mm TL. (A–B from reference 7, with author's permission.)

Myomeres
Preanal 15, postanal 19–21; total 34–36; predorsal 4; soft dorsal origin 15.[7]

Morphology
7.4–7.6 mm TL. Body laterally compressed; yolk absorbed; gut straight.[7]

Morphometry
See Table 135.

Fin Development
7.4 mm TL. Anal fin margins completely differentiated; adult complement of fin rays formed in dorsal and anal fins.[7]

7.6 mm TL. Dorsal fin completely differentiated; first pelvic fin rays formed; entire finfold absorbed.[7] Adult complement of fin rays formed in pectoral fins.[7]

9.0 mm TL. Adult complement of caudal and pelvic fin rays formed.[7]

Pigmentation
7.4 mm TL. Cranial melanophores intensity increases with stellate melanophores outlining the optic lobe and the operculum, additional pigmentation at postanal myomere 5, alternating every second or third myosepta posteriorly, mid-ventrally, and at the base of caudal peducle.[7]

7.6 mm TL. Melanophores on the nape and beneath the spinous dorsal and soft dorsal incipient finfolds.[7]

7.7–10.3 mm TL. Future preorbital and postorbital bars form; breast melanophores become subdermal; ventral pigmentation found near throat and lepidiotrichia of anal fin; 7 areas of dorsal melanophores and 11 lateral blotches forming.[7]

JUVENILES

See Figure 126

Size Range
>10.3 mm to 26.4 mm TL;[7] 30–35 mm TL.[3,4]

Fins
Spinous dorsal VIII–X; soft dorsal rays 13–15; pectoral rays 11–13; pelvic spines/rays I/5; anal fin spines/rays II/8–10.[1–3]

Morphology
See Table 136.

11.6 mm TL. No swim bladder formed; gut straight; caudal fin truncate.[7]

11.9 mm TL. Infraorbital and lateral head canals form.[7]

12.1–13.3 mm TL. Scales present in posterior half of caudal peduncle.[7]

14.5 mm TL. Supraorbital, supratemporal, and preoperculomandibular head canals formed.[7]

14.7 mm TL. Nape, prepectoral, cheek, opercle, and breast unscaled; belly scaled.*

15.6 mm TL. Infraorbital canal complete with 10 pores extending to mid-orbit, squamation complete.[7]

15.8 mm TL. Preoperculomandibular canal completely formed with 10 pores.[7]

16.8 mm TL. Lateral line begin to form.[7]

26.4 mm TL. Infraorbital complete with retrogression to interrupted condition of one pore posterior and three pores anterior;[7] lateral line scales range from 41 to 54.[3]

Morphometry
See Table 135.

Pigmentation
10.5–12.0 mm TL. Cranial pigment found on snout, ventral operculum, anterior optic lobe and cerebellum; melanophores present on prepectoral and the base of caudal peduncle; 8 dorsal saddles formed; 11 distinct lateral blotches; 2 ventral saddles; melanophores on spinous dorsal fin form as a midstripe; soft dorsal, anal, and caudal fin pigmentation restricted to the proximal third of the fins.[7]

12.2–14.9 mm TL. A single line of pigment extends between the orbit from the anterior optic lobe to midnares; melanophores distributed in epaxial operculum, scattered hypaxially on the postanal area and the entire postcaudal base; 13 elliptical to oval lateral blotches; 8 dorsal saddles. Melanophores also found at the distal end of the soft dorsal fin; 3 diagonal stripes in the caudal fin.[7]

TAXONOMIC DIAGNOSIS OF YOUNG SLABROCK DARTER

Similar species: *Etheostoma kennicotti* and *E. squamiceps*.

Etheostoma smithi is sympatric with *E. kennicotti* and *E. squamiceps* throughout its range. *Etheostoma smithi* can be separated from other sympatric *Catonotus* by possessing 15 preanal myomeres, while *E. kennicotti* and *E. squamiceps* have 16 preanal myomeres. Postanal myomeres in *E. smithi* were more sparsely pigmented with melanophores, limited to the midventral yolk sac and midventral postanal myosepta. Larvae of *E. kennicotti* can be differentiated by the more spherical, larger yolk sacs and smaller head length/TL from *E. squamiceps*. *Etheostoma squamiceps* has melanophores distributed postanally, while *E. kennicotti* have melanophores limited primarily to the yolk sac.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 127)
Eggs. Eggs are attached to the underside of slab rocks in slab pools. Eggs are guarded by the attendant male.[4,7,11]

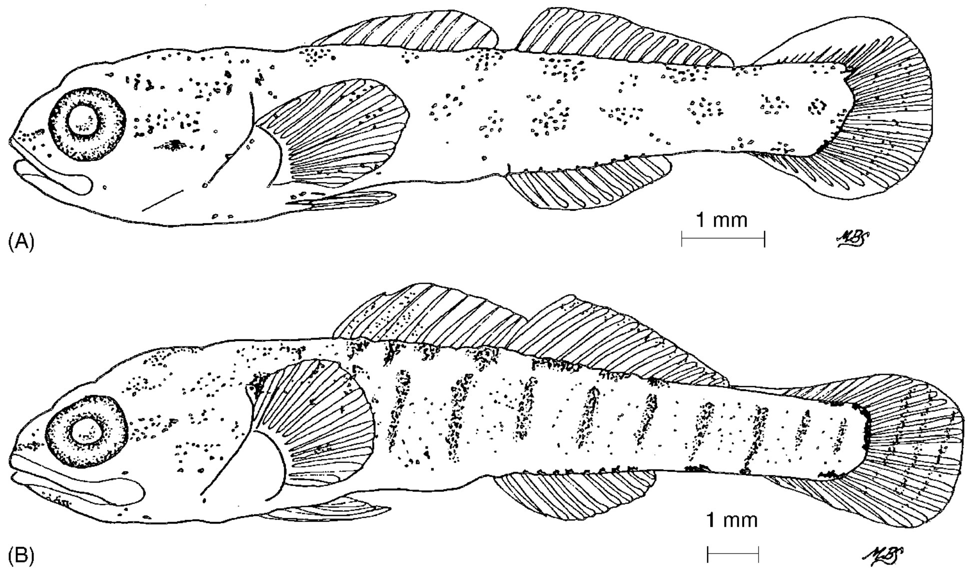

Figure 126 *Etheostoma smithi*, slabrock darter, Ferguson Creek, KY: (A) 11.9 mm TL, early juvenile , (B) 18.9 mm TL, juvenile. (A–B from reference 7, with author's permission.)

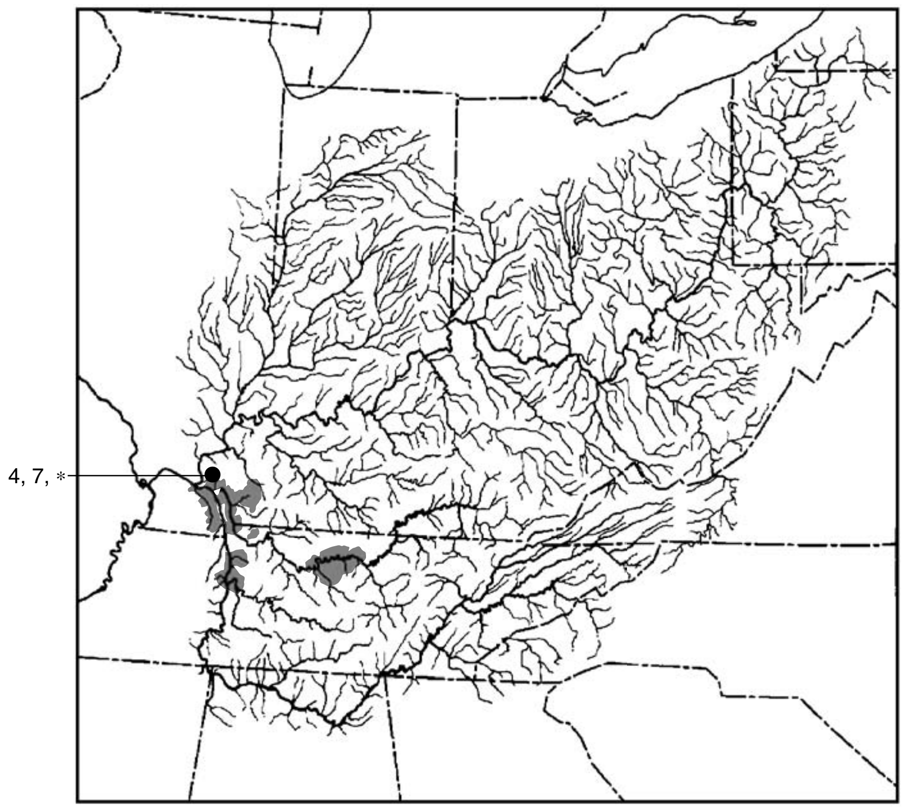

Figure 127 Distribution of slabrock darter, *E. smithi* from the Ohio River. Numbers refer to reproductive data based on the reference cited.

Yolk-sac larvae. Remain in gravel interstices until yolk absorption is complete; posses extensive vitelline vein networks, consistent with a subterranean, benthic lifestyle.[7, *]

Post yolk-sac larvae. Demersal, remain in close association with the substrate.[4,7]

Juveniles. Age 0 *E. smithi* occupy slab pools; however, many were still found in nonslab pools and slab riffles.[4,7]

Early Growth

Etheostoma smithi grew to be 18.9 mm TL after 30 days.*

Feeding Habits

Larva and early juvenile diets include chironomids, ephemeropterans, copepods, trichopterans, cladocerans, ostracods, and amphipods.[7]

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* T.P. Simon, unpublished data.

ORANGETHROAT DARTER

Etheostoma (*Oligocephalus*) *spectabile* (Agassiz)

Etheostoma: various mouths; *spectabile*: conspicuous.

RANGE

Etheostoma spectabile is widespread and abundant west of the Mississippi River, from southern NE and IA south to TX. East of the Mississippi River the species occurs throughout IL, IN, and OH, much of the Ohio River Valley from eastern KY downstream, southern Great Lake tributaries in OH and southern MI, the Cumberland drainage below Cumberland Falls, and in the lower Tennessee drainage upstream to Pickwick Reservoir.[1–5]

HABITAT AND MOVEMENT

The preferred habitat of *E. spectabile* is small to medium upland streams where it occurs in sluggish flowing, gravel-bottom runs and pools. It also occurs in slower waters near the margins of riffles. The species is also common in spring habitats.[1–4] Orangethroat darters occur among vegetation (*Nasturtium*, *Cladophora* strands, *Myriophyllum*, and *Elodea*) often found hidden beneath overhanging banks or stream margins. The species occurs in sluggish current over a variety of substrates including sand, gravel, and detritus to silty gravel.[*,1–4] In streams, males occupy riffles throughout the year, while during the reproductive period the females remain downstream in pool habitat until ready to reproduce.* Migrations occur during the winter months between the pools and riffles, and the specimens that stay on the riffles often bury themselves into the gravel to conserve energy.* The species often occurs with detritus or near undercut or brushy banks.[4] It is often associated with vegetation, brush, or rocks that provide protection.[2,3]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma spectabile is found in the tributary streams of the lower Tennessee and middle and lower Cumberland Rivers, KY and TN.[1–4] The species occurs throughout the tributaries of the Wabash River drainage, IL and IN; throughout central and southwestern OH; and northern KY.[*,1–3]

SPAWNING

Location

Spawning occurred over fine gravel in shallow stream riffles at depths <0.3 m in slow flow.[2–10,12,13,*]

Season

Spawning season occurs from mid-March to May.[*,4–8,18]

Temperature

Spawning occurs at temperatures between 10 and 27°C;[10,*] in KS at 16–22°C;[14] spawning occurred in the laboratory between 17 and 26°C.[18]

Fecundity (see Table 136)

Females (48–60 mm TL) collected in early March from Boone Creek, McHenry County, IL, had mean ovaries that were 16.14% of the body weight, containing 1185.5 total ova averaging 0.68 mm diameter.* Our data from an unnamed Creek in the Green River drainage, Russell County, KY, had mean ovaries that were 17.7% of the body weight, containing 1687. Total ova averaging 0.88 mm diameter.* Small[8] reported 300–1200 eggs from KY; and Hubbs et al.[9] reported only 20–250 ova. Clearly, Hubbs et al.[9] counted only mature and ripe eggs while counts by Small[8] were more similar to the total number of ova determined in this study.

Sexual Maturity

Adults live to reach age 3;[5,7] maturity is suspected to be at age 1 at lengths as small as 30 mm SL.[4] Adult males (56–69 mm TL) from IL had testes that were 1.44% of the body weight on April 2.* Male tuberculation may develop on anal spines and rays, pelvic spine and rays, lower caudal fin rays, lower pectoral fin rays, and ventral scales of the belly and caudal peduncle. Genital papillae of males are flattened and triangular. Female genital papillae is short, tubular, and rounded at the tip.[*,2] Females

Table 136

Fecundity data for orangethroat darter from an unnamed Creek, Green River drainage, Russell County, KY.*

			Number of Ova			
Date	TL (mm)	GSI	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
April 2	64	17.1	1898	353	199	1.33
	61	15.3	1594	426	186	1.33
	61	17.5	1544	378	197	1.33
	56	12.2	1298	242	183	1.12
	51	23.9	1298	290	141	1.25
	50	20.6	1458	310	130	1.25
	47	18.0	1130	227	112	1.25
	46	18.0	929	220	119	1.18
	44	15.0	726	153	81	1.11
	43	19.4	798	184	65	1.25

>30 mm SL are all sexually mature.[4,5] Males <40 mm TL are all immature, while all males >40–45 mm TL are mature.*[,4,5] Males exhibit sexually dimorphic traits during the reproductive season with the increase in brightly colored pigmentation and extension of a broad flap that supports a smaller terminal section.*[,2,5,6]

Spawning Act

The reproductive mode of *E. spectabile* is a burier.[3] Males defend territories and are generally aggressive toward other males that enter into their reproductive space. Males court females by circling and erecting their fins. Females select spawning sites in open fine gravel areas and bury their bodies into the fine gravel and release eggs that are fertilized by the male. The male mount the female and maintain an S-shaped configuration with their vents juxtaposed. One to three eggs per spawning event are deposited into the gravel.*

EGGS

Description

Egg diameters from Boone Creek, McHenry County, IL, were 1.30–1.50 mm in diameter.* Eggs from Boone Creek are spherical, mean = 1.36 mm diameter (range = 1.30–1.50 mm); translucent; demersal; and nonadhesive. Eggs possess translucent, pale amber yolk (mean = 1.3 mm diameter; range = 1.28–1.42 mm); a single oil globule (mean = 0.28 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.* Egg size varies within populations, among populations, and among females. Egg size is largest when water temperature is coldest.[19] Eggs in TX did not show effects from female body size and averaged 1.515 ± 0.002 mm.[9] There is a trend for small eggs west to east and south to north.[20] Eggs from Edwards Plateau, TX, were the largest, 1.52–1.57 mm in diameter;[19] followed by the eastern edge of the plateau, which were 1.36–1.48 mm in diameter; Boone Creek, IL,[19,]* and the Illinois River system in AR eggs ranged between 1.31 and 1.41 mm;[20] the White River system was 1.36–1.46 mm diameter;[20] MO streams' were 1.24 mm in diameter;[11] and in MI 1.24 mm in diameter.[6–7]

Incubation

Hatching occurs after 98–156 h at an incubation temperature of 21.1–22°C;* hatching occurs in 216–240 h at an incubation temperature of 17–18°C.[10] Eggs hatched in 228–240 h at 16.5–18.5°C;[6–7] 192 h at incubation temperatures of 18ºC and 144–168 h at incubation temperatures of 21–25°C.[18]

Development

Unknown.

YOLK-SAC LARVAE

See Figure 128

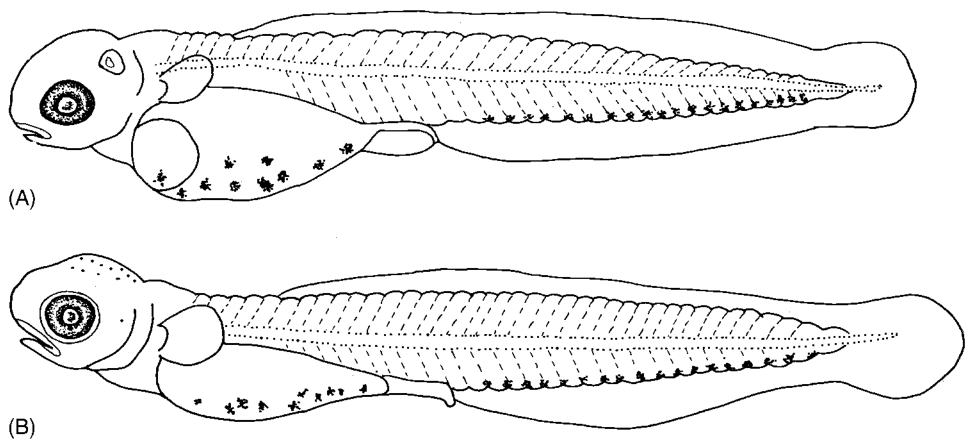

Figure 128 *Etheostoma spectabile*, orangethroat darter, Boone Creek, McHenry County, IL: (A) yolk-sac larva, 5.2 mm TL, lateral: (B) yolk-sac larva, 6.2 mm TL, lateral views. (A–B original drawings.)

Size Range
IL populations from Bull Creek, Lake County, hatch between 5.5 and 6.7 mm TL;* and absorb yolk by 8.8 mm TL.*

Myomeres
Preanal 16 (*N* = 7); postanal 19 (3) or 20 (4) (*N* = 7, mean = 19.6); with total 35 (3) or 36 (4) (*N* = 7, mean 35.6).*

Morphology
5.5–6.7 mm TL (*newly hatched*). Body terete; snout blunt; with functional jaws, upper jaw even with lower jaw; well developed pectoral fins without incipient rays; yolk sac small (18.9% TL), oval to tapered posteriorly; yolk translucent clear to pale amber, with a single oil globule; complex plexus of vitelline veins present mid-ventrally on the yolk sac; head not deflected over the yolk sac; and eyes oval.*

7.0–8.9 mm TL. Digestive system functions before complete yolk absorption by 7.2 mm TL;* yolk sac absorbed by 8.9 mm TL.*

Morphometry
See Table 137.*

Fin Development
See Table 138.*

5.5–6.7 mm TL. Well-developed pectoral fins without incipient rays.*

Pigmentation
5.5–6.7 mm. (*newly hatched*). eyes pigmented; no melanophores found dorsally over either the anterior or posterior cerebellum or nape; no melanophores distributed laterally, or dorsally over the gut posterior to the yolk sac; ventral pigmentation consists of a mid-ventral stripe of stellate melanophores surrounding the vitelline vein on the yolk sac, and punctuate melanophores present along every mid-ventral postanal myosepta.*

7.0–8.9 mm TL. No dorsal pigmentation. Ventral pigmentation consists of single mid-ventral melanophores from the breast to the anus; and staggered, paired melanophores extend from the anus to the caudal peduncle.*

POST YOLK-SAC LARVAE

See Figure 129

Size Range
9.0–15 mm TL.*

Myomeres
Preanal 16 (*N* = 28); postanal 19 (14) or 20 (14) (*N* = 28, mean = 19.5); with total 35 (14) or 36 (14) (*N* = 28, mean = 35.5).*

Morphology
9.0–9.2 mm TL. Yolk absorbed.*

9.6–10.1 mm TL. Operculum and gill arches function and premaxilla and mandible form.*

10.2–12.1 mm TL. Neuromast development occurs mid-laterally from the anterior trunk posteriad. No

Table 137

Morphometric data expressed as percent TL for young *E. spectabile* from Illinois.[23,*]

	TL Grouping				
Length Range (mm)	**5.5–7.2**	**7.6–9.4**	**9.9–11.7**	**12.6–15.5**	**18.0**
N	**18**	**13**	**10**	**23**	**11**
ED	6.1	7.2	7.3	7.2	5.5
	(0.9)	(1.1)	(1.0)	(0.7)	(0.6)
HL	13.8	20.2	24.6	23.9	23.1
	(1.1)	(1.5)	(1.2)	(0.9)	(0.8)
Preanal	49.2	50.0	51.0	50.0	50.0
	(1.1)	(0.6)	(0.6)	(0.7)	(0.7)
PosAL	50.8	50.0	49.0	50.0	50.0
	(1.1)	(0.6)	(0.6)	(0.7)	(0.7)
SL	96.2	95.3	86.4	85.6	83.1
	(1.5)	(2.3)	(0.3)	(2.1)	(0.2)

Note: A single standard deviation is expressed in parentheses.

Table 138

Meristic counts and size (mm TL) at the apparent onset of development for *E. spectabile*.*

Attribute/event	*Etheostoma spectabile**	Literature
Branchiostegal Rays	6,6	6,6[2–4]
Dorsal Fin Spines/Rays	IX-XIV/10–14	IX-XIV/9–14[2–4]
First spines formed	10.2–10.5	
Adult complement formed	11.0	
First soft rays formed	7.0–8.4	
Adult complement formed	11.8	
Pectoral Fin Rays	12–13	12–16[2,3]
First rays formed	7.0	
Adult complement formed	10.1	
Pelvic Fin Spines/Rays	I/5	I/5[2,3]
First rays formed	10.7	
Adult complement formed	15.1	
Anal Fin Spines/Rays	II/7–10	II/7–10[2–4]
First rays formed	8.7–9.4	
Adult complement formed	11.4	
Caudal Fin Rays	vii–xi, 7–9 + 7–8, viii–xi	14–17[4]
First rays formed	7.0–7.2	
Adult complement formed	11.1	
Lateral Line Scales	48–55	39–67[2–4]
Myomeres/Vertebrae	36–43/38–42	Unknown/38–42[2,3,22]
Preanal myomeres	16	
Postanal myomeres	19–20	

swim bladder forms; gut straight, without striations.*

Morphometry
See Table 137.*

Fin Development
See Table 138.*

9.0–9.2 mm TL. First rays form in caudal fin; soft dorsal fin rays and branchiostegal rays form by 9.2 mm.* Anal fin rays form 8.7–9.4 mm.

9.6–10.1 mm TL. Pelvic fin buds form anterior to dorsal fin origin after complete yolk absorption.*

10.2–12.1 mm TL. Notochord flexion precedes caudal fin ray development by 10.2 mm; and adult complement of pectoral fin rays form by 12.1 mm TL.*

10.2–14.5 mm TL. Dorsal and anal fanfold partially differentiated (12.2–12.5 mm); spinous dorsal forms (12.2–12.7 mm); first pelvic fin rays form (12.7 mm); complete adult fin ray counts in median fins (13.0–13.9 mm). Spinous dorsal fin origin situated over preanal myomere 4, soft dorsal origin over preanal myomer 17;* both finfolds completely differentiated by 14.5 mm TL.*

Pigmentation
9.0–9.2 mm TL. Dorsal pigmentation consists of expanded melanophores over the optic lobe. Lateral pigmentation present dorsally over the stomach and gut. Ventral pigmentation consists of single mid-ventral melanophores scattered from the breast to the anus; staggered, paired melanophores extend from the anus to the caudal peduncle.*

9.6–10.1 mm TL. Dorsum of cranium with several large melanophore clusters on cerebellum; laterally a single series of subdermal melanophores extend from the gut to the anus, no other melanophores found laterally along the midline. Ventral pigmentation includes a series of melanophores mid-ventrally from the breast to the anus; two clusters of mid-ventral postanal melanophores begin at postanal myomeres forming pairs, stellate melanophores at each mid-ventral postanal myosepta.*

10.2–11.6 mm TL. Several melanophores on cranium and soft dorsal fin origin extend to midfin. Lateral melanophores distributed over the otic capsule and operculum; present over gut extending posteriorly from mid-anal fin to the caudal peduncle. Ventral pigmentation consists of a single series of melanophores from the breast to the anus and scattered from the anal fin to the caudal peduncle.*

JUVENILES

See Figure 129

Size Range
15.0–16.0 mm* to 30 mm TL.*[,4]

Fins
15.0–16.0 mm TL. Complete adult fin ray counts in median fins; first pelvic fin rays form; by 15.1 mm caudal fin truncate rays with segmentation.* Dorsal and anal finfolds completely differentiated.*

Larger juveniles. Spinous dorsal fin VIII–XII; soft dorsal rays 11–15; pectoral rays 11–14; anal fin rays II 4–8; pelvic fin rays I 5; caudal fin rays 14–17.[1–5]

Morphology
15.0–18.0 mm TL. Lateral line begins to form. Squamation intiates at 15.7 mm TL.*

18.5–21.1 mm TL. Squamation complete; cheek with at least a few scales posterior to the eye; nape, opercles, and belly scaled; breast and prepectoral area naked.*

Total vertebrae count 35–37 including one urostylar element. Scales in the lateral series incomplete with 10–38 pored scales and 30–52 total scales in lateral range from TN.[2–4] Gill membranes narrowly joined, frenum present. Supratemporal canal complete.*

Morphometry
See Table 137.*

18.0–22.9 mm TL. Average predorsal length 30.5% TL.

Pigmentation
15.0–16.0 mm TL. Outline of cerebellum and optic lobe covered with melanophores; seven dorsal saddles apparent, on nape, anterior spinous dorsal fin origin, mid-spinous dorsal fin, anterior spinous dorsal fin insertion, immediately in the posterior soft dorsal fin origin, soft dorsal fin insertion, and over the caudal peduncle. Lateral pigmentation includes the beginning of the weak preorbital bar formation; pigment in the hypaxial portion of the operculum; and beginning of 8–9 elliptical mid-lateral clusters of melanophores. Ventral pigmentation forming a series of melanophores between the anal fins, extending to the caudal peduncle;

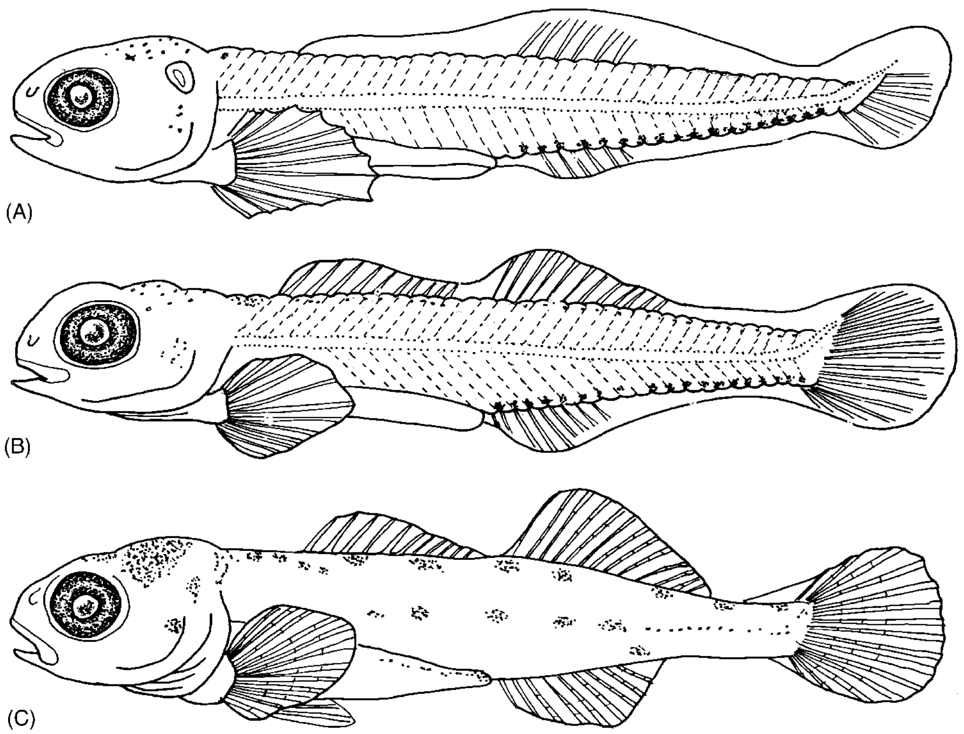

Figure 129 *Etheostoma spectabile*, orangethroat darter, Boone Creek, McHenry County, IL: (A) post yolk-sac larva, 8.8 mm TL, (B) 12.0 mm TL, lateral, (C) early juvenile, 15.6 mm TL, lateral view. (A–C original drawings.)

two clusters of postanal pigmentation present at the midanal fin and at the mid-caudal peduncle. Scattered melanophores outline the caudal fin rays; a single stripe on the spinous dorsal and anal fins; and few melanophores in the epaxial portion of the pectoral fin found.*

18.0–30.5 mm TL. Preorbital bar, cerebellum, and optic lobe pigmentation dense; seven dorsal saddles from the nape to the caudal peduncle. Eight–nine vertical stripes forming posterior the head. Ventral pigmentation includes a series of melanophores extending from the anal fin insertion to the caudal fin base. Spinous dorsal fin with a distal and mid-fin stripe; soft dorsal fin with a mid-fin stripe; pectoral fin with several scattered melanophores in the epaxial half of the fin; and caudal fin with melanophores outlining the caudal fin base. No pigmentation present in the pelvic or anal fins.*

TAXONOMIC DIAGNOSIS OF YOUNG ORANGETHROAT DARTER

Similar species: members of subgenus *Oligocephalus.*[3]

Adult. *Etheostoma spectabile* is similar to *E. caeruleum*. The species differs from *E. caeruleum* by not having any red coloration in the anal fin and lacking horizontal lines on the upper sides. Caudal fins of *E. spectabile* possess 15–16 principal caudal rays, while *E. caeruleum* possesses 17 principal caudal rays.*

Larva. The early life history of *E. spectabile* is similar to *E. caeruleum.* The two species can be differentiated by their pigmentation, differences in preanal myomere counts, and postanal myomeres. *Etheostoma spectabile* possesses 16 preanal and between 19 and 20 postanal myomeres, while *E. caeruleum* possesses 15 preanal and 21–22 postanal myomeres.*

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 130)
Eggs. Buried in fine gravel in slow flowing runs and riffles or buried in gravel beneath vegetation in slow sluggish flow streams in spring habitat.*[,2–15]

Yolk-sac larvae. Yolk-sac larvae remain buried in gravel pore spaces; the species is benthic and rarely

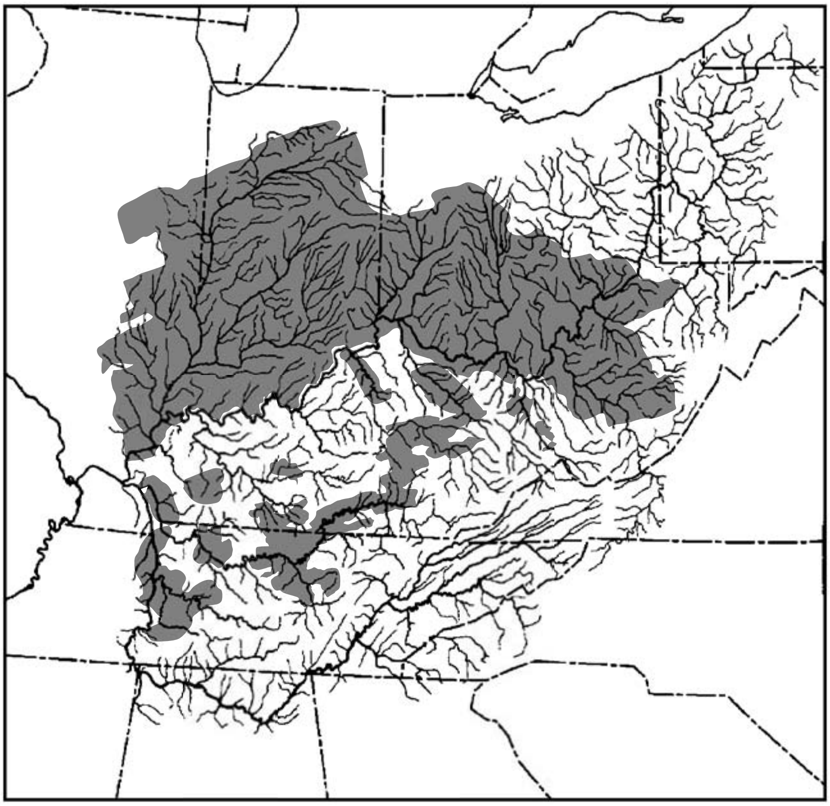

Figure 130 Distribution of orangethroat darter, *Etheostoma spectabile* from the Ohio River system (shaded area).

Table 139

Average calculated lengths (mm TL) of young orangethroat darter from several states.*[,4,8]

State	Age 1	Age 2	Age 3
Kentucky (mean)[8]	36–44	60–66	68
Illinois (Bull Creek)*	40–45	50–55	60+
Indiana (Richland Creek)*	37–42	50–54	62–65
Tennessee[4]	30–35	49–55	60+

would can be collected from the pelagic drift.* The vitelline vein plexus on the ventral yolk sac is consistent with other burier species.[16]

Post yolk-sac larvae. Larval drift is benthic, staying in close association with the substrate. The precocious development of fin rays in the paired and median fins enables the species to inhabit the slower flowing margins of natal habitats along the edges of riffles or flowing pools in springs.* Young darters are found to congregate in the nests of smallmouth bass soon after hatching.[11]

Juveniles. Early juveniles utilize downstream pools and margins of run and riffle areas as nursery habitats.*

Early Growth (see Table 139)
Apparently individuals do not exceed 3 years of age.[4] During their first year of life young darters

attain 30–35 mm TL in TN.[4] Orangethroat darters from Boone Creek, McHenry Country, IL, attained 32–36 mm TL during their first year of life.* Egg size did not affect the time of hatching but did affect the size of the larvae at hatching.[20] A regression equation shows that the size at hatching (mm TL) is $Y = 2.39\ X + 4.75$, $r = 0.356$, $p < 0.001$ where X is the egg weight in grams.[20] Young darters grew 6–21.5 mm in 6 weeks at 26°C, but only to 12.5 mm at 15°C.[21]

Feeding Habits
The main components of the diet in IL include midge and blackfly larvae, mayfly nymphs (*Baetis* and *Stenonema*), isopods, amphipods, and caddisfly larvae.[14] Juvenile specimens (15.8–22.5 mm TL) from Richland Creek, Monroe County, IN, ate copepods, daphnids, midge larvae, and caddisfly larvae*.

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* Original fecundity data for orangethroat darter from the unnamed Creek, Green River drainage, Russell County, KY. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Original early life history developmental series cultured from laboratory spawned specimens from Bull Creek, Lake County, IL. Specimens curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

SPOTTAIL DARTER

Etheostoma (*Catonotus*) *squamiceps* Jordan

Etheostoma: various mouths; *squamiceps*: scaled head, referring to scales on cheek, opercle, and breast.

RANGE

Etheostoma squamiceps occurs in the Cumberland River drainage, KY and TN, Tradewater River and direct tributaries of the Ohio River, KY and southern IL and IN. Disjunct populations occur in tributaries of the lower Wabash River.[4]

HABITAT AND MOVEMENT

Etheostoma squamiceps is an inhabitant of small- to medium-sized streams of low to moderate gradient. It occurs in quiet pools beneath stones, brush, aquatic macrophytes, or undercut banks. The species is tolerant of some turbidity, but not siltation.[1] In Big Creek, IL, even though sympatric with *E. kennicotti* occupies the shallow, slab rock pools.[3]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma squamiceps is widespread, but not common in the Green and Red River systems of the Cumberland River drainage, KY and TN. The species is more abundant in the Tradewater River and nearby tributaries of the Ohio River, KY and IL. Occurs in the Cache River, southeastern IL, and tributaries of the Wabash River, from Spencer to Posey Counties, IN.[4]

SPAWNING

Location
Eggs are attached beneath slab rocks previously selected and guarded as nesting territories by the males.[3]

Season
Spawning occurs from late March until May in IL.[3]

Temperature
Spawning occurs from 14 to 19°C.[3]

Fecundity (see Table 140)
The number of ovarian eggs range from 28 to 357.[3] Age 1 females, 32–43 mm SL has between 44 and 80 ova; age 2 females, 41–58 mm SL range between 28 and 357 eggs.[3] Ovary weights are 17.7% of the total body weight.* Female *E. squamiceps* shows statistically significant increasing fecundity (ANOVA $F = 7.678$, $p = 0.024$) with increasing length. Females between 38 and 69 mm collected in early April had 45–109 large mature ova.*

Sexual Maturity
Males and females are sexually mature at age 2; a few age 1 females of 35–40 mm may have spawned.[3]

Spawning Act
Etheostoma squamiceps is an egg clusterer. Males establish territories beneath slab rocks. Preceding spawning, males periodically leave the nest stone to court females. Courting consists of the male swimming near the female, displaying bold pigment patterns, spreading fins, and tail wag. The female once under the nest stone remains passive. The male is very active, darting, nudging the female, and bobbing his spinous dorsal fin up and down. The female eventually selects a site under the stone and they invert together while laying and fertilizing eggs. The spawning position is head-to-head while the male is positioned tightly alongside the female. Inversions last up to 5 s, with 15 s to several minutes elapsing between inversions. Eggs are concentrated in a constricted area but never laid on top of other eggs. Males spawn with multiple females but never more than one at a time. Males vigorously guard the eggs against potential predators; females do not.[3]

EGGS

Description
Mature ova are spherical, translucent, with a single oil globule; demersal, adhesive, narrow perivitelline space, and an unpigmented and unsculptured chorion.[5] Eggs from Big Creek, IL, ranged 1.4–1.9 mm in diameter.[5]

Table 140

Fecundity data for spottail darter from an unnamed creek, Cheatham Co., TN.

Length (mm TL)	Ovary Weight (mg)	Number of Ova: Ripening Oocytes (LA)	Number of Ova: Mature Oocytes (EM, MA, LM)	Number of Ova: Ripe Eggs (MR, RE)	Egg Diameter (mm)
38	65.5	225	72	45	1.33
39	83.6	248	82	45	1.42
43	190	395	97	94	1.66
43	160	432	136	56	1.66
43	184	377	87	80	1.66
44	201	466	114	73	1.66
45	112	382	147	64	1.42
45	194	408	170	99	1.66
46	123	389	135	77	1.42
69	384	655	201	109	1.66

Incubation
At 14–18°C, hatching occurred after 384 h; at 18–22°C hatching occurred in 270–275 h; and at 22–26°C hatching occurred at 125–130 h.[3]

Development
Unknown. Development has not been described but is probably similar to *E. flabellare*.

YOLK-SAC LARVAE

See Figure 131

Size Range
Newly hatched at 5.6–6.1 to 6.8 mm.[5,6]

Myomeres
Preanal 16, postanal 18–19; 34–35 total.[5,6]

Morphology
5.6–6.1 mm TL. Body laterally compressed, yolk sac large, spherical (ca. 25.9% SL); yolk amber, with a single anterior oil globule; head not deflected over the yolk sac; jaws developed; eyes circular.[5,6]

6.2–6.9 mm TL. Spinous dorsal fin origin over preanal myomere 6, soft dorsal origin situated over preanal myomere 15.[5,6]

Morphometry
See Table 141.

5.6–6.1 mm TL. Predorsal length 32.9% SL.[5,6]

Fin Development
(See Table 142)

5.6–6.1 mm TL. Well-developed pectoral fin with 12 incipient rays; dorsal and anal finfolds continuous.[5,6]

5.8–6.2 mm TL. First rays formed in pectoral and caudal fins.[5,6]

6.4–6.6 mm TL. Spinous and soft dorsal rays form simultaneously; first anal fin rays form by 6.6 mm.[5,6]

Pigmentation
5.6–6.1 mm TL. Heavily pigmented; cranium with melanophores distributed over the posterior orbit and the outside margin of the cerebrum; optic lobe with six rows of melanophores extending to the nape; a mid-lateral stripe of melanophores extending from the apex of preanal myomeres 2–14; melanophores extension into epaxial sections of preanal myomeres 6, 7, and 12, into hypaxial sections of preanal myomeres 11–13; a narrow band of melanophores at mid-ventral yolk sac; concentrated melanophores present at the anterior yolk sac; several rows of melanophores extend from the gut to the anus; paired melanophores at each postanal myomere; scattered pigment outlines all myosepta extending into epaxial and hypaxial sections.[5,6]

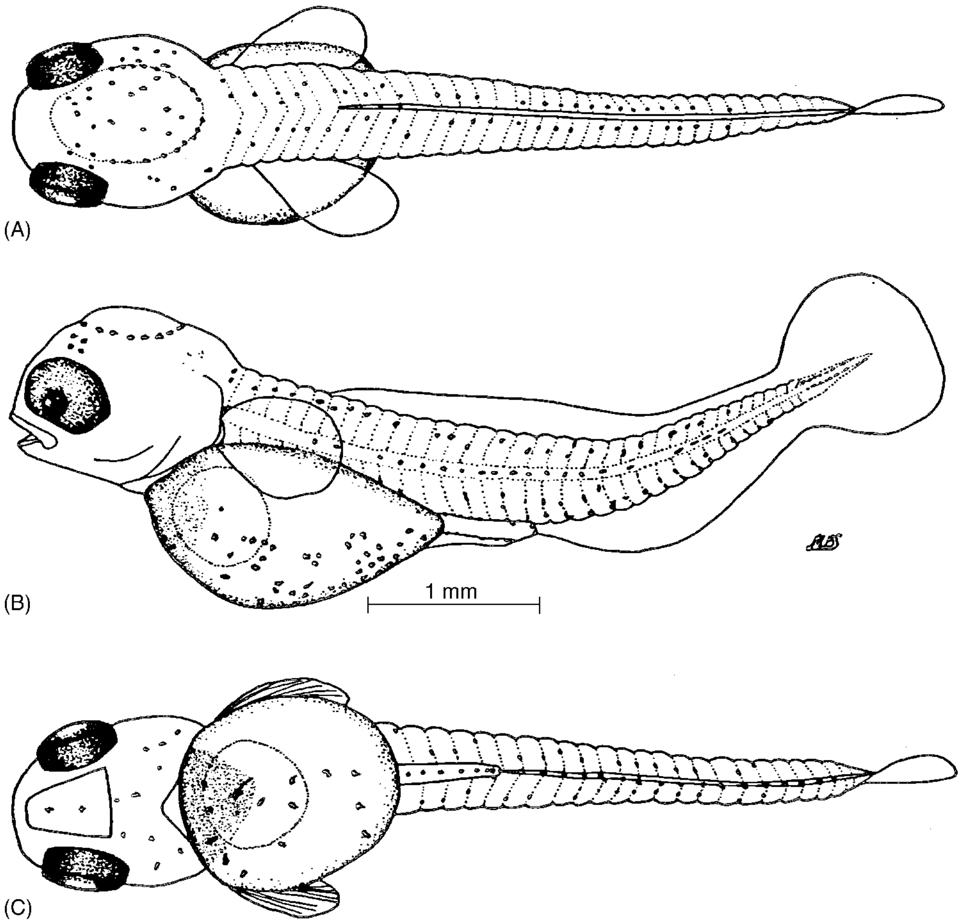

Figure 131 *Etheostoma squamiceps*, spottail darter, Big Creek, IL yolk-sac (newly hatched) larva, 5.7 mm TL: (A) dorsal, (B) lateral, and (C) ventral views. (A–C from reference 6, with author's permission.)

Table 141

Morphometric data expressed as percentage of HL and TL (Mean ± SD) for young *E. squamiceps* from southern Illinois and Kentucky.[5,6]

	TL Groupings							
Length Range (mm)	**5.7–6.9**	**7.5–12.0**	**13.6–15.6**	**16.7–19.3**	**19.5–21.2**	**22.8–25.1**	**26.4–28.8**	**29.3–33.1**
N	**20**	**11**	**3**	**4**	**4**	**9**	**5**	**8**
As Percent HL								
SnL	12.7 ± 1.3	19.9 ± 1.1	20.4 ± 0.4	17.5 ± 1.4	16.7 ± 2.5	18.1 ± 0.7	17.4 ± 1.5	20.2 ± 0.8
ED	41.5 ± 0.8	31.6 ± 2.0	30.4 ± 0.4	26.3 ± 1.3	24.8 ± 1.2	25.6 ± 0.2	27.2 ± 1.3	28.4 ± 0.2
As Percent TL								
HL	21.6 ± 0.5	26.3 ± 2.3	24.4 ± 1.3	26.4 ± 0.3	27.0 ± 1.2	24.6 ± 0.5	24.5 ± 0.6	23.6 ± 0.6
Preanal	54.9 ± 0.1	53.1 ± 1.3	50.8 ± 1.6	51.5 ± 1.0	50.8 ± 0.3	51.6 ± 0.5	50.9 ± 0.8	50.6 ± 0.4
PosAL	45.1 ± 0.1	46.9 ± 1.3	49.2 ± 1.6	48.5 ± 1.0	48.2 ± 0.3	48.4 ± 0.5	49.1 ± 0.8	49.4 ± 0.4
SL	95.6 ± 0.1	86.7 ± 2.5	81.4 ± 0.4	83.3 ± 1.6	82.2 ± 1.3	83.4 ± 0.6	83.7 ± 0.7	83.4 ± 0.7
MAXL-Y	25.9							
GBD	22.8 ± 1.3	16.7 ± 2.3	18.0 ± 0.5	18.0 ± 0.6	19.0 ± 1.7	17.2 ± 0.6	17.1 ± 1.3	17.7 ± 1.0
BDA	9.9 ± 0.4	11.6 ± 2.0	14.0 ± 0.6	14.2 ± 0.3	15.7 ± 2.5	15.0 ± 0.3	14.4 ± 1.0	14.3 ± 1.3
CPD	4.4 ± 0.3	6.8 ± 1.2	8.1 ± 0.5	8.7 ± 0.7	9.4 ± 0.7	9.3 ± 0.3	9.6 ± 0.7	9.6 ± 0.3

Table 142

Meristic counts and size (mm TL) at the apparent onset of development for *E. squamiceps*.[6]

Attribute/Event	*Etheostoma squamiceps*[6]	Literature
Branchiostegal Rays	6,6	6,6[1–4,7]
Dorsal Fin Spines/Rays	VII–(VIII)–XI/11–13–15	VII–XI/12–14[1–4,7]
First spines formed	6.4–6.5	
Adult complement formed	7.4	
First soft rays formed	6.4–6.5	
Adult complement formed	7.4	
Pectoral Fin Rays	12–13	10–12[1–4,7]
First rays formed	5.8–6.2	
Adult complement formed	6.4	
Pelvic Fin Spines/Rays	I/5	I/5[2–3,7]
First rays formed	8.4	
Adult complement formed	13.4	
Anal Fin Spines/Rays	II/6–7	II/6–9[1–4,7]
First rays formed	6.3–6.6	
Adult complement formed	7.0	
Caudal Fin Rays	x–xiii, 8–7 + 6–7, ix–xii	15–17[4,7]
First rays formed	5.8	
Adult complement formed	7.2	
Lateral Line Scales	37–(44)–57	41–60[2–4,7]
Myomeres/Vertebrae	34–35/36	Unknown/unknown
Preanal myomeres	16	
Postanal myomeres	18–19	

6.2–6.8 mm TL. Reduction in melanophores along preanal midlateral stripe and ventrally along postanal myomeres.[5,6]

POST YOLK-SAC LARVAE

See Figures 132 and 133

Size Range
6.8 to 13.6 mm TL.[5,6]

Myomeres
Preanal 16, postanal 18–19; 34–35 total.[5,6]

Morphology
6.8 mm TL. Yolk sac absorbed.[5,6]

7.1–8.5 mm TL. Notochord flexion.[5,6]

10.7 mm TL. No swim bladder formed, gut straight.[5,6]

12.0 mm TL. Infraorbital, lateral, and preoperculomandibular canals form; squamation begins.[5,6]

Morphometry
See Table 141.

7.0 mm TL. Predorsal length 36% SL.[5,6]

Fin Development
See Table 142.

6.7–7.1 mm TL. Incipient anal fin margin partially differentiated.[5,6]

6.9–7.4 mm TL. Pelvic buds formed anterior to dorsal fin origin.[5,6]

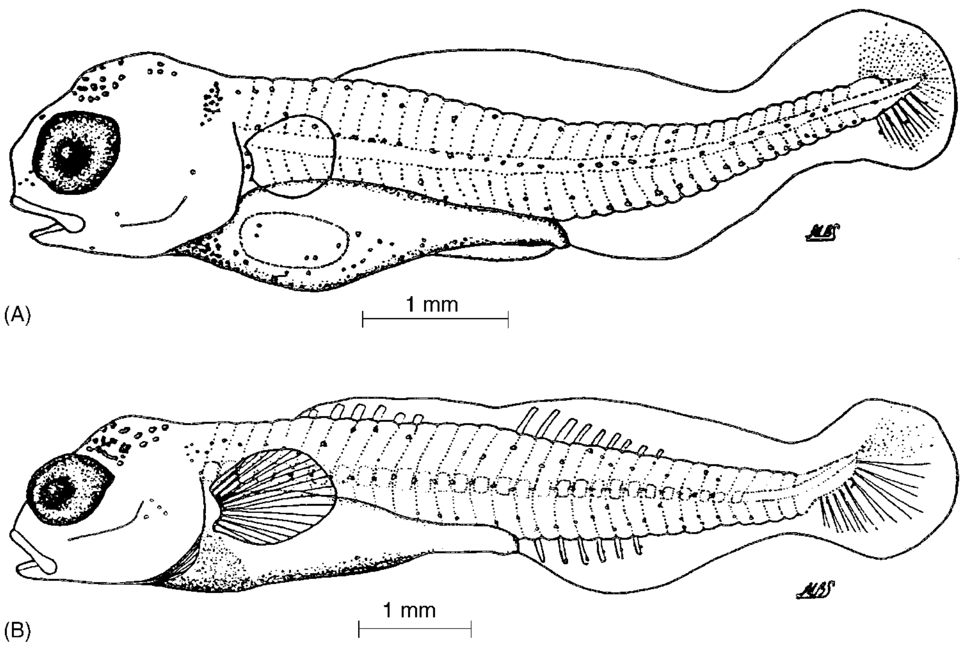

Figure 132 *Etheostoma squamiceps*, spottail darter, Big Creek, IL: (A) post yolk-sac larva 6.8 mm TL, lateral view, (B) post yolk-sac larva 8.6 mm TL, lateral view. (A–B from reference 6, with author's permission.)

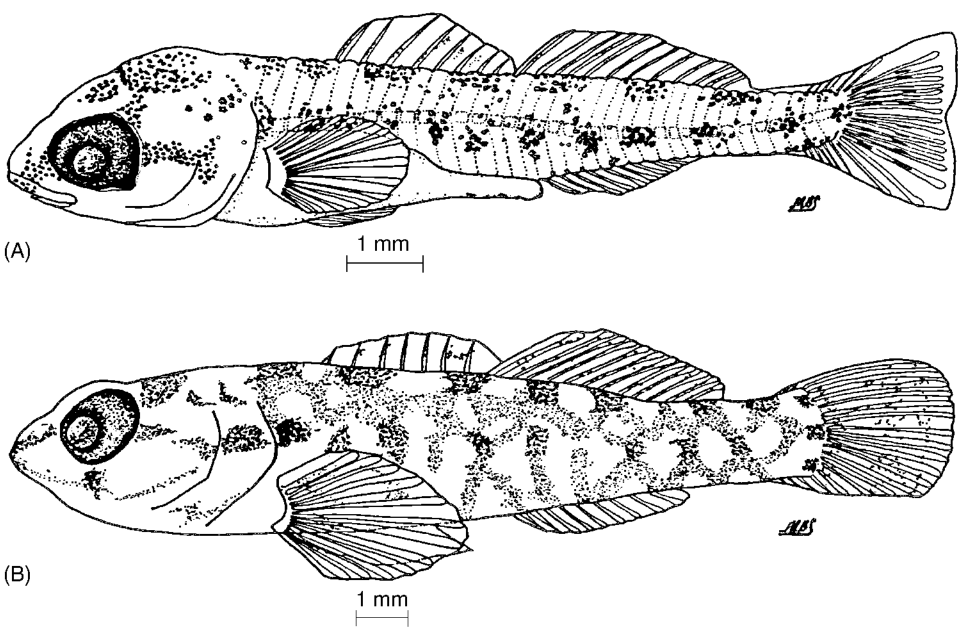

Figure 133 *Etheostoma squamiceps*, spottail darter, Big Creek, IL, (A) post yolk-sac larva, 13.6 mm TL, lateral view, and (B) early juvenile, 16.7 mm TL, lateral view. (A–B from reference 6, with author's permission.)

7.1–7.8 mm TL. Incipient dorsal fin margin partially differentiated, completely differentiated by 8.4 mm; caudal fin rounded; anal fin margin completely differentiated.[5,6]

8.4 mm TL. First pelvic fin rays formed.[5,6]

Pigmentation

7.1–8.0 mm TL. Future preorbital bar forms, series of oblique melanophores found posterior to jaw; base of breast with concentrated melanophores forming a single series of pigment extending from throat to posterior anus; several melanophores present at anterior base of spinous dorsal surface; melanophores on prepectoral, developing anal fin lepidotrichia, and two lines of pigment in ventral half of caudal fin.[5,6]

8.0–9.2 mm TL. Preorbital and postorbital bars formed, future suborbital bar forming; ventral pigment near throat and lepidotrichia of anal fin; 15–16 mid-lateral clusters of melanophores, 13–14 areas of dorsal concentration.[5,6]

10.7–12.0 mm TL. Suborbital bar formed; melanophores covering cerebrum and nape; mid-lateral rectangular blotches with scattered melanophores connecting vertically to 14 dorsal saddles; scattered melanophores on the spinous and the soft dorsal surface.[5,6]

JUVENILES

See Figure 133

Size Range
13.6 mm[5] TL to 35 mm SL.[3]

Fins
Spinous dorsal VII–VIII–XI; soft dorsal rays 11–15; pectoral rays 11–13; pelvic spines/rays I/5; anal spines/rays II/6–7; primary caudal rays 8–7 + 6–7, secondary rays x–xiii, ix–xii.[1,2,4–6]

Morphology
13.6–15.6 mm TL. Lateral line scales 37–57; vertebrae 36.[1,2,4–6] Infraorbital canal complete with seven pores extending to anterior of midorbit.[5,6]

16.7 mm TL. Lateral canal pores 5, preoperculomandibular pores 10, supraorbital pores 3, and supratemporal canal pores 2; lateral line begins to form.[5,6]

20.0–23.9 mm TL. Lateral line completely formed extending to soft dorsal fin; squamation complete.[5,6]

24.5–27.8 mm TL. Infraobital canal completely formed with retrogression to interrupted pore condition of four anterior and four posterior. Scales present on cheeks, opercle, preopercle, breast, nape, and belly.[5,6]

Morphometry
See Table 141.

Pigmentation
13.6–16.7 mm TL. Juvenile pigmentation consists of distinct preorbital, postorbital, and suborbital bars; melanophores found on ventral opercle, several radiating from orbit posteriorly, dorsally covering cerebrum, optic lobe, and nape; scale edges outlined; three distinct spots on hypural plate; a single mid-ray stripe on caudal fin; a single continuous stripe near anal fin; pectoral and pelvic fins without pigment.[5,6]

22.0–33.0 mm TL. Regulated patterns of early juveniles changing to vermiculate; mottled pattern of adults; spinous and soft dorsal with three and four incomplete stripes; pectoral fin with four or five incomplete stripes; anal and pelvic fins without pigment; no humeral spot present.[5,6]

TAXONOMIC DIAGNOSIS OF YOUNG SPOTTAIL DARTER

Similar species: other members of subgenus *Catonotus.*

See diagnostic discussion in *E. kennicotti* account.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 134)
*Eggs***.** Eggs are laid beneath shallow, slab rock pools where they are guarded by an attendant male.[1–6]

Yolk-sac larvae. Remain closely associated with the substrate and are primarily demersal. Yolk-sac larvae leave the nest stone soon after hatching, seeking refuge among the gravel substrate.[3,5,6] The vitelline vein plexus includes a large network of branched veins, that are adapted for oxygen transfer through the substrate interstitial pores.*

*Post yolk-sac larvae***.** Demersal, remain in close association with the substrate.* Larvae mainly rest on the substrate or dart about in short jerky movements.[5,6] Larval forms occupy non-slab pools to a greater extent throughout the year and are found around the margins of streams to a greater extent than adults.[3]

*Juveniles***.** Strong preference for slab pools in Big Creek, IL. Only rapid swimming involves escape

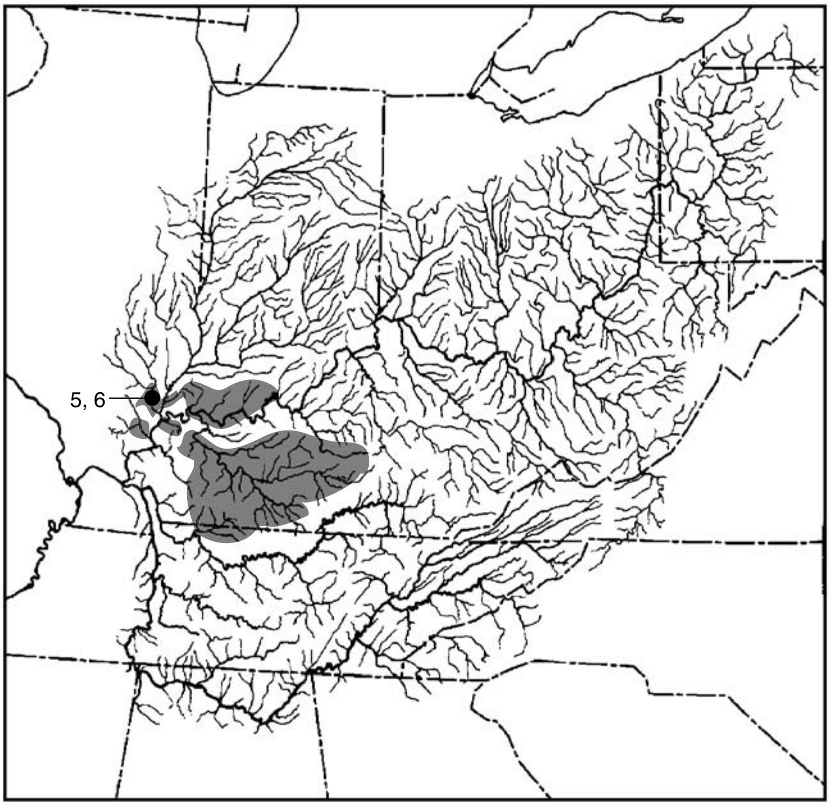

Figure 134 Distribution of spottail darter, *Etheostoma squamiceps* from the Ohio River system (shaded area) and areas where early life history information has been collected. Numbers indicate (circle) appropriate references.

maneuvers, which usually involves distances <2 m. The greatest density is 2.0 m^2 in slab pools in April.[3]

Early Growth

Mid-July specimens from Big Creek, IL, were 12 mm.[3] *Etheostoma squamiceps* reach one half of the first year's mean growth in about 12 weeks.[3] Age 1 males average 34 mm SL and range between 27.1 and 43.2 mm SL. Age 1 females average 36.2 mm SL and range between 28.0 and 43.1 mm SL.[3]

Feeding Habits

Age 0 specimens feed mainly on mayflies, copepods, chironomids, cladocerans, and ostracods.[3]

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* Original fecundity data from unnamed creek, Cheatham Co., TN. Specimens curated at Northeast Louisiana University, Museum of Zoology, Monroe.

SPECKLED DARTER

Etheostoma (*Doration*) *stigmaeum* (Jordan)

Etheostoma: various mouths; *stigmaeum*: speckled.

RANGE

Etheostoma stigmaeum occurs along the Gulf Coast from the Pensacola Bay system of FL and AL to the Sabine River basin of LA. In the Mississippi River drainage, the species occurs north through LA, MS, and western TN to the Ozark region of AR, OK, KS, and MO, and in the Cumberland and Green River drainages of KY and TN.[1–5]

HABITAT AND MOVEMENT

The speckled darter inhabits the moderate to high gradient, clear to slightly turbid, large streams and moderate-sized rivers. Adults prefer the unsilted gravel and sand substrates in riffles,[6] the fast and slow runs, and flowing pools and backwaters below rapid riffles.[7]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma stigmaeum occurs in the Barren and Green River systems of the Ohio River drainage, the Cumberland drainage (except for Caney Fork) upstream through Big South Fork, the Hatchie River system, TN, from several other direct tributaries to the Mississippi River in MS, in the Tennessee River drainage in Clarks River and Jonathan Creek in western KY, the Duck and Buffalo river system, TN, and Bear Creek, AL.[5]

SPAWNING

Location

Egg sites include riffle habitats over fine gravel or coarse sand substrates in moderate current.[6,15]

Season

In AL, spawning aggregates of adults assemble between mid-February and mid-March on riffles (E. Tyberghein, personal communication). Spawning occurs in southern portions of the range during March and during April in northern portions of the range.[2,4] Reproduction in KY and TN occurs during April;[6] during mid-March until May in AR;[8,12] occurs during April and May in KS.[13,14]

Temperature

Spawning temperatures range from 16 to 20°C.[9,10]

Fecundity (see Table 143)

Female *E. stigmaeum* showed statistically significant increasing fecundity (ANOVA, F = 63.077, p>0.0001) with increasing length. Females 50–51 mm collected on April 11, 1981 had 75–94 large mature ova, while several 49 mm females had 36-92 large mature ova (Table 143).* Fecundity is estimated to be 300 eggs for age 1 and 2 females, and as many as 440 eggs for age 2 females.[16]

Sexual Maturity

Sexually mature at age 1 when males and females reach about 35 mm SL.[16]

Spawning Act

Etheostoma stigmaeum is an egg burier.[9,10] Reproductive behavior is typical of other egg buriers as described by Page.[11] Egg sites include riffle habitats over fine gravel or coarse sand substrates in moderate current; adults maintain a head-to-head orientation with vents juxtaposed.[6] A territorial male pursues a female and mounts her.[6] Eggs are buried shallowly while a male straddles the nape region of the female with his pelvic fins while flexing his caudal peduncle downward to approximate their urogenital papillae.[6,14] Eggs are laid individually in gravel substrates, generally 3–5 during a single spawning event, but possibly range as many as 7.[6]

EGGS

Description

Ovarian examination showed that ovoid latent ova were 0.4 mm, early maturing small spherical

Table 143

Fecundity data for *E. stigmaeum* from Buffalo River, Duck River drainage, Lawrence Co., TN.*

		Number of Ova			
Length (mm TL)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR&RE)	Egg Diameter (mm)
40	801	371	77	55	1.17
41	59.2	342	69	65	1.11
41	54.9	318	58	54	1.11
42	88.9	430	95	60	1.11
43	80.8	467	70	57	1.17
49	125	618	140	36	1.25
49	91.9	492	95	92	1.11
50	144	606	154	94	1.17
50	88.8	568	112	75	1.11
51	167	498	193	118	1.17

ova averaged 0.77–0.83 mm, and large mature ova averaged 1.1–1.25 mm.* Eggs from AL were spherical, mean = 1.7 mm diameter (range: 1.5–1.8 mm), while TN and KY eggs averaged 1.7 mm in diameter; translucent, demersal, and nonadhesive. Eggs possess a translucent clear yolk (mean = 1.5 mm diameter); a single oil globule (mean = 0.4 mm); a narrow perivitelline space (mean = 0.8 mm); and an unsculptured and unpigmented chorion.[9,10]

Incubation
Hatching occurs after 216–240 h at an incubation temperature of 17–20ºC.[9,10]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 135

Size Range
4.2–5.4 mm.[9,10]

Myomeres
Preanal 18(91) or 19(1)(*N* = 92, mean = 18.0); postanal 21(31), 22(58), or 23(3) (*N* = 92, mean = 21.7); total and 39(34), 40(56), or 41(2) (*N* = 92, mean = 39.7).[9,10]

Morphology
4.2–5.2 mm TL. Newly hatched larva from AR hatch at 4.2–4.6 mm, while AL specimens hatch at 5.1–5.2 mm; yolk-sac larvae have a laterally compressed body; round snout; functional jaws, upper jaw even, to slightly overhanging lower jaw; yolk sac moderate (16.2% TL), rectangular; yolk translucent clear, with a single oil globule; single mid-ventral vitelline vein on yolk sac; head not deflected over the yolk sac; eyes oval in AR specimens, spherical in AL.[9,10]

4.6–5.1 mm TL. Digestive system functional before complete yolk absorption (4.6–5.1 mm).[9,10]

Morphometry
See Table 144.[9,10]

Fin Development
See Table 145.

4.2–5.2 mm TL. Newly hatched larva with well-developed pectoral fins without incipient rays.[9,10]

Pigmentation
4.6–5.4 mm TL. Newly hatched larva with pigmented eyes; dorsum without pigmentation. Lateral melanophores above the gut, radiating mid-ventrally along the myoseptum from almost every postanal myomere. Ventral melanophores with a discrete band of melanophores mid-ventrally from the oil globule to the anus.[9,10]

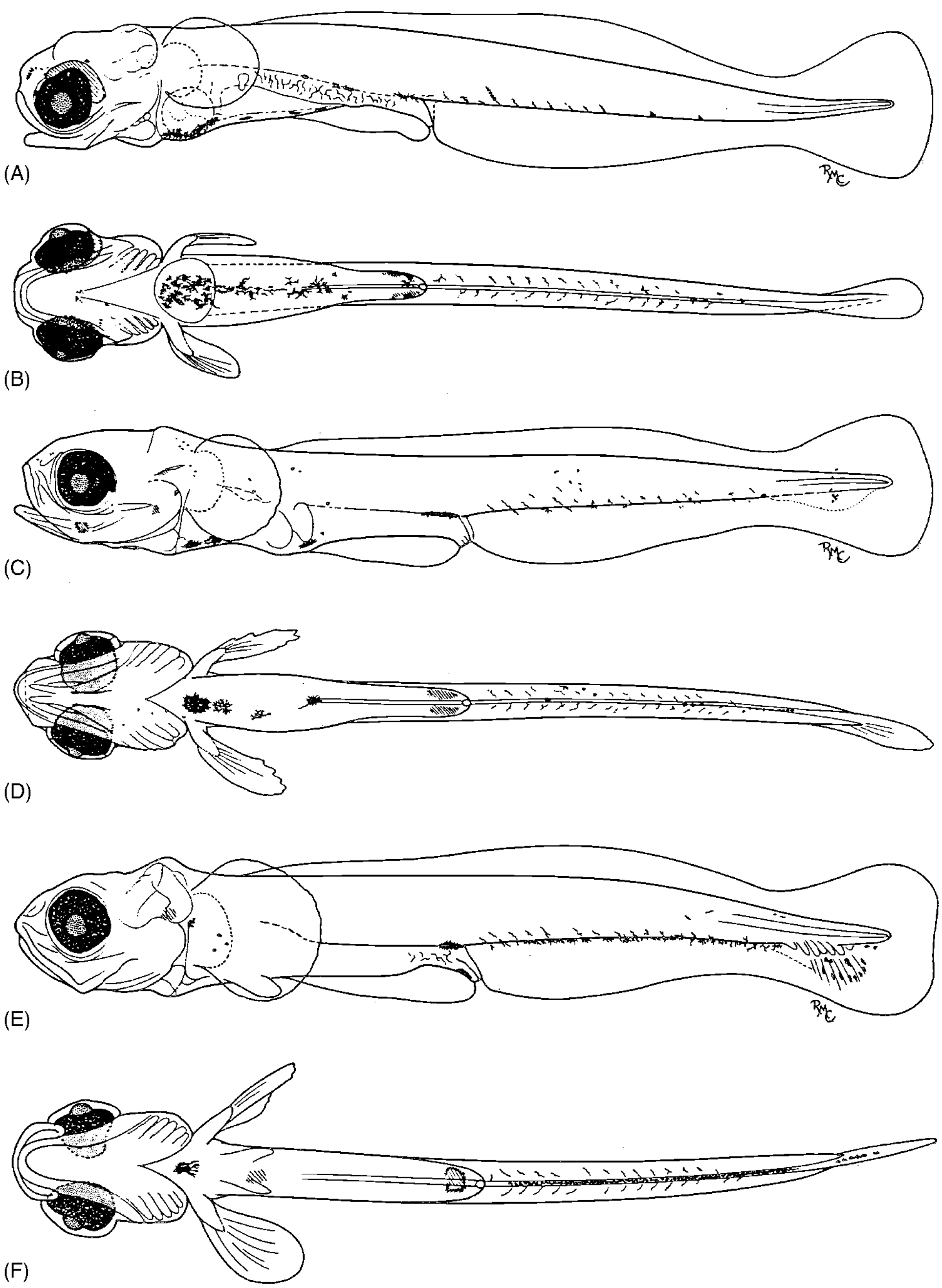

Figure 135 *Etheostoma stigmaeum*, speckled darter, Cache River, Black Swamp Wildlife Management Area, AR. Yolk-sac larva, 5.4 mm TL; (A) lateral, (B) ventral views; post yolk-sac larva, 6.6 mm TL, Tallapoosa River, Elmore Co., AL, (C) lateral, (D) ventral views; post yolk-sac larva, 7.4 mm TL, Tallapoosa River, Elmore County, AL, (E) lateral, (F) ventral views (A–F from reference 9, 10, with author's permission).

POST YOLK-SAC LARVAE

See Figures 135 and 136

Size Range

5.4–10.7 mm.[9,10]

Myomeres

Preanal 18(91) or 19(1)(*N* = 92, mean =18.0); postanal 21(31), 22(58), or 23(3); (*N* = 92, mean = 21.7); total with 39(34), 40(56), or 41(2) (*N* = 92, mean = 39.7).[9,10]

Morphology

5.4 mm TL. Operculum and gill arches functional.[9,10]

6.2–6.8 mm TL. Premaxilla and mandible formed (6.6 mm). Notochord flexion precedes caudal fin

Table 144

Morphometry of young *E. stigmaeum* grouped by selected intervals of total length (N = sample size).[9,10]

	Total Length (TL) Intervals (mm)							
	4.19–6.00 (N = 38)		6.01–7.60 (N = 25)		8.31–9.92 (N = 22)		10.1–11.3 (N = 6)	
Characters	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
Length (% of TL)								
Upper jaw[a]	23.5 ± 5.52	(0.12–0.42)	23.9 ± 4.46	(0.20–0.47)	26.3 ± 2.51	(0.37–0.65)	25.7 ± 3.19	(0.60–0.77)
Snout[a]	17.5 ± 5.22	(0.07–0.34)	18.0 ± 3.34	(0.12–0.32)	20.6 ± 1.51	(0.31–0.49)	19.7 ± 3.05	(0.42–0.70)
Eye diameter[a]	36.3 ± 5.46	(0.18–0.48)	30.7 ± 4.53	(0.29–0.58)	30.8 ± 15.6	(0.44–1.92)	27.1 ± 3.12	(0.62–0.80)
Head	18.5 ± 1.32	(0.73–1.18)	19.8 ± 1.52	(1.10–1.71)	21.9 ± 1.85	(1.53–2.30)	24.2 ± 1.89	(2.16–2.95)
Predorsal	27.8 ± 2.06	(1.12–1.82)	27.3 ± 2.99	(1.45–2.44)	30.6 ± 2.90	(2.30–3.49)	29.6 ± 1.19	(3.00–3.49)
Dorsal insertion					32.7 ± 10.4	(0.00–4.58)	34.8 ± 18.1	(0.00–5.21)
D2 origin					34.4 ± 12.9	(0.00–5.18)	38.2 ± 20.4	(0.00–5.81)
D2 insertion					42.6 ± 19.3	(0.00–5.18)	49.2 ± 26.3	(0.00–5.81)
Preanal	49.7 ± 2.81	(2.12–3.21)	53.1 ± 3.56	(2.82–4.39)	53.4 ± 2.06	(4.23–5.40)	53.3 ± 0.95	(5.24–6.00)
Postanal	50.2 ± 2.85	(1.88–3.24)	47.0 ± 3.50	(2.71–3.50)	46.6 ± 2.06	(3.81–4.84)	46.7 ± 0.96	(4.58–5.26)
Standard	95.6 ± 1.44	(3.91–5.82)	94.9 ± 2.78	(5.73–7.00)	88.0 ± 1.36	(7.20–8.76)	85.6 ± 1.24	(8.77–9.54)
Yolk sac	16.2 ± 5.85	(0.36–1.24)						
Fin Length (% of TL)								
Pectoral	9.47 ± 1.55	(0.34–0.64)	9.18 ± 3.18	(0.32–1.42)	13.1 ± 2.98	(0.72–1.72)	16.3 ± 1.65	(1.40–2.00)
Pelvic			3.57 ± 2.69	(0.12–0.41)	6.10 ± 2.82	(0.26–1.06)	9.13 ± 2.07	(0.62–1.32)
Spinous dorsal					15.4 ± 1.88	(1.18–1.78)	15.1 ± 0.14	(1.61–1.72)
Soft dorsal					16.4 ± 1.65	(1.18–1.65)	16.4 ± 1.98	(1.38–2.00)
Caudal	4.35 ± 1.44	(0.10–0.43)	5.07 ± 2.78	(0.12–0.99)	12.0 ± 1.36	(0.88–1.39)	14.4 ± 1.24	(1.25–1.72)
Body Depth (% of TL)								
Head at eyes	14.2 ± 1.42	(0.60–0.95)	13.7 ± 1.49	(0.70–1.18)	14.3 ± 2.94	(1.10–1.93)	14.6 ± 1.15	(1.39–1.76)
Head at Pl	12.8 ± 1.27	(0.49–0.81)	12.8 ± 1.40	(0.67–1.10)	14.4 ± 1.43	(1.02–1.52)	15.9 ± 0.46	(1.55–1.78)
Preanal	7.26 ± 1.01	(0.24–0.52)	8.11 ± 1.09	(0.40–0.78)	9.72 ± 0.97	(0.72–1.12)	10.9 ± 0.34	(1.10–1.24)
Mid-postanal	5.33 ± 0.78	(0.16–0.38)	5.90 ± 0.78	(0.28–0.52)	6.95 ± 0.57	(0.50–0.73)	7.40 ± 0.50	(0.68–0.89)
Caudal peduncle	2.52 ± 0.41	(0.10–0.20)	2.59 ± 1.24	(0.12–0.38)	3.81 ± 3.47	(0.40–0.76)	6.23 ± 1.44	(0.78–0.84)
Yolk sac	6.78 ± 1.71	(0.22–0.50)						
Body Width (% of HL)								
Head	69.2 ± 7.43	(0.52–0.82)	65.0 ± 5.65	(0.68–1.12)	65.5 ± 19.8	(1.04–1.93)	56.1 ± 4.68	(1.34–1.67)
Myomere Number								
Predorsal	5.00 ± 0.00	(5.00–5.00)	4.96 ± 0.20	(4.00–5.00)	5.00 ± 0.00	(5.00–5.00)	4.67 ± 0.52	(4.00–5.00)
Soft dorsal	18.0 ± 0.00	(18.0–18.0)	18.0 ± 0.00	(18.0–18.0)	18.0 ± 0.22	(18.0–19.0)	17.8 ± 0.41	(17.0–18.0)
Preanal	18.0 ± 0.00	(18.0–18.0)	18.0 ± 0.00	(18.0–18.0)	18.0 ± 0.22	(18.0–19.0)	18.0 ± 0.00	(18.0–18.0)
Postanal	22.0 ± 0.00	(22.0–22.0)	21.8 ± 0.60	(21.0–23.0)	21.1 ± 0.29	(21.0–22.0)	21.2 ± 0.41	(21.0–22.0)
Total	40.0 ± 0.00	(40.0–40.0)	39.8 ± 0.60	(39.0–41.0)	39.1 ± 0.35	(39.0–40.0)	39.2 ± 0.41	(39.0–40.0)

[a] Proportion expressed as percent head length.

Note: Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

Table 145

Meristic counts and size (mm TL) at the apparent onset of development for *E. stigmaeum*.[9,10]

Attribute/event	*Etheostoma stigmaeum*[9,10]	Literature
Branchiostegal Rays	6,6	6,6[2–5,12]
Dorsal Fin Spines/Rays	X–XII/11–12	X–XIV/11–13[2–5,12,14]
First spines formed	9.2–9.5	
Adult complement formed	9.7–9.9	
First soft rays formed	8.3–8.6	
Adult complement formed	8.8–9.6	
Pectoral Fin Rays	13	12–16[2–4,12,14]
First rays formed	8.7	
Adult complement formed	9.1–9.8	
Pelvic Fin Spines/Rays	I/5	I/5[2–4,12,14]
First rays formed	9.2–9.7	
Adult complement formed	9.2–9.7	
Anal Fin Spines/Rays	II/8	II/8–10[2–5,12,14]
First rays formed	7.1	
Adult complement formed	8.5–8.7	
Caudal Fin Rays	viii–ix, 8–9 + 8–7, viii–x	
First rays formed	6.2–6.8	
Adult complement formed	8.6–11.1	
Lateral Line Scales	42–53	44–53[2–5,12,14]
Myomeres/Vertebrae	39–41/40–42	Unknown/40–42[2–4, 12]
Preanal myomeres	18–19	
Postanal myomeres	21–23	

ray development (6.1–6.8 mm); neuromast development occurs mid-laterally from the anterior trunk posteriad (6.6 mm).[9,10]

7.4–8.0 mm TL. No swim bladder formed; gut straight with striations, portion of gut posterior to stomach normal in length.[9,10]

8.7–9.2 mm TL. Lateral line began forming.[9,10]

Morphometry
See Table 144.[9,10]

Fin Development
See Table 145

6.2–6.8 mm TL. Notochord flexion precedes caudal fin ray development (6.1–6.8 mm).[9,10]

8.0–8.6 mm TL. Rays in the anal fin and branchiostegal rays formed (8.0 mm); soft dorsal fin rays formed (8.3–8.6 mm); pelvic fin buds formed anterior to dorsal fin origin after complete yolk absorption (8.5–8.6 mm).[9,10]

8.7 mm TL. Pectoral fin rays first formed.[9,10]

8.7–8.8 mm TL. Dorsal and anal finfold partially differentiated.[9,10]

8.3–10.7 mm TL. Spinous dorsal fin origin situated over preanal myomere 4–5, soft dorsal origin over preanal myomere 18–19 (8.3–10.7 mm). Average predorsal length 30.6% SL (range: 25.9–36.1% SL), and 28.4% TL (range = 24.1–33.5% TL).[9,10]

9.2–10.7 mm TL. First spinous dorsal rays formed (9.2–9.5 mm); first pelvic fin ray formed (9.2–9.7 mm); complete adult fin ray counts in median fins (9.2–10.7 mm).[9,10]

9.7–10.7 mm TL. Both finfolds completely differentiated.[9,10]

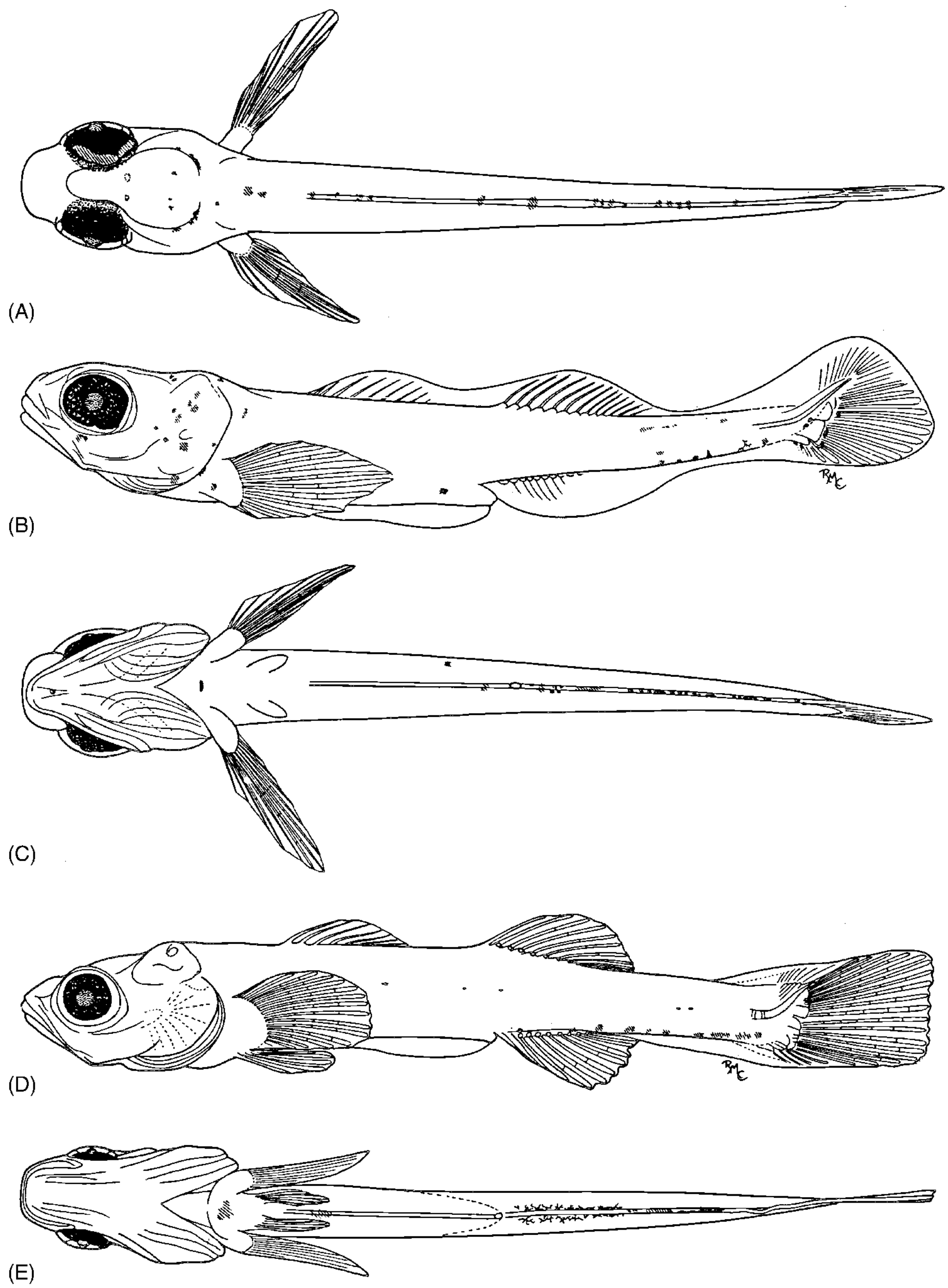

Figure 136 *Etheostoma stigmaeum*, speckled darter, Cache River, Black Swamp Wildlife Management Area, AR. Post yolk-sac larva, 8.0 mm TL (A) dorsal, (B) lateral, (C) ventral views; 10.6 mm TL, (D) lateral, (E) ventral views. (A–E from reference 9 and 10, with author's permission.)

Pigmentation

6.0–6.8 mm TL. Melanophores cluster over future anal fin, forming a discrete melanophore over the anus; melanophores surround the notochord. Ventral melanophores distributed on the breast and stomach in a single line, radiating to midline from mid-ventral position.[9,10]

6.9–7.4 mm TL. Similar to previous length interval with the exception of melanophores distributed on the pectoral girdle; melanophores on the hypural plate and developing caudal fin rays; and melanophores dorsally and ventrally near the anus.[9,10]

7.6–9.9 mm TL. Melanophores present on the cerebellum and posteriorly from the nape to the future soft dorsal fin insertion; on the otic capsule and epaxial operculum; and vertically on the base of the caudal fin. Ventral melanophores on the chin, breast, and from the future anal fin insertion to the caudal fin base.[9,10]

JUVENILES

Size Range
10.7 mm TL[9,10] to 35 mm SL.[16]

Fin Development
Branchiostegal rays 6,6;[2–5,9,10,12] dorsal fin spines/rays X–(X–XII)–XIV/(11–12)–13;[2–5,12,14] pectoral fin rays 12-(13)-16;[2–4,9,10,12,14] pelvic fin spines/rays I/5;[2–4,9,10,12,14] anal fin spines/rays II/8–10;[2–5,9,10,12,14] caudal fin rays viii-ix, 8-9+8-7, viii–x.[9,10]

Morphology
10.7 mm TL. Caudal fin truncate; upper jaw even with lower jaw, becoming subterminal.[9,10]

>11.2 mm TL. Supraorbital, infraorbital, lateral, and subtemporal head canals formed.[9,10]

Early juvenile. Infraorbital, lateral, and supratemporal head canals not interrupted, preoperculomandibular canal complete with 10 pores, infraorbital pores 6.[3,9,10]

28.9 mm. Initiation of squamation unknown; squamation complete; cheek naked or with few embedded scales, opercle scaled, breast naked, nape scaled posteriorly but naked with embedded scales anteriorly.[2,3,9,10]

Total vertebrae count 39–41 (N = 3, mean = 40.0), including one urostylar element[9–10] or 40–42.[2,4,12] Scales in the lateral series ranging from 42 to 53.[3,9,10,12,14]

Morphometry
See Table 144.[9,10]

Pigmentation
11.3 mm TL. Several melanophores mid-laterally, from the tip of the pectoral fin to the caudal peduncle. Ventral melanophores on the breast; concentrated near the anal fin lepidiotrichia interdigitation with the pterigiophores; clustered from the anal fin insertion to the caudal fin base.[9,10]

TAXONOMIC DIAGNOSIS OF YOUNG SPECKLED DARTER

Similar species: members of *Doration*.

Adult. The *E. stigmaeum* group consists of three populations,[4] which are divided into two species, *E. jessiae* and *E. stigmaeum*, and either one or two additional forms.[2,3] *Etheostoma stigmaeum* has no premaxillary frenum, less than 50% of the cheek is scaled, and has an average of 33 pored lateral line scales. Another undescribed subspecies has a complete or nearly complete scaled cheek, no premaxillary frenum, and an average of 45 pored lateral line scales. The undescribed form occurs in the Collins and Rocky Rivers, headwater tributaries of the Caney Fork, Cumberland River, TN. The resurrected *E. meadiae* (Jordan and Evermann) occurs in the Clinch and Powell Rivers of TN and VA and is of undetermined status.[1]

Larva: *Etheostoma stigmaeum* can be distinguished from *E. jessiae* based on postanal melanophore pattern and precocious ontogenetic development. *Etheostoma stigmaeum* possesses radiating melanophores at every postanal myoseptum while *E. jessiae* has several distinct melanophores at the future anal fin insertion. *Etheostoma stigmaeum* develops fin elements at smaller length intervals than *E. jessiae.*[9,10]

Variation
AR and AL populations are significantly different in hatching length, eye shape, and most ontogenetic events. No differences in meristic, morphometric, or pigmentary attributes were discernable. The AR population is recognized as a new subspecies.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 137)
Eggs. Egg sites include riffle habitats over fine gravel or coarse sand substrates in moderate current.[6,15]

Yolk-sac larvae. Aquarium observations indicate that speckled darter larvae are pelagic immediately after hatching.[9,10]

Post yolk-sac larvae. Larvae become demersal only at lengths greater than 9 mm remaining in close association with the substrate. In the Tallapoosa River, AL,

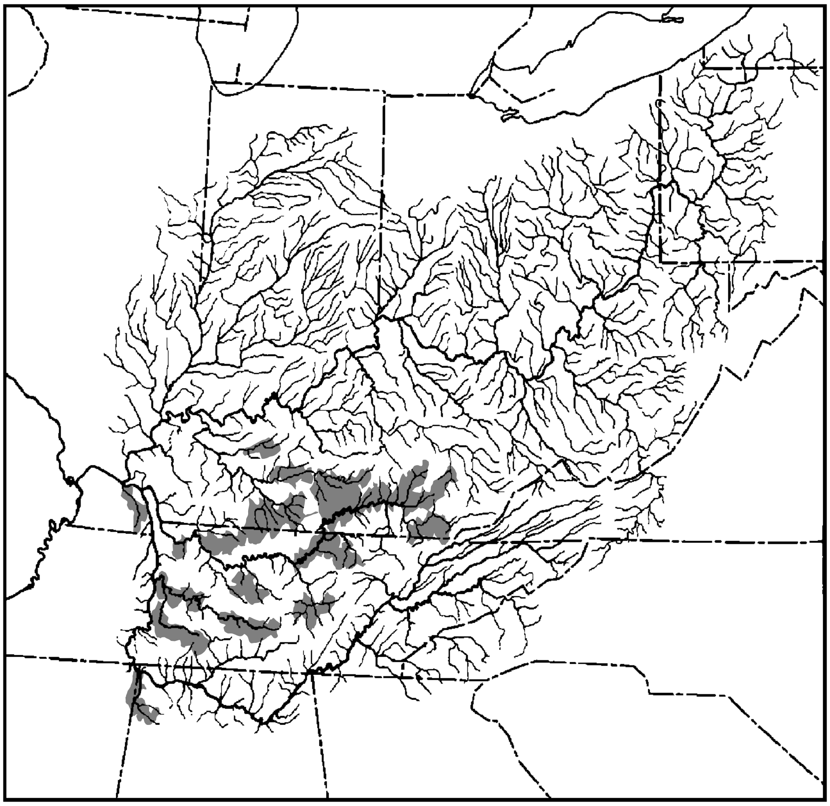

Figure 137 Distribution of speckled darter, *Etheostoma stigmaeum* in the Ohio River system (shaded area).

larvae and early juveniles utilize the downstream pools and backwater areas adjacent to spawning riffles as nursery habitats.[9,10]

Juveniles. Juveniles greater than 25 mm TL are found on the margins of the riffle.[9,10]

Early Growth (see Table 146)
Age 1 individuals are 35 mm SL in AL.[16]

Feeding Habits
Diet is dominated by midge larvae (58%) and supplemented with microcrustaceans and mayfly nymphs.[5]

Table 146

Average calculated lengths (mm SL) of young speckled darter in Alabama.[16]

	Age		
State	1	2	3
Alabama[16]	35	38–41	

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Material Examined: AL: Elmore Co.: lower Tallapoosa River, backwater, LRRC 657 (1); LRRC 663 (13); uncatalogued Alabama Power Cooperative (35). AR: Woodruff County: Cache River, Rex Hancock/Black Swamp Wildlife Management Area, 3 miles SE Gregory, Point Twp. T 6N R 3W, RW uncatalogued (77).

* Original fecundity data for speckled darter from the Buffalo River, Duck River drainage, Lawrence Co., TN. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Early life history developmental series cultured from laboratory-spawned specimens from lower Talapoosa River, Elmore County, AL. Specimens curated at the Division of Fishes, Aquatic Research Center, Indiana, Biological Survey, Bloomington, IN.

STRIATED DARTER

Etheostoma (*Catonotus*) *striatulum* Page and Braasch

Etheostoma: various mouths; *striatulum*: refers to the striated appearance from the faint dark horizontal lines along the side.

RANGE

The striated darter is confined to tributaries of the Duck River in Bedford, Lewis, Marshall, and Maury Counties, TN.[1–5]

HABITAT AND MOVEMENT

The preferred habitat of the striated darter is slab rock pools in small to medium low-gradient creeks.[1-6] The species occurs in limestone bed streams beneath slab stones, brush, and ledges.[1–4]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

The striated darter is extremely localized, occurring in streams tributary to the Duck River in Bedford, Lewis, Marshall, and Maury Counties, TN.[1,2] The species has been extirpated from the type locality and it may be found in less than a dozen creeks throughout the four county area, making it extremely vulnerable to significant depletion.[2,4]

SPAWNING

Location
Underside of slab rocks[2–6], similar to other *Catonotus*.

Season
Spawning occurs from mid-March through mid-April.[2, 4, 6]

Temperature
Unknown.

Fecundity
Females produced about 50 ova (range: 19–108) per year.[4,6] Females may possess up to 108 eggs.[6]

Sexual Maturity
Adults rarely live past age 1;[4,6] however, maturity is reached at 30 mm SL for females and 35 mm SL for males.[6] Male tuberculation was absent, and female genital papillae have an oval pad with radiating grooves. Males exhibited sexually dimorphic traits during the reproductive season with an increase in bright pigmentation on the fins. The genital papilla is a small trianglar flap.[2,3,6]

Spawning Act
The reproductive mode of striated darter is a clusterer.[6] Adults deposit their eggs on the underside of slab rocks where they are guarded by a male.[6] Males court females by erecting fins, intensifying their color, and wagging their caudal fin. When a female enters a nest she assumes a belly-up position. The male joins her, pressing alongside, and spawning occurs with 2–5 eggs deposited during each encounter.[6] A nest may contain as many as 155 eggs from several different females.[2]

EGGS

Description
Unknown.

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown to 30–35 mm SL.[6]

Fin Development
Larger Juveniles. Spinous dorsal fin VIII–IX; soft dorsal rays 7–10; pectoral rays 10–12; anal fin rays II 7–10; pelvic fin rays I 5; caudal fin rays 14–17.[1-3]

Morphology
Scales in the lateral series incomplete with 2–18 pored scales and 40–46 total scales in the lateral series from TN.[2,3]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG STRIATED DARTERS

Similar species: similar to other members of the *Catonotus* subgenus. Early life stages may be indistinguishable from other populations.[3]

Adult. *Etheostoma striatulum* is similar to other *Catonotus*.

Larva. Aspects of the early life history for *E. striatulum* are unknown.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 138)
Eggs. Eggs are laid on the underside of slab rocks.[2-6]

Yolk-sac larvae. Unknown.

Post yolk-sac larvae. Unknown.

Juveniles. Juveniles were found in the gently flowing pools and riffle edges among the slab rocks.[6]

Early Growth (see Table 147)
Specimens reach 30–35 mm SL at age 1.[3]

Feeding Habits
The diet of both juveniles and adults consists of midge larvae and microcrustaceans.[2,3]

Table 147

Average calculated lengths (mm SL) for young striated darter in Tennessee.

	Age	
State	1	2
Tennessee[2,3]	30–35	60

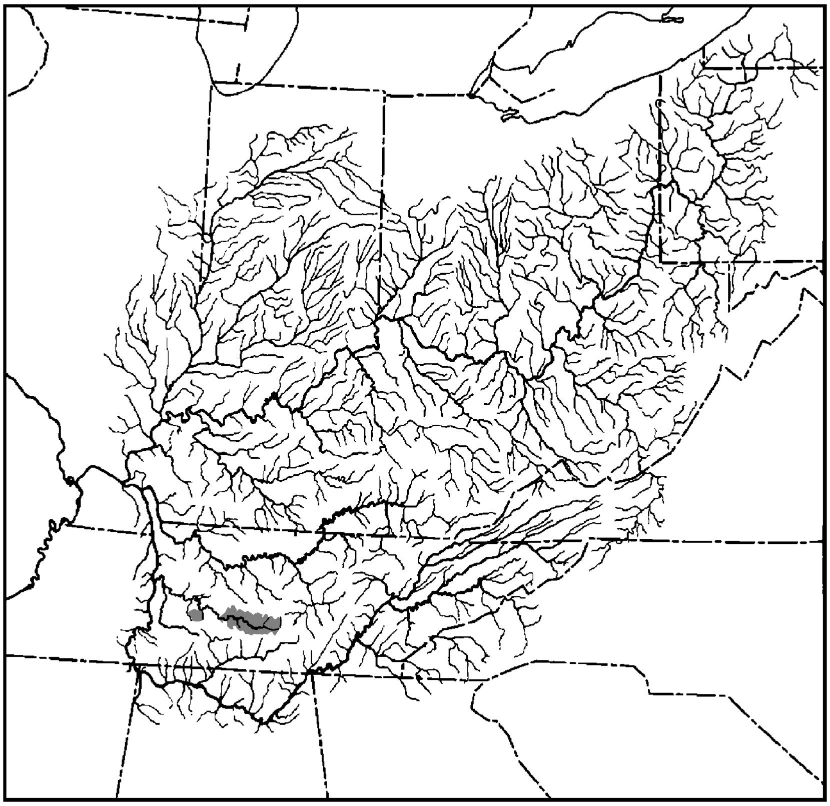

Figure 138 Distribution of striated darter, *Etheostoma striatulum* from the Ohio River (shaded area).

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GULF DARTER

Etheostoma (*Oligocephalus*) *swaini* (Jordan)

Etheostoma: various mouths; *swaini*: is named after Joseph S. Swain, an ichthyologist and mathematician at Indiana University active in the 1800s.

RANGE

The gulf darter is more commonly known from the Coastal Plain where it occurs from western tributaries of the Mississippi River, TN, to GA, AL, MS and LA.[1–4] The species is restricted to a single creek in the Bear Creek system, MS, but has not been collected from the TN portion of that same creek.[1–4]

HABITAT AND MOVEMENT

The preferred habitat of the gulf darter is sand and clay-bottomed streams in small- to medium-sized streams with moderate current.[1–4] The species often occurs with detritus or near undercut or brushy banks.[4] It is often associated with vegetation, brush, or rocks that provide protection.[2]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Confined to a single stream in the Bear Creek system, MS, in the Tennessee River drainage.[4]

SPAWNING

Location
Spawning occurred on coarse gravel riffles at depths of 10–20 cm in moderate flow.[4,5]

Season
Spawning season is March–April in KY and TN,[4,6] and during February and March in MS and LA.[2] Breeding occurred in February to March in southern MS.[5]

Temperature
Unknown.

Fecundity (see Table 148)
Ova numbered between 7–90 (mean = 39) ova per female.[4,5] Our data shows that females 47–59mm TL had 317–613 ova in their ovaries in late March from LA.* This significant difference can only be a result of Ruple et al.[5] counting only mature ova rather than all ova in the ovaries.

Sexual Maturity
Adults live to reach age 3;[1–5] however, maturity is suspected to be at age 1 for females.[5] An adult male (54 mm TL) from LA had testes that were 1.02% of the body weight on March 2.* Male tuberculation was absent and females had a short tubular genital papilla.*[,2] Females 38 mm TL were all sexually mature, while 40–53 mm TL females were mature in western TN.[4,5] Males less than 40 mm TL were all immature, while all males larger than 40–53 mm TL were mature.*[,4] Males exhibited sexually dimorphic traits during the reproductive season, with an increase in brightly colored pigmentation and the extension of a small and triangular genital papillae; while females had distended abdomens and a short tubular genital papilla.*,[2,5,6]

Spawning Act
The reproductive mode of *E. swaini* is a burier.[3,5] Females bury their eggs in gravel.[5]

EGGS

Description
Egg diameters from MS were 1.1–2 mm.[3,5] Eggs from Boque chitto, Washington Parish, LA, are spherical, mean = 1.3 mm diameter (range= 1.2–1.4 mm); translucent; demersal; and nonadhesive. Eggs possess translucent, pale-amber yolk (mean = 1.2 mm diameter; range= 1.1–1.3 mm); a single oil globule (mean = 0.31 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.*

Incubation
Unknown.

Table 148

Fecundity data for gulf darter from Lawrence Creek, Boque-Chitto drainage, Washington Parish, LA.*

			Number of Ova			
Date	TL (mm)	GSI	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
March 27	59	6.4	486	75	51	1.17
	57	6.7	524	49	40	1.33
	55	8.3	371	68	40	1.25
	54	6.8	415	83	52	1.33
	51	4.6	269	43	52	1.17
	48	9.9	409	72	46	1.42
	47	13.3	391	88	41	1.42
	47	11.9	393	58	47	1.25
	45	9.7	231	50	36	1.33
	45	6.5	239	51	37	1.25

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Cahaba River, AL specimens are reported from 6.8 to 7.6 mm TL.[8]

Myomeres
Preanal 16–17, postanal 19, total 35–36.[8]

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

See Figure 139

Size Range
Cahaba River, AL specimens ranged from 8.1 to 10.4 mm TL.[8]

Myomeres
Preanal 16–17, postanal 19, total 35–36.[8]

Morphology
8.1 mm TL. Larvae are robust, possessing a large head and a well-developed mouth.[8,*]

Morphometry
8.1 mm TL. Snout length/HL: 19.0%; eye diameter/HL: 33.3%; head length/TL: 20.5% ; preanal length/TL: 52.2%; postanal length/TL: 47.8%; standard length/TL: 94.6%; pectoral fin length/TL: 8.0%; head depth/TL: 15.6%; anal depth/TL: 9.8%; midpostanal depth/TL: 7.3%; and caudal peduncle depth/TL: 4.9%.[8,*]

Fin Development
8.1 mm TL. Median finfolds present with first rays forming in hypural portion of caudal fin.[8]

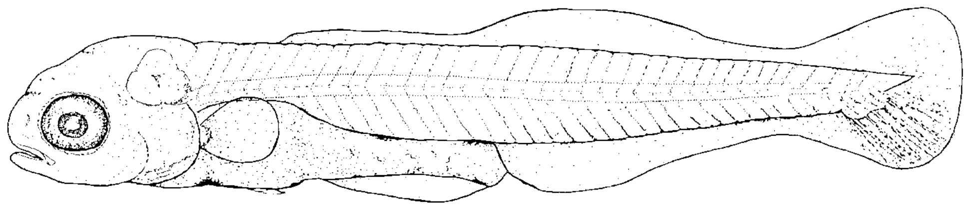

Figure 139 *Etheostoma swaini*, gulf darter: post yolk-sac larva, 8.1 mm TL, lateral view, Cahaba River, AL. (Redrawn from reference 8, with author's permission.)

Pigmentation
8.1 mm TL. A single large melanophore is present near the gular region with several more extending along the ventral gut. Several melanophores are distributed on the dorsal gut. Pigment is distributed on the postanal myosepta forming a V-shaped series of melanophores.[8]

JUVENILES

Size Range
>10.4 mm[8] to 38–40 mm TL.[*,4]

Fins
Larger juveniles. Spinous dorsal fin IX–XII; soft dorsal rays 10–14; pectoral rays 11–15; anal fin rays II 6–8; pelvic fin rays I/5; caudal fin rays 14–18.[1–4]

Morphology
Total vertebrae count 35–37 including one urostylar element. Scales in the lateral series incomplete with 28–46 pored scales and 35–53 total scales in the lateral range from TN.[2–4]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG GULF DARTERS

Similar species: members of subgenus *Oligocephalus*[5] and *Fuscatelum*.

Adult. *Etheostoma swaini* is similar to *E. asprigene* and *E. parvipinne.* The species differs from *E. asprigene* in having a depigmented nape, with scales absent or embedded, and lacking a dark blotch at the posterior base of the spinous dorsal fin. *Etheostoma swaini* is sympatric with *E. parvipinne* but differs in possessing red colors and broadly connected gill membranes.

Larva. The early life history of *E. swaini* is similar to *E. asprigene.* The two species can be differentiated by their pigmentation. *Etheostoma asprigene* does not possess gular region melanophore clusters. *Etheostoma swaini* possesses more preanal myomeres and fewer postanal myomeres than *E. asprigene.*

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 140)
Eggs. Eggs are buried in the interstitial spaces of gravel riffles.[3,5]

Yolk-sac larvae. Yolk-sac larvae were collected from habitats with abundant woody structure and vegetation at water depths of 0.49–1.0 m with current velocities of 2.15–3.93 cm/s.[8]

Post yolk-sac larvae. Larvae were collected from habitats with abundant woody structure and vegetation. Larvae were collected from water depths of 0.49 m with current speeds of 3.93 cm/s.[8]

Juveniles. Early juveniles utilize the downstream pools and backwater areas adjacent to spawning riffles as nursery habitats.*

Early Growth (see Table 149)
Apparently, individuals do not exceed 3 years of age.[4,5] Young darters attained 38 mm TL in MS[5], and 40–53 mm TL in TN.[4]

Figure 140 Distribution of gulf darter, *Etheostoma swaini* from the Ohio River (shaded area).

Table 149

Average calculated lengths (mm TL) of young gulf darters in Mississippi[5] and Tennessee.[4]

State	Age 1	Age 2	Age 3
Mississippi (mean)[5]	38	48	53
Tennessee[4]	40–53	55–65	66–77

Feeding Habits

The main components of the diet in MS include midge larvae, suplemented with isopods and immature blackflies, *Stenonema* mayflies, hydroptilid and hydropsychid caddisflies, and dragonflies; juveniles eat small, midge larvae, copepods, and cladocera.[2,5] Specimens from TN eat midge larvae exclusively.[4]

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* Original fecundity data for gulf darter from Lawrence Creek, Boque-Chitto drainage, Washington Parish, LA. Specimens are curated at Northeast Lousiana University, Museum of Zoology, Monroe, LA.

SWANNANOA DARTER

Etheostoma (*Poecilichthys*) *swannanoa* Jordan and Evermann

Etheostoma: various mouths; *swannanoa*: named after the location where some of the material was collected, in the South Fork of the Swannanoa River at Black Mountain, NC.

RANGE

Etheostoma swannanoa is an endemic species of the upper Tennessee River system. The species occurs in tributaries of the Powell River, VA, and in the French Broad River, TN, VA and NC.[4] The swannanoa darter has been collected from the Nolichucky, Watauga, Holston, and Clinch River basins.[2,3,5,6]

HABITAT AND MOVEMENT

The swannanoa darter inhabits high gradient, clear, small- to large-sized streams in the Blue Ridge Province. The species is primarily an upland one occupying riffles and flowing pools over boulder and bedrock substrates in cool montane streams.[2–4,6]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma swannanoa is confined to the headwaters of the Tennessee River mostly in the Blue Ridge, in the Clinch and Powell River systems (VA but not TN), and through the upper Holston and French Broad Rivers along the TN, VA, and NC borders.[4]

SPAWNING

Location

Egg sites include flowing pool habitats over algal mats or aquatic macrophytes with gravel substrates in slight- to moderate- current.[7]

Season

Spawning aggregates of adult males assemble between mid-February and early March in flowing pool habitat. Swannanoa darters are reported to spawn during April at 8°C,[5] which was confirmed from TN, where spawning occurred from late March to late April.[7]

Temperature

Etheostoma swannanoa initiated spawning at 8°C.[5]

Fecundity (see Table 150)

Female swannanoa darter showed statistically significant increasing fecundity (ANOVA, $F = 31.908$, $p \geq 0.001$) with increasing length. Three 74 mm females collected on April 7, 1981, had 87–160 large mature ova, while a 50 mm female had 72 large mature ova (Table 150).*

Sexual Maturity

Sexual maturity occurs at age 1 at about 45 mm.[4]

Spawning Act

Aquarium observations indicated that adults maintained a head-to-head orientation with vents juxtaposed. A male followed a female into the aquatic macrophytes and mounted her. Eggs were laid one at a time in the mats, generally 2–3 during a single spawning event.[7]

EGGS

Description

Ovarian examination showed that ovoid latent ova were 0.45–0.5 mm, early maturing ova averaged 1.0–1.25 mm, and large mature ova averaged 1.33–1.66 mm.* Eggs from Walden Creek, TN, are spherical, mean = 1.9 mm diameter (range: 1.8–2.1 mm); translucent; demersal; and adhesive. Eggs possess translucent clear to pale-yellow yolk (mean = 1.75 mm diameter; range: 1.6–1.9 mm); a single oil globule (mean = 0.45 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[7]

Incubation

Unknown.

Table 150

Fecundity data for *E. swannanoa* from Walden Creek, Sevier County, TN.

Length (mm TL)	Ovary weight (mg)	Number of Ova: Ripening Oocytes (LA)	Number of Ova: Mature Oocytes (EM, MA, LM)	Number of Ova: Ripe Eggs (MR, RE)	Egg Diameter (mm)
50	230	647	275	72	1.53
52	297	705	255	96	1.53
58	314	1104	305	116	1.33
66	585	978	338	125	1.66
68	585	1570	488	99	1.66
72	691	1501	499	108	1.16
73	629	1998	518	197	1.53
74	793	2484	538	151	1.66
74	773	2748	442	160	1.53
74	745	1978	541	87	1.66

Development
Unknown.

YOLK-SAC LARVAE

See Figure 141

Size Range
6.2–6.5 to 7.8–8.1 mm.[7]

Myomeres
Preanal 17 (2), 18 (1), 19 (18), 20 (10), 21 (11), or 22 (3) (N = 45, mean = 19.8); postanal 22 (15), 23 (22), or 24 (9) (N = 45, mean = 23.4), and total myomeres 39 (1), 40 (1), 41 (6), 42 (10), 43 (15), 44 (11), 45 (2) (N = 45, mean = 43.6).[7]

Morphology
6.2–6.5 mm TL. Newly hatched larvae with terete body; snout round; functional jaws, upper jaw even or extending slightly past lower jaw; yolk sac moderate (19.6% TL), oval to tapered posteriorly; yolk translucent, pale yellow, with a single oil globule; vitelline vein plexus mid-ventrally on yolk sac; head not deflected over the yolk sac; eyes spherical.[7]

7.1–8.1 mm TL. No swim bladder forms; gut straight, without striations, gut posterior to stomach normal in length (7.1–8.1 mm). Digestive system functions before complete yolk absorption (7.4–7.7 mm); operculum and gill arches function (7.7 mm).[7]

Morphometry
See Table 151.[7]

Fin Development
See Table 152.

6.2–6.5 mm TL. Newly hatched larvae with well-developed pectoral fins without incipient rays.[7]

Pigmentation
6.2–7.0 mm TL. Eye pigmented; a single melanophore dorsally on the cranium; melanophores distributed laterally over the gut; ventral pigmentation consists of mid-ventral melanophores outlining the vitelline vein plexus and the gut; and paired stellate melanophores at postanal myosepta[7].

7.1–8.1 mm TL. Dorsum of cranium has melanophores over optic lobe and cerebellum, nape, and from mid-dorsal finfold to the caudal peduncle. Laterally, subdermal melanophores are present on midoperculum; subdermal melanophores present dorsally over the gut, cutaneous melanophores over posterior gut; subdermal melanophores from posterior stomach to the mid-postanal trunk; and at midline outlining notochord; ventrally, a large accumulation of melanophores present on breast, extending posteriorly to the anus; mid-ventral postanal myosepta with stellate melanophores from the anus to the caudal peduncle.[7]

POST YOLK-SAC LARVAE

See Figures 141 and 142

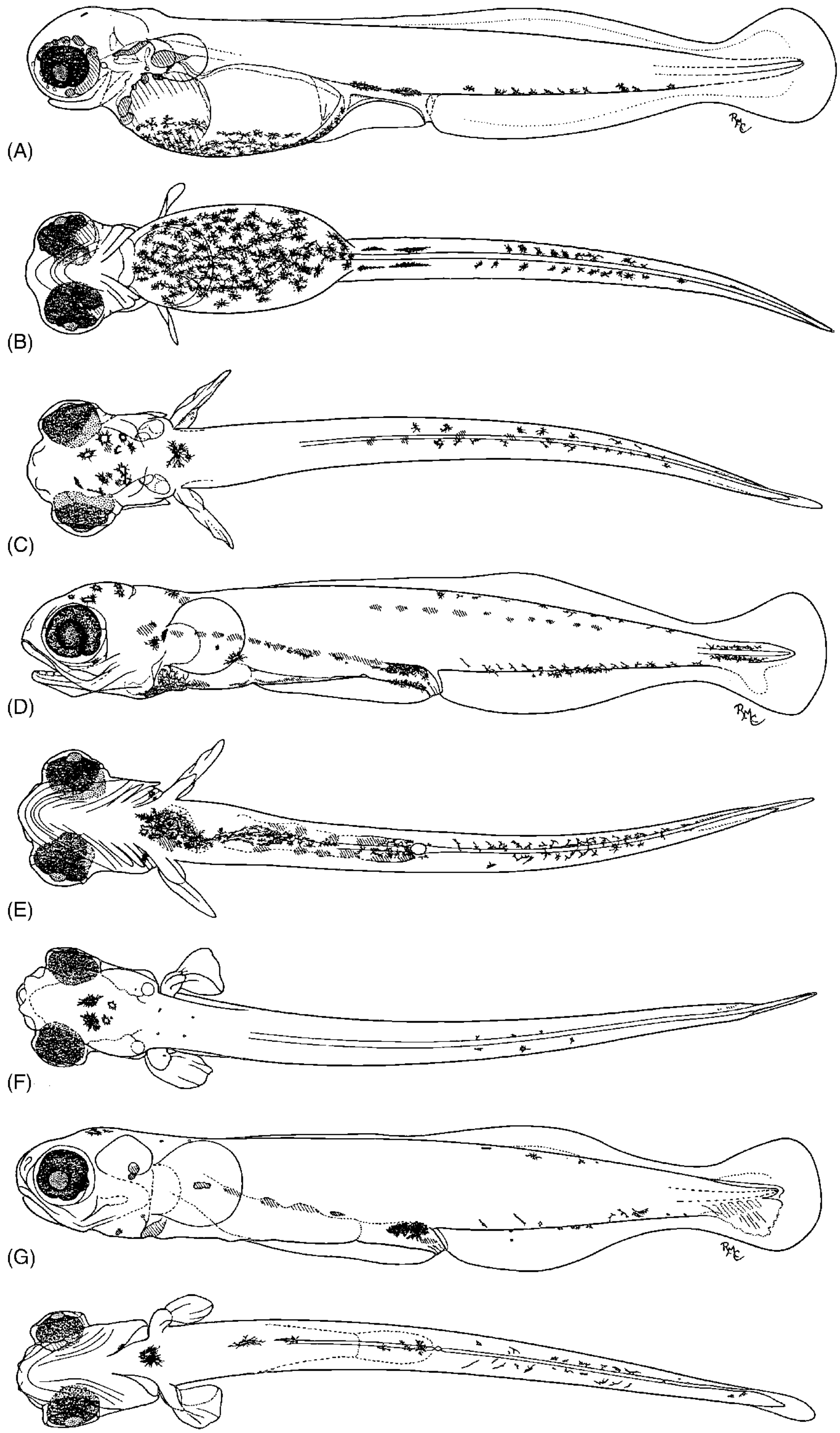

Figure 141 *Etheostoma swannanoa*, swannanoa darter, Walden Creek, Sevier County, TN. Yolk-sac larva, 7.1 mm TL: (A) lateral, (B) ventral views; post yolk-sac larva, 8.0 mm TL: (C) dorsal, (D) lateral, (E) ventral views; post yolk-sac larva, 10.8 mm TL: (F) dorsal, (G) lateral, (H) ventral views. (A–H from reference 7, with author's permission.)

Size Range

7.8–8.2 to 17.5 mm.[7,*]

Myomeres

Preanal 17 (2), 18 (1), 19 (18), 20 (10), 21 (11), or 22 (3) (N = 45, mean = 19.8); postanal 22 (15), 23 (22), or 24 (9) (N = 45, mean = 23.4); and total 39 (1), 40 (1), 41 (6), 42 (10), 43 (15), 44 (11), 45 (2) (N = 45, mean = 43.6).[7]

Morphology

7.8–8.1 mm TL. Yolk absorbed.[7]

Table 151

Morphometry of young *E. swannanoa* grouped by selected intervals of total length (N = sample size).[7]

	Total Length (TL) Intervals (mm)									
	5.48–7.98 (N = 30)		8.04–9.82 (N = 22)		10.0–10.7 (N = 4)		12.4–14.0 (N = 4)		14.2–15.4 (N = 3)	
Characters	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
Length (% of TL)										
Upper jaw[a]	27.4 ± 4.84	(0.22–0.51)	29.4 ± 6.18	(0.24–0.66)	34.7 ± 4.85	(0.60–0.80)	31.9 ± 5.81	(0.56–0.92)	28.8 ± 3.10	(0.82–0.94)
Snout[a]	14.8 ± 4.83	(0.08–0.54)	14.5 ± 2.92	(0.16–0.32)	17.3 ± 1.71	(0.32–0.38)	18.7 ± 0.86	(0.42–0.54)	17.9 ± 2.01	(0.50–0.58)
Eye diameter[a]	40.0 ± 3.51	(0.38–0.60)	40.5 ± 4.22	(0.53–0.74)	38.1 ± 2.44	(0.71–0.81)	35.2 ± 2.10	(0.84–0.94)	31.5 ± 0.95	(0.90–1.04)
Head	17.8 ± 0.97	(1.00–1.46)	18.0 ± 1.30	(1.19–1.84)	19.6 ± 0.61	(2.00–2.09)	19.2 ± 0.52	(2.40–2.76)	21.3 ± 0.95	(2.94–3.20)
Predorsal	28.4 ± 2.66	(1.22–2.66)	29.0 ± 1.53	(2.16–2.86)	25.5 ± 0.63	(2.58–2.76)	26.0 ± 0.98	(3.26–3.68)	24.9 ± 4.39	(2.82–4.12)
Dorsal insertion					29.5 ± 7.47	(2.58–4.26)	46.8 ± 1.78	(5.52–6.74)	45.0 ± 3.38	(5.82–7.24)
D2 origin					31.0 ± 10.4	(2.58–4.86)	50.7 ± 0.96	(6.26–7.20)	47.8 ± 3.38	(6.26–7.84)
D2 insertion					36.2 ± 20.8	(2.58–4.86)	71.4 ± 1.46	(6.26–7.20)	69.7 ± 3.06	(6.26–7.84)
Preanal	51.8 ± 2.05	(3.08–4.26)	53.1 ± 1.60	(4.22–5.40)	53.8 ± 1.19	(5.24–5.80)	52.9 ± 0.67	(6.47–7.40)	51.8 ± 2.69	(6.96–8.03)
Postanal	48.2 ± 2.05	(2.12–3.82)	46.5 ± 1.83	(3.68–4.42)	46.1 ± 1.25	(4.68–4.90)	47.1 ± 0.68	(5.92–6.56)	48.4 ± 2.65	(6.48–7.48)
Standard	96.4 ± 0.60	(5.26–7.70)	95.9 ± 0.55	(7.72–9.40)	92.0 ± 3.96	(8.94–10.2)	88.5 ± 1.09	(10.8–12.4)	83.5 ± 7.14	(10.7–13.4)
Yolk Sac	19.6 ± 13.0	(0.16–2.26)	5.81 ±	(0.50–0.50)						
Fin Length (% of TL)										
Pectoral	8.36 ± 1.89	(0.36–0.84)	9.13 ± 0.81	(0.68–0.98)	8.53 ± 0.70	(0.80–0.98)	11.4 ± 3.49	(0.92–1.90)	16.2 ± 2.99	(1.84–2.68)
Pelvic					3.60 ± 0.57	(0.32–0.42)	4.87 ± 2.25	(0.38–1.00)	9.05 ± 4.40	(0.65–1.90)
Spinous dorsal					16.1	(1.68–1.68)	20.8 ± 2.50	(2.14–3.06)	20.0 ± 1.21	(2.66–3.12)
Soft dorsal					20.9	(2.18–2.18)	20.7 ± 0.78	(2.44–2.91)	22.0 ± 1.45	(3.13–3.32)
Caudal	3.63 ± 0.60	(0.18–0.38)	4.05 ± 0.55	(0.22–0.42)	8.01 ± 3.96	(0.44–1.24)	11.5 ± 1.09	(1.38–1.62)	16.5 ± 7.14	(1.66–3.52)
Body Depth (% of TL)										
Head at eyes	13.8 ± 0.66	(0.71–1.13)	13.9 ± 0.79	(1.10–1.44)	14.3 ± 0.55	(1.47–1.52)	14.0 ± 0.36	(1.78–1.93)	14.3 ± 0.70	(1.98–2.14)
Head at Pl	14.4 ± 3.30	(0.80–1.55)	12.7 ± 1.07	(0.92–1.40)	13.8 ± 0.66	(1.30–1.52)	14.1 ± 0.95	(1.59–2.12)	16.6 ± 1.21	(2.20–2.54)
Preanal	8.96 ± 1.00	(0.40–0.76)	9.56 ± 1.41	(0.54–1.19)	11.0 ± 1.35	(1.01–1.32)	12.9 ± 2.97	(1.06–2.08)	14.3 ± 0.21	(2.00–2.22)
Mid-Postanal	6.62 ± 0.77	(0.29–0.58)	7.12 ± 1.11	(0.36–0.86)	8.13 ± 1.34	(0.72–1.04)	8.57 ± 1.61	(0.76–1.29)	9.34 ± 0.35	(1.30–1.41)
Caudal peduncle	1.91 ± 1.19	(0.15–0.26)	2.72 ± 0.98	(0.22–0.42)	4.87 ± 0.72	(0.41–0.58)	6.80 ± 1.10	(0.64–1.06)	7.46 ± 0.23	(1.02–1.17)
Yolk Sac	8.37 ± 5.47	(0.14–1.50)	5.81	(0.50–0.50)						
Body Width (% of HL)										
Head	71.6 ± 6.28	(0.72–1.06)	67.8 ± 4.98	(0.98–1.28)	63.3 ± 4.64	(1.20–1.44)	63.3 ± 3.10	(1.52–1.64)	59.3 ± 4.00	(1.74–1.96)
Myomere Number										
Predorsal	4.40 ± 0.50	(4.00–5.00)	4.82 ± 0.40	(4.00–5.00)	4.50 ± 0.58	(4.00–5.00)	4.25 ± 0.55	(4.00–5.00)	4.50 ± 0.71	(4.00–5.00)
Soft dorsal			22.0 ± 0.71	(21.0–23.0)	22.0 ± 0.00	(22.0–22.0)	21.8 ± 0.55	(21.0–22.0)	21.5 ± 0.71	(21.0–22.0)
Preanal	19.4 ± 1.07	(17.0–22.0)	20.1 ± 1.11	(18.0–22.0)	20.8 ± 0.55	(20.0–21.0)	20.8 ± 0.55	(20.0–21.0)	20.5 ± 0.71	(20.0–21.0)
Postanal	23.0 ± 0.81	(22.0–24.0)	23.0 ± 0.62	(22.0–24.0)	22.8 ± 0.55	(22.0–23.0)	22.8 ± 1.01	(22.0–24.0)	22.5 ± 0.71	(22.0–23.0)
Total	42.3 ± 1.21	(39.0–44.0)	43.0 ± 1.09	(41.0–45.0)	43.5 ± 0.58	(43.0–44.0)	43.5 ± 1.29	(42.0–45.0)	43.0 ± 0.00	(43.0–43.0)

[a] Proportion expressed as percent head length.

Note: Characters expressed as percent total Length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

8.0–8.9 mm TL. Premaxilla and mandible form (8.0–8.5 mm); neuromast development occurs midlaterally from the anterior trunk posteriad (8.0–8.9 mm).[7]

9.0–9.2 mm TL. Notochord flexion precedes caudal fin ray development.[7]

9.0–10.7 mm TL. Branchiostegal rays form.[7]

10.8–14.7 mm TL. Upper jaw even with lower jaw, becoming subterminal.[7]

11.8–14.4 mm TL. Lateral line forms (11.8–14.4 mm); squamation initiated (14.2 mm).[7]

Morphometry
See Table 151.[7]

At lengths less than 10.0 mm, average predorsal length 29.8% SL (range = 23.2–30.2% SL), and 28.7% TL (range= 22.3–29.1% TL).[7]

Fin Development
See Table 152.

8.1–9.8 mm TL. First rays form in caudal fin.[7]

9.0–11.8 mm TL. Spinous dorsal fin origin situated over preanal myomere 4–5, soft dorsal origin over preanal myomere 21–22 (9.0–11.8 mm).

9.7–10.7 mm TL. Spinous dorsal (10.0–10.4 mm); pectoral fin (10.4 mm); anal fin (10.0–10.4 mm); soft dorsal fin rays form (10.4 –10.7 mm); dorsal and anal finfold partially differentiated (9.7–10.7 mm).[7]

10.4–13.0 mm TL. Pelvic fin buds formed anterior to dorsal fin origin after complete yolk absorption.[7]

12.3–12.4 mm TL. First pelvic fin ray formed (12.3 mm); complete adult fin ray counts in median fins, including segmentation in caudal fin (12.4 mm).[7]

Table 152

Meristic counts and size (mm TL) at the apparent onset of development for *E. swannanoa*.[7]

Attribute/Event	*Etheostoma swannanoa*[7]	Literature
Branchiostegal Rays	6,6	6,6[2,4,5]
Dorsal Fin Spines/Rays	X–XI/12–14	X–XIII/11–14 [2-5,9]
First spines formed	10.0–10.4	
Adult complement formed	12.3–13.9	
First soft rays formed	10.4–10.7	
Adult complement formed	12.3–13.9	
Pectoral Fin Rays	15	14–17 [2-5]
First rays formed	10.4	
Adult complement formed	12.4	
Pelvic Fin Spines/Rays	I/5	I/5[2-5]
First rays formed	12.3	
Adult complement formed	12.3–14.2	
Anal Fin Spines/Rays	II/8–9	II/7–9 [2-5,9]
First rays formed	10.0–10.4	
Adult complement formed	10.4–12.4	
Caudal Fin Rays	vii–xi, 8–9 + 7–8, vi–ix	14–17 [4]
First rays formed	8.1–9.8	
Adult complement formed	10.4–13.9	
Lateral Line Scales	43–54	46–62 [2-5,9]
Myomeres/Vertebrae	39–45/40–43	Unknown/40–43 [2-4,10]
Preanal myomeres	17–22	
Postanal myomeres	22–24	

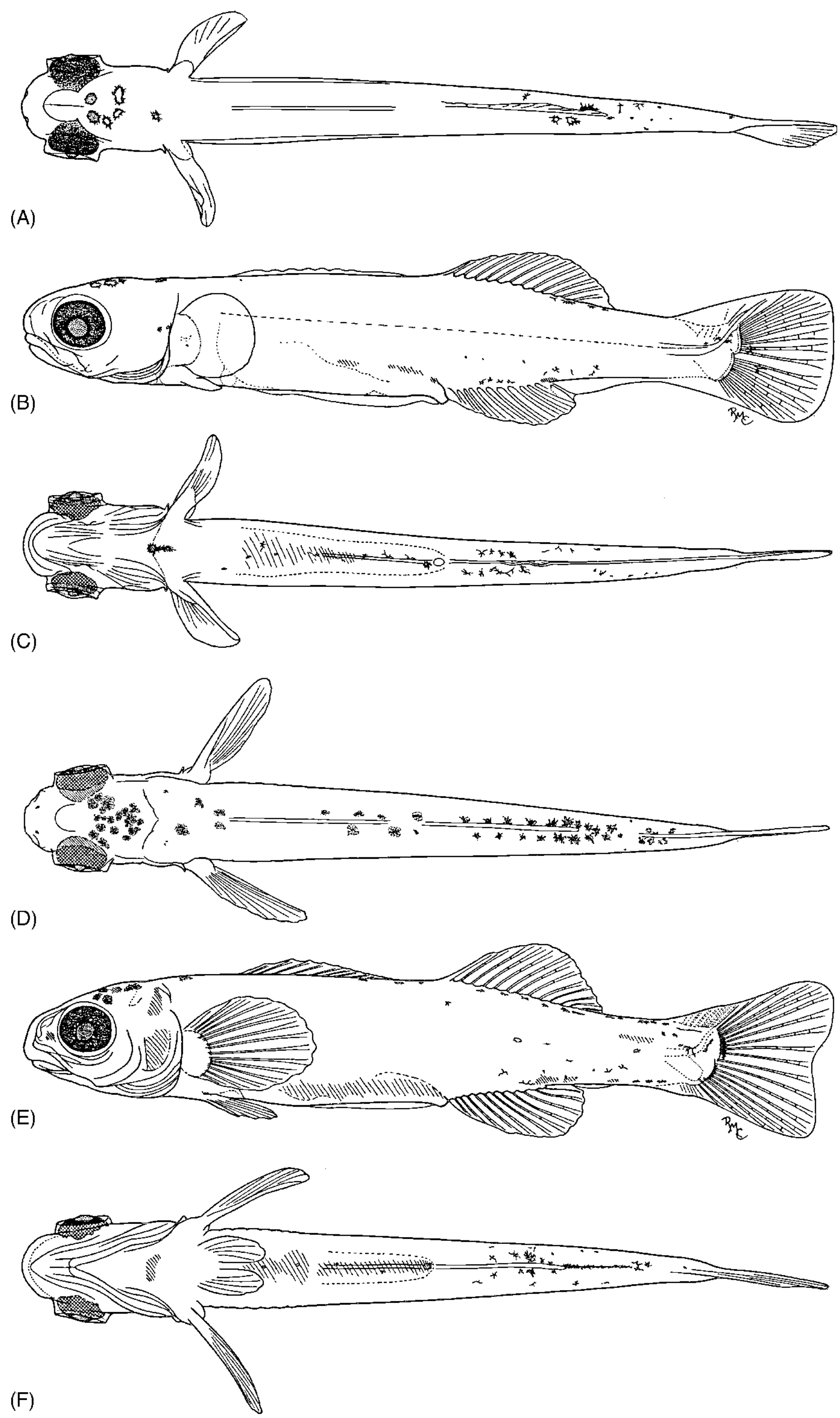

Figure 142 *Etheostoma swannanoa*, swannanoa darter, Walden Creek, Sevier County, TN. Post yolk-sac, 14.7 mm TL: (A) dorsal, (B) lateral, (C) ventral views; early juvenile, 17.5 mm TL, (D) dorsal, (E) lateral, (F) ventral views. (A–F from reference 7, with author's permission.)

13.0–13.4 mm TL. Both finfolds completely differentiated (13.0–13.4 mm).[7]

Pigmentation

8.3–10.8 mm TL. A cluster of melanophores dorsally over the nape and future soft dorsal fin; melanophores laterally over gut; clustered over anus; postanal pigmentation includes a few punctate melanophores distributed on the finfold and radiating towards the midline along the myosepta.[7]

12.4–13.4 mm TL. Dorsum of cranium with several large clusters of melanophores; dorsum of body from midsoft dorsal fin to soft dorsal insertion with scattered stellate melanophores; laterally, subdermal melanophores over stomach, and cutaneous melanophores over anal fin; ventrum with melanophores in interpelvic area, from the stomach to the anus; several pairs of melanophores from anus to mid-caudal peduncle.[7]

13.4–15.7 mm TL. Dorsum of cranium with several large clusters of melanophores; dorsum of body from midsoft dorsal fin to soft dorsal insertion with scattered stellate melanophores; laterally subdermal melanophores over stomach, and cutaneous melanophores over anal fin; ventrum with melanophores in interpelvic area, from the stomach to the anus; and forming several pairs of melanophores from anus to mid-caudal peduncle.[7]

JUVENILES

See Figure 142

Size Range
17.5–45 mm TL.[7]

Fin Development
Branchiostegal rays; 6,6[2,4,5,7] dorsal fin spines/rays (X–XI)–XIII/11–(12–14);[2–5,7,9] pectoral fin rays 14–(15)–17;[2–5,7] pelvic fin spines/rays I/5;[2–5,7] anal fin spines/rays II/7–(8–9);[2-5,7,9] caudal fin rays vii–xi, 8-9+7-8, vi-ix[7] or 14–17.[4]

Morphology
17.5 mm TL. Supraorbital, infraorbital, lateral, and subtemporal head canals form; caudal fin emarginate;[7] infraorbital, lateral, and supratemporal head canals not interrupted, preoperculomandibular canal complete with 10 pores, infraorbital pores 7.[3,5]

>17.5 mm TL. Squamation complete; cheek, opercle, and breast naked, nape is completely scaled.[2,3,8]

Lateral line scales 43–54[7] or 46–62.[2–5,9]

Morphometry
See Table 151.[7]

Pigmentation
17.5 mm TL. Similar to previous length interval with the exception of the mid-dorsal melanophores extending from the mid-spinous dorsal fin posteriorly to the caudal peduncle; laterally melanophores from midanal fin to caudal peduncle; a vertical line of melanophores in epaxial and hypaxial caudal fin base; ventrum of belly from the pelvic fin tips to the anus with several melanophores along mid-line; scattered melanophores from midanal fin to mid-caudal peduncle; a cluster of melanophores occur from the anal fin insertion along the mid-ventrum to the caudal peduncle.[7]

TAXONOMIC DIAGNOSIS OF YOUNG SWANNANOA DARTER

Similar species: members of subgenus *Poecilichthys*
Adult. The *E. thalassinum* species group previously consisted of three species; *E. thalassinum, E. inscriptum,* and *E. swannanoa.*[5] The swannanoa darter is most similar to *E. inscriptum* which has more green on the body, and to *E. thalassinum,* which has 7 rather than 6 dorsal saddles. The species is distinguished from the rest of the subgenus by possessing breeding tubercles on males; nape and belly scaled; cheek, opercle, and breast naked; dorsal spines 12; anal fin rays 8–9; lateral line scales 46–62; infraorbital pores 8; and preoperculomandibular pores 10.[3,5]

Larva. The larval stages of *E. swannanoa* are most similar to other members of the *E. variatum* species group rather than *E. inscriptum*. The species can be differentiated from *E. inscriptum* based on the absence of dorsal pigmentation, greater preanal (17–22) and total (mean = 43.6) myomere counts. The larval stages of *E. swannanoa* possess the characteristic mid-ventral, postanal pigmentation, small pectoral fins, and tapered yolk-sac shape of other members of the subgenus *Poecilichthys*. It can be separated from other members of the subgenus by the yolk-sac pigmentation, precocious development of cranial and lateral pigmentation, and presence of subdermal pigmentation over the dorsal gut.[7]

Variation
No intraspecific variation is observed among the swannanoa darters from Walden Creek. *Etheostoma swannanoa* possess more preanal myomeres than other members of the *E. thalassinum* species group. Ontogenetic development is consistent with other members of the subgenus *Poecilichthys*.[7]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 143)
Eggs. Eggs sites include flowing pool habitats over algal mats or aquatic macrophytes with gravel substrates in slight to moderate current.[7]

Yolk-sac larvae. Aquarium observations indicate swannanoa darter larvae were pelagic immediately after hatching.[7]

Post yolk-sac larvae. Larvae and early juveniles utilized the downstream pools and backwater areas adjacent to spawning areas as nursery habitats. All length intervals, less than 14 mm, were collected by surface dip-net sampling from pools of Walden Creek, Sevier Co., TN. Larvae were associated with abundant rooted aquatic macrophytes in early May becoming demersal only at lengths greater than 15.4 mm, at which time they remain in close association with the substrate.[7]

Juveniles. Juveniles, greater than 17.5 mm TL are the smallest individuals found on the margins of the riffle and flowing pool habitat in an unnamed tributary to Walden Creek.[7]

Early Growth (see Table 153)
Rapid growth is exhibited with lengths of 45 mm attained by Age 1 and apparent sexual maturity.[4]

Feeding Habits
Unknown.

Table 153

Average calculated lengths (mm TL) of young swannanoa darter in Tennessee.[4]

	Age		
State	1	2	3
Tennessee[4]	45		<96

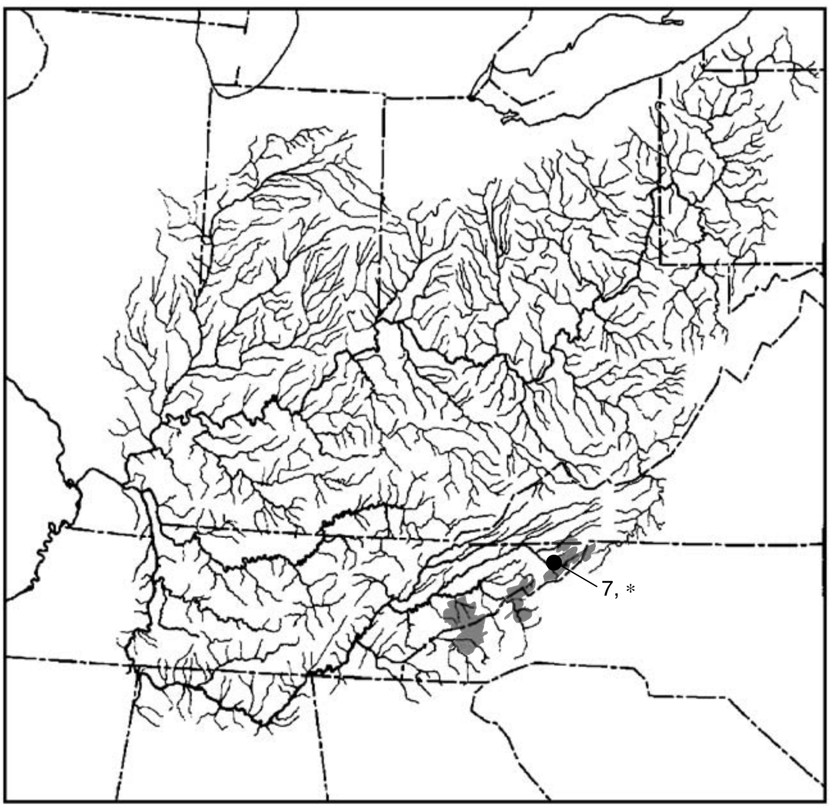

Figure 143 Distribution of swannanoa darter, *Etheostoma swannanoa* in the Ohio River system (shaded area).

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Material Examined: TN: Sevier Co.: Paint Creek, at Paint Creek Recreation Area, TV 762 (2). Walden Creek, at Wears Valley, TV 2603 (2); TV 3095 (2); TV 3096 (5); TV 3096 (8 eggs); TV reference specimens (14); TV 2604 (22). Unnamed tributary Walden Creek, below Cove Mountain Road, TV uncatalogued (16).

* Original fecundity data for swannanoa darter from Walden Creek, Sevier County, TN. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe. Early life history developmental series cultured from TVA laboratory spawned specimens curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

TIPPECANOE DARTER

Etheostoma (*Nothonotus*) *tippecanoe* Jordan and Evermann

Etheostoma: various mouths; *tippecanoe*: after the Tippecanoe River, IN, the type locality.

RANGE

Etheostoma tippecanoe is widely ranging and disjunct in the Ohio River basin from the Allegheny River, PA to the Tippecanoe River, IN; southward to the middle Cumberland River, Duck River, and upper Tennessee River, TN and VA.[1–11]

HABITAT AND MOVEMENT

Etheostoma tippecanoe usually inhabits riffle areas of medium- to large rivers or large creeks adjacent to large rivers. Occurs in moderate current, over clean gravel substrates, at depths of 10–50 cm;[2] In KY and OH; prefers long riffles; slow to moderate current, over clean sand, gravel, and rubble substrates;[3] Taken during all months of the year; moves but slightly deeper into the substrate of the same riffle during the winter months.[11]

DISTRIBUTION AND OCCURENCE IN THE OHIO RIVER SYSTEM

Etheostoma tippecanoe is sporadic to common; several populations decimated; Allegheny drainage, PA;[1] maybe reduced to Big Darby and Deer Creeks in the Scioto River basin, OH;[3] occurs in the Tippecanoe River and lower White River, IN;[*,11,12] discovery of the species in the Kentucky, Green, Cumberland, and Tennessee River basins did not occur until after World War II. Coarse mesh seines used in strong current impinges individuals, causing records to be variable;[2] due to their small size, often may be overlooked causing rarity to be an artifact of sampling procedures.[11]

SPAWNING

Location

Spawn at a depth of 350 mm, in a riffle run with swift current adjacent to macrophyte growth;[6] eggs attach to any firm substrate that prohibits further burial.[7,8] *Etheostoma tippecanoe* belongs to the egg burierguild.[6] Spawning occurs beneath the substrate, and eggs are attached to firm objects.[8,11]

Season

Spawning occurs in the Tippecanoe River, Pulaski County, IN, during June.[8] Ovarian stage, Gonadal somatic index, nuptial coloration, and tuberculation indicate a single reproductive season from mid-June until late-July,[11] and during July in the Green River, Green County, KY.[6]

Temperature

Spawning begins at temperatures ranging from 24 to 27°C;[6] field observations found daytime water temperatures range 23–27°C.[11]

Fecundity (see Table 154)

Gonadal somatic index average 965; three size classes of ova exist; class 1 and 2 eggs numbered between 1–58 and 0–72, respectively; class 3 ova ranged between 55 and 236. No correlation observed between numbers of mature ova (class 1) and adjusted body weight nor between mature ova and standard length.[6] Ovarian eggs matured in batches of about 3-5 ova.[11] In the Tippecanoe River, clutch size ranged from 15 to 152 mature oocytes and average 84.3. Larger females produce larger clutches (r = 0.01; P<0.01).[11] Female *E. tippecanoe* from the Clinch River did not show statistically significant increase in fecundity with increase in length. Females 29–33 mm collected in early June and late July had 19–52 large mature ova.*

Sexual Maturity

Males and females are sexually mature at age 1. Females mature at lengths between 21.2 and 27.2 mm, while males mature between 22.5 and 30.8 mm.[6,11]

Spawning Act

Etheostoma tippecanoe is an egg clumper. The Tippecanoe darter is polygamous, exhibiting male polygyny and female polyandry. Males establish territories around cobble or large gravel. The dominant male excavates a cavity beneath a rock without any apparent entrance or exit. The female when ready to spawn approaches the guarded territory,

Table 154

Fecundity data for Tippecanoe darter from the Clinch River, Tennessee River drainage, Scott Co., VA, and Big Darby Creek, Scioto River drainage, Pickaway Co., OH.

		Number of Ova			
Length (TL)	Ovary weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
33	65.1	434	65	49	1.25
33	38.4	354	61	52	1.05
29	19.8	205	28	19	1.11
33	13.2	413	67	0	0
33	15.2	392	56	0	0
33	13.3	442	62	0	0
32	12.5	386	67	0	0
31	2.9	184	25	0	0

The male is intensely territorial, guarding an area around a rock (even when removed), where eggs are laid in 8–46 cm depths in either the heads or tails of riffles.[11] In turbid runoff conditions, the species abandons territories more readily than other darters.[3] A male may excavate a cavity beneath one of the large rocks. Subsequent observations revealed that females buried themselves completely in the gravel during egg-laying, often to depths of 350 mm, and the male remained above the gravel directly over them.[11] Egg masses are clustered together, but not in a grape-like adhesive cluster as in other *Nothonotus*.[8] Spawning territories are guarded exclusively by the males.[8] Courting consists mainly of an intensely colored male making a lateral display, which leads the female into the cavity. One such observation is of male that was brilliant orange on the side and dark orange with dark blue breast. The male and female both burrowed to the bottom of the aquarium. The female arched her body and deposited 3–4 eggs in a small cluster. The male, usually positioned laterally alongside the female, raised his head, and arched his caudal peduncle pressing his genital papilla downward, quivering and extruded milt for a few seconds. Unlike other burying species that move through the substrate while depositing eggs, the Tippecanoe darter usually remains in a stationary position and only moves slightly from a central location. Spawning occurs over an extended period of time, in short bursts of 5 s vibrations. A total of 3–4 eggs are laid during any single spawning event. The eggs may be layered and tend to be concentrated in the furthest portion of the cavity.* Females spawn with the dominant male that is able to defend a territory. None of the females spawn with a nondominant male, although a nest cavity was constructed. The nondominant male never attempts to "sneak" into the nest cavity nor is he ever observed attempting to fertilize the eggs in the burrowed position. The movement of the female was often below the substrate and movement was laterally, submerged from beneath the stone. Spawning was only observed between a single male and a single female, but there were several occasions when a male was observed with more than a single female beneath the stone in the nest cavity. Parental care is not provided, rather only the nest cavity and territory are guarded.*[,11]

EGGS

Description

Ovarian examination of Clinch River, VA, and Big Darby, OH, specimens show that ovoid, cream colored, latent ova range from 0.2 to 0.36 mm; early maturing; small, spherical, light yellow colored ova range from 0.66 to 0.71 mm; large mature, orange colored ova ranged from 1.05 to 1.11 mm.* Mature ova are demersal, adhesive, and spherical; possess a single oil globule, a narrow perivitelline space, and an unsculptured chorion.[7,8,11] Green River eggs average 1.4 mm in diameter;[6] while eggs from the Tippecanoe River eggs average 1.4 mm and ranged between 1.2 and 1.5 mm in diameter.[8,11] Eggs from both areas are transparent and possess amber yolk.[8,11] Eggs spawned by a single female from seven clutches have a much narrower range from 1.3 to 1.4 mm diameter, with a mean of 1.35 mm.[11]

Incubation

Eggs cultured in laboratory aquaria at 22°C hatched after 144–168 h;[8] hatched in 9 days at 24.5°C.[6]

Laboratory- spawned clutches hatch 144–168 h at 22–23°C; 110–124 h at 24–25°C.[11]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 144

Size Range
Newly hatched at 3.8; yolk absorbed by 5.0 mm TL, IN; [7] 5.05–5.12 mm TL newly hatched KY.[6]

Myomeres
Predorsal myomeres 5; preanal 15-16, postanal 18-19; 33-35 total.[7]

Morphology
3.8 mm SL. Pale yellow, translucent yolk, small (26.7% SL) oval yolk sac; cranium anteriorly enlarged extending beyond the snout; eyes spherical; a single mid-ventral serpentine vitelline vein, originated at the single anterior oil globule and proceeded mid-ventrally along the yolk sac; head not deflected over the yolk sac; jaws developed.[7]

3.9–4.8 mm TL. Body laterally compressed; head small with stomodeum becoming functional jaws.*

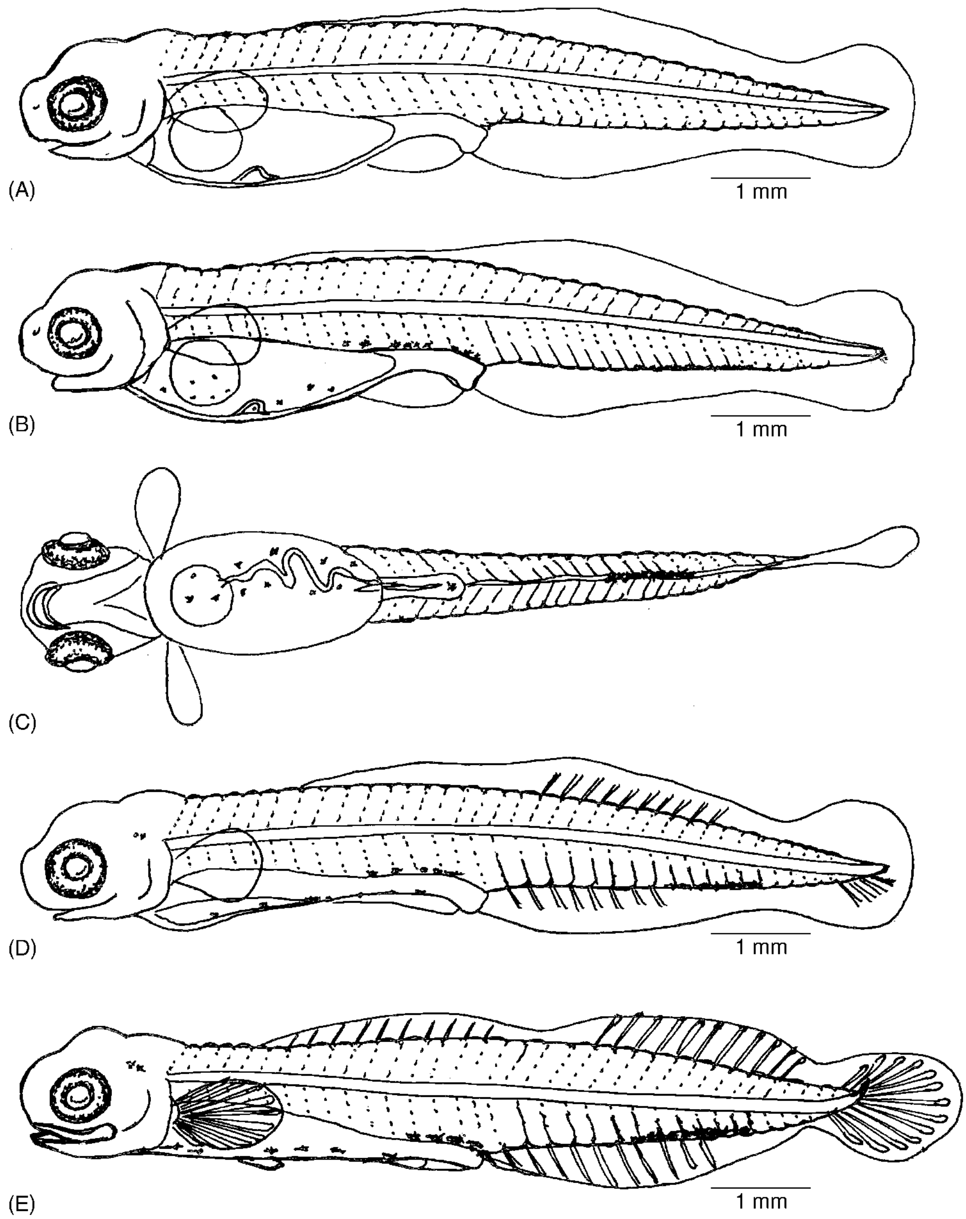

Figure 144 *Etheostoma tippecanoe*, Tippecanoe darter, Tippecanoe River, IN. Newly hatched yolk-sac larva, 3.8 mm TL, (A) lateral view; yolk-sac larva 4.8 mm TL, (B) lateral view, (C) ventral view. Post yolk-sac larva, 5.4 mm TL, (D) lateral view. Post yolk-sac larva 7.4 mm TL, (E) lateral view. (From reference 11, with author's permission.)

Morphometry
See Table 155.

Fin Development
See Table 156.

3.8–4.8 mm SL. Incipient median finfolds complete; pectoral fins well developed; no incipient fin rays in any median of paired fin.[7]

4.9 mm TL. Soft dorsal and anal finfolds contain the rudiments of 10 and 8 incipient rays, respectively.[7]

Pigmentation
3.8–4 mm SL. Melanophores distributed on the oil globule; dorsally on gut, ventral anus, first 14 hypaxial postanal myosepta and outlined the vitelline vein; ventral cluster of melanophores diagnostic of subgenus *Nothonotus* over future anal fin.[7]

4.8–5 mm TL. melanophores increase on the posterior part of the abdomen over the gut; chromatophores on the underside of the yolk sac outline the S-shaped vitelline vein curves. Melanophores increasing over future anal fin position.[11]

POST YOLK-SAC LARVAE

See Figure 144

Size Range
Yolk absorbed post 5.0[7]–15 mm TL.*

Myomeres
Predorsal 5; preanal 15–16, postanal 18–19; 33–35 total.[9]

Morphology
5.0 mm SL. Yolk absorbed; digestive system functional.[7]

Morphometry
See Table 155.

Fin Development
See Table 156.

5 mm SL. Soft dorsal and anal finfolds contain the rudiments of 10 and 8 incipient rays, respectively.[7]

5.4 mm TL. Incipient soft dorsal, anal, and caudal fin rays form;[11] pectoral and spinous dorsal fins without fin rays; no pelvic fin bud; median finfolds not differentiated.[11]

7.4 mm TL. Adult complement of fin spines and rays form in all median and paired fins. Pelvic fin bud formed, median finfolds partially differentiated.[11]

8 mm TL. Pelvic fin forms and pelvic finfold differentiated.[11]

Pigmentation
5 mm TL. Similar to previous length interval.[7]

5.4 mm TL. Melanophores present posterior of the eye, on the breast, and dorsal and ventral portions of the gut near the anus; cluster of melanophores posterior anal fin insertion.[11]

7.4 mm TL. Melanophores extend ventrally from the last several anal fin rays to caudal peduncle; melanophores dorsally over the gut extend onto anal fin origin; outline hypaxial myosepta dorsally to notochord from first anal spine to caudal peduncle.[11]

8 mm TL. A few more melanophores present on the posterior part of the abdomen; chromatophores beneath the breast are characteristically arranged in continuous S-shaped curves.[8]

JUVENILES

Size Range
>15.0 mm[*,11] to 21–31 mm TL.[*,6,11]

Fins
Spinous dorsal X–XIV; soft dorsal rays 10–13; pectoral rays 11–14; pelvic spines/rays I/5; anal spines/rays II/7–10.[2,9]

Morphology
Squamation complete by 14 mm TL in IN.

Branchiostegal membranes narrowly connected; snout moderately pointed; nape, cheek, and breast unscaled; opercle scaled; belly unscaled anteriorly and often along midline; total lateral line scales 40–65; total vertebrae 35–37.[9,13]

Morphometry
Unknown.

Pigmentation
23 mm TL. Olive-brown dorsally; yellow-brown laterally; often has a more mottled pattern on female

Table 155

Morphometric data expressed as percentage of HL and TL for young *Etheostoma tippecanoe* from Indiana.[8,*]

	TL Groupings		
Length Range (mm)	**4.0–5.0**	**5.4–8.0**	**14.0**
N	**7**	**5**	**1**
	Mean ± SD (Range)	**Mean ± SD (Range)**	**Mean**
As Percent TL			
SnL	3.8 ± 1.1 (2.8–6.3)	3.3 ± 0.3 (3.0–3.5)	3.4
PEL	12.7 ± 1.6 (7.2–15.3)	6.1 ± 0.3 (5.9–6.3)	6.2
OP1L	20.9 ± 1.3 (15.9–24.1)	17.4 ± 0.3 (17.1–17.6)	17.4
ODL	34.7 ± 2.8 (27.1–46.9)	29.6 ± 1.7 (24.6–33.6)	26.7
PVL	58.7 ± 2.1 (53.4–65.2)	51.3 ± 0.8 (49.2–53.0)	49.8
PCL	105.9 ± 1.1 (102.0–108.4)	94.6 ± 1.1 (88.7–97.0)	88.9
MAXL–Y	26.7 ± 1.2 (24.7–31.5)		
P1L	7.6 ± 0.8 (5.2–9.9)	12.4 ± 0.6 (10.6–13.4)	12.4
HD	16.7 ± 0.9 (13.7–18.0)	14.1 ± 0.1 (14.1–14.2)	14.1
OP1D	20.8 ± 2.3 (14.7–27.8)	13.7 ± 1.0 (12.0–16.4)	13.2
OD1D	22.4 ± 2.7 (14.3–28.2)	12.2 ± 0.2 (12.0–12.7)	12.2
OD2D	10.6 ± 1.2 (8.4–12.0)	10.9 ± 0.2 (10.6–11.2)	10.8
BPVD	10.7 ± 1.5 (8.9–13.0)	9.1 ± 0.1 (9.0–9.2)	9.1
MPMD	9.2 ± 0.7 (7.9–9.7)	5.1 ± 0.1 (4.9–5.2)	5.1
AMPMD	4.7 ± 1.5 (3.1–6.1)	3.6 ± 0.1 (3.5–3.7)	3.5
MAX–YD	16.4 ± 2.2 (8.3–23.1)		
BPEW	16.5 ± 1.2 (12.8–20.7)		
OP1W	13.9 ± 2.0 (9.4–16.8)		
OD1W	17.7 ± 1.8 (10.4–22.4)		
OD2W	8.9 ± 0.9 (6.9–11.1)		
BPVW	9.4 ± 0.9 (6.9–11.6)		
AMPMW	4.4 ± 0.3 (2.4–5.4)		
MAXW–Y	18.1 ± 2.1 (10.4–24.8)		

Table 156

Meristic counts and size (mm TL) at the apparent onset of development for *E. tippecanoe*.

Attribute/Event	*E. tippecanoe*	Literature
Branchiostegal Rays	6,6	6,6[2,9,14]
Dorsal Fin Spines/Rays	XI–XIII/10–13	X–XIV/10–13[2,9,14]
First spines formed	7.4	
Adult complement formed	8.0	
First soft rays formed	4.9–5.3	
Adult complement formed	7.4	
Pectoral Fin Rays	12–13	11–13[2,9,14]
First rays formed	7.0	
Adult complement formed	7.4	
Pelvic Fin Spines/Rays	I/5	I/5[2,9,14]
First rays formed	7.4	
Adult complement formed	15.1	
Anal Fin Spines/Rays	II/7–8	II/ 7–9[2,9,14]
First rays formed	4.9–5.3	
Adult complement formed	7.4	
Caudal Fin Rays	vii–xi, 7–9 + 7–8, viii–xi	14–16[14]
First rays formed	5.4	
Adult complement formed	7.4	
Lateral Line Scales	45–56	40–56[2,9,14]
Myomeres/Vertebrae	33–35/35–37	Unknown/38–42[2,9,13–14]
Preanal myomeres	15–16	
Postanal myomeres	18–19	

than male; fins of the female are spotted; median fins without dark margins; male median fins dark basally and margined with a light gold band. Body of the male gold or orange with 4–11 blue-black vertical bars laterally and a blue breast. Both sexes have two prominent yellow or orange spots on the caudal peduncle base.[9]

TAXONOMIC DIAGNOSIS OF YOUNG TIPPECANOE DARTER

Similar species: *E. tippecanoe* is similar to other members of the *Nothonotus* subgenus.

This species can be separated from other *Nothonotus* species by the presence of an enlargement on the anterior cranium. In addition, the species hatches at a smaller length and possesses a distinct pigmentation pattern.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 145)

Eggs. Eggs are adhesive and deposited on impermeable substrates, which impede further burial by the female.[6–8]

Yolk-sac larvae. Larvae remain buried in gravel substrates; they are sensitive to light, which reduces survivorship until post yolk absorption.*

Post yolk-sac larvae. Demersal, remain buried in the interstitial pores of cobble substrates usually on the edges of the riffle.*[,11]

Juveniles. Usually in gentle to moderate currents along the margins of riffles. In the Green River, juveniles occur over shallow currents (0.08–0.15 m), in slower riffle areas.[6]

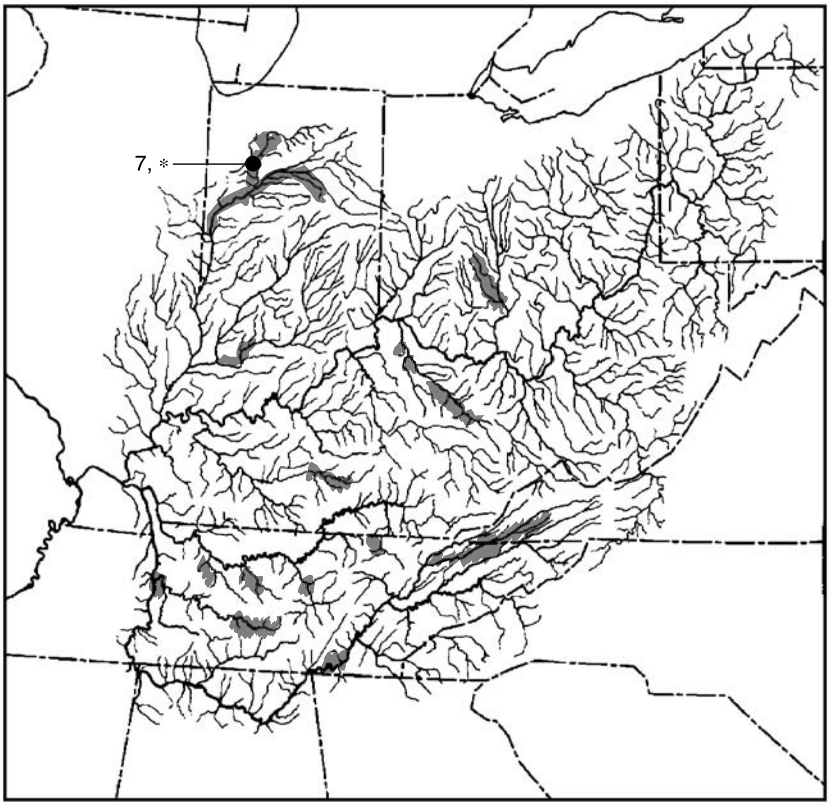

Figure 145 Distribution of Tippecanoe darter, *E. tippecanoe* in the Ohio River system (shaded area) and areas where early life history information has been collected (circle). Numbers indicate appropriate references.

Early Growth
Most of total growth (67%) is achieved within the first 6 months of life. A single specimen, 14 mm TL, collected from the Tippecanoe River, IN, in early August and had full squamation.* In OH, October specimens range between 20 to 28 mm TL.[3] Tippecanoe darters grow at a decreasing rate and males grow faster than females. At 9 months old, males are longer than females, averaging 29.0 and 23.8 mm SL, respectively.[11]

Feeding Habits
Tippecanoe darters are primarily insectivores and invertivores.[11] The majority of the diet of Tippecanoe darter comprises midges and aquatic insects.[10] The smallest darters consume chironomid and ephemeroptera larvae in the greatest numbers and caddisflies and microcrustaceans in a lesser number.[11]

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Material Examined: IN: Carroll County: Tippecanoe River, SR 18 bridge (LRRC uncatalogued)(6); Pulaski County: Tippecanoe River, 2.3 miles S Winamac (LRRC uncatalogued)(7).

* Original fecundity data for tippecanoe darter is from the VA: Scott Co: Clinch River (Tennessee River drainage), HWY 421 bidge at Speers Ferry above CR 645 bridge (3) June 26 1980; RM 211.1 above US 421 bidge at Speers Ferry (1) June 4 1980; OH: Pickaway Co: Big Darby Creek (Scioto River drainage), SR 104 bridge (4), July 22 1976. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe, LA. Early life history developmental series cultured from laboratory spawned specimens from Tippecanoe River. Specimens curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

TUSCUMBIA DARTER

Etheostoma (*Psychromaster*) *tuscumbia* Gilbert and Swain

Etheostoma: various mouths; *tuscumbia*: named in honor of Chief Tuscumbia and after the great spring, the species type locality.

RANGE

Etheostoma tuscumbia inhabits the ponded limestone spring-fed habitats of the southern bend of the Tennessee River in northern AL. The species presence in the adjacent limestone region of MS has not been verified, and it is considered extirpated.[1–6,9]

HABITAT AND MOVEMENT

Etheostoma tuscumbia inhabits well-vegetated areas with clean substrates of fine gravel with clear water quality and temperatures between 15.5 and 17°C. Adults prefer springs with good flow and have not been captured in brooks or springs with slow or intermittent flows.[1–7,9]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma tuscumbia is extirpated from TN, formerly occurred in Big Spring at Dry Creek Cave, Hardin Co., TN, which is now beneath Pickwick Reservoir. In AL, the species survives in at least ten locations but has probably been extirpated from several others.[2–7]

SPAWNING

Location
Spawning occurs in clean gravel where the male and female bury and release eggs in well-oxygenated gravel open areas in slight to moderate current.[7]

Season
Ripe males and females were collected throughout the year since in springs these fish inhabit at constant temperature; however, peak reproduction only occurs between January and March.[7]

Temperature
Spawning activity initiated in January through March, but does not seem to be a relationship with temperature since constant conditions between 15.5 and 17°C occur throughout the year in Buffler Spring, Lauderdale County, AL.[7]

Fecundity (see Table 157)
Gravid females have 40–100 ova depending on body size.[7] Our data suggest that females have between 53 and 106 large ova in early April. The low gonadosomatic index suggests that either the females had already begun spawning or that ovaries never get as large as other darter species. This is possibly a result of the constant spring temperatures.*

Table 157

Fecundity data for Tuscumbia darter from Tuscumbia Spring, Colbert Co., AL.*

			Number of Ova			
Date	TL (mm)	GSI	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
April 2	47	8.4	200	37	106	1.00
	45	4.7	163	20	53	0.90
	44	3.7	140	42	65	1.00

Sexual Maturity
Adults live to reach age 3,[2,7] however, maturity is suspected to be at age 1.[2] An adult male (54.7 mm TL) from AL had testes that were 1.26% of the body weight on March 24.* Male tuberculation is absent and females have a long tubular genital papilla.* Males do not exhibit sexually dimorphic traits during the reproductive season, with the exception of the genital papillae from the cloacal pad, while females have distended abdomens and a long tubular genital papilla.* In AL, females 44–47 mm TL were mature.*

Spawning Act
The reproductive mode of *E. tuscumbia* is a burier.[2,3,*] In aquarium observations, the male displays lateral and erect spinous dorsal fins to potential female mates. An interested female aligns her body laterally to the male. The male follows the female to the egg site, usually an open gravel area, and with the male mounted on the back of the female and their vents juxtaposed, the female presses her body into the gravel and buries her vent, depositing eggs as the male fertilizes the eggs.* Adults maintain a head-to-head orientation with vents juxtaposed and pressed into the substrate. Eggs are laid individually or at the most in groups of 2–3 eggs. No parental care was provided before or after the eggs were laid.*

EGGS

Description
Eggs from Buffler Spring, Lauderdale County, AL, are spherical, mean = 1.2 mm diameter (range: 1.0–1.5 mm); translucent; demersal; and nonadhesive. Eggs possess translucent, orange yolk (mean = 1.1 mm diameter; range: 0.9–1.4 mm), a single oil globule (mean = 0.5 mm), a narrow perivitelline space (mean = 0.1 mm), and an unsculptured and unpigmented chorion.*

Incubation
Hatching occurs after 120 h at an incubation temperature of 17°C.[2,7]

Development
Unknown.

YOLK-SAC LARVAE

Size Range
AL populations from Buffler Spring, Lauderdale Co., hatch at 4 mm and absorbs their yolk sac by 6.4 mm TL.[7]

Myomeres
Preanal 16 (N = 2); postanal 22 (N = 2); total 38.[7]

Morphology
4.0 mm TL (newly hatched). Body terete; snout blunt, with nonfunctional jaws, upper jaw even to lower jaw; developed pectoral fins without incipient rays; yolk sac moderate (27.4% TL); oval to tapered posteriorly; yolk translucent pale orange, with a single oil globule; single serpentine vitelline vein midventrally on yolk sac; head not deflected over the yolk sac; eyes oval.[*,7]

5.2–6.4 mm TL. Digestive system function; yolk mostly absorbed; operculum and gill arches function; premaxilla and mandible form.[7]

Morphometry
Unknown.

Fin Development
4.0–6.4 mm TL. Well-developed pectoral fins without rays evident.[7]

Pigmentation
4.0–6.4 mm TL (newly hatched). Eye pigmented; melanophores absent dorsally over posterior cerebellum or nape; melanophores distributed laterally absent; ventral pigmentation consists of mid-ventral paired series of punctate melanophores forming a band near the vitelline vein on the yolk sac and punctate melanophores along every mid-ventral postanal myosepta.[7]

POST YOLK-SAC LARVAE

Size Range
6.4 mm TL[7] to unknown lengths.

Myomeres
No information.

Morphology
No information.

Morphometry
No information.

Fin Development
No information.

Pigmentation
No information.

JUVENILES

Size Range
Unknown to 44 mm TL in AL.*

Fins
Larger juveniles: Spinous dorsal VIII–XI, soft dorsal 11–14; pectoral rays 10–13; anal rays I 7–9; pelvic rays I 5; caudal rays 15–16.[2–5,7]

Morphology
Total vertebrae count range between 35 and 37.[2–5,7] Scales in the lateral series incomplete with about 15–30 pored scales and mean scales 37–51.[2–5,7]

Morphometry
No information.

Pigmentation
No information.

TAXONOMIC DIAGNOSIS OF YOUNG TUSCUMBIA DARTER

Similar species: member of monotypic subgenus *Psychromaster.*[2–4]

Adult. *Etheostoma tuscumbia* is limited to the southern bend of the Tennessee River. *Etheostoma tuscumbia* has a well-scaled head and additional scales on the cheeks, which separate it from *E. crossopterum, E. neopterum, E. parvipinne,* and *E. nigripinne.*

No intraspecific variation of *E. tuscumbia* could be studied due to limited availability of material. The species differs from *E. squamiceps* species complex in myomere count modes, yolk-sac size and shape, and pigmentation. All other members of the *E. squamiceps* species group have large spherical yolk sacs; lower preanal (mode 15) myomeres counts than *E. tuscumbia*; while the mode for postanal myomeres overlapped with other taxa (22). The shape and absorption of the yolk sac is similar to other *Etheostoma.**

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 146)
Eggs. Egg sites include the open areas of high volume spring flows where they are buried in clean gravel substrates in slight to moderate current.[2,7]

Yolk-sac larvae. Aquarium observations indicate tuscumbia darter yolk-sac larvae are pelagic immediately after hatching; capable of rising 100 mm into the water column.*

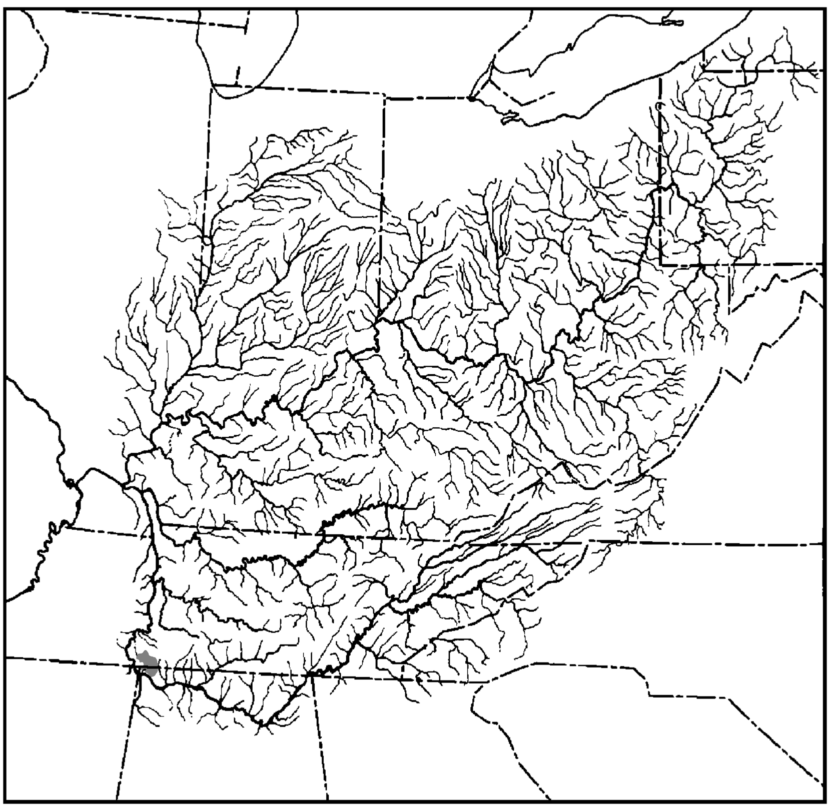

Figure 146 Distribution of tuscumbia darter, *E. tuscumbia* in the Ohio River system (shaded area).

Post yolk-sac larvae. No information.

Juveniles. Tuscumbia darters are demersal; juvenile darters are collected from beneath algal mats and aquatic vegetation (*Nasturtium* and *Myriophyllum*) in run habitat usually over gravel substrates.[2,*]

Early Growth (see Table 158)
Etnier and Starnes[2] and Koch[7] reported Tuscumbia darters surviving 2 to 3 years, with age 1 fish averaging 30 mm at first reproduction. Larvae grow 2 mm in their first 10 days of life.[2]

Feeding Habits
Koch reported juveniles having a large niche breadth.[7,8] The diet of Tuscumbia darters include a large percentage of spring invertebrates including amphipods, physid snails, and midge larvae, and lesser numbers of isopods and small crayfish.[8] Feeding occurs primarily between April and June and minimally from December to February.[7,8]

Table 158

Average calculated lengths (mm TL) of young Tuscumbia darters in Alabama.

	Age		
State	**1**	**2**	**3**
Alabama[7]	30	45–54	65

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* Original fecundity data for Tuscumbia darter from Tuscumbia Spring, Colbert County, AL. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe, Louisiana. Original data from T.P. Simon, unpublished.

VARIEGATE DARTER

Etheostoma (*Poecilichthys*) *variatum* Kirtland

Etheostoma: various mouths; *variatum*: variegated.

RANGE

Etheostoma variatum occurs in the Ohio River basin above the Falls of the Ohio, from the Whitewater River and Blue River, IN;[1–4] throughout the upper Kentucky and Licking Rivers, KY.[5] It occurs in the Kanawha River, WV, below the falls, northward into French Creek and the Allegheny River drainage, PA,[6] into tributaries of the Allegheny River, NY,[7] and Monogehala Rivers, WV.[2,3] The species is considered by many ichthyologists to be virtually identical to *E. tetrazonum*, and could be considered an allopatric subspecies rather than a distinct species. The most recent common ancestor had a widespread preglacial distribution from the upper Teays system westward to the lower Missouri system.[8] Absence of this species from the Wabash, Green, and Tennessee River systems indicate that the most recent common ancestor was not present in the preglacial Ohio or Tennessee Rivers and did not utilize the lower Ohio River in its dispersal.[8]

HABITAT AND MOVEMENT

The variegate darter inhabit moderate- to high-gradient, clear, large streams to moderate-sized rivers draining the western Allegheny and Interior Plateau. Adults prefer unsilted riffles with coarse sand or fine gravel with large boulders,[6] and clean glacial rubble and boulders.[9]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma variatum occurs in the Ohio River basin above the Falls, from the Whitewater River and Blue River, IN;[1–4] throughout the upper Kentucky and Licking Rivers, KY.[5] It occurs in the Kanawha River, WV, below the falls, northward into French Creek and the Allegheny River drainage, PA;[6] into tributaries of the Allegheny River, NY;[7] and Monogehala Rivers, WV.[2,3]

SPAWNING

Location

Spawning occurs in the typical egg-burying reproductive mode with eggs usually buried behind permanent rock outcroppings or boulders.[10]

Season

Spawning occurs from mid-April until mid-May in Big Darby Creek,[11] OH, and late spring in PA.[6] Spawning aggregates of adults assemble over coarse gravel substrates in early February, March, and April.[7]

Temperature

Adults in spawning condition present on the riffles of Big Darby Creek, OH, in March at temperatures of 10°C.[11]

Fecundity

A single 62 mm female collected from Big Darby Creek, Franklin County, OH, had an ovary weight of 121 mg, and 157 small ovoid ova, 81 small spherical ova, an 63 large mature ova. The number of total ova was 301 (T.P. Simon, unpublished data).

Sexual Maturity

Unknown.

Spawning Act

Etheostoma variatum is an egg burier.[10] Eggs are deposited in gravel substrates near rocks or other similar structures. Reproductive behavior is initiated by the female, which swims around the aquarium, pausing in open areas, rising to the water surface and sinking to the bottom. The males in the vicinity become attracted and follow the female to the selected spawning location. The female noses her body into the substrate and remains stationary, at which time the male mounts the female. The pair is observed to remain stationary and vibrate as egg and sperm are released. Aquarium observations from adult brood stock from French Creek, PA, indicate that reproductive behavior is typical of other egg buriers with the release of eggs occurring below the substrate.

The female is not observed to select the spawning location, rather the males establish a territory, usually behind large rocks, and court interested females with lateral displays and erect fins. The female and male swim together into a position behind the rock, with the male mounted on the females back, and the pelvic fins resting on the females spinous dorsal fin. The female, with her vent buried in the gravel, moves in a jerking motion through the gravel depositing eggs, which are concurrently fertilized by the male. The male is thought to be territorial in the defense and establishment of a "preferred" spawning area; however after fertilization of the ova did not provide any parental care to the eggs.[10,11]

EGGS

Description

Ovarian examination of a single female from Big Darby, OH, show that ovoid latent ova were 0.41 mm, early maturing ova average 0.83 mm, and large mature ova averaged 1.33 mm (T.P. Simon, unpublished data). Eggs of the variegate darter from French Creek, PA, mean = 1.9 mm diameter (range: 1.8–2.0 mm) are spherical, translucent, with pale yellow yolk (mean = 1.8, range: 1.7–1.9 mm), demersal, and adhesive. Eggs possess a single, orange oil globule (mean = 0.5 mm), and a moderate perivitelline space (mean = 0.1 mm), and an unsculptured and unpigmented chorion.[10]

Incubation

Eggs hatch in 312–336 h at an incubation temperature of 10–22ºC.[7,11]

Development

Limited information is available for embryonic development.[11]

YOLK-SAC LARVAE

See Figure 147

Size Range

6.9–8.0 mm.[10]

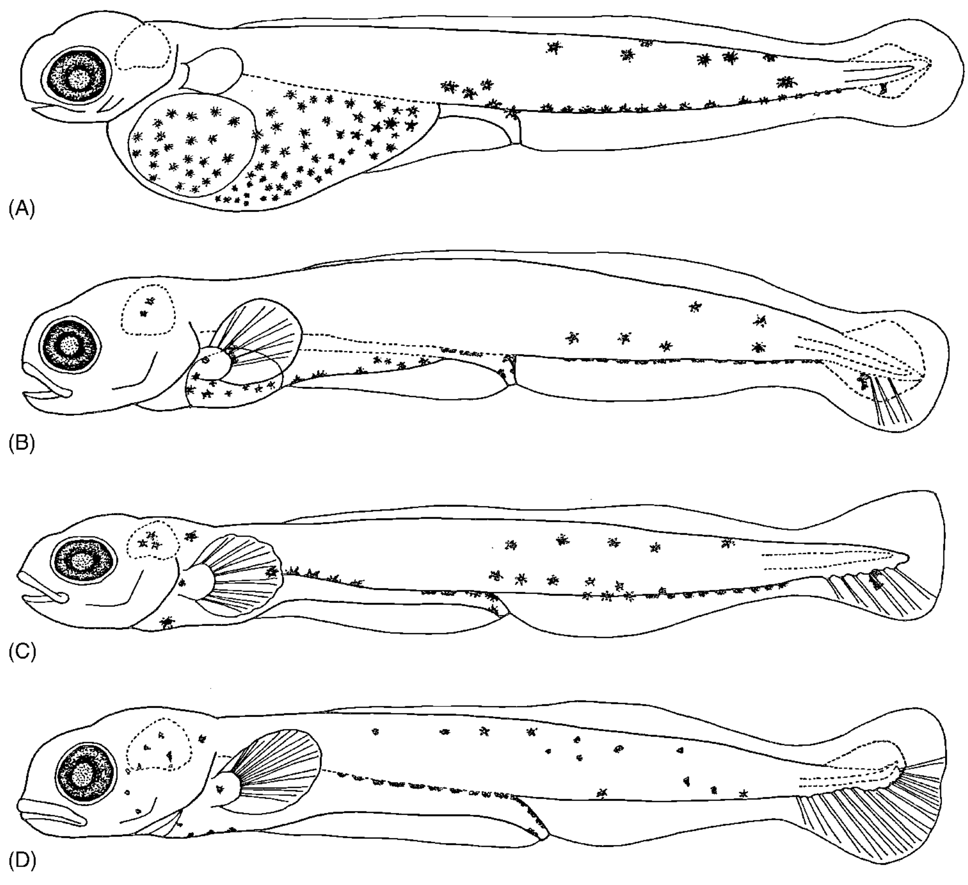

Figure 147 *Etheostoma variatum*, variegate darter, Big Darby Creek, Pickaway Co., OH. Yolk-sac larva, 6.9 mm TL, (A) lateral view. Yolk-sac larva, 8.0 mm TL, (B) lateral view. Post yolk-sac larvae, 8.1 mm TL, (C) lateral view. Post yolk-sac larvae, 9.3 mm TL, (D) lateral view. (A-D from reference 10, with authors permission.)

Myomeres
Preanal 18 ($N = 6$); postanal 22 ($N = 6$); total 40 ($N = 6$).[10]

Morphology
6.9 mm TL. Newly hatched larva with terate body; snout round, with functional jaws; upper jaw extending past lower jaw; yolk sac moderate (21.7% TL), tapered posteriorly; yolk translucent pale yellow, with a single oil globule; single, mid-ventral vitelline vein on yolk sac; head not deflected over the yolk sac; eyes spherical.[10]

7.3 mm TL. Digestive system functional prior to complete yolk absorption.[10]

8.0 mm TL. Premaxilla and mandible form.[10]

Morphometry
See Table 159.

Fin Development
6.9 mm TL. Newly hatched larva with pectoral fins present without incipient rays.[10]

Pigmentation
6.9 mm TL. Newly hatched larva with pigmented eyes; no melanophores dorsally; laterally, melanophores at the base of the anus near the connection of the gut with the body; mid-lateral melanophores in epaxial portions of the musculature from the anus to the caudal peduncle; ventrally, scattered, stellate melanophores cover the entire yolk sac; on the ventral portion of the gut at the anus; mid-ventral melanophores at most postanal myosepta; a cluster of melanophores near the future anal fin insertion to the mid-caudal peduncle.[10]

8.0 mm TL. Melanophores laterally found in the epaxial and hypaxial musculature near the mid-line from the anus to the caudal peduncle; melanophores dorsally over the gut; and outline the notochord terminus.[10]

POST YOLK-SAC LARVAE

See Figure 147

Size Range
8.1 mm[10] to unknown length.

Myomeres
Preanal 18 ($N = 6$); postanal 22 ($N = 6$); and total 40 ($N = 6$).[10]

Morphology
8.1 mm TL. Operculum and gill arches are functional; and yolk is absorbed (8.0 to 8.1 mm).[10]

9.2–9.3 mm TL. Notochord flexion proceeds caudal fin ray formation.[10] No swim bladder formed; gut straight, without striations; portion of gut posterior to stomach normal in length.[10]

>9.3 mm TL. Due to limited study material, indication of when the spines of the dorsal fin form and the sequence of other ontogenetic events is not determined, except that occurrence is at lengths greater than 9.3 mm.[10]

Morphometry
See Table 159.[10]

Fin Development
8.1 mm TL. First rays simultaneously form in pectoral, branchiostegal, and caudal fins.[10]

9.3 mm TL. Soft dorsal and anal rays begin to form;[10] dorsal and anal finfolds partially differentiated (9.3 mm).[10]

8.1–9.3 mm TL. Spinous dorsal fin origin situated over preanal myomere 5, soft dorsal at myomeres 20–22 (8.0–9.3 mm):[10] Average predorsal length 28.7% SL (range: 23.4–32.9% SL) and 27.6% TL (range: 22.3–30.7% TL).[10]

>9.3 mm TL. Due to limited study material, indication of when the spines of the dorsal fin form and the sequence of other ontogenetic events is not determined, except that occurrence is at lengths greater than 9.3 mm.[10]

Pigmentation
8.1–8.3 mm TL. Similar to previous length interval, with exception of ventrally, melanophores present mid-ventrally on breast, concentrating in the throat region.[10]

9.0–9.3 mm TL. Melanophores present laterally on the cranium, several over the otic capsule and on cheek; scattered mid-laterally along the midline, and dorsally from the stomach to the anus; ventrally covering the mid-ventral postanal myosepta and at the base of the hypural plate.[10]

Table 159

Morphometry of young *E. variatum* grouped by selected intervals of total length (*N* = sample size).[10]

	Total Length (TL) Intervals (mm)			
	7.14–8.10 (*N* = 4)		9.24–9.32 (*N* = 2)	
Characters	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
Length (% of TL)				
Upper jaw[a]	32.6 ± 15.9	(0.27–0.82)	38.0 ± 14.8	(0.50–0.94)
Snout[a]	16.4 ± 3.73	(0.18–0.28)	22.8 ± 4.24	(0.36–0.50)
Eye diameter[a]	34.5 ± 3.77	(0.45–0.52)	28.4 ± 8.06	(0.44–0.62)
Head	17.8 ± 1.14	(1.18–1.55)	20.3 ± 0.99	(1.82–1.94)
Predorsal	26.0 ± 3.21	(1.59–2.27)	30.7	(2.86–2.86)
Dorsal insertion			25.6 ± 36.2	(0.00–4.77)
D2 origin			27.5 ± 38.9	(0.00–5.13)
D2 insertion			38.3 ± 54.2	(0.00–5.13)
Preanal	53.2 ± 0.34	(3.82–4.30)	51.9 ± 2.43	(4.64–5.00)
Postanal	46.8 ± 0.36	(3.32–3.83)	48.1 ± 2.40	(4.32–4.60)
Standard	96.8 ± 1.27	(6.80–7.89)	95.0 ± 2.69	(8.68–8.95)
Yolk Sac	21.7 ± 14.8	(0.91–2.30)		
Fin Length (% of TL)				
Pectoral	9.88 ± 2.42	(0.45–0.91)	12.3 ± 1.56	(1.04–1.25)
Pelvic				
Spinous dorsal			20.5	(1.91–1.91)
Soft dorsal			21.5	(2.00–2.00)
Caudal	3.23 ± 1.27	(0.13–0.34)	5.00 ± 2.69	(0.29–0.64)
Body Depth (% of TL)				
Head at eyes	11.3 ± 1.76	(0.77–1.10)	13.4 ± 1.27	(1.16–1.32)
Head at Pl	14.9 ± 3.66	(0.95–1.36)	12.9 ± 1.13	(1.12–1.27)
Preanal	7.54 ± 0.47	(0.57–0.64)	8.35 ± 0.14	(0.76–0.79)
Mid-postanal	6.09 ± 0.44	(0.45–0.52)	6.87	(0.64–0.64)
Caudal peduncle	3.05 ± 0.98	(0.18–0.36)	3.99 ± 0.14	(0.36–0.38)
Yolk sac	9.74 ± 5.09	(0.50–0.95)		
Body Width (% of HL)				
Head	58.3 ± 6.58	(0.75–0.88)	54.2 ± 0.57	(0.98–1.06)
Myomere Number				
Predorsal	6.00 ± 0.00	(6.00–6.00)	6.00 ± 0.00	(6.00–6.00)
Soft dorsal	18.0	(18.0–18.0)	18.0	(18.0–18.0)
Preanal	18.0 ± 0.00	(18.0–18.0)	18.0 ± 0.00	(18.0–18.0)
Postanal	22.0 ± 0.00	(22.0–22.0)	22.0 ± 0.00	(22.0–22.0)
Total	40.0 ± 0.00	(40.0–40.0)	40.0 ± 0.00	(40.0–40.0)

[a] Proportion expressed as percent head length.

Note: Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

JUVENILES

Size Range

Unknown.

Fins

Branchiostegal rays 6,6;[2,3,7,9,10] dorsal fin spines/rays XI–(XII)–XIII/(12–13)–15;[2,3,6,7,10,12,14,16] pectoral fin rays 14–(15)–16;[2,3,7,9,10,12] pelvic fin spines/rays I/5;[2,3,7,9,10] anal fin spines/rays II/8–(9)–10;[2,3,6,7,10,12,14,16] caudal fin rays ix–xi, 9 + 8, viii–x.[10]

Morphology

>19 mm TL. Adult complements of fin rays completely formed six weeks after hatching when juveniles resembled adults (possibly 19 mm).[11]

Adult development relevant to juvenile stages include the head canal and squamation patterns. Infraorbital, lateral, supratemporal, and preoperculomandibular canals complete; infraorbital with 6–9 pores (usually 8), preoperculomandibular pores 7–11 (usually 10), lateral canal pores 5.[3,12] Squamation consists of a naked cheek; scaled opercle, nape, breast, and belly.[2,3,12] Lateral line scales 56–59[10] or 48–60[2,3,6,7,9,12,14,16] and vertebrae 40 to 41.[2,3,9,10,15]

Morphometry
Unknown.

Pigmentation
Unknown.

TAXONOMIC DIAGNOSIS OF YOUNG VARIEGATE DARTER

Similar species: *E. variatum* is a part of the *E. variatum* species group of the subgenus *Poecilichthys*, no designated subspecies are recognized.[12]

The variegate darter is distinguished from other saddle darters based on four distinct dorsal saddles, cheeks unscaled, a blunter snout, and 48–60 lateral line scales.[2,12] It is differentiated from other members of the subgenus *Poecilichthys* by possessing breeding tubercles on both sexes, unscaled cheek, variably scaled opercle, scaled nape, breast, and belly, dorsal spines usually 12–13, anal rays 9–10, infraorbital canal pores 8, and preoperculomandibular pores 10.[3]

Larva. The variegate darter becomes the type species for the resurrected subgenus *Poecilichthys* since the subgenus *Etheostoma* is paraphyletic. The species is distinguished from all other known members of the *E. variatum* species group based on myomere count differences and pigmentation. Despite negligible differences in lateral line scale counts, *E. tetrazonum* and *E. variatum* are virtually identical.[2] Larval characteristics suggest these two are distinct species, since *E. variatum* has lower preanal (17–18) myomere counts than does *E. tetrazonum* (20–22). *Etheostoma variatum* has more pigmentation than either *E. histrio* or *E. rupestre*, and is similarly pigmented midventrally with subspecies of *E. blennioides* and *E. zonale*. Both the variegate darter and each of the subspecies possess numerous scattered melanophores ventrally on the yolk sac. *Etheostoma variatum* differs from the other subspecies of the *E. blennioides* species group in postanal pigmentation, possessing a single midventral cluster of melanophores from the area of the future anal fin insertion to the caudal peduncle base, and possesses additional melanophores at most postanal myosepta and mid-lateral pigmentation.[10]

Variation
Study of the intraspecific variation of *E. variatum* is not conducted due to limited study material. The species is most similar to the Missouri saddled darter; however, can be distinguished by the lower preanal myomere counts and the presence of pigmentation mid-laterally along the postanal myosepta.[10]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 148)
Eggs. Spawning occurs in the typical egg-burying reproductive mode with eggs usually buried behind permanent rock outcroppings or boulders.[10]

Yolk-sac larvae. Variegate darters are pelagic after hatching in aquaria.[12]

Post yolk-sac larvae. Variegate darters were collected in night surface plankton nets from the mainstem Ohio River, ORM 53.9, New Cumberland Pool, probably as a result of high discharge from local streams, during mid-May.[13] Variegate darter densities in mid-May were 0.04/100 m^3.[13]

Juveniles. Juvenile variegate darters between 18–26 mm SL are collected from the edge of shallow riffles (<0.3 m) in slow current.[10] Density of juveniles in late October was 4 individuals/m^3 on Big Darby Creek, Pickwick Co., OH.[10]

Early Growth (Table 160)
Juveniles collected in October from Ohio reached 30–58 mm.[9]

Feeding Habits
Etheostoma variatum generally eat four or more taxa and have the largest diet among darters in French

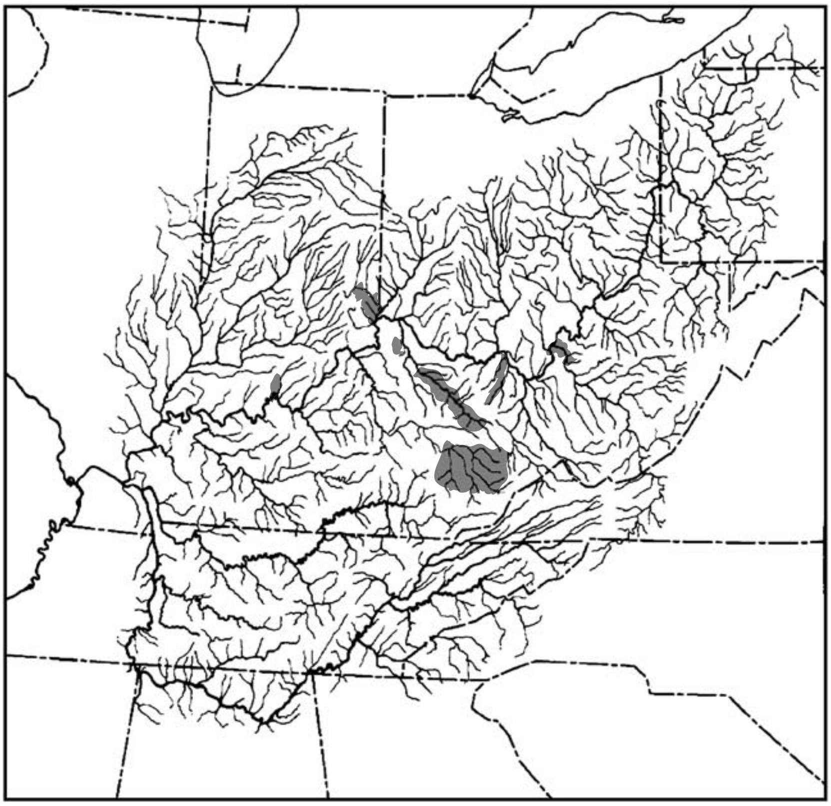

Figure 148 Distribution of variegate darter, *E. variatum* in the Ohio River system (shaded area).

Table 160

Average calculated lengths (mm TL) of young variegate darters in Ohio.

	Age			
State	**1**	**2**	**3**	**4**
Ohio[9]	36–69	79–84	86–94	110

Creek, PA, and consume preys that are generally 3–4 mm.[17] Eat mayflies, caddisflies, and microcrustaceans.[10]

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Material Examined: OH: Jefferson Co.: Ohio River, ORM 53.9, New Cumberland Pool, near Stratton, GM 8341 (2). Pickaway Co.: Big Darby Creek, lower 20 miles, approximately 25 miles SW Columbus, OSM uncatalogued (4).

STRIPED DARTER

Etheostoma (*Catonotus*) *virgatum* (Jordan)

Etheostoma: various mouths; *virgatum*: streaked.

RANGE

Etheostoma virgatum is moderately common in three disjunct populations in the Cumberland River drainage, TN and KY.[1–3]

HABITAT AND MOVEMENT

The preferred habitat of the striped darter is small streams in areas with gentle currents adjacent to riffles, with substrates of sand, gravel, and larger rocks. Migrations occur during March to preferred spawning habitats.[1,2]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma virgatum occurs in the extreme eastern Highland Rim in Rockcastle and adjacent river systems, KY, upper Caney Fork system and Nashville basin from the Stones River system downstream to western Montgomery County, TN.[1–3]

SPAWNING

Location
Underside of rocks and slab rocks in areas with slightly less current.[1,2] Nest typically has a single entrance on the downstream side of the rock.[1,2]

Season
Spawning occurs from mid-April through May.[1,2]

Temperature
Migrations begin at temperatures of 10°C.[1,2]

Fecundity (Table 161)
Females contain about 40 mature ova with ranges between 9 and 93, but nests contain an average of 361 (range: 48–887) eggs.[1,2]

Sexual Maturity
Sexual maturity occurs by age 1, however, age 1 males were not involved in spawning while age 1 and 2 females were.[1,2] Females 36–50 mm TL were mature in TN.*

Spawning Act
Adults deposit their eggs on the underside of rocks or slab rocks where they are guarded by a male. Males construct and defend nests similar to other *Catonotus* in areas with slightly less current.[1,2]

EGGS

Description
Mature eggs are dark orange, spherical;* 2.5 mm in diameter;[1,2] eggs from West Fork Stone River, Rutherford Co., TN* are similar to eggs from Calf Killer River, Putnam Co., TN, and are spherical, mean = 2.2 mm diameter (range: 2.0–2.6 mm), translucent, demersal, and adhesive. Eggs possess translucent, dark orange yolk (mean = 2.1 mm diameter; range: 1.9–2.3 mm), a single oil globule (mean = 0.26 mm), a narrow perivitelline space (mean = 0.1 mm), and an unsculptured and unpigmented chorion.*

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Newly hatched larvae were 6.5 mm TL.[1,2] Length at yolk absorption unknown.

Myomeres
Preanal 16, postanal 22.*

Morphology
6.5 mm TL (*newly hatched*). Body terete; snout blunt; with functional jaws, upper jaw even, slightly extending past lower jaw; well-developed pectoral

Table 161

Fecundity data for striped darters from Harpeth River and West Stone River, Rutherford County, TN, and Calf Killer River, Putnam County, TN.*

			Number of Ova			
Date	TL (mm)	GSI	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
March 28	47	11.4	391	106	97	1.25
	44	18.3	334	92	73	1.42
	44	4.1	297	69	32	1.00
	42	8.3	327	65	53	1.11
	41	10.2	320	66	50	1.25
	41	7.2	313	54	39	1.17
	41	10.3	271	59	42	1.25
	38	4.8	294	39	21	1.11
	36	4.8	251	37	23	1.00
April 18	50	10.0	248	54	36	1.53

fins without incipient rays; yolk sac large (36.6% TL), round to spherical; yolk translucent dark orange, with a single oil globule; complex plexus of vitelline veins midventrally on yolk sac; head not deflected over the yolk sac; eyes spherical.[*,2]

Morphometry
Unknown.

Fin Development
6.5 mm TL. Well-developed pectoral fins without incipient rays.[*,2]

Pigmentation
6.5 mm TL (*newly hatched*). Eyes pigmented; melanophores dorsally over the anterior and posterior cerebellum and nape; melanophores distributed laterally, dorsally over the gut posterior the yolk sac; ventral pigmentation consists of scattered mid–ventral stripe of stellate melanophores outlining the vitelline vein on the yolk sac, and punctate melanophores along every mid–ventral postanal myosepta.[*,2]

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown to lengths of 36 mm TL.*

Fins
Larger Juveniles. Spinous dorsal fin 7–10; soft dorsal rays 11–17; pectoral rays 10–14; anal fin rays II 7–11; pelvic fin rays I 5; caudal fin rays 16–18.[1–4]

Morphology
Vertebrae 35–37. Scales in the lateral series incomplete with 6–20 pored scales and with 38–58 total scales in the lateral series from TN. Cheeks, opercle, nape, breast, and prepectoral area without scales; belly fully scaled. Infraorbital and supratemporal canals interrupted.[1–3]

Morphometry
Unknown.

Pigmentation
Back with 4–8 saddles and sides with 9–12 small mid-lateral blotches. Lateral marked with 10–12 horizontal dark lines. A dark humeral spot present, and an oblique pale bar bordered by black present on the cheek. Anterior membrances of spinous dorsal fin blackened proximal and medial. Soft dorsal, pectoral, anal, and caudal fins speckled.

TAXONOMIC DIAGNOSIS OF YOUNG STRIPED DARTER

Similar species: similar to other members of subgenus *Catonotus*. Early life stages may be indistinguishable from other species.[3] In study area it is sympatric with *E. flabellare, E. squamiceps,* and *E. crossopterum.*[1]

Adult. *Etheostoma virgatum* is similar to *E. flabellare.* Both of the *Catonotus* species should be easily differentiated based on myomere counts, differences in yolk sac size, and differences in pigmentation.*

Larva. A limited ontogenetic series of the early life history stages for *E. virgatum* makes it difficult to differentiate it from other *Catonotus* species.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 149)
Eggs. Eggs are laid on the underside of slab rocks.[1,2]

Yolk-sac larvae. Buried in gravel after hatching beneath spawning nests.[1,2]

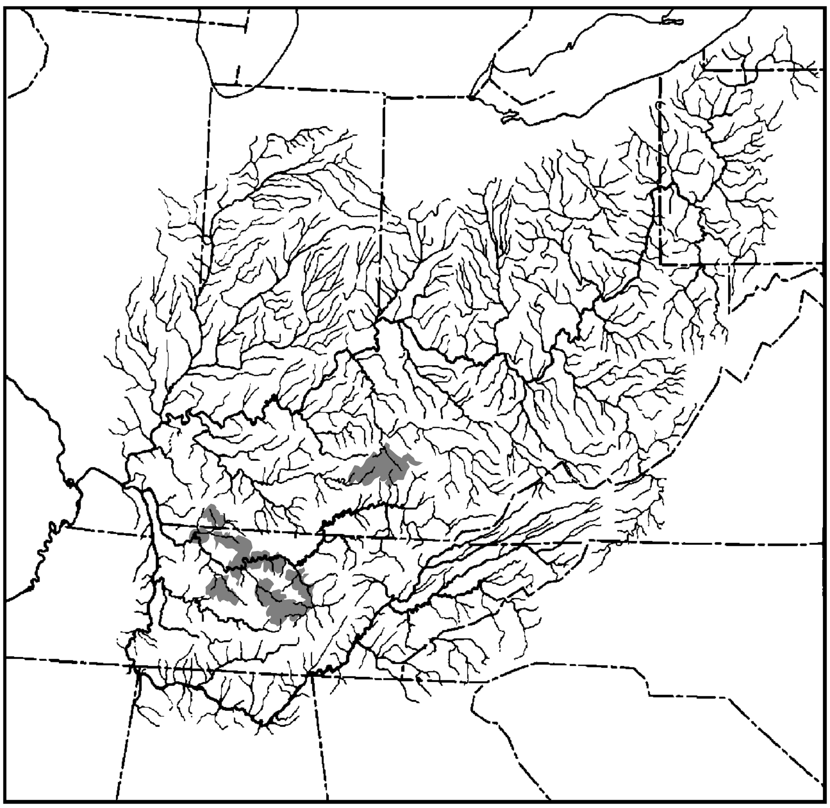

Figure 149 Distribution of striped darter, *E. virgatum* from the Ohio River system (shaded area).

Post yolk-sac larvae. Unknown.

Juveniles. Unknown.

Early Growth (see Table 162)
Mean standard length at age 1 was 28.5 mm for males and 30.6 mm for females.[1,2]

Feeding Habits
Unknown.

Table 162

Average calculated lengths (mm SL) of young striped darters in Tennessee.

State	Age 1	2	3
Tennessee[1]	28.5–30.6	46–50	78

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* Original fecundity data for striped darters from Harpeth River and West Stone River, Rutherford County, TN, and Calf Killer River, Putnam County, TN. Specimens are curated at Northeast Louisiana University, Museum of Zoology, Monroe, LA. Other original data from T.P. Simon, unpublished data.

WOUNDED DARTER

Etheostoma (*Nothonotus*) *vulneratum* (Cope)

Etheostoma: various mouths; *vulneratum*: wounded.

RANGE

Etheostoma vulneratum ranges from the upper Tennessee River system in VA, TN, and NC. Occurs in the Duck River, a lower Tennessee River tributary.[1] The species was previously considered a subspecies of the *E. maculatum* complex, but has been elevated to full specific status.[2]

HABITAT AND MOVEMENT

Etheostoma vulneratum usually inhabits the strong riffles of large streams where it is found over coarse gravel and rubble.[1] Inhabits areas in heads or in tails riffles where large cobble or boulders are present and current does exceed 0.8 ft/s.[5]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma vulneratum is endemic to the study area. Found in the Duck River and upper Tennessee River tributaries including the Little, Nolichucky, and Holston rivers, TN.[3]

SPAWNING

Location
Spawning occurs on the underside of rocks at depths of 250 mm, in slow current in midchannel.[4] Egg mass often found in a wedged area where two supporting stones abutted.[5]

Season
Spawning occurs from March to June, TN;[4]late May to late July, in the Little River, TN.[5]

Temperature
Spawning begins at temperatures between 16 and 20°C.[4,5]

Fecundity
Unknown. 16 egg masses examined in the Little River, TN, averaged 48 eggs ranging between 17 and 166 eggs.[5] These clutches may be the result of several spawnings.*

Sexual Maturity
Assume that maturity is similar to *E. maculatum,* most mature by 48 mm SL at age 2. Some females may mature by 32 mm SL or age 1.*

Spawning Act
Etheostoma vulneratum is an egg clumper.*[,5–8] Males establish territories and defend these areas for periods of a few minutes to a week. Males follow females who invade the territory. The female move under the rock and commence laying eggs. Egg laying occurs over an extended time period. During the spawning act, one or both fish will emerge and wander, as much as 1 m, feeding. One of the fish is under the rock most of the time while spawning. The female moves under the rock and turns either sideways or upside down. The male positions over her back, settles in the same direction, and vibrates at the same time eggs are released. Females often lay eggs even when the males are not present. At the conclusion of spawning, the female vacates the nest, while the male remains. The male may not be guarding the eggs as much as the territory. Males often remain at the nest long after the eggs hatch. Also, sudden changes in water depth cause the male to leave. Eggs are also found in nests that were evacuated by the male.[5]

EGGS

Description
Mature ova are demersal, adhesive, and spherical; pale yellow yolk, possessing a single oil globule, a narrow perivitelline space, and a sculptured, unpigmented chorion.[8] Eggs averaged 3.0 mm in diameter and ranged between 2.8 and 3.1 mm.[4]

Incubation
Eggs cultured in laboratory aquaria at 24°C hatched after 168 h.*

Development
Unknown.

YOLK-SAC LARVAE

See Figure 150

Size Range
8.3–9.0 mm SL, or 8.5–>9.3 mm TL.[4] Information presented in Simon et al. (1987) was mistakenly labeled *E. sanguifluum* rather than the nominal *E. vulneratum*.

Myomeres
Preanal 20; postanal 18–20; 38–40 total.[9]

Morphology
8.5–9.3 mm TL. A large larvae, body laterally compressed; functional mandible and maxillary; possess a large (32.6% SL), spherical yolk sac with translucent pale yellow yolk; head not deflected over the yolk sac; a single serpentine vitelline vein, originate at the single anterior oil globule and proceed mid-ventrally along the yolk-sac.[4] Yolk nearly absorbed at 9.3 mm TL.[4]

Morphometry
See Table 163.

Fin Development
8.5–9.3 mm TL. Well developed pectoral fins; dorsal and anal finfold continuous.[4]

Pigmentation
8.5–9.3 mm TL. Melanophores present on the posterior cerebrum, nape, prepectoral, dorsal yolk sac and gut, and ventral gut. A doble row of single melanophores present on the dorsum, and a few punctuate melanophores present on the ventral yolk and oil globule. Paired rows of melanophores ventrally between the anus and postanal cluster.[4]

POST YOLK-SAC LARVAE

Size Range
>9.3 mm TL[4] to unknown length.

Myomeres
Preanal 20, postanal 18–20; total 38–40.[4]

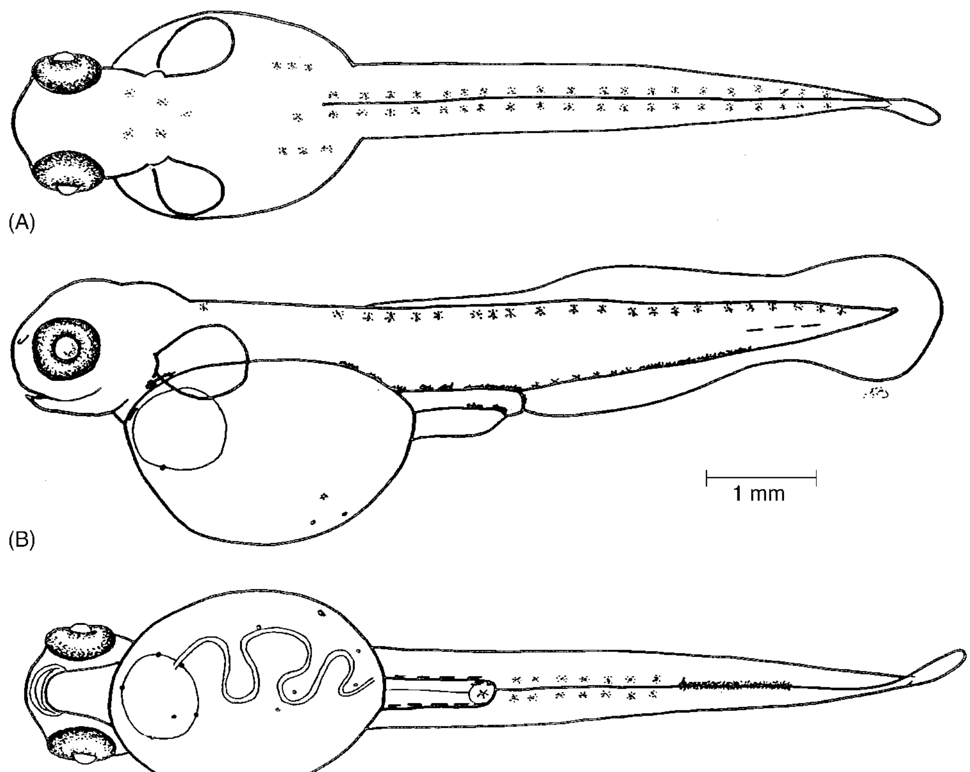

Figure 150 *Etheostoma vulneratum*, wounded darter, Little River, Blount Co., TN, 8.5 mm SL, (A) dorsal, (B) lateral, and (C) ventral aspects. (A-C from reference 4, with author's permission.)

Table 163

Morphometric data expressed as percentage of TL for young *E. vulneratum* from Tennessee.[4]

Length Range (mm)	TL Groupings 8.5–9.3	
N	6	
	Mean ± SD	Range
As Percent TL		
SnL	1.8 ± 0.3	1.8–2.0
PEL	8.9 ± 0.3	8.4–9.9
OP1L	15.9 ± 1.0	14.4–17.3
ODL	33.4 ± 2.7	29.6–37.7
PVL	56.2 ± 1.1	49.4–58.1
SL	97.4 ± 0.4	96.8–97.6
MAXL-Y	32.6 ± 0.3	32.3–33.0
P1L	7.6 ± 0.5	7.0–8.6
HD	12.8 ± 0.6	11.7–13.6
OP1D	21.6 ± 1.4	20.4–23.6
OD1D	22.3 ± 2.0	18.6–23.4
OD2D	10.3 ± 0.4	9.9–11.0
BPVD	10.3 ± 0.4	9.9–11.0
MPMD	8.3 ± 0.3	7.7–8.9
AMPMD	3.8 ± 0.6	2.9–4.8
MAX-YD	17.3 ± 1.8	12.2–19.9
BPEW	11.7 ± 0.4	11.1–12.1
OP1W	13.0 ± 1.1	10.0–14.7
OD1W	15.6 ± 1.3	13.5–15.7
OD2W	6.2 ± 0.8	4.7–10.8
BPVW	6.2 ± 0.8	4.7–10.8
AMPMW	2.7 ± 0.7	2.4–3.3
MAXW-Y	17.3 ± 1.8	14.2–18.1

Morphometry
See Table 163.

Fin Development
9.3 mm TL. Fin rays develope in caudal fin; no other rays or anlagen present.[4]

Pigmentation
9.3 mm TL. Melanophores present on the posterior cerebrum, nape, prepectoral, dorsal yolksac and gut, and ventral gut; a double row of single melanophores present on the dorsum, and a few punctate melanophores present on the ventral yolk and oil globule, paired rows of melanophores ventrally between the anus and postanal cluster.[4]

JUVENILES

Size Range
Unknown to 32–48 mm SL.[6]

Fins
Spinous dorsal XII-XIII; soft dorsal rays 11–13; pectoral rays 13–14; pelvic spines/rays I/5; anal spines/rays II/7–10.[1–7]

Morphology
Total lateral line scales, 55–61; total vertebrae 39–41.[1–7]

Pigmentation
32–48 mm SL. dorsum dusky; saddles indistinct, may be a large stripe from snout to spinous dorsal fin; lateral blotches are indistinct and vary in number. At least posterior third of body has dark horizontal bands. Red spots developed on body with encircled dark rings. Lower side and belly dusky, narrow humeral bar partly hidden behind pectoral fin.[1]

TAXONOMIC DIAGNOSIS OF YOUNG WOUNDED DARTER

Similar species: *E. vulneratum* is a member of the egg-clumper group along with *E. maculatum, E. aquali, E. camurum, E. chlorobranchium,* and *E. sanguifluum.*[7–9]

These species possess more than 19 preanal myomeres, large (>32.0% SL) spherical yolk sacs, and dorsal pigmentation in either a single or double row, and a series of mid-lateral dashes near the caudal peduncle. Within this group, *E. vulneratum* exhibits the largest egg diameter and size at hatching, while *E. maculatum* is most similar to *E. vulneratum* but hatches at 5.0 mm SL. Larvae of *E. aquali* can be distinguished from the other species based on the cross-hatched or brushed melanophores that cover the vitelline vein.[7]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 151)
Eggs. Eggs are deposited on the underside of flat rocks in the head or tail of riffles.[5]

Yolk-sac larvae. Preferred juvenile habitats described as nursery areas for *E. vulneratum.*[5] Yolk-sac larvae remain partially buried in the substrate during yolk

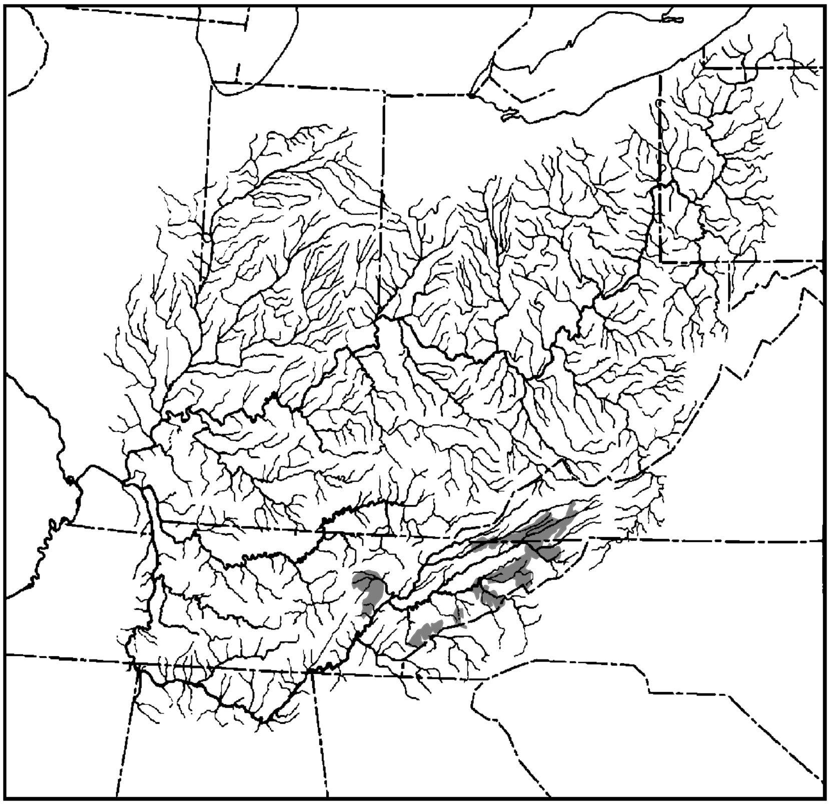

Figure 151 Distribution of wounded darter, *E. vulneratum* in the Ohio River system (shaded area).

absorption, after absorption probably drift downstream into nursery pools.*

Post yolk-sac larvae. Found in pools immediately downstream of riffle reproduction areas.*

Juveniles. Prefer the transition zone between the tail of the riffle and the downstream pool; water depth is 1.5–3.0 m and the current varies from moderate to gentle. Juveniles seek sheltered areas with moderate to slow current.[5]

Early Growth
At age 1, juveniles reach 22–40 mm.[5–8]

Feeding Habits
Etheostoma vulneratum feeds primarily on dipterans, tendipeds, tipulids, and simulids, and hydracarina, baetid mayflies, and various caddisflies (to a limited extent).[5]Adult food during the winter months is 90% midge larvae, during warmer months midge larvae; accounts for 70% of the diet.[9]

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9. Bryant, R.T. 1979.

* Original observations from T.P. Simon, unpublished data.

BOULDER DARTER

Etheostoma (*Nothonotus*) *wapiti* Etnier and Williams

Etheostoma: various mouths; *wapiti*: Native American name for elk, referring to the type locality in the Elk River.

RANGE

Etheostoma wapiti is known from the Elk River system, AL and TN.[1–3]

HABITAT AND MOVEMENT

Etheostoma wapiti inhabits deep, flowing pools with bolder substrates in large creeks and rivers. All adults have been collected from limestone rubble from broken mill dams and bridges or natural accumulations of limestone slabs.[3] Juveniles apparently disperse widely and have appeared in several Elk River collections from gravel riffles in lower Indian Creek.[3]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

The species has been collected from lower Richland Creek and the mouth of Indiana Creek, Giles County, TN; and the main channel of Elk River from Fayetteville, Lincoln County, TN downstream to RM 29.7, just above the Wheeler Reservoir embayment and half a mile below Alabama SR 127 (Smith Hollow) bridge, Limestone County.[3] Extirpated from Shoal Creek, Lauderdale County, AL, since 1884.[4]

SPAWNING

Location
Rubble limestone substrates are essential spawning substrates.[3]

Season
Likely occurs in late April and May.[4]

Temperature
Unknown.

Fecundity
Unknown.

Sexual Maturity
Unknown.

Spawning Act
Unknown.

EGGS

Description
Unknown.

Incubation
Unknown

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fins
Branchiostegal rays 6,6; dorsal spines/rays XII–(XIII)–XIV/11–(12)–13; pectoral rays 12–(13–14); pelvic fin spines/rays I/5; anal spines/rays II/7–(8)–9; and caudal fin rays 17.[4]

Morphology
Vertebrae 39(4), 40 (5), or 41 (1).[4] Lateral line scales complete with 56–64 (55–69).[4]

Larger juveniles: Scales absent from nape, breast, and prepectoral area; cheeks usually with a few embedded scales near postorbital spot; belly and opercles fully scaled.[4] Supratemporal and infraorbital canals complete.[4]

Morphometry
Unknown.

Pigmentation
Background color olivaceous, with 8–9 dorsal saddles and 10–11 midlateral blotches often present. Sides with 10–14 dark horizontal lines between scale rows. Dark suborbital bar, humeral spot, and pair of submedian but discrete basicaudal spots present.

TAXONOMIC DIAGNOSIS OF YOUNG BOULDER DARTER

Similar species: similar to other *Nothonotus.*

Adults. *Etheostoma rufilineatum* has orange lips , horizontal dark marks on the cheeks (vertical suborbital bar in *E. wapiti*), red and orange fin and body pigment in males, and large black spots on median fins in females. It is sympatric but differs in possessing a more blunt snout, more distinct pale submarginal bands on median fins, a blue breast, red spots on the sides, little sexual dimorphism, and lacking a suborbital bar and any scales on the cheek.

Larvae. No information is available on early life history development.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 152)
Eggs. Unknown.

Yolk-sac larvae. Unknown.

Post yolk-sac larvae. Unknown.

Juveniles Juveniles apparently disperse widely and have appeared in several Elk River collections from gravel riffles in lower Indian Creek.[3]

Early Growth
Unknown; maximum total length 84 mm in TN;[3] maximum size 43–70 mm in AL.[4]

Feeding Habits
Diet includes aquatic insect larvae and other riffle-dwelling invertebrates.[4]

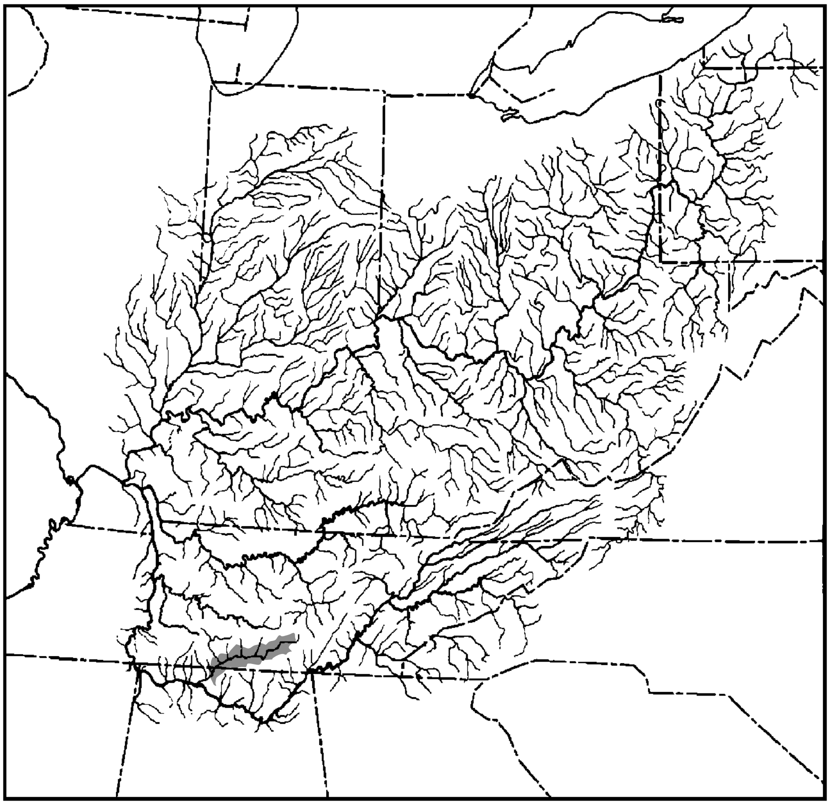

Figure 152 Distribution of boulder darter, *E. wapiti* in the Ohio River system (shaded area).

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BANDED DARTER

Etheostoma (*Nanostoma*) *zonale* (Cope)

Etheostoma: various mouths; *zonale*: banded.

RANGE

Etheostoma zonale occurs below the Fall Line of the Mississippi River from the Ohio River, IN, IL and KY; east to the Allegheny River basin in PA and NY.[1–6] *Etheostoma vinctipes* is elevated as a valid species from the *Etheostoma zonale* complex based on ontogentic differences, thus limiting *E. zonale* to the Ohio River drainage.[7] The species is primarily an upland species avoiding lowland gradients.[1–6] Introduced and established in the Susquehanna and upper Savannah rivers.[12]

HABITAT AND MOVEMENT

Etheostoma zonale inhabits moderate-gradient, clear to slightly turbid, large streams to moderate-sized rivers. Adults prefer unsilted gravel substrates with aufwuchs and algal growth or aquatic macrophytes in riffles and fast runs.[3–5] Prefer swift riffles of moderately large cobble or gravel, slabs, and small boulders in moderate-sized streams and rivers including extensive mats of aquatic vegetation, particularly *Podostemum* and attached mosses[9]. Winter movement occurs when adults move off from riffles into downstream run habitats, burying themselves for the winter in the gravel interstitial spaces (T.P. Simon, personal observation).

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

The elevation of *E. vinctipes* and former recognition of *E. lynceum*,[8] limits the distribution of *E. zonale* to the eastern two-thirds of KY, avoiding the lower Kentucky River, most of the Blue Grass region, and areas above Cumberland Falls.[5] Limited to Shoal and Cypress Creeks, the Paint Rock and Elk River systems on the north side of the Tennessee River, and a single collection in the Bear Creek system in Franklin County, AL.[9] Occurs throughout the Tennessee and Cumberland Rivers.[12]

SPAWNING

Location

Egg sites include riffle habitats over algal mats on gravel substrates in slight to moderate current (T.P. Simon and B.E. Fisher, unpublished data). Spawning occurs on rocks covered with algae,[19] eggs are attached to strands of algae that grow on boulders.[20]

Season

Breeding coloration of males intensifies in late February and spawning in TN occurs in April and May.[12] Spawning aggregates of adult males assemble between mid-April and early May on riffles in Laughery Creek, IN.[7] Banded darters spawn during April and May in IN[7] and May and June in PA.[6]

Temperature

Males reach the spawning riffles when temperatures reach 12°C in Laughery Creek, IN (T.P. Simon and B.E. Fisher, unpublished data). Spawning initiated in western PA when temperatures reach 17.2°C.[6]

Fecundity

Female banded darters show statistically significant increases in fecundity (ANOVA, $F = 531.1$, $p > 0.0001$) with an increase in length. A 63 mm female has 124 large mature ova, while two 61 mm females have 75 to 102 large mature ova (Table 164).* Age 2 and 3 TN females averaged 128 large mature ova, while the maximum number of ova in an age 1 female was 77 ova.[12]

Sexual Maturity

Females are sexually mature at 35 mm in TN and PA.[6–12] Spawning coloration of mature spawning males is diagnostic between *Etheostoma vinctipes* and *E. zonale*. *Etheostoma vinctipes* possesses dark green throat, breast, and lateral bands; thus, the common name of jade darter, while *E. zonale* has lime green throat, breast, and lateral bands.[7]

Spawning Act

Etheostoma zonale is an egg-attacher depositing eggs in algal mats.[7] A male spawns with more than one

Table 164

Fecundity data for *E. zonale* from Buffalo River, Duck River drainage, Lewis County, TN.*

Length (TL)	Ovary Weight (mg)	Number of Ova: Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
41	79.8	412	109	36	1.25
43	72.7	457	128	25	1.42
43	96.8	541	91	37	1.33
45	108	565	122	49	1.42
55	194	789	239	97	1.25
57	268	878	205	82	1.33
57	238	951	176	76	1.42
61	271	998	282	75	1.42
61	291	1074	278	102	1.42
63	242	1191	248	124	1.25

female, and a female may spawn with four different males during each spawning (T.P. Simon, unpublished data). Eggs sites include riffle habitats over algal mats on gravel substrates in slight to moderate current. The male defends a territory where rival males are chased away. When a prospective female approaches, the male presents a lateral display and tail wags in front of the female. The female selects the spawning site as the male follows. Adults maintain a head-to-head orientation with vents juxtaposed. A male entices a female into the algal mats and mounts her. The male intertwines his body in a serpentine position alongside the female and moves through the algal mat depositing eggs. Eggs are laid one at a time in the mats, generally 2–3 during a single spawning event (T.P. Simon and B.E. Fisher, personal observation).

EGGS

Description

Ovarian examination of TN specimens showed that ovoid latent ova were 0.4 mm, early maturing ova averaged 0.83–0.95 mm, and large mature ova averaged 1.25–1.42 mm.* TN specimens had mean 1.08 early maturing ova and 1.7 mm diameter for mature ripe ova.[12] Eggs from the Susquehanna River, PA, and Laughery Creek, IN, were spherical, mean = 1.4 mm diameter (range: 1.2–1.6 mm), translucent, demersal, and nonadhesive; eggs possed translucent clear yolk (mean = 1.3 mm diameter; range: 1.1–1.5 mm); a single oil globule (mean = 0.26 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[7]

Incubation

Hatching occurs after 168 h at an incubation temperature of 20°C.[7–12]

Development

Unknown.

YOLK-SAC LARVAE

See Figure 154

Size Range

TN specimens hatched at 4.3 mm,[12] while PA individuals hatch at 6.2–6.5 ; yolk absorption by 7.0 mm[7]

Myomeres

Preanal 17 (32), 18 (23), 19 (100), 20 (6), 21 (5), or 22 (6) in PA (*N* = 172, mean = 18.7); postanal 21 (15), 22 (156), or 23 (1) (*N* = 172, mean = 21.9); total 39 (31), 40 (22), 41 (106), 42 (5), 43 (4), 44 (1), and 45 (3) (*N* = 172, mean = 40.7). Hiwassee River race specimen, preanal 18 postanal 23, with total 41.[7] Preanal 17–22[7] or 14–15, 17–19;[15,16] postanal 21–23[7] or 22.[15,16]

Morphology

6.2–6.5 mm TL. Newly hatched PA specimens have a terete body; blunt snout, with functional jaws, lower jaw even, slightly extending past upper

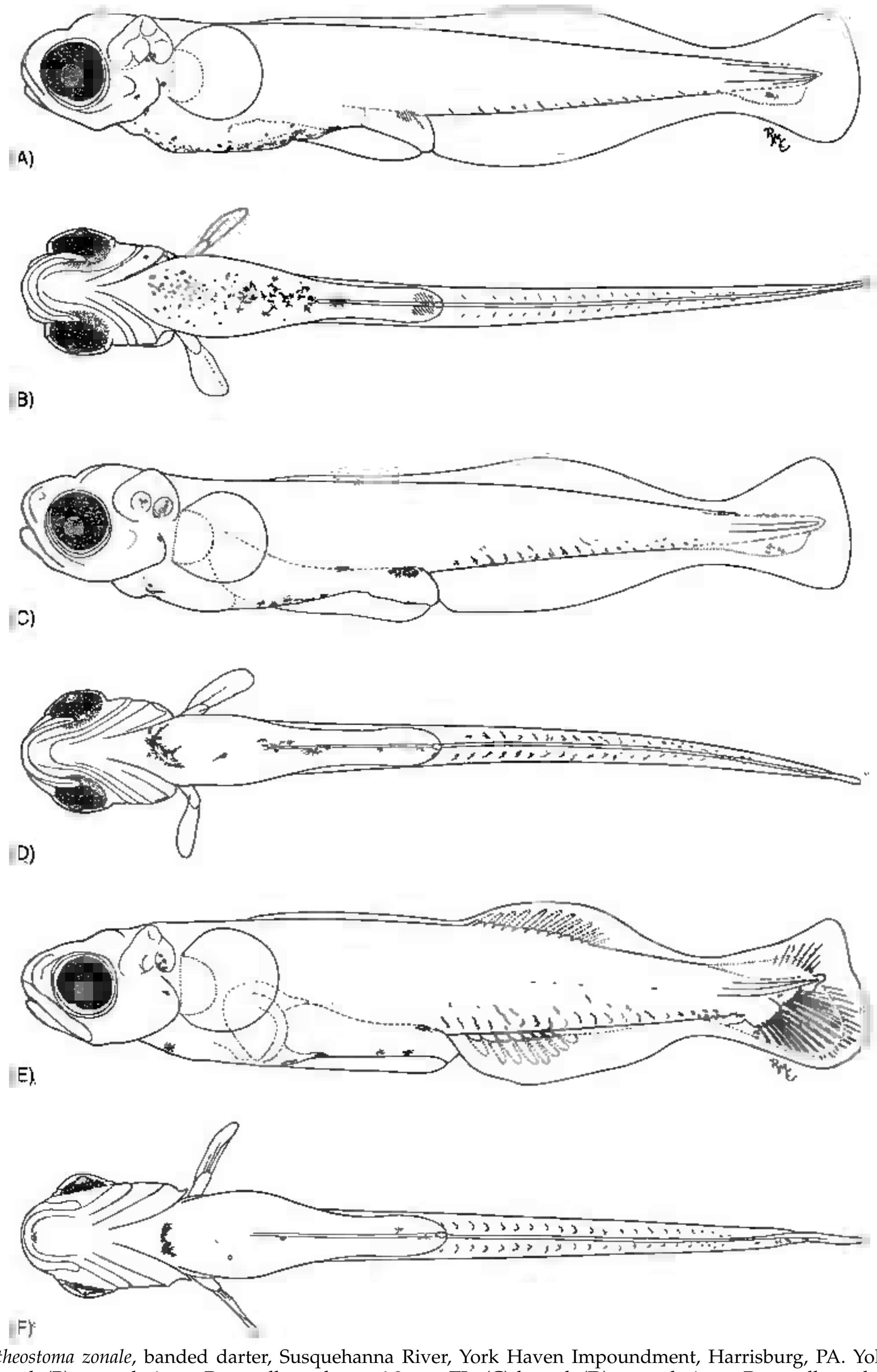

Figure 153 *Etheostoma zonale*, banded darter, Susquehanna River, York Haven Impoundment, Harrisburg, PA. Yolk sac larva, 6.5 mm TL: (A) lateral, (B) ventral views. Post yolk-sac larva, 6.8 mm TL: (C) lateral, (D) ventral views. Post yolk-sac larva, 8.8 mm TL: (E) lateral, (F) ventral views. (A-F from reference 7, with author's permission.)

jaw; yolk sac moderate (24.7% TL), oval to tapered posteriorly; yolk translucent clear to pale yellow, with a single oil globule; vitelline vein plexus mid-ventrally on yolk sac; head not deflected over the yolk sac; eyes spherical in TN and PA individuals.[7]

6.3–6.5 mm TL. Premaxilla and mandible form.[7]

6.6–6.9 mm TL. Digestive system functional prior to complete yolk absorption; operculum and gill arches functional (6.8 mm).[7]

Morphometry
See Table 165.

Fin Development
See Table 166.

6.2–6.5 mm TL. Newly hatched PA specimens have well-developed pectoral fins without incipient rays.[7]

Pigmentation
6.2–6.5 mm TL. Newly hatched larvae with pigmented eyes; no melanophores dorsally; few melanophores distributed laterally; a single melanophore typically present at otic capsule; dorsally over the gut. Ventral pigmentation consists of a mid-ventral stripe of stellate melanophores outlining the vitelline vein on the yolk sac, and radiating melanophores along every mid-ventral postanal myosepta.[7]

6.8–7.0 mm TL. Predominantly similar to previous length interval with the exception of ventral pigmentation; mid–ventral melanophores on the yolk sac become few, punctate and subdermal.[7]

POST YOLK-SAC LARVAE

See Figure 153 and 154

Size Range
7.1 to 11.4–12.5 mm TL.[7]

Myomeres
Preanal 17 (32), 18 (23), 19 (100), 20 (6), 21 (5), or 22 (6) in PA (N = 172, mean = 18.7); postanal 21 (15), 22 (156), or 23 (1) (N = 172, mean = 21.9); total 39 (31), 40 (22), 41 (106), 42 (5), 43 (4), 44 (1), and 45 (3) (N = 172, mean = 40.7). Hiwassee River specimen preanal 18; postanal 23; total 41.[7] Preanal 17–22[7], 14–15, or 17–19;[15,16] postanal 21–23[7] or 22.[15,16]

Morphology
7.1 mm TL. Yolk absorbed.[7]

7.4–8.0 mm TL. No swim bladder forms; gut straight, with striations; portion of gut posterior stomach normal in length.[7]

8.5–9.6 mm TL. Notochord flexion preceding caudal fin ray development.[7]

10.7–11.4 mm TL. Branchiostegal rays form.[7]

11.2 mm TL. Supraorbital, infraorbital, lateral, and subtemporal head canals form (11.2 mm); infraorbital, lateral, and supratemporal head canals not interrupted preoperculomandibular canal complete with 10 pores, and infraorbital pores 7.[3,7]

11.8 mm TL. Neuromast development occurs mid laterally from the anterior trunk posteriad (11.8 mm).[7]

Morphometry
See Table 165.

Fin Development
See Table 166.

7.1–8.0 mm TL. First rays formed in pectoral fin (7.2–7.3 mm), caudal fin (7.1–8.0 mm); soft dorsal fin rays formed (7.3–8.0 mm).[7]

7.6–8.2 mm TL. Anal fin rays formed.[7]

8.2–9.7 mm TL. Notochord flexion precedes caudal fin ray development (8.5–9.6 mm); spinous dorsal forms (8.2–9.7 mm).[7]

9.7–10.7 mm TL. Dorsal and anal finfold partially differentiated.[7]

7.9–11.1 mm TL. Pelvic fin buds formed anterior to dorsal fin origin after complete yolk absorption.[7]

10.4–11.4 mm TL. Both finfolds completely differentiated.[7]

Pigmentation
7.1–8.2 mm TL. Predominantly similar to previous length interval with the exception of ventral pigmentation. Mid-ventral melanophores on the yolk sac become few, punctate, and subdermal.[7]

8.3–9.7 mm TL. A cluster of melanophores surrounding the opercular region, laterally outline the operculum and prepectoral base, and ventrally between the isthmus. Anterior postanal myosepta pigmentation migrate to mid-lateral from mid-ventral myosepta.[7]

9.8–11.4 mm TL. Dorsum of cranium with pigmentation outlining the brain, ventrum of chin, and at future postorbital position on the operculum; a lateral stripe of punctate melanophores runs from the pectoral fin to the upturned notochord; a second line of melanophores extend in the hypaxial musculature from the anus to the caudal peduncle.[7]

Table 165

Morphometry of young *E. zonale* grouped by selected intervals of total length (N = sample size).[7]

	Total Length (TL) Intervals (mm)									
	6.10–7.99 (N = 62)		8.06–9.81 (N = 43)		10.2–11.9 (N = 28)		12.0–13.9 (N = 36)		14.2–14.4 (N = 4)	
Characters	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
Length (% of TL)										
Upper jaw[a]	36.5 ± 5.04	(0.38–0.76)	34.6 ± 3.94	(0.38–0.76)	35.2 ± 4.68	(0.53–0.91)	33.5 ± 4.04	(0.68–1.14)	35.0 ± 4.63	(0.91–1.29)
Snout[a]	19.4 ± 3.32	(0.15–0.38)	20.1 ± 3.32	(0.23–0.46)	21.2 ± 3.26	(0.30–0.68)	20.8 ± 2.71	(0.46–0.76)	21.7 ± 1.91	(0.61–0.76)
Eye diameter[a]	36.7 ± 3.64	(0.42–0.51)	33.9 ± 2.98	(0.46–0.69)	32.5 ± 3.67	(0.61–0.84)	30.0 ± 2.11	(0.68–0.91)	29.5 ± 1.98	(0.84–1.04)
Head	19.4 ± 1.20	(1.14–1.90)	19.3 ± 1.60	(1.22–2.05)	19.7 ± 1.57	(1.72–2.66)	20.6 ± 0.95	(2.35–3.04)	21.9 ± 0.69	(3.04–3.24)
Predorsal	34.5 ± 7.49	(1.37–4.26)	41.6 ± 11.9	(1.67–5.63)	33.2 ± 10.2	(2.05–5.71)	26.0 ± 5.48	(1.90–4.03)	30.0 ± 3.59	(3.96–5.09)
Dorsal insertion			42.0 ± 11.7	(1.67–5.63)	44.6 ± 6.79	(2.58–5.83)	41.9 ± 6.35	(3.19–6.54)	49.3 ± 2.70	(6.70–7.65)
D2 origin			42.2 ± 11.8	(1.67–5.63)	50.9 ± 6.09	(2.58–6.47)	48.9 ± 6.42	(4.10–7.30)	53.4 ± 2.35	(7.38–8.17)
D2 insertion			47.2 ± 17.7	(1.67–5.63)	69.6 ± 6.98	(2.58–6.47)	68.3 ± 6.24	(4.10–7.30)	72.3 ± 3.21	(7.38–8.17)
Preanal	50.7 ± 1.34	(3.04–4.41)	51.8 ± 1.93	(3.88–5.55)	52.3 ± 1.22	(5.10–6.61)	51.7 ± 1.00	(6.16–7.23)	51.9 ± 0.45	(7.38–7.46)
Postanal	49.3 ± 1.37	(3.04–3.96)	47.5 ± 4.95	(1.67–5.02)	47.7 ± 1.23	(4.87–5.82)	48.3 ± 1.00	(5.56–6.84)	48.1 ± 0.45	(6.77–7.00)
Standard	87.5 ± 1.73	(5.33–7.30)	87.8 ± 2.80	(6.86–8.98)	88.1 ± 1.79	(9.06–10.7)	87.4 ± 1.13	(10.7–12.2)	85.1 ± 0.37	(12.1–12.2)
Yolk sac	24.7 ± 1.66	(1.52–1.83)								
Fin Length(% of TL)										
Pectoral	9.90 ± 1.63	(0.53–1.22)	10.4 ± 2.07	(0.61–1.67)	12.3 ± 3.44	(0.91–2.96)	13.1 ± 2.23	(1.07–2.43)	17.0 ± 1.85	(2.28–2.84)
Pelvic	0.13	(0.01–0.01)	0.89 ± 0.46	(0.01–0.12)	4.36 ± 3.78	(0.01–1.48)	8.85 ± 3.03	(0.10–1.75)	14.9 ± 0.62	(2.00–2.24)
Spinous dorsal			16.9	(1.52–1.52)	15.2 ± 3.46	(0.84–2.43)	15.9 ± 2.56	(1.14–2.66)	19.3 ± 1.08	(2.56–2.89)
Soft dorsal			21.8 ± 4.73	(1.60–2.74)	19.5 ± 1.40	(1.90–2.54)	19.4 ± 1.04	(2.21–3.20)	19.0 ± 0.91	(2.58–2.92)
Caudal	12.5 ± 1.73	(0.53–1.22)	12.2 ± 2.80	(0.38–2.04)	11.9 ± 1.79	(0.99–2.13)	12.6 ± 1.13	(1.29–2.04)	14.9 ± 0.37	(2.05–2.20)
Body Depth (% of TL)										
Head at eyes	15.6 ± 1.31	(0.91–1.52)	15.1 ± 2.11	(1.14–2.05)	14.7 ± 2.53	(1.37–3.27)	14.4 ± 0.82	(1.67–2.06)	14.7 ± 0.73	(1.98–2.24)
Head at Pl	16.2 ± 1.43	(0.76–1.52)	16.8 ± 1.33	(1.14–1.75)	16.1 ± 0.89	(1.52–2.05)	16.2 ± 1.08	(1.67–2.51)	16.9 ± 0.82	(2.28–2.58)
Preanal	10.6 ± 1.29	(0.53–1.14)	12.4 ± 1.34	(0.84–1.37)	14.3 ± 1.25	(1.14–1.90)	14.8 ± 1.04	(1.45–2.21)	15.0 ± 0.86	(1.98–2.28)
Mid-postanal	15.0	(1.02–1.02)			8.64	(1.02–1.02)				
Caudal peduncle	4.61 ± 0.76	(0.23–0.68)	5.90 ± 1.30	(0.30–0.84)	8.13 ± 1.06	(0.46–1.22)	8.39 ± 0.70	(0.91–1.29)	8.89 ± 0.57	(1.19–1.37)
Yolk sac	8.70 ± 3.07	(0.38–1.52)								
Body Width (% of HL)										
Head	74.2 ± 6.59	(0.84–1.37)	73.3 ± 8.85	(0.91–1.60)	69.1 ± 8.55	(1.29–1.67)	66.6 ± 4.88	(1.52–2.06)	64.1 ± 3.14	(1.94–2.05)
Myomere Number										
Predorsal	7.84 ± 0.49	(6.00–8.00)	7.93 ± 0.34	(6.00–8.00)	7.79 ± 0.83	(4.00–8.00)	8.00 ± 0.00	(8.00–8.00)	7.75 ± 0.55	(7.00–8.00)
Soft dorsal			19.0 ± 0.00	(19.0–19.0)	18.0 ± 0.00	(18.0–18.0)	18.0 ± 0.00	(18.0–18.0)	18.0	(18.0–18.0)
Preanal	18.6 ± 0.71	(17.0–19.0)	18.4 ± 1.14	(17.0–23.0)	19.0 ± 1.85	(17.0–24.0)	19.1 ± 1.41	(17.0–22.0)	18.3 ± 1.31	(17.0–20.0)
Postanal	22.0 ± 0.13	(22.0–23.0)	22.0 ± 0.00	(22.0–22.0)	21.9 ± 0.45	(21.0–23.0)	21.8 ± 0.42	(21.0–22.0)	21.5 ± 0.58	(21.0–22.0)
Total	40.6 ± 0.73	(39.0–42.0)	40.4 ± 1.12	(39.0–45.0)	40.9 ± 1.53	(39.0–45.0)	40.9 ± 1.26	(39.0–44.0)	39.8 ± 1.01	(39.0–41.0)

[a] Proportion expressed as percent head length.

Note: Characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.

Table 166

Meristic counts and size (mm TL) at the apparent onset of development for *E. zonale.*

Attribute/event	*E. zonale*	Literature
Branchiostegal Rays	6,6[7]	4–6,4–6[4,8,13,17]
Dorsal Fin Spines/Rays	XI/11–12[7]	VIII–XIII/9–13[4,8,13,17]
First spines formed	8.2–9.7[7]	11–12[15,16]
Adult complement formed	10.8–11.7[7]	14.5–6.7[15,16]
First soft rays formed	7.3–8.0[7]	11–12[15,16]
Adult complement formed	10.4–11.4[7]	14.5[15,16]
Pectoral Fin Rays	13–14[7]	12–16[4,8,13,17]
First rays formed	7.2–7.3[7]	11–12[15,16]
Adult complement formed	8.4–9.3[7]	14.5[15,16]
Pelvic Fin Spines/Rays	I/5[7]	I/5[4,8,13,17]
First rays formed	11.4–12.3[7]	11–12[15,16]
Adult complement formed	11.7–12.4[7]	14.5–16.7[15,16]
Anal Fin Spines/Rays	II/7–9[7]	II/6-9[4,8,13,17]
First rays formed	7.6–8.2[7]	11–12[15,16]
Adult complement formed	9.3–10.5[7]	14.5–16.7[15,16]
Caudal Fin Rays	viii, 8 + 7, iii[7]	15–17[15,16]
First rays formed	7.1–8.0[7]	7–8[15,16]
Adult complement formed	11.8–12.2[7]	14.5–16.7[15,16]
Lateral Line Scales	39–57[7]	39–63[4,8,13,17]
Myomeres/Vertebrae	39–45/39–40[7]	36–37/37–41[4,813,14,17]
Preanal myomeres	17–22[7]	14–15, 17–19[15,16]
Postanal myomeres	21–23[7]	22[15,16]

11.5–11.8 mm TL. Dorsum of cranium with pigmentation outlining the brain, ventrum of chin, and at future postorbital position on the operculum; a lateral stripe of punctate melanophores runs from the pectoral fin to the upturned notochord; a second line of melanophores extend in the hypaxial musculature from the anus to the caudal peduncle.[7]

JUVENILES

See Figure 154

Size Range
11.5[7]–31 to 35 mm.[12]

Fins
Branchiostegal rays 6,6[7] or 4–6,4–6;[4,8,13,17] dorsal fin spines/rays VIII–(XI)–XIII/9–(11–12)–13;[4,7,8,13,17] pectoral fin rays 12–(13–14)[7]–16;[4,8,13,17] pelvic fin spines/rays I/5;[4,7,8,13,17] anal fin spines/rays II/6–(7–9);[4,7,8,13,17] caudal fin rays viii, 8 + 7, viii[7] or 15–17.[15,16]

Morphology
Lateral line scales 39 to 57[7] or 39 to 63;[4,8,13,17] vertebrae 39 to 40[7] or 37 to 41.[4,8,13,14,17]

11.8–13.1 mm TL. Upper jaw equal with lower jaw, becoming subterminal.[7]

11.8–14.4 mm TL. Lateral line begins to form.[7]

>14.4 mm TL. Initiation of squamation.[7]

24.5 mm TL. Squamation complete.[7]

Early juvenile. Cheek, breast, and belly varies from naked to embedded scales; nape and opercle are completely scaled.[2–4,7]

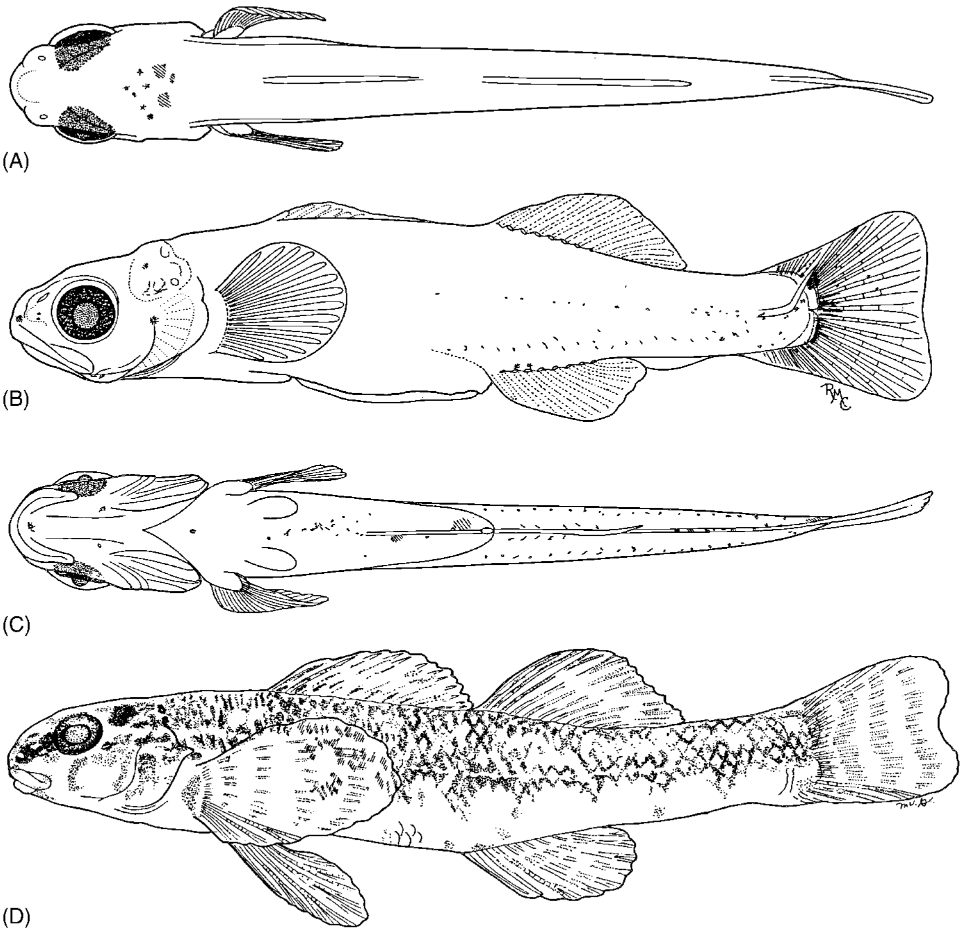

Figure 154 *Etheostoma zonale*, banded darter, Susquehanna River, York Haven Impoundment, Harrisburg, PA. Post yolk-sac larva, 12.3 mm TL: (A) dorsal, (B) lateral, (C) ventral views. Juvenile, 40 mm TL: (D) lateral view. (A-D from reference 7, with author's permission.)

Morphometry
See Table 165.[7]

Pigmentation

12.1–13.0 mm TL. Similar to previous length interval with the exception of the midlateral melanophore stripe contracting from the anus to midcaudal peduncle; the second hypaxial line of pigment accumulates just above the midventral melanophores of the anal fin lepidiotrichia interdigitation with the pterigiophores.[7]

14.4–19.0 mm TL. Preorbital bar well developed but postorbital bar consists of only a single melanophore; dorsum of cranium with two distinct lines of melanophores; laterally, edge of operculum outlined with melanophores, a series of melanophores occur over the gut and a series of vertical hypaxial melanophores at the caudal peduncle base; ventral melanophores between the pelvic on the breast, and at almost every postanal myosepta radiating dorsally from the mid-ventrum the mid-lateral.[7]

20–40 mm TL. Well-developed preorbital and postorbital bar formed, cranial pigmentation consists of discrete melanophores over the cerebellum and optic lobe, hypaxial section of operculum, and weakly formed suborbital bar. In the dorsum from the nape to caudal fin base six blotches or saddles. Lateral body coloration green, 6–10 lateral bands of green vertical pigment. Ventral aspect unpigmented. Spinous and soft dorsal fins and anal fin with two oblique stripes of melanophores, pectoral and caudal fins with 4 or 5 vertical bands of melanophores, and pelvic fin unpigmented.[7]

TAXONOMIC DIAGNOSIS OF YOUNG BANDED DARTER

Similar species: member of subgenus *Nanostoma*.

Adult. The *E. zonale* group formerly consisted of ten taxonomically recognizable populations which were divided into two recognized subspecies: *E. z. zonale* and *E. z. lynceum*.[2–4] Etnier and Starnes[8] resurrected *E. lynceum* from synonymy with *E. zonale*.

Etheostoma zonale can be differentiated from *E. lynceum* based on modes of 46–56 lateral scales and 15–23 scales around the caudal peduncle. *Etheostoma lynceum* has modes of 39–43 lateral line scales and 12–18 scales around the caudal peduncle. *Etheostoma zonale* occurs below the Mississippi River Fall line throughout the Ohio River basin, western tributaries of Lake Michigan, and in the upper Savannah River, SC, while *E. lynceum* occurs below the fall line in western tributaries of the Mississippi River, MS and TN, and in the Gulf Coast drainage, MS, LA, and southwestern AL.[2–4] *Etheostoma vinctipes* is elevated to species status based on ontogenetic development and is limited to the upper Mississippi River from the Meramec and Missouri Rivers, MO, northward to the Minnesota and Zumbro Rivers, MN, occurring east and west of the drainage.[7]

The species *E. zonale* considered here, consists of six races and three racially intergrading populations. The races studied in this presentation include the Hiwassee River and Ohio River. Primary differences recognized by Tsai and Raney[4] were based on lateral line scale counts, branchiostegal rays, vertebrae, scalation on the cheek and breast, and anal fin ray counts. The Ohio River race possesses a nearly naked or completely naked breast and can be separated from *E. vinctipes* that has a heavily scaled breast. The Ohio River race is widely distributed in the Ohio River and tributaries above the Kentucky River in IN, OH, and WV, western PA, and southwestern NY, and differs from the Tennessee River race in lower lateral line scale counts.

The Hiwassee River race is the only race which possesses six branchiostegal rays, otherwise it is very similar to the South Fork Holston River and Tennessee River races. Synapomorphies between the South Fork Holston River and Hiwassee River races include partially scaled cheek, but differs in a partially naked belly in the Hiwassee populations and a scaled belly in the South Fork Holston River. Cheek squamation and number of branchiostegal rays separate this species from the Tennessee River race. The Hiwassee River race is distributed only in the Hiwassee and Little Tennessee Rivers.[4]

Larva. The *E. zonale* complex is considered here to encompass six races that are distributed throughout the Ohio River drainage above the Kentucky River to the upper Allegheny River, PA and NY, and the upper Savannah River. All races of *E. zonale* possess high preanal myomere counts, slower ontogenetic development relative to size, and lack excessive pigmentation on the cranium and midventrally on the yolk sac.[7]

Variation

Etheostoma zonale is recognized as morphologically different from *E. vinctipes* based on ontogenetic, morphometric, and meristic characters. The two species differ in adult male breeding coloration and in body depth anterior the spinous dorsal origin. *Etheostoma vinctipes* has a deeper body depth than *E. zonale* and has darker green colors in spawning males. The Ohio River race specimens possess more preanal myomeres (17–22) than the Hiwassee River race (18). Illinois specimens of *E. vinctipes* have ontogenetically faster yolk depletion between 6.1 to 6.8 mm, while Ohio River race *E. zonale* specimens are not absorbed until 6.8–7.1 mm. Both races of *E. zonale* have spherical eyes. Based on the extremes in ontogenetic variation between the development of fin ray elements and other morphological features, the Ohio River race of *E. zonale* is less derived than the upper Mississippi River *E. vinctipes*. Removal of *E. vinctipes* from synonymy with *E. zonale* and elevation to species *E. vinctipes* Jordan is warranted. The Hiwassee and Ohio River races remain in the *E. zonale* complex as distinct races until further analysis can be completed.[7]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 155)

Eggs. Egg sites include riffle habitats over algal mats on gravel substrates in slight to moderate current (T.P. Simon and B.E. Fisher, unpublished data).

Yolk-sac larvae. Aquarium observations indicate that banded darter larvae are pelagic immediately after hatching.[7]

Post yolk-sac larvae. Larva become demersal only at lengths greater than 13 mm, at which time they remain in close association with the substrate. Banded darter larvae from the upper Ohio River, just upstream of the New Cumberland Lock and Dam, ORM 53.9, were collected in equal numbers from surface and bottom drift samples from late April to late July.[21] The maximum densities of banded darters, were 0.1/10 m^3 during late July 1988, but comprised less than 0.1/10 m^3 of the relative abundance of the ichthyoplankton collected in the mainstem Ohio River during 1987.[21,22] In the Susqehanna River, PA, larvae use the downstream pools and backwater areas adjacent to spawning riffles as nursery habitats. All length intervals, less than 14 mm, were collected in surface drift samples from the Susquehanna River.[15]

Juveniles. In the Susqehanna River, PA, early juveniles utilize the downstream pools and backwater areas adjacent to spawning riffles as nursery

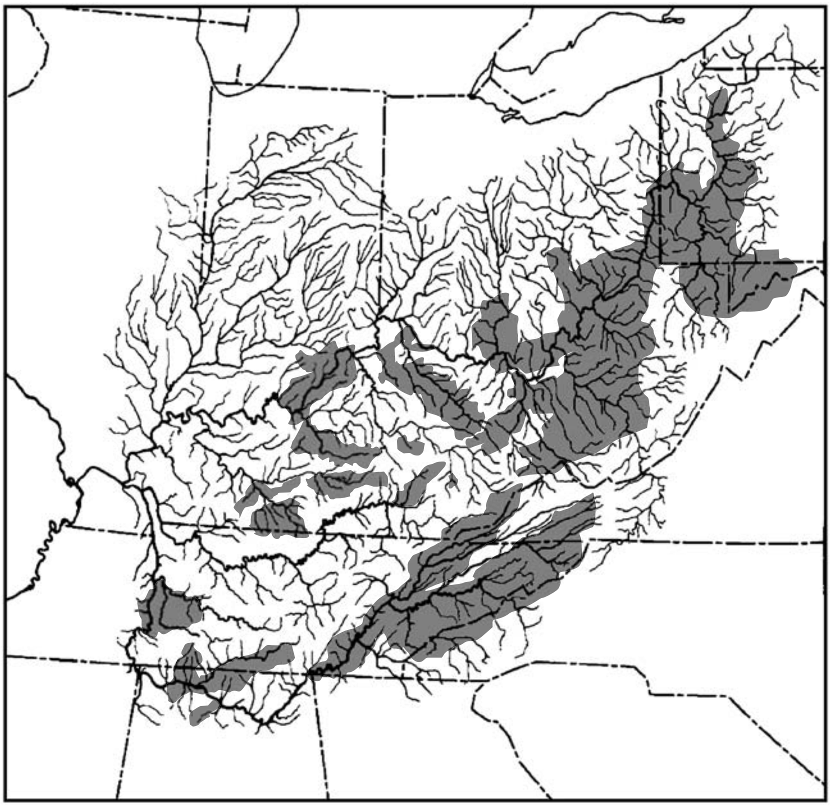

FIGURE 155 Distribution of banded darter, *E. zonale* in the Ohio River system (shaded area).

habitats.[15] Juveniles, greater than 25 mm TL are the smallest individuals found on the margins of the riffle and flowing pool habitat in IN streams tributary to the Tippecanoe River and in Laughery Creek. After spawning season ends most darters drift from smaller streams downstream to deeper water.[17]

Early Growth (Table 167)
Trautman (1981) reported banded darter juveniles collected from OH in October to reach 20–43 mm. Longevity reported to 3 or more years for a PA population.[6]

Table 167
Average calculated lengths (mm TL) of young banded darters in several states.

State	Age 0	1	2	3	4
Ohio[17]	20–43				
Tennessee[12]		25–35 SL			
Wisconsin[18]		36.5	50.2	55.1	61.3

Feeding Habits
Larval specimens from the Susquehanna River, near Three Mile Island, feed on vegetable matter and most specimens greater than 9.0 mm have green gut tracts.[15] *Etheostoma zonale* consumed a diet of midge and mayfly larvae, with lesser amounts of blackflies and trichopteran larvae.[9,10] TN specimens consumed predominately midge larva.[12]

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Material Examined: PA: Susquehanna River, Three Mile Island Nuclear Station, BFL 76-221 (185); LRRC 837 (23). Susquehanna River, York Haven Impoundment, near Middleton, BFL uncatalogued (1). OH: Ohio River, ORM 76.7, Pike Island Pool, near Brilliant, GM 76-6-4-85 (1). IN: Ripley County: Laughery Creek, Versailles State Park LRRC 1000 (45). TN: Megs County: Hiwassee River, HRM 6.1, TV 1689 (1).

* Original fecundity data from specimens collected from Buffalo River, TN. Specimens curated at Northeast Louisiana University, Museum of Zoology, Monroe, LA.

BANDFIN DARTER

Etheostoma (*Ulocentra*) *zonistium* Bailey and Etnier

Etheostoma: various mouths; *Ulocentra*: complete spine; *zonistium*: band fin.

RANGE

Etheostoma zonistium is found in the Tennessee River basin where it occurs in Coastal Plain stream habitat in KY, TN, AL, and MS.[1] The species occurs east of the lower Tennessee River in Pony Creek and in the Land-Between-the-Lakes area, southwestern KY.[5] Restricted to the northwestern part of Bear Creek system (Pennywinkle and Little Cripple Deer Creeks, Tishomingo Co., MS),[11] AL and MS, Black Warrior River system of Lawrence and Winston Co., AL,[13] and also Spring Creek, Hatchie River drainage, south of Bolivar, Hardeman Co., TN.[1–5]

HABITAT AND MOVEMENT

The bandfin darter inhabits low gradient, clear, small- to medium-sized streams along the Coastal Plain. Adults prefer fine sand and gravel substrates in riffles and pools with slight to moderate current.[1,5,7,14]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Etheostoma zonistium is described from populations in the Bear Creek system, small tributaries to the Tennessee River in western Lauderdale Co., AL.[13] In MS, the species is found only in the Bear Creek, Tennessee River, and Yellow Creek drainages.[11] Generally distributed and abundant in Clarks and Blood river drainages, Jonathan Creek, and Billie Branch.[4] In the Tennessee River drainage, the distribution reflects the boundary between the Coastal Plain and western Highland Rim.[5]

SPAWNING

Location

Ripe females are collected from emergent vegetation, tree roots, and brush piles in KY.[14]

Season

Spawning probably continues from March until May or June in KY;[14] however, an April to May breeding season is indicated for TN populations.[1]

Temperature

Spawning in West Fork Clarks River, Calloway Co., KY, occurs when temperatures reach 11–17°C.[7–14]

Fecundity

The mean number of large ripe ova in age 1 females was 77, and age 2 and 3 females averaged 128 large ripe ova. These values were considered underestimates of fecundity because of the smaller ova that would mature during the breeding season.[7–14]

Sexual Maturity

Bandfin darter reach maturity at age 1 when fish are between 25 and 35 mm SL in TN. In West Forks Clarks River, KY, age 1 females averaged 31 mm and males 34 mm.[7–14]

Spawning Act

Etheostoma zonistium is an egg attacher.[12] Spawning was observed on darters obtained from West Fork Clarks River, Calloway Co., TN.[7–14] The observations are based on spawning pairs maintained in laboratory aquaria. Egg sites include the slight depressions on the vertical sides of rocks and less often horizontal tops of rock, and on *Ceratophyllum*.[7–14] The male approaches the female and crosses over her dorsum in a zig-zag pattern. The male stimulates the female by rubbing his pectoral fin, and occasionally his chin, on the nape of the female. The female leads the male to the egg deposition site. The female with a head-up position is mounted by the male. The male body movements resemble an S-shape, with the caudal peduncle of the male wrapped around that of the female. Adults maintain a head-to-head orientation with vents juxtaposed and pressed against the rock surface and vibrated. The pair is observed to switch positions on the rock depositing eggs on different sections of the same or different rock. Each adult is promiscuous, spawning with multiple partners on different rocks. The female, when left unattended, spawns with any male available, and is observed to spawn with two males simultaneously.

No cleaning of the rock surface or parental care is provided before or after the eggs are laid.[7–14]

EGGS

Description
Eggs from the West Fork Clarks River, Calloway Co., TN, are spherical, mean = 1.7 mm diameter (range: 1.5–2.1 mm), translucent, demersal, and adhesive. Eggs possess translucent, pale yellow yolk (mean = 1.6 mm diameter; range: 1.3–2.0 mm), a single oil globule (mean = 0.5 mm), a moderate perivitelline space (mean = 0.1 mm), and an unsculptured and unpigmented chorion.[12]

Incubation
Hatching occurs after 163–170 h at an incubation temperature of 18–22°C. [7–14]

Development
Unknown.

YOLK-SAC LARVAE

See Figure 157

Size Range
4.1–4.3 mm to 5.2 mm.[12]

Myomeres
Preanal 15 (3), 16 (4), or 18 (2)(*N* = 9, mean = 16.1); postanal 22 (7) or 23 (2)(*N* = 9, mean = 22.2); total 37 (1), 38 (6), or 40 (2)(*N* = 9, mean = 38.3).[12]

Morphology
4.1–4.3 mm TL. Newly hatched larvae with terete body; snout blunt, with functional jaws, upper jaw even, slightly extending past lower jaw; well-developed pectoral fins without incipient rays;[12] yolk sac small (24.2% TL), oval to tapered posteriorly; yolk translucent, pale yellow, with a single oil globule; single serpentine vitelline vein mid-ventrally on yolk sac; head not deflected over the yolk sac; and eyes oval.[12]

4.9 mm TL. Digestive system functions prior to complete yolk absorption.[12]

Morphometry
See Table 168.[12]

Fin Development
See Table 169.

4.1–4.3 mm TL. Newly hatched larva with well-developed pectoral fins without incipient rays.[12]

Pigmentation
4.1–4.3 mm TL. Newly hatched larva with pigmented eyes; melanophores dorsally outlining the optic lobe and over posterior cerebellum or nape; dorsal melanophores distributed posteriorly, to dorsal fin origin; laterally, melanophores dorsally over the gut; ventral pigmentation consists of a mid-ventral series of scattered, punctate melanophores, forming a band near the vitelline vein on the yolk sac; punctate melanophores ventrally outline the gut; paired punctate melanophores along almost every mid-ventral postanal myosepta.[12]

4.7–5.2 mm TL. Cranial melanophores distributed over the cerebellum and extending onto the nape; several lateral melanophores distributed posterior to the eye. A single series of melanophores extends from the shoulder to midanal fin; subdermal pigmentation outlines the stomach and gut dorsally; several melanophores occur at the base of the notochord. Ventral melanophores occur on the chin, from the breast to the anus in either a single or double row, and mid-ventral postanal myosepta with expanded stellate melanophores at every junction forming a continuous line.[12]

POST YOLK-SAC LARVAE

See Figures 156 and 157

Size Range
5.2 mm TL[12] to unknown length <21.2 mm.[12]

Myomeres
Preanal 15 (3), 16 (4), or 18 (2)(*N* = 9, mean = 16.1); postanal 22 (7) or 23 (2)(*N* = 9, mean = 22.2); total 37 (1), 38 (6), or 40 (2)(*N* = 9, mean = 38.3).[12]

Morphology
5.3 mm TL. Operculum and gill arches function.[12]

5.6 mm TL. Premaxilla and mandible form.[12]

7.0 mm TL. Neuromast development occurs mid-laterally from the anterior trunk posteriad; branchiostegal rays form and notochord flexes.[12]

7.0–21.2 mm TL. No additional specimens are available for study between 7.0–21.2 mm.[12]

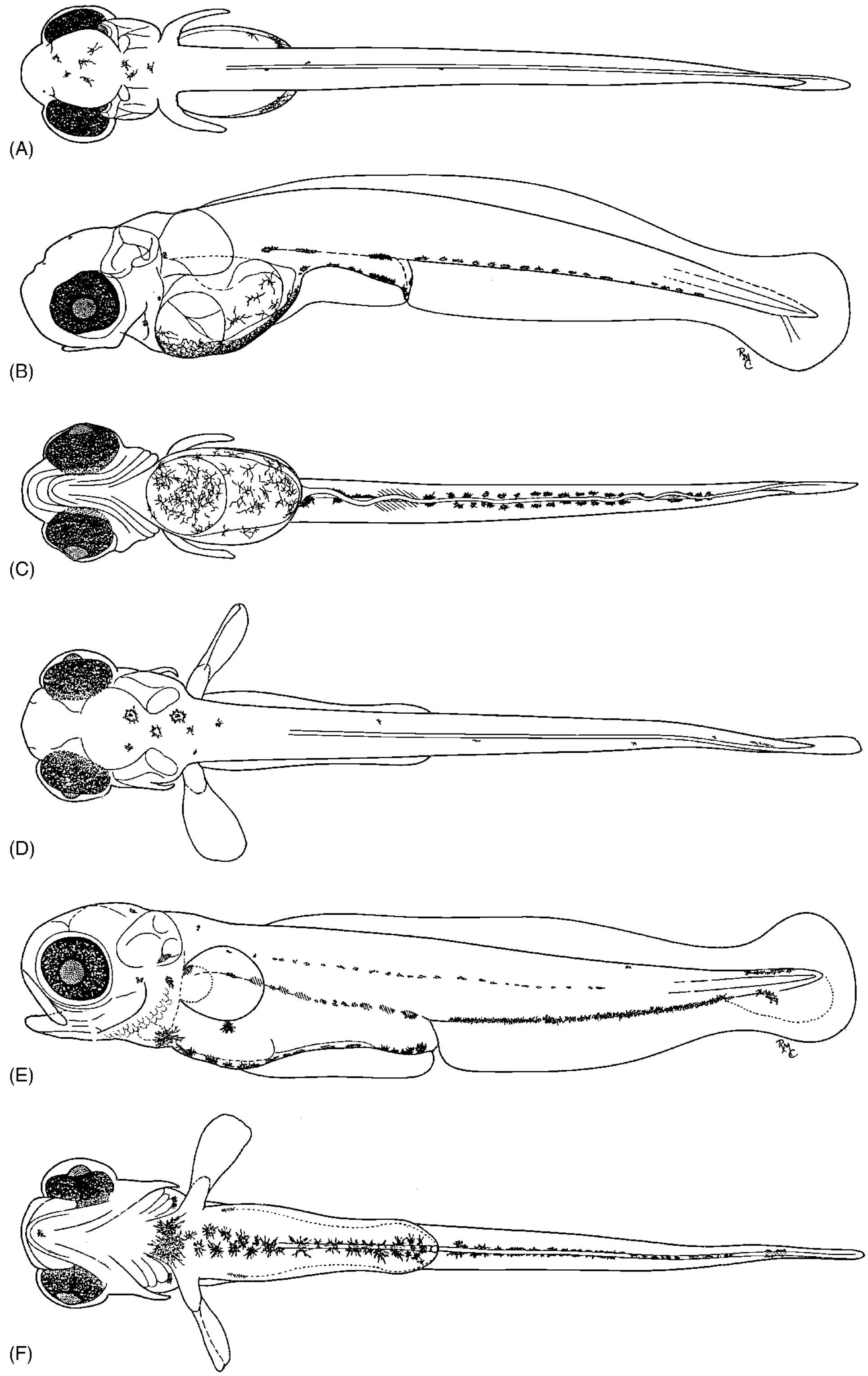

FIGURE 156 *Etheostoma zonistium*, bandfin darter, West Fork Clarks River, Graves Co., TN. Yolk sac larva, 4.2 mm TL: (A) dorsal, (B) lateral, (C) ventral views. Post yolk-sac larva, Turkey Creek, Benton County, TN, 5.5 mm TL: (D) dorsal, (E) lateral , (F) ventral views. (A-F from reference 12, with author's permission.)

Morphometry
See Table 168.

Fin Development (Table 169)
5.6 mm TL. First rays form in caudal fin.[12]

>7.0 mm TL. Pelvic fin buds form anterior to dorsal fin origin after complete yolk absorption; formation of spinous and soft dorsal, anal, pectoral, and pelvic rays; dorsal and anal finfold partially differentiated (7.0 mm).[12]

Table 168

Morphometry of young *E. zonistium* grouped by selected intervals of total length (N = sample size).[12]

	Total Length (TL) Intervals (mm)							
	4.01–4.91 (N = 4)		5.23–5.60 (N = 2)		7.04 (N = 1)		21.2–23.2 (N = 3)	
Characters	Mean ± SD	Range	Mean ± SD	Range	Mean	Range	Mean ± SD	Range
Length (% of TL)								
Upper jaw[a]	21.2 ± 3.58	(0.12–0.25)	30.7 ± 0.28	(0.34–0.37)	26.7	(0.40)	25.9 ± 3.86	(1.07–1.28)
Snout[a]	13.7 ± 3.00	(0.08–0.12)	12.2 ± 1.98	(0.13–0.15)	14.0	(0.21)	21.1 ± 0.61	(0.92–0.96)
Eye diameter[a]	48.9 ± 6.04	(0.35–0.44)	39.4 ± 0.85	(0.44–0.47)	35.3	(0.53)	27.4 ± 1.30	(1.19–1.30)
Head	18.0 ± 2.04	(0.65–0.98)	21.3 ± 0.42	(1.10–1.21)	21.3	(1.50)	20.5 ± 1.19	(4.22–4.64)
Predorsal	23.5 ± 5.85	(0.75–1.53)	25.8 ± 4.24	(1.19–1.61)	26.1	(1.84)	25.1 ± 1.21	(5.28–5.64)
Dorsal insertion					26.1	(1.84)	44.3 ± 2.16	(9.00–10.2)
D2 origin					26.1	(1.84)	46.1 ± 2.14	(9.42–10.6)
D2 insertion					26.1	(1.84)	64.1 ± 3.82	(9.42–10.6)
Preanal	48.2 ± 1.00	(1.91–2.39)	49.4 ± 2.05	(2.51–2.85)	50.0	(3.52)	47.9 ± 1.93	(9.89–11.6)
Postanal	51.9 ± 1.12	(2.10–2.52)	50.6 ± 2.12	(2.72–2.75)	50.0	(3.52)	52.1 ± 1.91	(11.2–11.6)
Standard	95.8 ± 1.13	(3.87–4.62)	96.1 ± 0.57	(5.05–5.36)	94.3	(6.64)	83.1 ± 0.62	(17.5–19.4)
Yolk Sac	23.2 ± 1.63	(0.93–1.09)						
Fin Length (% of TL)								
Pectoral	9.16 ± 1.51	(0.34–0.49)	10.9 ± 2.97	(0.46–0.73)	11.8	(0.83)	18.2 ± 0.72	(3.72–4.42)
Pelvic							13.6 ± 1.61	(2.62–3.26)
Spinous dorsal							19.1 ± 1.42	(3.72–4.56)
Soft dorsal							18.0 ± 1.74	(3.64–4.26)
Caudal	4.24 ± 1.13	(0.14–0.29)	3.86 ± 0.57	(0.18–0.24)	5.68	(0.40)	16.9 ± 0.62	(3.56–3.80)
Body Depth (% of TL)								
Head at eyes	15.7 ± 2.00	(0.54–0.89)	16.5 ± 0.71	(0.84–0.95)	15.2	(1.07)	12.3 ± 0.84	(2.62–2.73)
Head at Pl	17.6 ± 1.72	(0.74–0.83)	16.4 ± 0.71	(0.83–0.95)	16.1	(1.13)	14.3 ± 1.30	(2.97–3.22)
Preanal	8.06 ± 0.47	(0.31–0.43)	8.75 ± 0.71	(0.43–0.52)	9.52	(0.67)	13.0 ± 1.13	(2.72–2.92)
Mid-postanal	6.07 ± 0.77	(0.22–0.34)	6.55 ± 0.14	(0.34–0.37)	6.53	(0.46)	9.02 ± 0.80	(1.92–2.08)
Caudal peduncle	3.14 ± 0.50	(0.12–0.15)	3.60 ± 0.28	(0.18–0.21)	3.41	(0.24)	7.15 ± 0.87	(1.42–1.64)
Yolk Sac	10.0 ± 3.73	(0.23–0.53)						
Body Width (% of HL)								
Head	80.3 ± 9.34	(0.44–0.83)	71.9 ± 1.13	(0.80–0.86)	69.3	(1.04)	46.7 ± 4.09	(2.00–2.16)
Myomere Number								
Predorsal	3.75 ± 0.55	(3.00–4.00)	4.00 ± 0.00	(4.00–4.00)	4.00	(4.00)	4.00 ± 0.00	(4.00–4.00)
Soft dorsal	16.0 ± 0.00	(16.0–16.0)	16.0 ± 0.00	(16.0–16.0)	16.0	(16.0)	17.0 ± 0.00	(17.0–17.0)
Preanal	15.8 ± 0.55	(15.0–16.0)	15.0 ± 0.00	(15.0–15.0)	16.0	(16.0)	18.0 ± 0.00	(18.0–18.0)
Postanal	22.0 ± 0.00	(22.0–22.0)	23.0 ± 0.00	(23.0–23.0)	22.0	(22.0)	22.0 ± 0.00	(22.0–22.0)
Total	37.8 ± 0.55	(37.0–38.0)	38.0 ± 0.00	(38.0–38.0)	38.0	(38.0)	40.0 ± 0.00	(40.0–40.0)

[a] Proportion expressed as percent head length

Note: characters expressed as percent total length (TL) or head length (HL), with a single standard deviation, and range of values in parentheses.)

Table 169

Meristic counts and size (mm TL) at the apparent onset of Development for *E. zonistium.*

Attribute/event	*Etheostoma zonistium*	Literature
Branchiostegal Rays	5,5[12]	5,5[1,2,4,7]
Dorsal Fin Spines/Rays	X–XI/11–12[12]	IX-XII/10–12[1,2,4,7]
First spines formed	>7.0[12]	
Adult complement formed	>7.0[12]	
First soft rays formed	>7.0[12]	
Adult complement formed	>7.0[12]	
Pectoral Fin Rays	15[12]	13–15[1,2,4,7]
First rays formed	>7.0[12]	
Adult complement formed	>7.0[12]	
Pelvic Fin Spines/Rays	I/5[12]	I/5[1,2,4,7]
First rays formed	>7.0[12]	
Adult complement formed	>7.0[12]	
Anal Fin Spines/Rays	II/8[12]	II/6–8[1,2,4,7]
First rays formed	>7.0[12]	
Adult complement formed	>7.0[12]	
Caudal Fin Rays	viii–xi, 8–9 + 8–9, ix–x[12]	15–18[1,4]
First rays formed	5.6[12]	
Adult complement formed	>7.0[12]	
Lateral Line Scales	46–53[12]	40–52[1,2,4,7]
Myomeres/Vertebrae	37–40/37–39[12]	Unknown/37–39[1,2,4]
Preanal myomeres	15–18[12]	15[7,14]
Postanal myomeres	22–23[12]	21[7,14]

7.0–21.2 mm TL. No additional specimens are available for study between 7.0 and 21.2 mm.[12]

Pigmentation

5.2–5.6 mm TL. Cranial melanophores distributed over the cerebellum and extend onto the nape; several lateral melanophores observed posterior to the eye. A single series of melanophores extends from the shoulder to midanal fin; subdermal pigmentation outlines the stomach and gut dorsally; several melanophores occur at the base of the notochord. Ventral melanophores occur on the chin, from the breast to the anus in either a single or double row, and mid-ventral postanal myosepta with expanded stellate melanophores at every junction, forming a continuous line.[12]

5.9–7.0 mm TL. Melanophores extend further onto the dorsum; distributed from the nape to posterior edge of the caudal peduncle. Lateral melanophores occur on the otic capsule and operculum; a mid-lateral series of melanophores extends from the shoulder to the caudal peduncle; dorsum of the stomach and gut; and in the epaxial and hypaxial musculature of the caudal fin. Ventral melanophores occur from the breast to the anus, continuing postanally to the caudal peduncle.[12]

JUVENILES

See Figure 157

Size Range

<21.2 mm[12] to 25 mm SL–34 mm TL.[4]

Fins

21.2 mm TL. Pelvic fin formed anterior to dorsal fin; dorsal and anal finfold differentiated; complete adult fin ray counts in median fins.[12]

15.2 to <21.3 mm TL. Spinous dorsal fin origin situated over preanal myomere 3–4, and soft dorsal

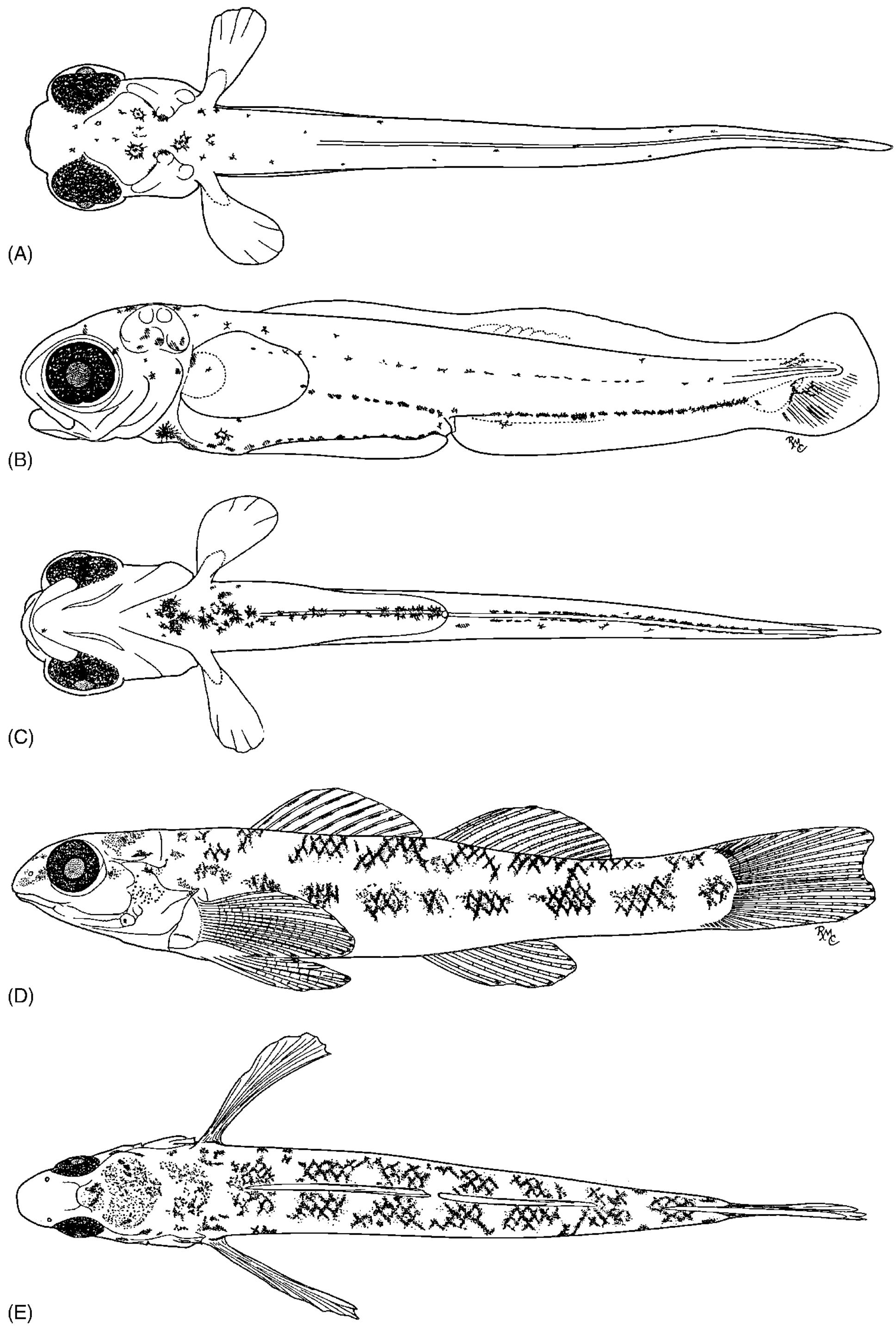

FIGURE 157 *Etheostoma zonistium*, bandfin darter, Turkey Creek, Benton Co., TN. Post yolk-sac larva, 7.0 mm TL: (A) dorsal, (B) lateral, (C) ventral views. Juvenile, West Fork Clarks River, Graves County, TN, 23.3 mm TL, (D) lateral, (E) dorsal views. (A-E from reference 12, with author's permission.)

origin over preanal myomere 16–17 (5.2–21.3 mm). Average predorsal length 26.9% SL (range: 21.1–28.4% SL) and 24.7% TL (range: 19.4–26.1% TL).[12]

Juvenile. Caudal fin slightly emarginate.[1,2,4]

Morphology

21.2 mm TL. Branchiostegal rays 5.[12]

15.2 to <21.3 mm TL. No swim bladder forms; gut straight, without striations, portion of gut posterior to stomach normal in length.[12]

<21.2 mm TL. Initiation of squamation; formation of lateral line.[12]

21.2 mm TL. Infraorbital, lateral, subtemporal, and preoperculomandibular head canals form.[12]

23.3 mm TL. Infraorbital, lateral, and supratemporal head canals not interrupted; preoperculomandibular canal complete with 8 to 10 pores; infraorbital pores 5, 7–9.[12]

Juvenile. Upper jaw equal with lower jaw, subterminal; juvenile squamation patterns include cheek scales, usually embedded (may be absent dorsally). Cheek, opercle, nape, and belly are completely scaled. Breast squamation variable, either naked or scaled on posterior half.[1,2,4]

Morphometry
See Table 168.

Pigmentation
21.2–23.2 mm TL. Cranium with distinct preorbital bar, and subtle suborbital bar; cranium with melanophores concentrated over the optic lobe and cerebellum; dorsum with eight dorsal saddles from the nape, spinous dorsal fin origin, mid-spinous dorsal fin, spinous dorsal fin insertion, soft dorsal fin origin, soft dorsal fin insertion, caudal peduncle, and caudal fin base. Lateral melanophores form a continuous midlateral stripe from the edge of the opercle to the caudal fin base. Ventrum with melanophores over anal fin and at anal fin lepidiotrichia with pterigiophores; spinous dorsal fin with four stripes of melanophores from the proximal to distal edge; soft dorsal with three equidistant stripes; caudal fin with scattered melanophores on the membranes of the fin, the pectoral, pelvic, and anal fins are unpigmented.[12]

TAXONOMIC DIAGNOSIS OF YOUNG BANDFIN DARTER

Similar species: members of subgenus *Ulocentra*.

Synonymy. *Etheostoma* sp. (*Lowland snubnose darter*) Burr, 1980, Brimleyana 3: 78 (Kentucky distribution). *Etheostoma* sp. (*Redbelly snubnose darter*) Kuehne and Barbour, 1983: 92 to 93, Pl. 11 (distribution and life history characteristics). *Etheostoma* sp. (*Bandfin darter*) Burr and Warren, 1986: 328 (distribution and habitat). Carney, 1985, Unpublished M.S. Thesis, Southern Illinois University at Carbondale (life history and comparative morphology). *Etheostoma rufescens* Gill, 1982, Trop. Fish Hobbyist (color plate, *nomen nudum*). *Etheostoma* sp. (*Lowland snubnose darter*) Page, 1981, Occ. Pap. Mus. Nat. Hist. Univ. Kansas, 90: 1 to 69 (combination of *E. zonale* with snubnose darters to synonomize *Ulocentra* with subgenus *Nanostoma*). Page, 1983: pl 15 (color photograph). Page, 1985, Ill. Nat. Hist. Surv. Bull. 33: 280 (reproductive mode designation as an attacher).[12]

Adult. *Etheostoma zonistium* can be differentiated from other members of the *E. duryi* species group on the basis of the presence of vomerine teeth and lack of a premaxillary frenum; modally possessing 10 rather than 11 dorsal spines, and 5 branchiostegal rays 5.[1] Pigmentation differs from all other *Ulocentra* by displaying six distinct alternating bands in the spinous dorsal fin; lateral blotches ovoid and confined to the lateral line area; lower side and venter orange to yellow below lateral stripe in adult males.[1,2,5] *Etheostoma zonistium* has modes of 40–52 lateral line scales and usually 10–13 scales around the caudal peduncle. *Etheostoma zonistium* occurs in the western tributaries of the Tennessee River system, TN and KY.[1,2,5]

Larva. *Etheostoma zonistium* is virtually identical with other members of the *E. duryi* species group in pigmentation, development, and myomere counts. All species have overlapping moderate preanal (16 to 18) myomere counts, while *E. duryi* typically has low postanal (22) myomere counts. The species is distinguished from *E. flavum* by possessing a larger yolk sac and less lateral and ventral pigmentation on the yolk sac.[12]

Variation
No intraspecific variation was exhibited between the two populations of *E. zonistium* studied. *Etheostoma zonistium* is similar to other members of the *E. duryi* species group based on pigmentation and ontogenetic events. *Etheostoma zonistium* hatches at smaller length intervals than other species. Pigmentation is similar to other members of the species group with cranial pigmentation, ventral yolk-sac melanophores, and mid-ventral postanal myoseptum. Dorsal pigmentation extends only to the dorsal finfold origin until 5.5 mm and it is not until greater lengths that melanophores extend more posteriorly.[12]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (see Figure 158)
Eggs. Eggs are collected from near-shore habitats usually associated with tree roots or rubble.[12]

Yolk-sac larvae. Aquarium observations indicate bandfin darter larvae are epibenthic immediately

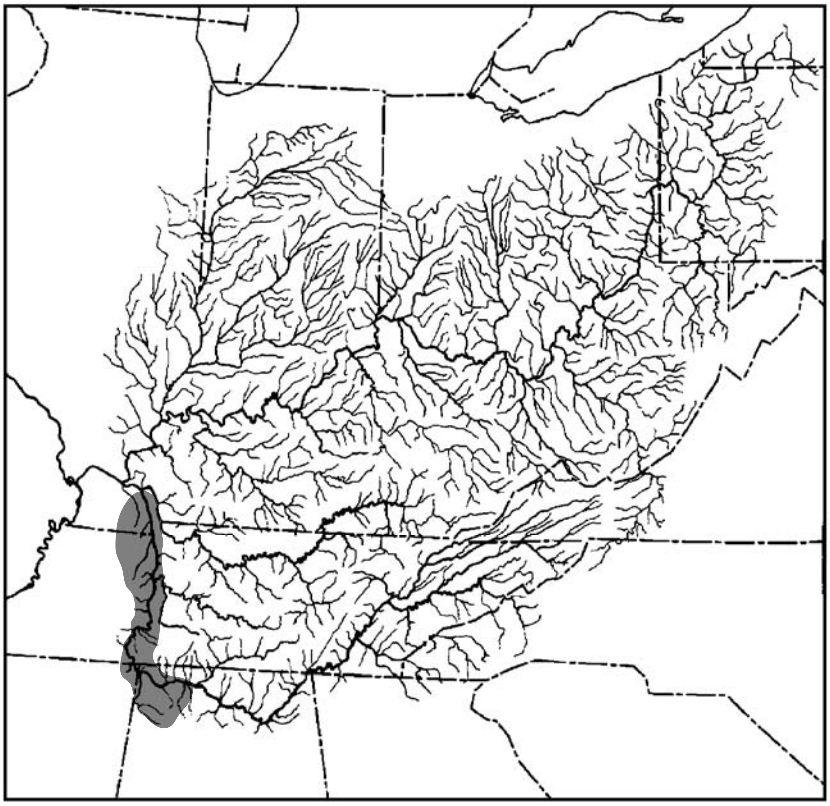

Figure 158 Distribution of bandfin darter, *E. zonistium* in the Ohio River system (shaded area).

after hatching. Yolk-sac larvae are collected in epibenthic dipnet samples from the near-shore habitats usually associated with tree roots or rubble.[12]

Post yolk-sac larvae. Larva become demersal at lengths greater than 7.0 mm. They remain in close association with the substrate. Bandfin darter larvae from TN, are collected in equal numbers from pool areas behind tree roots and other structures that act as obstructions in flowing habitat during mid-March. All length intervals are collected in epibenthic dipnet samples from the near-shore habitats usually associated with tree roots or rubble.[12]

Juveniles. Early juveniles utilize the downstream pools and backwater areas adjacent to spawning pools as nursery habitats. Juveniles are collected in epibenthic dipnet samples from the near-shore habitats usually associated with tree roots or rubble.[12] Females outnumber males 1.7:1.[7–14]

Early Growth (Table 170)
Hatchlings average 4.3 mm TL[4]. Maximum life span is 3 years.[4] Males are slightly larger than females at age 1.[7–14]

Table 170

Average calculated lengths (mm SL) of young bandfin darters in several states.

	Age	
State	**1**	**2**
Kentucky[7,14]	33.8	
Mississippi[11]		50
Alabama[1]		57

Males have a greater mortality rate than females during age 0. Survivorship is high with 59.4% of the individuals reaching age 1, but only 18.8% reaching age 2.[7–14]

Feeding Habits
Diet is primarily microcrustaceans, aquatic insects, especially midge larvae.[4,7,11,14]

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GENUS
Percina Haldeman

Thomas P. Simon

The genus *Percina* contains about 40 species that include the largest and least colorful members of the darters. Some members are diminutive and spectacularly colored, while most are drab and possess background colors of brown and olive that heightens during the spawning season with black accents. The genus is morphologically and behaviorally the least derived of the darters. The genus is defined by the presence of large scales that occur on the breast between the bases of the pelvic fins and a mid-ventral row may be present on the belly of the male and occasionally female; a complete lateral line with high-scale counts; a complete cephalic sensory canal system, with a mode of 8 infraorbital pores and 10 preoperculomandibular pores; separate to moderate connection of the gill membranes, six branchiostegal rays; and the remnants of the swim bladder (Page, 1974a). Ontogenetic traits that diagnose the genus include high preanal myomere counts (>18); a weakly formed mouth, pectoral fin, and small yolk-sac at hatching, single mid-ventral vitelline vein; narrow greatest body depth/TL at lengths <8.0 mm TL (<0.14), narrow body depth at anus/TL at lengths <8.0 mm TL (<0.080), narrow caudal peduncle depth/TL at lengths <8.0 mm TL (<0.035), and generally possessing a pelagic existence at hatching (Simon, 1994).

Percina includes 16 species divided among 9 subgenera occurring in the Ohio River drainage (Table 171; Page, 1974a). Six species endemic to the drainage include *P. aurantiaca, P. macrocephala, P. oxyrhyncha, P. squamata, P. tanasi,* and *P. strictogaster*. Perhaps the most famous of all darters is the snail darter *P. tanasi*, which held up the construction of the Tellico Dam (Etnier, 1976b). Representatives of all nine subgenera of *Percina* occur in the Ohio

Table 171

Common and scientific names of darters in the genus *Percina* occurring in the Ohio River drainage with subgeneric membership following Page (1974a).

Tangerine darter	*P. aurantiaca* (Cope)	*Hypohomus*
Blotchside logperch	*P. burtoni* Fowler	*Percina*
Logperch	*P. caprodes* (Rafinesque)	*Percina*
Channel darter	*P. copelandi* (Jordan)	*Cottogaster*
Gilt darter	*P. evides* (Jordan and Copeland)	*Ericosma*
Longhead darter	*P. macrocephala* (Cope)	*Alvordius*
Blackside darter	*P. maculata* (Girard)	*Alvordius*
Sharpnose darter	*P. oxyrhynchus* (Hubbs & Raney)	*Swainia*
Slenderhead darter	*P. phoxocephala* (Nelson)	*Swainia*
Roanoke darter	*P. roanoka* (Jordan and Jenkins)	*Alvordius*
Dusky darter	*P. sciera* (Swain)	*Hadropterus*
River darter	*P. shumardi* (Girard)	*Imostoma*
Olive darter	*P. squamata* (Gilbert and Swain)	*Swainia*
Blackfin darter	*P. stictogaster* Burr & Page	*Odontopholis*
Snail darter	*P. tanasi* Etnier	*Imostoma*
Saddleback darter	*P. vigil* (Hay)	*Imostoma*

River drainage. Significant understanding of *Percina* relationships is a result of the research of Bailey and Gosline (1955), Collette (1965), Page (1974a, 1976a, 1977, 1983a), and Page and Whitt (1973a, 1973b).

Reproductive biology is poorly known for most *Percina* species; however, the modified breast and belly scales vary by season with their presence signifying the approach of the spawning season. The scales may functionally serve as contact organs during spawning (Page, 1976a). All species that are currently known are gravel spawners, which exhibit a simple burying reproductive mode. This behavior is considered the least derived of all reproductive acts. We have contributed significantly to the knowledge of fecundity and ovarian development for most species in the study area.

Limited ontogenetic information is currently available for many species in this genus. Many are large river forms that makes collection and study difficult. Those species that are commonly found in small- to moderate-sized rivers have been well studied. Almost all members of *Percina* once hatched are pelagic and exhibit drift behavior that carries them long distances downstream from their spawning grounds to their nursery habitats. Several theories have been researched for understanding this behavior. Paine (1984) suggested that this behavior is meant to efficiently carry yolk-sac larvae from spawning grounds to plankton-rich nursery habitats. Simon (1994) suggested that the need for the larvae to grow quickly and respire efficiently, as a result of the simple single vitelline vein, enables them to utilize the warm well-oxygenated currents and conserve energy as they are transported to nursery habitats. Growth is optimized as larvae inhabit warm temperatures, yet it must balance against low dissolved oxygen levels. Paine and Simon agree that since most species possess a simple stomodeum at hatching, feeding cannot be a reason for drift. Perhaps, the harsh environmental conditions found on riffles and shoals where spawning occurs would reduce fitness of species; therefore, to conserve energy and reach the quiet waters that serve as nursery, habitats drift is the greatest fitness and energy-enhancing mechanism.

Many yolk-sac larvae of *Percina* species are photophobic and cannot tolerate light. The only species considered phototaxic attracted to light is *P. tansi.* As additional culture of *Percina* species is successfully completed, more research can be spent on determining the roles that light and dissolved oxygen have on larval survival.

TANGERINE DARTER

Percina (*Hypohomus*) *aurantiaca* (Cope)

Percina: a small perch; *aurantiaca*: orange-colored.

RANGE

Percina aurantiaca is endemic to the upper Tennessee River drainage. It occurs throughout the Emory, Little, Little Pigeon, Tellico, and Hiwassee Rivers, TN.[1–6] Its distribution has been fragmented by the storage reservoirs on those tributaries, but it continues to be widespread and abundant. It probably occurred in the main channel of Tennessee River prior to impoundments.[4] It also occurs in the South and North Forks of the Holston, Clinch, and Powell Rivers, VA.[5]

HABITAT AND MOVEMENT

Percina aurantiaca inhabits the clear portions of cool and warm streams and rivers in moderate gradient of large-to moderate-sized headwater tributaries of the Tennessee River.[4,5] Altitude of these habitats range from 260 to 550 m[4], and preferred gradient ranges between 18.7 and 28.6 ft/mile.[7] It occurs in deep riffles and runs with boulders, large rubbles, and bedrock substrates during the majority of the year or may perch on large boulders and logs in pools 2.5 m deep.[5] In VA it occurs over silty substrates, but spends as much as 25% of its time above the bottom in an epi-benthic lifestyle.[5] Models predicted that the preferred depth is between 0.51 and 0.75 m.[11] Movement into deeper pools occurs during the winter[4] ; large males occupy riffles during summer and fall in TN,[7] and during spring in swift runs and riffles.[8]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Percina aurantiaca has been collected from three VA tributaries including, Guest River and Copper Creek, Clinch River drainage, and lower Big Moccasin Creek, a tributary of the North Fork Holston River. It has been extirpated from Guest River, but appears stable in Copper Creek below Spivey Mill Dam.[5] It occurs in low abundance in the South Fork Holston River.[7]

SPAWNING

Location
Spawning habitats include gravel-sand substrates.[7] Spawning occurs in shallow water in moderate to swift current over gravel with some sand or with entirely sand.[5]

Season
Spawning males and females are gravid from April to mid-July in TN;[7] spawning is observed in late May in VA and during late June in TN.[5]

Temperature
Spawning in a raceway occured in mid-July at 14.5°C;[7] while field spawning was observed during late May at 21°C in the North Fork Holston River, VA;[5] and during late-June at 23°C in the Little Pigeon River, TN.[5]

Fecundity (see Table 172)
Female tangerine darter do not show statistically significant fecundity (ANOVA, $F = 0.146$, $p = 0.712$) with increasing length (Table 172).[9] A 116 mm females had 298 large mature ova, while several 112 mm females had 370–375 large mature ova.* May specimens possessed between 120 and 578 mature ova.[5] TN females produced between 400 and 1100 ova.[4] Little River, TN, females were mature by 102 mm.[9]

Sexual Maturity
Male specimens from TN had flowing milt and intense sexually dimorphic coloration that was present from April until July.[7] Males do not develop breeding tubercles but possess a thin keel on the lower caudal peduncle.[7] Some males are sexually mature during age 1 (61 mm), while most males are sexually mature at age 2 (71 mm).[7] Age 1 females are never found with mature ova, but age 2 females are all sexually mature.

Spawning Act
Percina aurantiaca is an egg burier. Spawning occurs in shallow water in moderate to swift current over gravel with some sand and in another sites entirely

Table 172

Fecundity data for *P. aurantiaca* from the Little River, TN and Little Pigeon, Hiwassee, and Emory-Obed Rivers, TN.

		Number of Ova			
Length (mm TL)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
Little Pigeon, Hiwassee, and Emory-Obed Rivers[7]					
74	—	250	140		
86.5	—	296	120		
89	—	450	193		
93	—	304	184		
98	—	414	0		
104	—	752	223		
120.5	—	567	578		
74	—	132	0		
88.5	—	399	159		
103	—	737	750		
65	—	2000+	0		
Little River[9]					
112	1947	1688	745	370	1.81
102	869	1065	512	342	1.54
104	818	998	587	300	1.54
112	2440	1539	854	375	1.81
109	1190	1178	698	354	1.54
107	1530	1109	713	345	1.66
107	938	945	595	339	1.54
106	2190	1398	1071	286	2.00
111	1630	1474	895	314	1.66
116	1580	1441	881	298	1.66

with sand.[5] The spawning act is typical of other egg-burying species. The female settles in the gravel and is mounted by a male who hovers over the female for 2–3 s, the male's pelvic fins folded over the female's opercular region so that the male's pelvics touches the back edge of the female's opercular flap. The male is perched more anteriorly on the female and has his caudal and anal fins on the same side. No noticeable rubbing of the male isthmus on the female nape is observed, and the pair always faced upstream into current. The male jerks vertically several times during the intense lateral quivering. The male quivers and then the female quivers and moves slowly forward depositing eggs into the gravel. The male's body is arched posteriad at a 30° angle horizontally to the female. The spawning act lasts 4–17 s and at the height of the spawning embrace the male caudal fin overlaps the female body. This action causes the female to rise from the substrate, depositing between 1 and 5 eggs that are fertilized. After 3–4 s, the female lowers her body back to the surface and quivering ceases. The activity causes the male to disengage from the female and then rest beside her. This resting behavior lasts for about 10 s, then the reproductive behavior starts again.[7]

EGGS

Description

Ovarian examination shows that ovoid-latent ova are 0.4 mm, early maturing ova averages 0.8–0.9 mm, and large mature ova averages 1.54–2.0 mm.* Eggs from TN are spherical, mean = 2.1 mm diameter (range: 1.9–2.4 mm); pellucid, demersal, and adhesive. Eggs possess translucent clear to pale yellow yolk (mean = 2.0 mm in diameter; range: 1.7–2.2 mm); a single oil globule (mean = 0.3 mm; range: 0.2–0.3 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.[7,*]

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILE

Size Range
Unknown to 61 mm males and 102 mm females.[7]

Fin Development
Branchiostegal rays 5, dorsal spines/rays XIII–(XIV-XV)–XVI/ 12–(13–14)–15;[1–5] pectoral rays 13–(14–15)–16;[1–5] anal spines/rays II/9–(10–11)–12;[1–5] caudal fin rays 17 (16–17).[1–4]

Morphology
Cheek, opercle, nape, and belly fully scaled; breast partly or fully scaled; mid-ventral scales of male weakly modified on interpelvic area and belly.[1–5] Lateral line complete, scales 84 (86–93) –99.[1–5] Vertebrae 43–46.[4]

Morphometry
Unknown.

Pigmentation
Lower and ventral side pale, subocular bar absent. Light olive along the backside; markings brown to black; lower side and abdomen creamy, with pale yellow gular region. Lateral body with 8–11 dark or black, moderately or broadly fused blotches that usually form a continuous stripe; blotches tend to become more diffused on the ventral side. Back has dark line extending along fin bases and with 10–12 small saddles, usually bilaterally symmetrical. Dorsolateral area slightly or quite dusky, with a longitudinal row of spots from the head to the dorsal fin.[5]

TAXONOMIC DIAGNOSIS OF YOUNG TANGERINE DARTERS

Similar species: *P. macrocephala*

Information lacking for early developmental phases. Juveniles most similar to *P. macrocephala,* which has a similar wide black lateral stripe but possesses a much more pointed snout, lacks bright colors, and also lacks the row of small black spots in the dorsolateral area.[4]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 159)
Eggs. Eggs are deposited in shallow water in moderate to swift current over gravel with some sand and sites entirely with sand.[5]

Yolk-sac larvae. No information available. Assumed to remain in the interstitial pore spaces until yolk absorb, then drift to nursery habitats in downstream shallow pools.[9]

Post yolk-sac larvae. Larvae occur along the edge of shallow pools and run habitats downstream from spawning riffles. These areas serve as nursery habitats.[7] Larvae are the only age class that occur in the shallow pool habitats.[7]

Juveniles. Juveniles occur along the edge of shallow pools and in downstream run habitats.[7] Juveniles are residents of the run habitats from July until mid-October, then moved downstream into deep pools with adults from early to late October.[7] A 25 mm, age 0 young-of-the-year individual was first collected in the run habitat on August 7, and by late August they were abundant. Age 1 fish return to run nursery habitats during the spring.

Early Growth (Table 173)
Rapid early growth suggests that post yolk-sac stages are short, probably not more than 5–6 weeks.[7] Sex ratios are 1.21 females per male. Survivorship shows that about 25% of the age 0 fish survive to age 1, 28.7% survive from age 1 to age 2, 23.7% survive from age 2 to age 3, and 8% survive from age 3 to age 4.

Feeding Habits
Percina aurantiaca is a visual sight feeding insectivore selecting feeder. Feeding behavior includes the upstream movement of individuals followed by vertical "climbing" of rocks. Individuals foraged for insects among the *Podostemum ceratophyllum. P. aurantiaca* is an opportunistic feeder.[7] Young-of-the-year's (39–58.5 mm) diet from the Emory-Obed River, TN, included immature mayflies, tendipedid midges, and some coleopteran.[7] The smallest juvenile specimen (28 mm) includes baetid mayflies.[7] A 31 mm juvenile had consumed 76 microcrustaceans, including cladocerans and cyclopoid copepods; and a baetid mayfly.[7]

Figure 159 Distribution of tangerine darter, *P. aurantiaca* in the Ohio River system (shaded area).

Table 173

Average calculated lengths (mm SL) of young tangerine darters from Tennessee and Virginia.

		Age				
State		**0**	**1**	**2**	**3**	**4**
TN[4]			50–60	85-90	105–120	130+(152)
VA[5]					90–115	130
Emory-Obed River[7]						
0	Male	42–49				
0	Female	39–52				
I	Male		—			
I	Female		69–72			
II	Male			86–91		
II	Female			80–105		
III	Male				90–109	
III	Female				100–115	
IV	Male					118–129
IV	Female					—

Maximum lengths are in parentheses.

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Material examined: TN: Little River, Blount County, HWY 73, ca. 3 miles S Walland, 7 April 1981 (30 ova); 9–10 April 1980 (40 ova); Old Walland Hwy at Parkway bridge 19 April 1984 (30 ova).

* T.P. Simon, original data.

BLOTCHSIDE LOGPERCH

Percina (*Percina*) *burtoni* Fowler

Percina: a small perch; *burtoni*: is a patronym for E. Milby Burton, former noted naturalist at the Charleston Museum, South Carolina, who collected the type specimen.

RANGE

Percina burtoni is a Tennessee and Cumberland River endemic that is fairly widespread throughout the Tennessee River drainage. It formerly occurred in the Cumberland River drainage of KY and TN, and may still persist in Little South Fork, a tributary of Big South Fork of Cumberland River, KY.[1–4]

HABITAT AND MOVEMENT

The blotchside logperch inhabits larger streams and rivers[3]; large creeks and small to medium sized rivers[5] having swift or moderate current.[2–4] It is sporadic in gravel bottomed riffles and the transition zones between riffles and pools.[7] Occasionally it is collected in pools or quiet waters avoiding silted areas.[6] Substrates are reported to be primarily gravel or rubble[6]; large gravel and small cobble[5] usually in water with depths of 0.5–1.0 m.[5–7] The blotchside logperch occurs approximately 25% of the tie on the bottom.[8] It occupies clear, warm waters and largely unsilted substrates,[6] and is intolerant of turbid waters.[2–6]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Percina burtoni is rare and localized in the Tennessee and Cumberland River drainages.[5,6] Consistently collected from portions of the Little and Duck Rivers, TN. Extirpated from the Cumberland River drainage, previously occurring in the Little South Fork, and from the Wolf and Obey Rivers.[5] Extirpated from the Little South Fork, KY, from the single collection locality where it was known.[9] In VA, it occurs in the North Fork Holston River, the lower section of major upper North Fork tributary (Laurel Creek), the Clinch River within 8 km of two tributaries (Copper Creek and Little River), and both of these Clinch River tributaries. Occurring in Copper Creek to the lower headwaters. Collected from the South Fork Holston River before impoundment. Might be expanding its range into the North Fork Holston River.[6]

SPAWNING

Location

Spawning habitat is clean loose gravel with moderate to strong flow. Gravid females and nuptial males were collected from Copper Creek and North Fork Holston River from the head of pools in mid- to late April.[6]

Season

Spawning occurs during April and May in TN;[5] and begins in April and extends to June in VA.[6]

Temperature

Spawning begins at 19°C.[6]

Fecundity (see Table 174)

A female collected from early April had mature ova within the tip of the genital papillae and three late April females were gravid. Females collected from mid- to late June were still capable of spawning.[6] Female blotchside logperch do not show statistically significant increasing fecundity with increasing length. A 98 mm female had 224 large mature ova, while a 100 mm female had 216 large mature ova (Table 174).*

Sexual Maturity

Male specimens in VA grew faster than females; all yearlings were immature.[6] Specimens attained sexual maturity at age 3.[5] Adult males that were sexually mature were 115–138 mm SL and the range of sexually mature females was 82–126 mm SL.[6] Males develop duskier pigmentation and intensified caudal peduncle spots; soft dorsal and anal fins; elongated fin lengths;[6] and nuptial tubercles develop on scales on ventral portions of body and caudal peduncle, including modified pelvic scale row, and tuberculate ridges on all spines and rays of anal and pelvic fins, lower rays of pectoral and caudal fins.[5] Males remain tuberculated from October to April and have large elongate anal fins. Tuberculate males shed their fin ridges and interconnecting

Table 174

Fecundity data for *P. burtoni* from Little River, Blount County, TN.*

Length (mm TL)	Ovary Weight (mg)	Number of Ova: Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
98	672	951	296	224	1.53
100	296	719	289	216	1.00

kertinized tissue in strips by early to mid-June.[6] Male genital papillae is a short, smooth or pitted tube otherwise similar to female genital papillae. Breeding females have enlarged abdomens, smaller anal fin lengths, and a short, mound-like, triangular, broadly rounded or truncate, smooth or ridged, tip often with one to several lobates on the genital papillae tube.[6]

Spawning Act
Unknown. Assumed to be similar to *P. caprodes*.[5]

EGGS

Description
Ovarian examination shows that ovoid latent ova are 0.4 mm, early maturing ova ranges between 0.7 and 0.8 mm, and large mature ova ranges between 1.0 and 1.53 mm.* Eggs from TN are spherical, mean = 1.53 mm in diameter (range: 1.0–1.5 mm); transparent, demersal, and adhesive. Eggs possess translucent, clear to pale yellow yolk (mean = 1.4 mm diameter; range: 0.9–1.4 mm); a single oil globule (mean = 0.4 mm; range: 0.2–0.5 mm); a narrow perivitelline space (mean = 0.1 mm); and an unsculptured and unpigmented chorion.*

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Field collected yolk-sac larva from the French Broad River were 7.9–9.1 mm; at yolk absorption <9.1 mm.*

Myomeres
Predorsal 5; preanal 21–22; postanal 21–23; total 42–44.[10]

Morphology
7.9–8.1 mm TL. Newly hatched larva with pigmented eyes; body terate in cross section; stomodeum present with no functional mouth parts; head not deflected over the yolk sac; pale yellow yolk; yolk-sac elongated and slender, tapering posteriorly; a single midventral vitelline vein is present; gut short.*

8.2–9.1 mm TL. Eyes spherical; gut straight; complete yolk absorption occurs by 9.1 mm;* gut relatively thick and heavily convoluted at 8.7 mm.*

Morphometry
See Table 175.

Fin Development
7.9–8.1 mm TL. Pectoral fin developed without incipient rays present.*

Pigmentation
7.94–8.1 mm TL. Eyes pigmented with melanophores; sparce pigmentation, limited principally to scattered melanophores at mid-ventral yolk sac, melanophores present at the mid-ventral area of every postanal myosepta.*

POST YOLK-SAC LARVAE

Size Range
Yolk absorbed before 9.1 mm; end of phase unknown.

Myomeres
Unknown.

Table 175

Morphometric data expressed as percentage of total length (TL) for young *P. burtoni* from the French Broad River, TN.*

	Total Length Groupings	
TL range (mm)	7.9-8.1	8.2-9.1
N	16	12
Ratios	Mean ± SD	Mean ± SD
SnL	3.5 ± 0.3	4.7 ± 0.7
ED	5.9 ± 0.2	6.7 ± 0.4
HL	18.3 ± 1.0	21.1 ± 2.1
PreAL	53.7 ± 0.5	51.6 ± 0.8
PosAL	46.3 ± 0.5	48.4 ± 0.9
SL	96.3 ± 0.6	95.8 ± 0.4
YSL	38.1 ± 2.6	
BDP1	11.2 ± 1.2	12.6 ± 1.4
BDA	7.1 ± 0.3	8.9 ± 0.9
CPD	3.4 ± 0.2	4.1 ± 0.3
YSD	23.5 ± 2.0	

Morphology
Unknown.

Morphometry

See Table 175.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown lengths to 82 mm TL.[6]

Fin Development
Larger juveniles. Spinous dorsal XV–XVIII; soft dorsal 13–16; pectoral rays 14–16; anal rays II 10–12; pelvic rays I 5.[2,3,5,6] Caudal fin truncate.

Morphology
Lateral scales 86–94, complete; frenum present; gill membranes moderately connected. Branchiostegal membranes moderately or broadly united, rays 6, 6. The cheek may support exposed scales or only a few embedded scales; nape and opercle are scaled; breast and belly are naked.[2,3,4,6] Modified midventral scales present in males.[4] Vertebrae 38–40.[2,3]

Morphometry
Unknown.

Pigmentation
Larger juveniles. Body straw colored to pale olive dorsally, pale to yellowish color on lower side; belly white. Dark olive to black lateral markings 9, extending from the head to the caudal base. Suborbital, preorbital, and postorbital bars well developed. Dorsum of body with 8–9 broad indistinct saddles. Eight or nine blotches occur along the midlateral surface and are connected by a midlateral stripe. Spinous dorsal fin with narrow dark marginal and broader basal dark bands separated by a clear area. Soft dorsal and caudal fins with brown tessellated markings on rays, all other fins clear.[2,3,5,6]

TAXONOMIC DIAGNOSIS OF YOUNG BLOTCHSIDE LOGPERCH

Similar species: similar to other members of subgenus *Percina*.[10]

Percina burtoni hatches at significantly greater lengths and is more robust than any other member of the *Percina* subgenus. It possesses characteristic logperch traits but on the basis of its size it would attain specific morphological markers at greater lengths than reported for logperch.*

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 160)
Eggs. Are laid in clean loose gravel with moderate to strong flow from the head of the pools.[6]

Yolk-sac larvae. Yolk-sac larvae exhibit pelagic drift.[10]

Post yolk-sac larvae. Unknown.

Juveniles: Unknown.

Early Growth (see Table 176)
Young-of-the-year from TN grow rapidly attaining lengths of 60–70 mm SL after the first years

Figure 160 General distribution of blotchside logperch in the Ohio River system (shaded areas).

Table 176

Average calculated lengths (mm SL) of young blotchside logperch in VA and TN.

	Age			
State	**1**	**2**	**3**	**4**
Virginia[6]		86–126	115–138	160
Tennessee[5]	60–70	100	—	160

growth, and may be 100 mm TL by the end of age 2[5] (Table 176).

Feeding Habits

Juveniles and young adults forage by flipping over stones with their large conical snout. Food items include larval aquatic insects, mayflies, caddisflies, stoneflies, midges, blackfly adults and larvae, and larval riffle beetles.[5] A specimen was photographed consuming the larvae of a caddisfly larvae after it had been dislodged by smashing its case against a rock.[5,6]

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* Original fecundity data. Original descriptive data from French Broad River, TN.

LOGPERCH COMPLEX

Percina (Percina) caprodes (Rafinesque)

Percina: a small perch; *Percina*: type subgenus for small perch genus; *caprodes*: resembles a pig, in reference to shape of the snout.

RANGE

Percina caprodes is the most widely distributed of all darters ranging from SK to eastern QU; south to the FL panhandle; west to the Red River system of TX. Occurs along the Atlantic Coast ranging from the Hudson River to the Potomac River estuary.[1–3]

HABITAT AND MOVEMENT

Percina caprodes is typically found in a variety of habitats from moderate-sized streams to large rivers and along the sandy beaches of lakes, as well as at considerable depths in some lakes. The species is not found in small streams, which lack chutes and strong riffles.[2–7] The logperch is the only darter that does well in reservoirs, ponds, and sloughs.[12] It is found over gravels, sand, and organic debris typically in moderate currents.[2–4] A change in climatic conditions may cause logperch to leave the breeding area. After the spawning season, the adults migrate to deeper waters of lakes or pools of streams.[2,3,30] Seasonal migrations occur with adults migrating from riffles and runs to pools during late Fall to Winter and return to shallows during the Spring to spawn.[*,11–14] Logperch have been collected from rivers and streams at depths of 1–3 m (5%), 3.1–6.0 m (5%), 6.1–12.0 m (10%), 12.1–24.0 m(44%), 24.1–50 m (17%), and more than 50 m (20%). It also has been collected from the Great Lakes at depths of 9–22 m.[31] The species is frequently collected in clear water at depths from 0.6 to 1.5 m over substrates of sand (34%), gravels (25%), boulders (14%), mud (10%), rubbles (9%), silt (7%), and hardpan (1%).[7]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Percina caprodes is generally distributed and common to abundant throughout the basin.[33,34] Four subspecies are recognized in the study area: *P. c. caprodes* occurs throughout the Ohio River basin, *P. c. semifaciata* occurs in IL and IN and northward;[2] and *P. c. fulvitaenia* occurs in KY.[4] The fourth is *P. c. manitou* that occurs in the upper Tippecanoe River drainage, IN, it is being considered for elevation to a full species (T.P. Simon, B.E. Fisher, and R.M. Strange, unpublished data).

SPAWNING

Location

Spawning occurs over sandy shorelines of lakes;[10] sand and gravel substrates of stream riffles and runs;[11] occurs in both quiet and fast moving water. Spawning is accomplished by burying of the female in waters 10.1 cm[11] to 2 m[14] over substrates of sand, gravel, and boulders.[2,3,8,10,12,14,16,17,24,35] Logperch in WI spawns in water at depths of 10–200 cm.[32] Eggs were found in shallow littoral zones buried in sand or gravel in areas of minimal current.[20]

Season

Spawning of logperch occurs during April in PA;[5] May in WV;[6] late May in NY;[7] during April in IL;[8] early April to late May in IN.[9] Spawning occurs from late April to early July in the Tippecanoe River, IN;* April to July over the entire range.[14] Outside the MI study area the species begins to spawn during April in KS;[36] late March or early April in OK;[37] April to July in MI;[10,11,38] December to mid-May in TX;[18,34] from mid-April to late May in AR;[13,34] June in Manitoba;[35] April to July in WI;[17,34] or late April to June in Upper Mississippi River;[20] during May and June in MN;[36] and during April and May in MO.[34–37] Female ovaries show differential stages of ova development during mid-June and mid-July. Females from the Tippecanoe River, IN, were spent by mid-July with no ripe ova found after the first week of August.* Spawning in laboratory aquaria occurred from early March to mid-June.*

Temperature

10–15°C in field observations;[13] but ripe females observed between 9 and 23°C.[13,20,*] 12–15°C in the Upper Mississippi River;[20] 15–18°C in PA.[5]

Fecundity (Tables 177 and 178)
Number of eggs increased with the size and age of the individuals. Number of egg complement varies with geographic distribution.[15] A female (84 mm SL) had 3085 ova; a single female during a spawning season may lay about 2000 ova.[10,14] Approximately 100 mature eggs plus large numbers of immature eggs;[16] numbers range between 1060 and 3172 ova.[9] A female collected in May from WI had ovaries that were 10% of the body weight, while in June to August it averaged 1%.[17] Fecundity ranges from 38 to 846 ova in WI;[17] between 1000 and 3000 ova per female.[14] Females having more ova or attaining larger sizes also bear more mature ova.* Females between 87.9 and 119 mm TL, contained 58–2182 undeveloped ova averaging 0.99 mm in diameter from the Tippecanoe River, IN.*

Sexual Maturity
Adults live to reach age 4;[17,32,38] however, maturity is generally at age 2 and seldom at age 1.[14] Adult males from Tippecanoe River, IN, had reduced testes between August and January. Testes of mature males became greatly enlarged and have had a fine granular appearance. Testes are much broadened and thickened anteriorly.* Testes of a 87 mm TL male was 0.082% of the body weight on May 22 that were 14 mm in length.* Males develop tuberculation on ventral scale rows that generally becomes inconspicuous thickening on posterior portion of the scale.*,[14] Females less than 64 mm SL by May are not sexually mature, 15% of females between 64 and 71 mm TL are mature, while females greater than 72 mm TL are mature.* Males less than 34 mm SL are all immature,[14] while 72% of 45–57 mm TL males are mature, and all males greater than 58 mm TL are mature. Males are larger than females with a mean TL of 42.5 mm compared to 42.0 mm TL for females. This difference is not considered sexually dimorphic by length. Males exhibit sexually dimorphic traits during the reproductive season with the development of nuptial tubercles on ventral scale rows, enlargement of soft dorsal and anal fins, development of an interrupted row of midventral scales along the breast, anal and pelvic fins more pigmented in males, and the male has a shorter and broadly conical genital papillae shape coming to a sharp or blunt point, while females have distended abdomens, an unscaled breast, and a shorter anal fin, and a digitiform, more elongate and flaccid, and somewhat flattened tube that touches the base of the anal fin.[14,16,*]

Spawning Act
Percina caprodes is an egg burier. Spawning occurred from early morning to early evening but did not occur at night.[14] The logperch is an intermittent spawner with the females spawning many times during the season depositing eggs daily. Field observations of reproduction behavior is based on specimens from MI.[16] Males form schools above an area of sand or gravel parallel to the shore line that may be up to 30 m in length. School formation is considered the most pleisiomorphic reproductive behavior. School formation is needed to keep and maintain males in a heightened reproductive state. Males are nonterritorial and do not exhibit any aggressive or fighting behavior in lakes, while in streams males protect a "moving territory" immediately surrounding a female that has entered the breeding grounds.[10,14] When a female enters the group she is pursued by one or more males. She swims through the group until she settles to the bottom and a male takes a position over the female

Table 177

Ovarian and fecundity data for logperch (87.9–119 mm TL; *N* = 12) from the Tippecanoe River, IN.*

		Percent Occurrence of Ova			
Date	Fecundity Range	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
August–December	388–1988	100	—	—	0.2
February	256–1281	100	—	—	0.22
March	322–2002	12	88	—	0.28
April	122–1566	—	75.6	24.4	0.99
May	58–2182	—	65.6	44.4	0.82
June	40–1115	—	83	17	0.80
July	32–1048	—	80	20	0.47

Table 178

Comparison of the number of ova per female logperch over range. Literature source is reported for each collection locality.

Location	Age	*N*	TL	Number of Ova
Michigan[10]	1	1	64	1060
	2	2	74–76	2000
	3	2	92–98	2712–3085
Wisconsin[32]	1	1	119	864
Missouri[16]				100
Ohio*	2			
Alum Creek		3	87–93	3047–4007
Indiana[9]				3172
Tennessee *	2			
Duck River		1	86	2542
	3	2	120–128	5578–5886
Robertson Creek	2	2	97–103	3136–5492
Texas[15]				
Colorado River			69–115	101–495
Guadalupe River			68–124	105–1750
Virginia*	3			
Powell River		3	115–143	6053.6

with pelvic fins clasping her head and his tail alongside hers. Numerous other males try to fertilize eggs along with the dominant male.[11] The female releases 10–20 eggs during each spawning act as the pair become almost completely buried by the swirling sand while vibrating. After spawning the female swims out from under the male either to spawn again with the same male or to return to deep water to rest.[17] Neither the male nor the female provide any parental care to either the eggs or larvae.*

EGGS

Description

Spherical, demersal, nonadhesive;* *P. c. semifaciata* eggs range from 1.08 to 1.36 mm in diameter from Mukwonago River, WI;[20] *P. c. caprodes* averages 1.12 mm from IN and OH;[5] 1.3 mm in MI.[10,14] Yolk pale yellow in color, with a single oil globule, a moderate perivitelline space (0.02 mm), and translucent smooth egg chorion.*[,10,14,20] Fertilized eggs are translucent, spherical, and slightly adhesive, averaging 1.4 mm in diameter (range: 1.1–1.7 mm).[16] Latent ova are 0.2–0.22 mm in diameter, early maturing and late maturing ova are 0.7–0.82 mm, and mean ripe ova are 1.0 mm in diameter.* Three size classes of ova are observed in females from the Tippecanoe River, IN, the smallest or immature ova are usually translucent to clear with no yolk development and a visible nucleus, mature ova are smaller and opaque white or light yellow ova, and ripe ova are golden to translucent yellow and averages 1.1 mm.*

Incubation

Hatching occurs in 120–144 h at 22°C;[20,27] 200 h at 16.5°C.[5] Successfully hatched between 11 and 30°C; developed at a wide range of temperatures between 22 and 26°C.[13]

Development

Cleavage, early embryonic development, and embryonic osteological development described from ON, Canada.[21]

YOLK-SAC LARVAE

See Figures 161 and 162

Size Range

4.3–5.9 mm TL[7] at hatching for *P. c. semifaciata*, yolk absorption complete by 6.5 mm TL;[20,21] 4.5–5.3 mm[22–25] to 6.3–7.0 mm.[5,25]

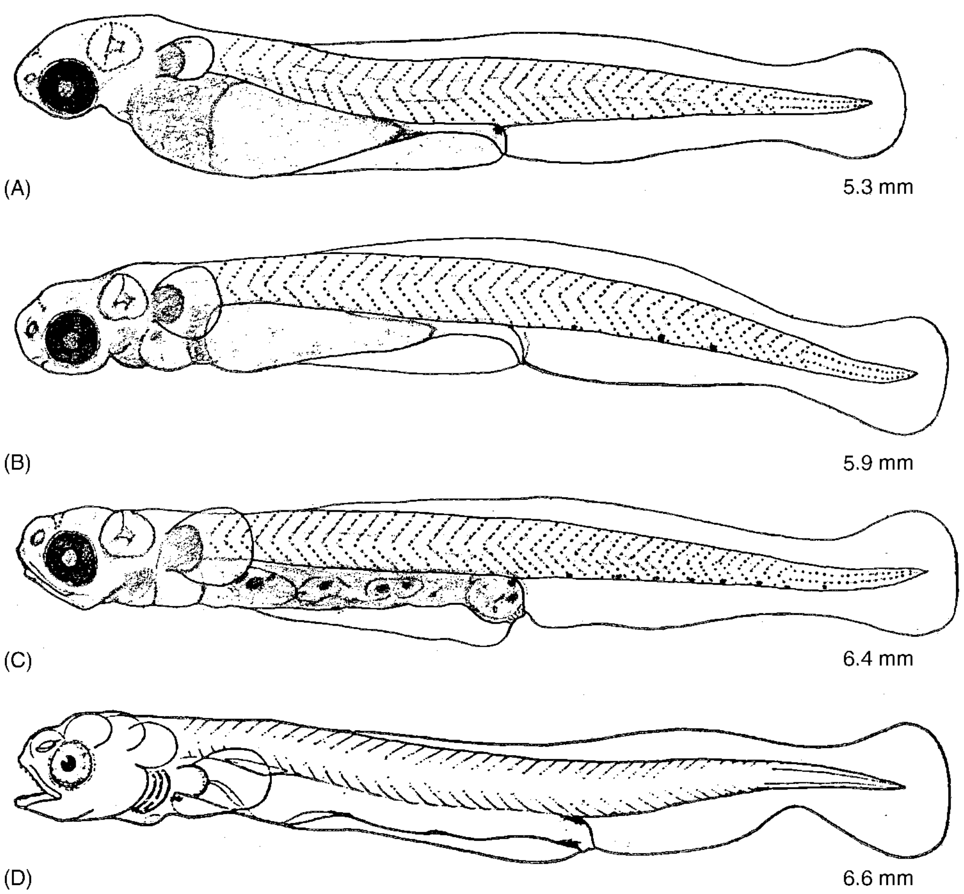


Figure 161 *Percina c. caprodes,* logperch, OK and OH: (A) yolk-sac larvae, 5.3 mm, lateral view, (B) yolk-sac larvae, 5.9 mm TL, lateral view, (C) Post yolk-sac larva, 6.4 mm TL, lateral view, and (D) Post yolk-sac larva, 6.6 mm TL, lateral view, Lake Erie, OH. (A-D redrawn from references 22 and 23.)

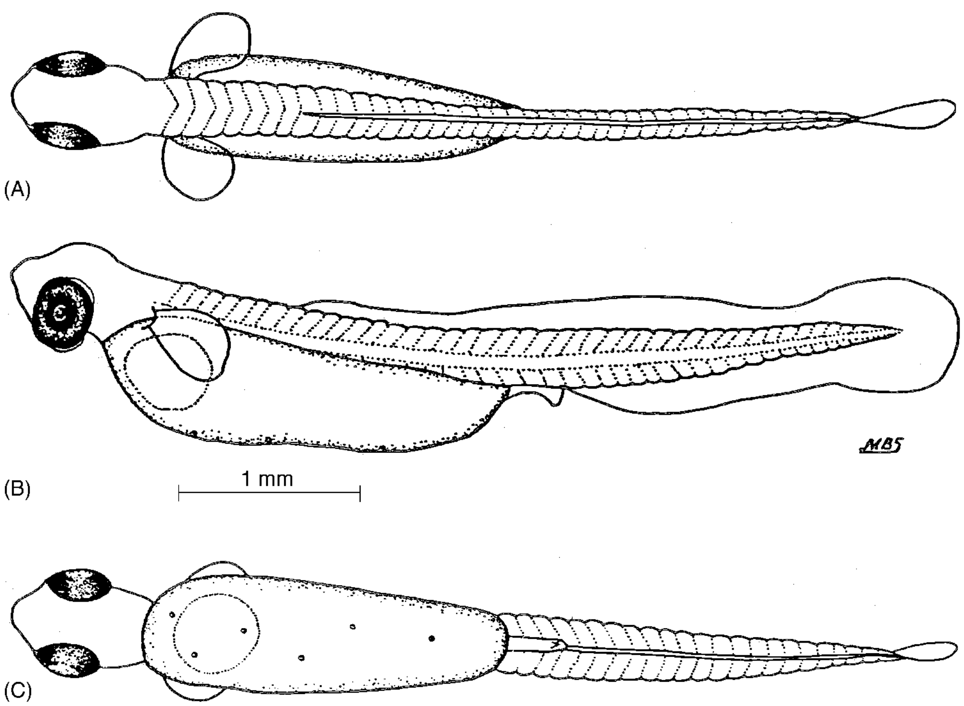


Figure 162 *Percina c. semifaciata,* logperch, Mississippi River, WI: (A–C). Yolk-sac larvae, 5.4 mm, dorsal, lateral, and ventral views. (A-C redrawn from reference 20, with author's permission.)

Table 179

Morphometric data expressed as percentage of head length (HL) and total length (TL) for young logperch from the upper Mississippi River, WI and MN; Ohio River, IN; and Tippecanoe River, IN.[20]

	Total Length Groupings			
TL range (mm)	**5.4–6.9**	**7.0–10.9**	**11.1–16.9**	**17.0–20.2**
N	**37**	**20**	**20**	**10**
Ratios	**Mean ± SD (Range)**	**Mean ± SD (Range)**	**Mean ± SD (Range)**	**Mean ± SD (Range)**
As Percent HL				
SnL	23.1 ± 2.4	21.7 ± 2.0	22.9 ± 2.2	25.0 ± 2.8
	(19.0–23.9)	(19.3–22.7)	(17.9–22.9)	(18.7–28.1)
ED	41.7 ± 3.1	33.1 ± 2.2	28.1 ± 1.7	27.5 ± 1.7
	(38.1–42.4)	(29.5–37.3)	(27.5–33.2)	(23.8–32.2)
As Percent TL				
HL	14.1 ± 1.1	18.4 ± 3.4	17.9 ± 1.2	18.2 ± 1.0
	(13.9–14.7)	(15.1–21.1)	(14.3–18.1)	(16.4–19.8)
HW	8.5 ± 1.7	11.8 ± 1.2	12.6 ± 2.3	12.9 ± 1.8
	(7.2–12.5)	(10.9–13.6)	(11.4–15.6)	(9.8–13.9)
PreDFL	33.2 ± .3.9	33.5 ± .3.6	32.2 ± 2.9	32.3 ± 3.2
	(25.1–38.1)	(29.8–34.9)	(27.1–34.6)	(26.5–33.6)
PreAFO	54.5 ± 0.4	54.1 ± 1.6	54.8 ± 2.7	54.5 ± 2.2
	(54.4–54.5)	(52.8–56.4)	(49.3–56.2)	(50.8–55.5)
PreAL	54.4 ± 0.4	54.1 ± 1.6	54.8 ± 2.7	54.5 ± 2.2
	(54.4–54.5)	(52.8–56.4)	(49.3–56.2)	(50.8–55.5)
PosAL	45.5 ± 0.2	45.9 ± 2.9	45.2 ± 2.9	45.5 ± 2.0
	(45.5–45.6)	(43.6–47.2)	(44.8–50.7)	(44.5–49.2)
SL	95.6 ± 0.6	90.4 ± 1.2	87.4 ± 1.7	86.4 ± 2.3
	(95.5–96.5)	(88.6–92.5)	(86.5–92.8)	(83.4–89.7)
YSL	40.1 ± 9.9			
	(32.4–52.8)			
P1L	5.5 ± 1.4	11.2 ± 3.1	12.8 ± 3.6	15.9 ± 2.9
	(3.4–7.7)	(9.8–12.8)	(9.5–15.5)	(9.3–16.7)
D1FL	66.8 ± 1.4	64.5 ± 6.7	20.1 ± 4.5	20.5 ± 2.9
	(64.5–79.6)	(63.1–77.2)	(17.9–23.9)	(17.4–23.9)
D2FL			14.9 ± 4.8	15.9 ± 1.6
			(11.4–18.8)	(12.6–19.0)
CFL	4.6 ± 1.4	9.6 ± 2.2	12.6 ± 2.0	12.5 ± 2.4
	(3.5–4.5)	(7.5–12.4)	(7.2–13.5)	(8.8–13.4)
BDE	11.3 ± 1.3	9.7 ± 1.0	7.7 ± 0.7	7.5 ± 0.9
	(9.4–13.9)	(8.3–10.2)	(6.8–8.4)	(6.2–7.9)
BDP1	12.4 ± 1.5	11.3 ± 1.3	10.8 ± 2.1	10.9 ± 1.8
	(9.8–15.2)	(9.2–13.0)	(8.6–14.1)	(8.3–11.6)
BDA	6.7 ± 0.3	8.2 ± 0.9	8.9 ± 0.5	9.5 ± 0.3
	(6.6–7.0)	(7.6–8.4)	(8.6–9.2)	(8.9–9.7)
MPosAD	5.3 ± 1.1	5.6 ± 0.5	6.0 ± 0.1	6.6 ± 0.4
	(4.5–6.2)	(5.0–6.1)	(5.8–6.1)	(6.0–7.0)
CPD	3.4 ± 0.2	3.0 ± 1.0	4.6 ± 0.4	4.8 ± 0.2
	(3.3–3.5)	(2.2–3.5)	(4.1–4.8)	(4.7–5.1)
YSD	6.7 ± 2.0			
	(1.3–10.1)			

Myomeres
Percina c. semifaciata: Total 41–43; preanal 23; postanal 20;[21] or total 39–46; preanal 19–24; postanal 18–23.[20]

Percina c. caprodes: Preanal 20–23; postanal 17–23.[5,22–25]

Morphology
5.4–6.3 mm TL. Body terrate in cross-section; stomodeum present with no functional mouth parts; head not deflected over the yolk sac; pale yellow yolk; yolk-sac elongate and slender, tapering posteriorly; a single mid-ventral vitelline vein is present; gut short.[*,20]

6.6–8.0 mm TL. Eyes spherical; gut straight; complete yolk absorption occurs by 6.5–7.0 mm.[5,21–25] or between 7.0 and 8.0 mm TL; gut relatively thick and heavily convoluted at 6.4 mm TL; teeth developed on jaws and gas bladder rudimentary at 6.6 mm TL.[20]

Morphometry
See Table 179.

Fin Development
See Table 180.

5.4–6.3 mm TL. Dorsal and anal finfolds complete, small pectoral buds; incipient rays absent from all median and paired fins.[20]

Pigmentation
5.4–6.0 mm TL. Percina c. semifaciata: Eyes pigmented with melanophores; sparce pigmentation, limited principally to scattered melanophores at midventral yolk sac, few to no melanophores present at midventral of postanal myosepta.[20]

Table 180

Meristic counts and size (mm TL) at the apparent onset of development for *P. c. caprodes* and *P. c. semifasciata.*

Attribute/Event	*Percina c. semifasciata*[20]	*Percina c. caprodes*[5,23,24]
Branchiostegal Rays	5,5[20]	5,5[5,23,24]
Dorsal Fin Spines/Rays	XII–(XII–XVI)/12–(13–14)–16[20]	VIII–(XIV)–XVI/14–(15–16)–18[5,23,24]
First spines formed	10.0–10.6[20]	12.1–15.6[5,23,24]
Adult complement formed	15.8–17.0 [20]	22.0[5,23,24]
First soft rays formed	10.0–10.6[20]	12.1–15.6[5,23,24]
Adult complement formed	15.8–17.0[20]	22.0[5,23,24]
Pectoral Fin Rays	(13–14)–15[20]	12–(14–16)–17[5,23,24]
First rays formed	7.1 [20]	15.6[5,23,24]
Adult complement formed	10.0 [20]	No information
Pelvic Fin Spines/rays	I/5[20]	I/5[5,23,24]
First rays formed	10.6[20]	9.0[5,23,24]
Adult complement formed	14.6 [20]	14.0[5,23,24]
Anal Fin Spines/rays	II/9–(10)–11[20]	II/8–(10–11)–13[5,23,24]
First rays formed	11.5 [20]	10.5–12.1[5,23,24]
Adult complement formed	15.8–17.0 [20]	15.0[5,23,24]
Caudal Fin Rays	vii–xv, 9+ 8, vii–xiv[20]	No information
First rays formed	7.5–9.2[20]	10.5–12.5[5,23,24]
Adult complement formed	12.2–14.6 [20]	15.0[5,23,24]
Lateral Line Scales	70–(79)–87[20]	67–(73–77)–99[5,23,24]
Myomeres/Vertebrae	39–(41)–46/42–(43)–44[20]	39–(43)–46/40–(42–45)–46[5,23,24]
Preanal myomeres	19–(22)–24 [20]	19–(23)–24[5,23,24]
Postanal myomeres	18–(19)–23[20]	16–22[5,23,24]

5.3 mm TL. Percina c. caprodes. Eye pigmented in smallest specimen described.[23]

5.9 mm TL. Percina c. caprodes. Ventrally, 2–3 faint pigment spots between the anus and end of tail.[23]

6.2–6.8 mm TL. Percina c. semifaciata. Pigment absent on cranium and along dorsum. Scattered melanophores present on the yolk sac, concentrating near midventral; dorsal outline of gut pigmented; single melanophores at every midventral postanal myoseptum.[20]

6.4 mm TL. Percina c. caprodes. Ventrally, eight evenly spaced spots between the anus and the end of the tail, pigment apparently developed on gut.[23]

6.6 mm TL. Percina c. caprodes. A large chromatophore at the base of each pectoral fin; three along ventral margin of intestine, distributed on, above, and below the anus, and a broken inconspicuous series on the ventral ridge to the caudal fin.[23]

POST YOLK-SAC LARVAE

See Figures 161 and 163–166.

Size Range

Percina c. semifaciata. 6.5 to 24.9 mm TL;[20] and *P. c. caprodes* 6.4 to 20.5 mm[23] TL.

Myomeres

Percina c. semifasciata: Total 39–46; predorsal 6–10; preanal 19–24; postanal 18–23.[20]

Percina c. caprodes: Preanal 19–24; postanal 16–22.[5,21–26]

Morphology

8.1–10.0 mm TL. Body relatively elongate,[23] somewhat compressed[22]; mouth large.[23]

11.0–12.2 mm TL. Notochord flexion.[5,24,25]

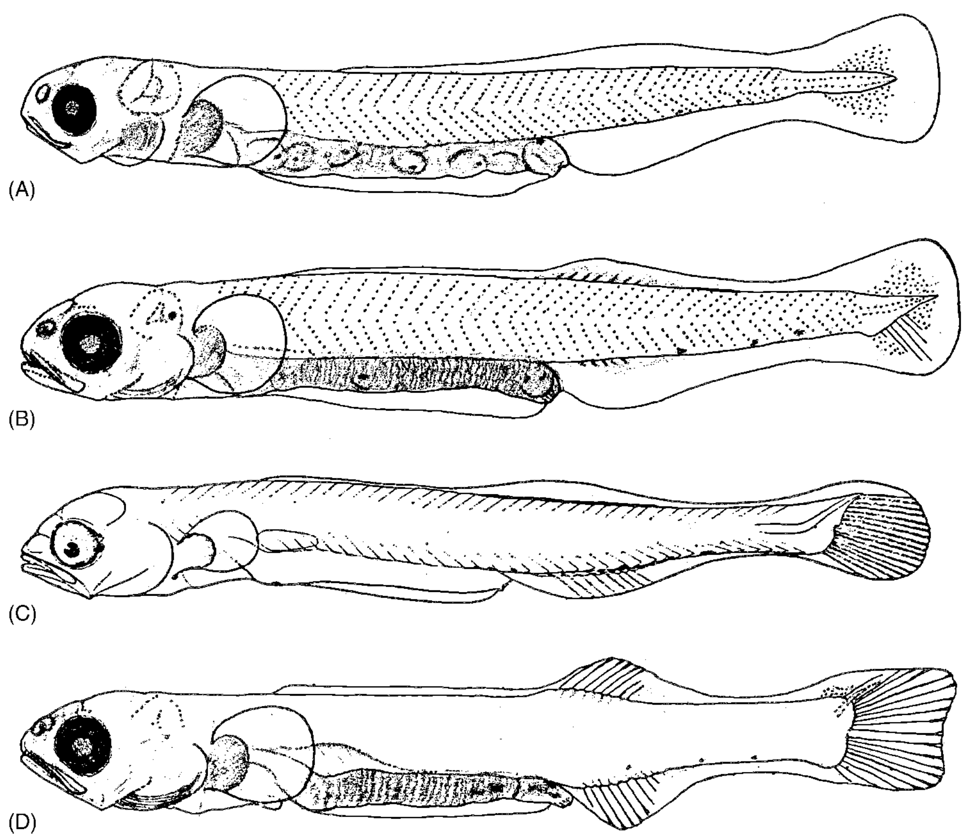


Figure 163 *Percina c. caprodes*, logperch, (A, B, D) OK and (C) OH: (A) Post yolk-sac larvae, 8.3 mm TL, lateral view; (B) 10.5 mm TL, lateral view; (C) 12.5 mm TL, Lake Erie, OH; and (D) 13.4 mm TL. (A-D redrawn from references 22 and 23 with permission.)

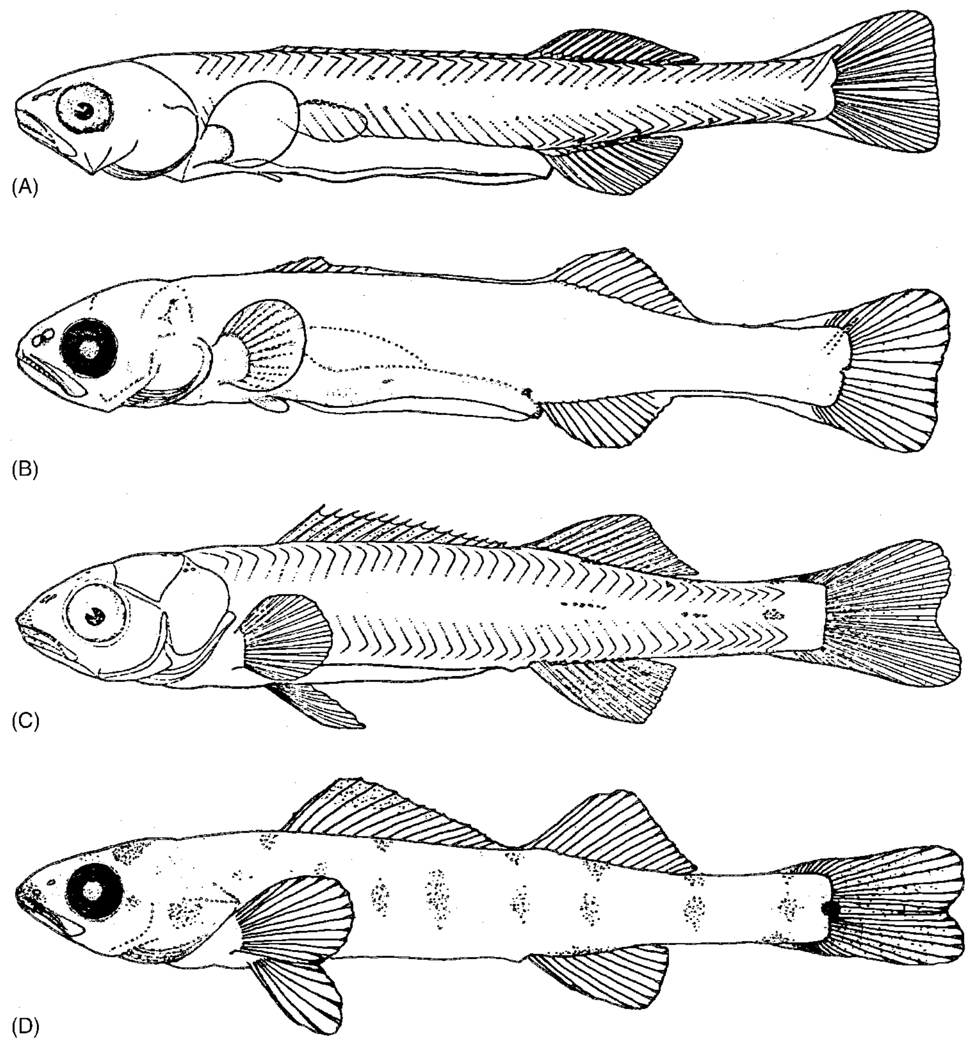


Figure 164 *Percina c. caprodes*, logperch: (A) larvae, 14.2 mm, Lake Erie, OH, lateral view, (B) post yolk-sac larvae, 15.0 mm TL, OK, (C) juvenile, 20.5 mm TL, lateral view, OK, and (D) juvenile, 25.3 mm TL; OH. (A-D redrawn from references 22 and 23 with permission.)

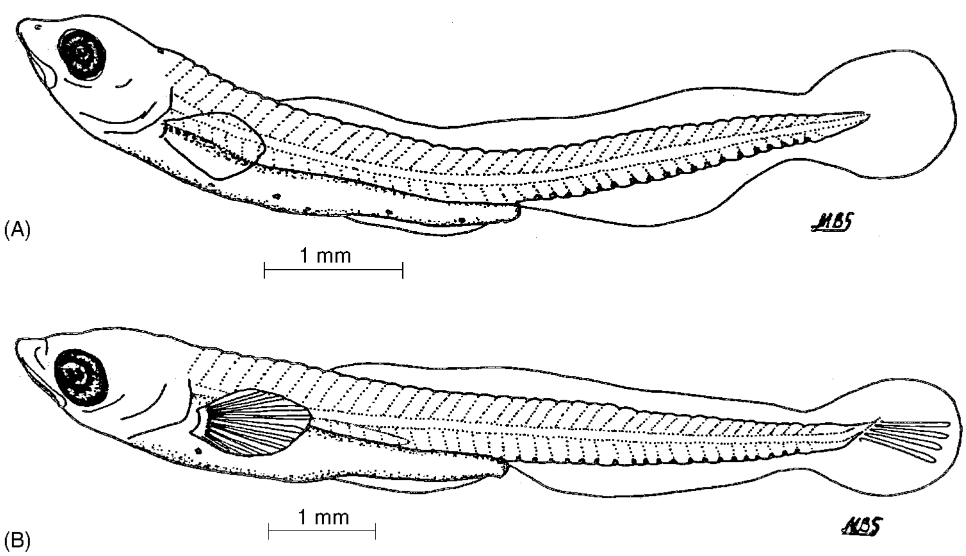


Figure 165 *Percina c. semifaciata*, logperch, Mississippi River, WI: (A) post yolk-sac larvae, 7.5 mm, lateral, view, (B) post yolk-sac larva, 9.2 mm, lateral view. (A-B redrawn from reference 20 with author's permission.)

12.8–18 mm TL. Snout pointed; body elongate; dorsal fin insertion 27% TL, anterior of anus; urostyle oblique between 12 and 15 mm.[20,22]

15.4–20.3 mm TL. Supraorbital, preoperculomandibular, subtemporal, and infraorbital head canals begins to form.[20]

Morphometrics
See Table 179.

Fin Development (Table 180)
7.1–8.0 mm TL. First pectoral fin rays forms between 7.1 and 8.0 mm.[20]

8.1–10.0 mm TL. Percina c. caprodes. Fin rays formed in caudal fins at 8.3 mm TL;[23] finfold complete, dorsal and anal finfolds differentiated.[23]

7.5–9.2 mm TL. Percina c. semifaciata. First caudal fin ray formed.[20]

10.5–12.2 mm TL. Percina c. caprodes. Anlagen of soft dorsal and anal fin rays present at 10.5 mm TL.[23] Elements of spinous dorsal fin bases evident and anal fin rays first evident at 12.2 mm TL.[22] Urostyle oblique at 12.2 mm TL.[22]

10.0–11.5 mm TL. Percina c. semifaciata. First dorsal rays formed in soft dorsal fin at 10.0–11.5 mm TL; spinous dorsal rays formed (10.6–14.4 mm TL). Pelvic fin buds formed anterior to dorsal fin origin between 10.0 and 10.9 mm, first pelvic fin rays formed by 10.6 mm TL; first anal fin ray formed at 11.5 mm.[20]

12.8–16.2 mm TL. Percina c. caprodes. Soft dorsal fin rays present by 13.4 mm TL.[23] Caudal fin emarginate and pelvic buds formed at 14.2 mm; pectoral fin rays present at 15.0 mm TL. Preanal finfold still evident and finfold still continuous between anal and caudal at 15.0 mm TL. Spinous dorsal fin ray anlagen present at 15.0 mm.[23]

11.6–18.6 mm TL. Percina c. semifaciata. Incipient dorsal finfold margin partially differentiated between 14.1 and 15.4 mm TL, completely differentiated by 15.8–17.0 mm TL; caudal fin lunate by 14.1 mm TL; incipient anal fin margin partially differentiated by 13.7–14.5 mm TL, completely differentiated by 16.9 mm TL.[20]

Pigmentation
7.1–7.9 mm TL. Percina caprodes semifasciata. Pigmentation essentially unchanged from previous condition with the exception of several melanophores forming at dorsal posterior base of the optic lobe at lengths greater than 7.6 mm ventral pigmentation becomes subdermal.[20]

8.5–10.9 mm TL. Percina c. semifasciata. Pig-ment absent on cranium and on dorsum. Single melanophore present on cleithra; several melanophores outline dorsal portion of gut near anus. Single midventral, punctate melanophores at almost every postanal myosepta becoming subdermal as length approaches 10.9 mm TL.[20]

11.4–13.7 mm TL. Percina c. semifasciata. Pigment absent over much of the body; several punctate melanophores present near anus outlining dorsal and ventral gut; most postanal pigmentation subdermal (not very visible); several punctate melanophores in midlateral surface; hypural plate with several melanophores near caudal fin rays.[20]

13.8–14.5 mm TL. Percina c. semifasciata. Pigmentation absent over much of the body; punctate melanophores at mid-ventral are of half point of the preanal segment; additional punctate melanophores present near anus; most melanophores subdermal, several melanophores at base of hypural plate.[20]

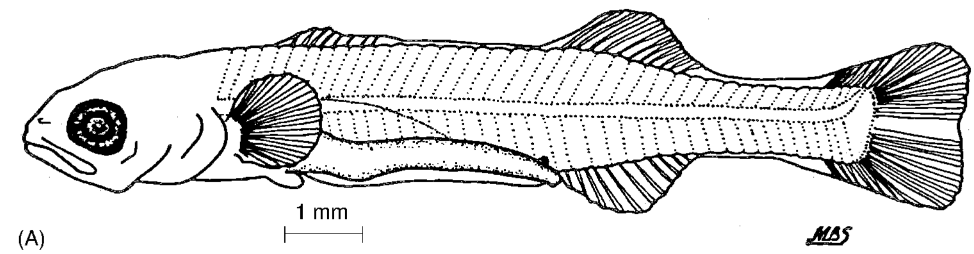
14.6–16.9 mm TL. Percina c. semifasciata. Limited pigmentation apparent; several punctate melanophores present on ventral, almost always near ventral portion of anus; postanal myomeres with pigment on myosepta above anal fin and caudal peduncle with subdermal pigment apparent at lengths approaching 16.9 mm TL; several mid-lateral punctate melanophores present near caudal peduncle near postflexion notochord.[20]

17.2–20.2 mm TL. Percina c. semifasciata. Punctate pigmentation present near ventral anus; punctate melanophores present at interdigitation of anal fin lepidiotrichia with pterigiophore extending onto the soft rays of the anal fin; midlateral, ventral, and dorsal accumulation of melanophores near caudal peduncle; pigment accumulates and forms a spot at the center of the caudal fin base.[20]

JUVENILES

See Figures 164 and 166

Size Range
20.5[22] to 54.7 mm or 58–72 mm.*[10]



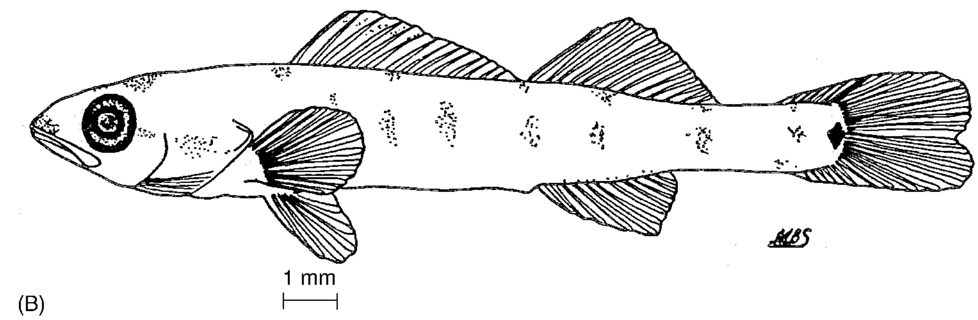


Figure 166 *Percina c. semifaciata,* logperch, Mississippi River, WI: (A) post yolk-sac larvae, 14.6 mm, lateral view, (B) juvenile, 26.5 mm TL, lateral view. (Redrawn from reference 20 with author's permission.)

Fins

18–20 mm TL. All median and paired fin rays distinct and with full complement of fin spines and rays. Finfolds completely differentiated, caudal fin emarginate.*

Larger juveniles. Percina c. caprodes. Spinous dorsal XII–XVII; soft dorsal 12–18; pectoral rays 12–15; anal rays I-II 9-12; pelvic rays I 5.[24] Caudal fin emarginate.[24]

Percina c. semifasciata. Spinous dorsal XII–XIV; soft dorsal 12–16; pectoral rays 13–15; anal rays II 9–10; pelvic rays I 5; caudal rays vii–xv, 9 + 8, vii–xiv.[20]

Morphology

20.8–23.3 mm TL. Preoperculomandibular, supratemporal, and lateral line canals formed by 20.8 mm TL, lateral line formed; supraorbital and infraorbital head canals formed by 23.3 mm TL. Mandible overhangs maxillary at all lengths. Scales initially forms posteriorly near caudal peduncle by 21.2–23.8 mm TL.[20]

26.0–28.8 mm TL. The cheek and opercle are scaled, breast is unscaled.[20]

Percina c. caprodes. Lateral scales 71–103,[24]total vertebrae 40–46.[2,3,5] *Percina c. semifasciata:* Lateral scales 70–87; total vertebrae 42–44.[20] Branchiostegal rays 5, 5. The cheek and opercle are scaled; breast is unscaled.[20] Cephalic sensory canals complete, lateral canal pores 5, supratemporal canal pores 3, supraorbital canal pores 4, coronal pore present; infraorbital canal pores 8; preoperculomandibular canal pores usually 10, range between 9 and 11.[7] Vertebrae 42–45.[3,4,10]

Morphometry

See Table 180.

Pigmentation

20.5–21.2 mm TL. Dorsum cranium pigmentation consists of punctate melanophores on snout, cerebrum, optic lobe, and laterally on operculum; melanophores present laterally beneath the pectoral fin, midlaterally at anal fin, at ventral caudal peduncle, and mid-laterally clustered at caudal peduncle. Several clusters of dorsal melanophores present at the base of the soft dorsal and at the base of the caudal fin. Melanophores scattered on interstitial membranes of spinous and soft dorsal fin and anal fin. A vertical line of melanophores located at the center of caudal fin base extending hypaxially on interstitial membranes.[20]

21.6–23.8 mm TL. Cranial dorsum distributed with stellate melanophores over cerebellum and optic lobe. Melanophores present on snout, mandible, and chin; weak postorbital bar formed; 7 oval midlateral clusters formed: present anterior to dorsal, posterior of anterior spinous dorsal, near the base of the posterior spinous dorsal, anterior of soft dorsal, at midsoft dorsal, posterior base of soft dorsal, and at caudal peduncle. Dorsally, 6 rectangular blotches present anterior to spinous dorsal, at spinous dorsal, at mid-spinous dorsal, at posterior base of soft dorsal, and at anterior base of secondary caudal fin rays. Subdermal dorsal pigment present on swim bladder. Postanal pigmentation present at interdigitation of pterigiophores with anal fin lepidiotrichia, and mid-ventral caudal peduncle base. Scattered melanophores present on membranes of spinous dorsal and caudal fin, and form a midstripe in the soft dorsal and anal fins. A mid-lateral spot at the base of caudal fin vertically radiating into hypaxial musculature.[20]

24.9–30.5 mm TL. Cranial pigmentation found over cerebrum and optic lobe; preorbital bar formed from snout pigmentation; maxillary and chin with melanophores; chevron-shaped cluster formed between operculum and optic lobe pigmentation; stellate melanophores outlining ventral portion of orbit. Vertical stripes numbering 11–13, radiating from dorsum with 8–9 extending past lateral line. Scattered melanophores on membranes of spinous dorsal, pectoral, and caudal fin; midstripe formed in soft dorsal and anal fin; pelvic fin devoid of pigment. A diamond-shaped cluster of melanophores on mid-lateral at the caudal base extending vertically into ventral hypaxial musculature.[20]

Larger juveniles. Dorsum yellow to dark olive; sides lighter and belly white; 15–25 dark olive to black, narrow zebra-like bands crossing over the back and vertically down the sides; bands alternating in length, with the shorter bands barely reaching the lateral line. Dorsal and caudal fins lightly barred; remaining fins clear to lightly pigmented along fin rays. Fin rays yellow in life. Suborbital bar distinct to vague. Black caudal spot about size of the pupil of eye.[17,23]

TAXONOMIC DIAGNOSIS OF YOUNG LOGPERCH

Similar species: other members of genus *Percina*.

Young logperch can be separated from all other larval *Percina* based on numbers of preanal myomeres (>19) and presence of pigmentation at every postanal myosepta.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 167)
Eggs. Approximately 10–20 eggs are buried in sand or sand-gravel shoals, while adults do not provide any protection or guard eggs, after spawning,[10,14,17,20] Embryos develop in the darkness of interstitial spaces of clean sand.*

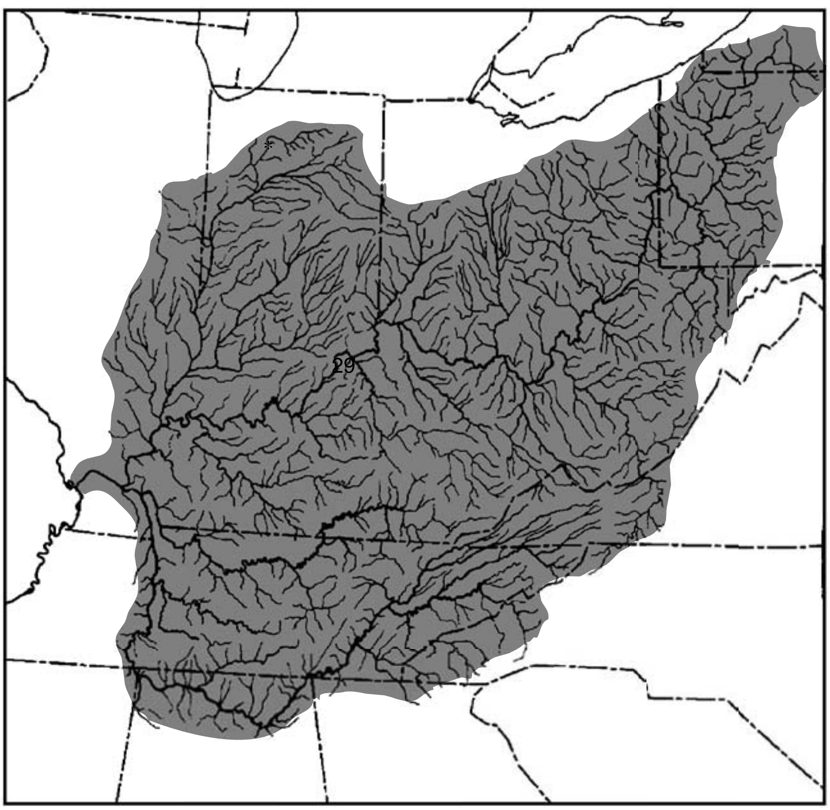


Figure 167 General distribution of logperch in the Ohio River system (shaded areas).

Yolk-sac larvae. Yolk-sac larvae were observed in drift collections when water temperatures approached 12.7°C. Collections in the Black River, WI, show a tendency toward surface drift.[20] Yolk-sac larvae are more restricted to shallow water than larvae.[23] They are significantly more abundant in surface drift collections from the main channel of the Ohio River than at mid- and bottom depths.[29] The largest proportion of larvae were collected during drift collections in April.[29]

Post yolk-sac larvae. Aquarium held northern logperch are observed to swim actively near the surface during daylight conditions. Exact characterization of larval microhabitat utilization is not possible since larvae are present in most habitat types encountered, with the exception of nonflowing waters.[20] Larvae are seldom taken at the bottom, they are more abundant in open waters; free swimming for over 30 days.[18] Larvae make diurnal migrations vertically, at the bottom during daytime, at the surface at night.[23]

Juveniles. Young 13.7–30.5 mm were collected from deep habitats, ranging from backwaters with muck and silt bottoms to main channel border sand substrates with slight current.[20]

Early Growth (Table 181)

Logperch average 71.5 mm TL at age 1.[3] Logperch are 59–72 mm SL in July, 63–79 mm in August, and 50–81 mm in September.[17] Four logperch raised in the laboratory were 4.6–4.9 mm by day 1, 5.1–6.2 mm SL by day 2, and 11–15.7 mm by day 32.[27] Growth in Rough River Lake, KY, for young logperch averages 1.4 mm/week during the first 3 weeks,[40] and in MI 0.40 mm/day the first month.[41] Young-of-the-year reach 51.2% of total growth during first year of life and 77.8% by the second year of life (see Figure 168).[39,*] Specimens collected from Kaskaskia River,

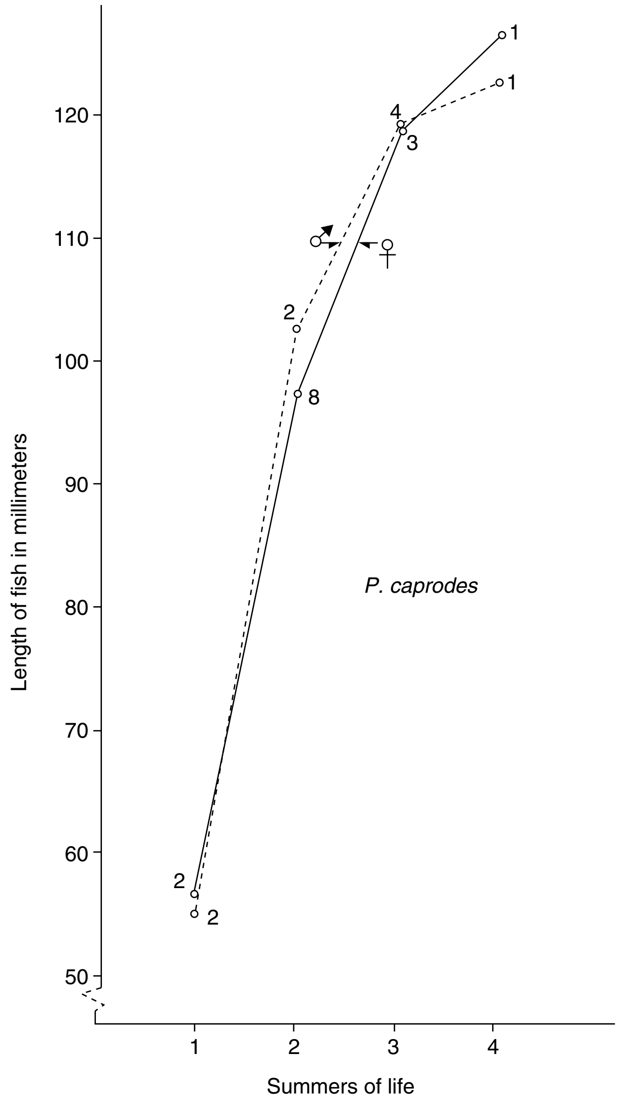


Figure 168 Growth trends for age classes of *P. caprodes* based on annual mean total lengths for populations from Kaskaskia River, near Sullivan, IL. (After reference 39.)

Table 181

Average calculated lengths (mm SL) of young logperch in several states.

State	Age 1	2	3	4
Ohio[52]	38	74	102	
Illinois[39]	72	106	122	
Wisconsin[32]				
Central	64	95	117	125
Northern	67	110		
Southern	74	105	122	132
Oklahoma[53]	43	81	107	124
Indiana*	56	82	117	132

IL, ranged between 29 and 50 mm during June, while southern WI specimens ranged between 59 and 72 mm SL in July, 63–79 mm SL in August, 50–81 mm during September in central WI, and 56–61 mm during October.[32] Young-of-the-year collected during September 1992 was 53–68 mm SL in the Tippecanoe Rivers, IN.* The length–weight relationships of logperch from the Kaskaskia River, IL, was log $W = -0.8150 + 1.2654 \log L$, where weight is in grams and total length is in mm.[39]

Feeding Habits

Logperch feed throughout the daylight hours.[32,39,42] Juveniles and young adults feed primarily on the ephemeropterans, chironomids, other Diptera, Plecoptera, Odonata, Coleoptera, gastropods, amphipods, microcrustacea, a few small fish and algae are major foods.[36,39,43–48] including the eggs of black basses in Bull Shoals, AR.[48] Logperch in reservoirs consume plankton and microcrustaceans more frequently in old reservoirs than in streams or new reservoirs. Larvae and juvenile logperch consume cladocerans and copepods.[28] In WI, logperch consumes fish eggs, entomostracans, leeches, plant remains, algae, silt, and debris;[49] or *Chironomus, Simulium,* and small crustacea, and small mollusks;[50] or caddisfly and midge larvae, small mollusks, mayfly nymphs, small crustaceans, and riffle beetles from Drywood Creek, WI.[17] Logperch are known to consume eggs, however, it has been reported that they consume their own eggs. As many as 20 eggs were found in logperch stomachs.[17] TN specimens had consumed midges, mayflies, caddisflies (especially hydropsyhids) riffle beetles, stoneflies, limpets, and fish eggs.[51] Young specimens from the Kaskaskia River, IL, consumed more Baetid mayflies, odonates, copepoda, and cladocera than adults.[39]

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* Original reproductive, early distribution, and growth information was obtained from adult and ichthyoplankton data collected by Large Rivers Research Station in the upper Mississippi River, Pool 7, WI, and Tippecanoe River, IN, during 1981–1994. Developmental data are from a series obtained from the upper Mississippi River, WI (LRRC larval fish reference collection numbers). Original fecundity data from Northeast Lousiana University Museum of Zoology from TN: Hawkins Co., Robertson Creek, RM 101.2, 18 April 1980; Marshall Co., Duck River, below Lillards Mill Dam at Islands, RM 179.1, 3 April 1985; Virginia, Lee Co., Powell River, Fletcher Ford, 1.9 R/M above TN-VA line, 22 April 1980.

CHANNEL DARTER

Percina (*Cottogaster*) *copelandi* (Jordan, 1877)

Percina: a small perch; *copelandi*: named after Herbert E. Copeland, who discovered the species.

RANGE

Percina copelandi is widespread, with disjunct distributions. It occurs from the Red and Arkansas River drainages of OK, AR, and northern LA; southeastern KS; and southwestern MO. In the Mississippi River drainage it occurs disjunctly in the lower Tennessee River drainage, KY and upper Tennessee River, TN and VA. Ranges northeast throughout the Ohio River drainage and lower half of the Great Lakes basin in Lakes Michigan, Erie, and Ontario. Disjunct populations occur in the St. Lawrence River drainage of southeastern Ontario, southwestern QU, NY and VT.[1–3]

HABITAT AND MOVEMENT

The channel darter inhabits low- and moderate-sized to large rivers[4] in sluggish riffles and runs of streams of moderate gradient;[5] in southern portions of its range, occurs in small to moderate sized rivers and large creeks typically in riffles of moderate to swift current over gravel or rock substrates.[9] Often associated with sandy area and gravel shoals;[5] mixed small gravel to medium rubble;[4] over sandy or gravel shoals off beaches;[6] found along wave washed lake beaches and pools of larger streams over a sand or gravel bottom;[7,11] inhabits large upland streams, rivers, and big rivers in moderate currents of raceways over substrates of gravel and sand;[8] prefers areas just upstream of riffles.[10] Stays in deeper water during the day moving into the shallows at night.[6,12] Commonly found in lakes or along littoral zones of large lakes;[11] collected from the mouth of the Maumee River, OH, from waters 3–4 m in depth;* or may remain in waters 0.9 m in depth whenever they are clear.[12] Commonly collected in pools avoiding silted areas.[2,3,8] The channel darter is tolerant of turbid waters;[7] or prefers clear water and a silt-free bottom.[9]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Percina copelandi in KY is sporadic and uncommon in the upper Green, middle Cumberland (below the falls), and upper Kentucky Rivers. Generally distributed and common in the Licking and upper Big Sandy River system.[8] One preimpoundment record occurs from the Blood River, Calloway Co. and is apparently extirpated.[8] In TN, it is currently restricted to the Big South Fork of the Cumberland, Clinch, and Powell Rivers above Norris Reservoir. Preimpoundment records exist from the Knoxville area, and the lower Tennessee River, and College Creek, a small tributary of the Nolichucky River at Tusculum, Greene Co. Sometimes common seasonally in some years, occurring more frequently in spring and summer collections.[5] Collected from the main channel of the Ohio River, including the Little Kanawha River drainage in WV.[10] Collected in PA from the Allegheny River.[7] Occurs in the Allegheny River in NY.[6] Collected from the Ohio River from the IN state line to the mouth of the Muskingum River, OH between 1925 and 1950, and from the Ohio River, Jefferson Co., OH in 1978, however, recent records from the Ohio River main stem have found it at a number of localities along the WV shoreline.[12,*] Indiana specimens have been collected from the Ohio River from the Uniontown Pool and from the lower Tippecanoe River.* It is restricted to the Clinch and Powell Rivers in VA; the populations being contiguous to the TN populations in the same rivers. The distribution of the channel darter in the Clinch may be affected as a result of the large fish kill in that stream in 1967.[4]

SPAWNING

Location

Spawns in swift current between small rocks and in fine gravel behind large rocks.[13–15]

Season

Spawning occurs during spring in WV[10] and AR[9] and southeastern Canada;[11] late-May in TN;[5] April to May in VA;[4] April and May in KS;[17] June and July in the Cheboygan River, MI;[13–15] June in OK.[16] hypothesized to occur in mid-June in NY when ripe males were collected 0.25 miles from the mouth of Eighteen Mile Creek.[20,21]

Temperature

Spawning begins at temperatures of 20–21°C in Cheboygan River, MI.[13–15]

Table 182

Ovarian and fecundity data for channel darters from the Caddo River, AR during late March 1986.*

Size (mm TL)	Ovary Weight (mg)	Total Fecundity	Number of Ova: Ripening Oocytes (LA)	Number of Ova: Mature Oocytes (EM, MA, LM)	Number of Ova: Ripe Eggs (MR, RE)	Egg Diameter (mm)
35	33.7	457	339	84	34	1.0
39	44.2	517	388	97	32	1.11
42	50.8	656	466	152	38	1.05
42	61.8	658	460	126	72	1.05
42	72.1	617	386	158	73	1.05
43	67.2	600	404	131	65	1.05
45	78.1	634	398	148	88	1.05
46	95.8	765	560	135	70	1.176
48	77.5	830	570	182	78	0.952
50	154	819	544	179	96	1.25

Table 183

Comparison of the number of ova per female channel darters from Arkansas and Michigan. Literature source is reported for each collection locality.

Location	Age	*N*	TL	Number of Ova
Arkansas*	2	10	35–50	655.3
Michigan[13]	1			357–415
	2			721

Fecundity (Tables 182 and 183)
Females that are age 1 have ova counts that range between 357 and 415 ova, while age 2 females average 721 ova. Actual number of eggs spawned in a territory may number 400.[3,13,14,15]

Sexual Maturity
Age of channel darters is estimated to be 2.5–3.5 years.[5] Specimens mature at age 1;[13–15] at approximately 35–40 mm TL.[5] Males are larger than females.[14] Sexual dimorphic traits of males include the enlargement of the lateral blotches, darkening of the breast. Pelvic and anal fins also blacken and dark bands in the spinous dorsal fin intensify. Nuptial tubercles on males limited to the ridges of the spines and rays of the anal and pelvic fins.[5,19]

Spawning Act
Percina copelandi is an egg burier. Spawning of the channel darter was observed beneath a dam in the Cheboygan River, MI, where water was 0.7–2.4 m in depth. Most spawning occurs in areas 0.61–1 m deep with swift currents (0.95 ft/s measured at bottom). Spawning occurs in swift currents where a male sets up a moving territory behind large rocks about 100 mm in diameter. Receptive females enter the territories and are mounted by the male. Spawning occurs in fine gravel and sand. The pair is buried in the gravel with the male on top of the female with his pelvic fins placed along side her, the pair moves forward and quivers as 4–10 eggs are released and fertilized. Females may spawn with several males. No parental care is provided to the eggs.[13–15]

EGGS

Description
Spherical, demersal, slightly adhesive; average diameter 1.4 mm; yolk orange in color, with a translucent smooth egg chorion.*[,13,16]

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

See Figure 169

Size Range
6.1 mm TL[20] specimen is illustrated by Fish (Figure 169).[20] This specimen has been tentatively assigned as *P. copelandi*; however, several of the characters described suggests that it may be a *Morone* larva.

Myomeres
Total 38; predorsal 13; preanal 14; postanal 24.[20]

Morphology
6.1 mm TL. Head not deflected over the yolk sac; jaws well developed; traces of yolk sac still evident; intestine is large and coiled; air bladder absent; notochord flexion has not occurred.[20]

Morphometry (Table 184)
Lengths and depths as percent TL: preanal length 42.6%; head length 19.7%; eye diameter (% HL) 21.7%; greatest body depth 16.4%; and depth at anus 18.0%.

Fin Development
6.1 mm TL. Dorsal and anal finfolds continuous; pectoral fin well developed; no incipient rays in either the dorsal or anal finfolds, caudal or pectoral fins.[20]

Pigmentation
6.1 mm TL. Eye pigmented, entire body unpigmented.[20]

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown lengths to 35–40 mm TL.[35]

Fin Development
26.5 mm TL. Dorsal and anal finfolds completely absorbed; pectoral and anal fin rays completely formed; spinous dorsal and soft dorsal fin spines and rays not completely formed.*

Larger juveniles: Spinous dorsal IX–XII; soft dorsal 10–14; pectoral rays 13–15; anal rays II 7–10; pelvic rays I 5.[2–5,11] Caudal fin emarginate to slightly notched; principal and secondary caudal rays xv, 8 + 7–8, xii.[*,5]

Morphology
Lateral scales 43–61, complete; frenum absent; gill membranes separate. Branchiostegal membranes with rays 6, 6. The cheek and opercle is scaled; and breast and prepectoral naked.[2–6] Modified midventral scales present in males.[5] Vertebrae 37–40.[2,3,5]

Morphometry
Unknown.

Pigmentation
26.5 mm TL. Preorbital bar formed, while postorbital and suborbital bands not formed; cerebellum covered with melanophores; lower half of the

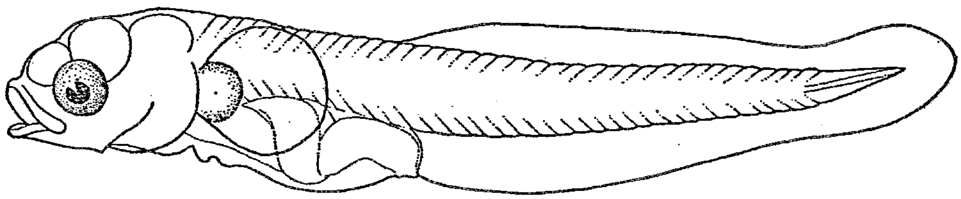

Figure 169 Development of *P. copelandi*, channel darter. 6.1 mm TL: yolk-sac larva. (Redrawn from reference 20, p. 373.)

Table 184

Morphometric data expressed as percentage of head length (HL) and total length (TL) for young channel darters from the Ohio River, IN and Lake Erie, OH.*[,20]

	Total Lengths		
TL range (mm)	**6.1**	**26.5**	**43.0**
***N* Ratios**	**1**	**1**	**1**
As Percent HL			
SnL	20.0	28.3	29.4
ED	28.0	30.4	30.6
As Percent TL			
HL	20.4	19.1	19.8
HW	18.5	17.2	16.4
PreDFL	38.7	28.5	26.7
PreAFO	42.8	51.1	51.6
PreAL	42.8	51.1	51.6
PosAL	57.2	48.9	48.4
SL	93.8	90.4	83.3
YSL	20.4		
P1L	7.4	17.7	—
D1FL	61.3	22.5	—
D2FL		23.1	—
CFL	7.2	9.6	—
BDE	14.3	11.3	—
BDP1	16.3	12.9	14.0
BDA	8.6	12.3	—
MPosAD	6.1	8.1	—
CPD	4.1	2.9	—
YSD	9.2		

operculum concentrated with melanophores. A line of melanophores extend from the pectoral fin origin to the caudal peduncle forming 10–14 horizontal, lateral blotches. Edges of scales above lateral line with scales outlined forming X, Y markings; concentrated pigmentation at interdigitation of anal fin rays with lepidiotrichia. No pigmentation on interstitial membranes of spinous and soft dorsal fins, anal, pelvic, or pectoral fins; forming a series of tessellated bands vertically on the caudal fin.*

43.0 mm TL. The dorsum is tessellated similar to *Boleosoma* with small zebra-like markings, but the brown patches along lateral line are more linear and form a lateral band, somewhat interrupted. Along dorsal ridge the brown spots are large and obvious and a black streak extends forward from eye to snout. Few chromatophores occur on fins, with the exception of a small black spot at the base of caudal fin, and a black spot occurs on anterior rays of spinous dorsal.[20]

Larger juveniles. Preorbital bar present; suborbital and postorbital bars absent. Dorsum and upper sides dark brown to straw; sides of head and lateral body silver with a small amount of blue-green iridescence. Mid-lateral series of 10 to 14 horizontally elongate dark blotches, rarely connected; above the lateral line a series of X, Y markings outline scale edges; saddles vague when present. Lower sides and venter pale to white. Spinous and soft dorsal clear or with slight stippling in soft rays; pectoral fins tessellated; anal and pelvic fin rays clear; caudal rays tessellated.[2–5,11]

TAXONOMIC DIAGNOSIS OF YOUNG CHANNEL DARTER

Similar species: similar to other members of subgenus *Cottogaster* and *Boleosoma* of the genus *Etheostoma.*

Percina copelandi is the only representative of *Cottogaster* in the study area. The lack of pigment in newly hatched *Percina copelandi* is different from members of subgenus *Boleosoma*, which possess melanophores alternating every fourth myosepta along the postanal length.*

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 170)
Eggs. Laid in shallow margins of streams and buried in gravel along areas with some current.[13–15] No parental care provided; and development occurs in the interstitial spaces.[13–15]

Yolk-sac larvae. Larvae are collected in early June by trawling from water 12 m deep near Point Abino on the Ontario shore.[20]

Post yolk-sac larvae. Unknown.

Juveniles: Occur in backwaters and pools that are flowing or, more frequently, sluggish; some fish are collected from areas adjacent to larger rivers.[13]

Early Growth (Table 185)
Young-of-the-year from TN are 35–40 mm SL after the first years growth;[5] age 0 specimens are 20–38 mm SL from OH.[12]

Feeding Habits
Juveniles and young adults eat small midges and mayfly nymphs, switching to larger aquatic insects and crustaceans.[4–7] Mostly chironomids dominated diet;[14,15] Lake Erie specimens from the Bass Island feed on midge larvae and mayfly nymphs, and consume contained appreciable amounts of algae and bottom detritus.[18]

Table 185

Average calculated total length (mm SL) of young channel darters in OH and TN.

State	Age 1	2	3
Ohio[12]	20–38	38–56	64
Tennessee[5]	35–40	50–55	60–70

Figure 170 General distribution of channel darter in the Ohio River system (shaded areas).

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* Original distribution information was obtained from Thomas P. Simon and the Ohio River Valley Water Sanitation Commission between 1988 and 2003. Developmental data are from a specimen obtained from the Ohio River, IN. Original fecundity information was from specimens curated at Northeast Louisiana University, Museum of Zoology, Monroe, LA; specimens from AR Clark Co., Caddo River, mouth of Caddo River, March 26 and 27, 1986.

GILT DARTER

Percina (*Ericosma*) *evides* (Jordan and Copeland)

Percina: a small perch; *evides*: beautiful.

RANGE

Percina evides has a decreasing range, represented by diminishing numbers in widely scattered populations and extirpations in many states.[1–5] The loss is especially evident in northern portions of the species range. The species has been extirpated from its type locality in the West Fork White River, IN, near Indianapolis,[12] and from the only known locations in IA[6] and IL.[7] The species has only been reported twice from Ohio prior to 1900;[8] a recent report from Fish Creek, Maumee River drainage, OH and IN, is erroneous. In NY it has only been found from three large riffles in the Allegheny River near Carrollton but not since 1937.[15] In WI and MN, it is rare to common often with a single individual constituting a record.[5,21] It is sporadic in the upper Green, upper KY, Licking, and upper Big Sandy Rivers, KY;[11] a preimpoundment record exists from the Blood River, Calloway County, KY.[11] It occurs in the Bear and Shoal Creek drainages, AL.[10] It is widespread in the upper Tennessee River drainage, VA[9] and is still widespread in the better quality rivers in TN.[4]

HABITAT AND MOVEMENT

Percina evides occurs in upland rivers where it inhabits shoal areas having moderate to swift current and substrates of gravel, sand, and scattered rubble without vegetation;[4,13,14,21] or only once with *Potemogeton*.[21] Preferred streams do not have silt and are usually clear or only slightly turbid.[4] In streams, adults and juveniles move into deep pools during the winter.[13] Adults prefer riffles and runs with unconsolidated gravel and small rubble. [9]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Percina evides is common in the upper Green River, [11] it is generally distributed in the Powell, Clinch, and North Fork Holston Rivers, and is localized in the lower South Fork Holston River, VA;[9] and new records occur for the upper Elk River, TN;[12] it has been collected from the West Fork White River near Paragon.[23] The species occurs in the middle Tippecanoe River, IN, and in the main channel of the Wabash River near the mouth of the Tippecanoe River, IN.[*,12]

SPAWNING

Location

Percina evides spawns in swift cobble runs;[13,14] or over gravel riffles in 0.3 m depths.[5] Spawning occurs over sand and gravel interspersed with cobble and boulder, in upper parts of riffles 0.3–0.6 m deep.[17] Our field observations confirmed spawning near lateral areas in the head of riffles in depths 0.3 m over gravel in moderate current.*

Season

Spawning season occurs from March to mid-June with the peak spawning period being in May and June;[2–10] or during June to mid-July in MN.[14] Our field observations from the Powell River, Clinch River, Hiwassee, and Little River drainages, TN, show that *P. evides* spawns from mid-April to early June.*

Temperature

Spawning occurs at temperatures of 17.2–20°C in VA;[9,13] 17–20°C in TN;[17] or at temperatures 17–23°C in MN;[14] our laboratory and field observations found spawning to occur at 14.5–22°C *

Fecundity (Table 186)

Sunset River populations from MN held between 132 and 347 mature ova[14] or 132–397 mature ova.[24] Adult females collected from WI in late-June from the Black River have ovaries that are 5% of the body weight.[5] The relationship between fecundity (F) and body length (SL) was Log $F = -4.542 + 3.975$ log SL.[24] Female *Percina evides* from the Hiwassee River do not show statistically significant increasing fecundity based on mature ova (ANOVA, $F = 0.675$, $p = 0.433$) with increasing length, but is significant for total ova (ANOVA, $F = 13.607$, $p = 0.006$). Females between 57 and 73 mm collected from mid-April to mid-May had 32–128 large mature ova

Table 186

Fecundity data for gilt darter from the Black River (Mississippi River drainage), Jackson County, WI[5] and from the Hiwassee River, Polk County, TN.*

		Number of Ova			
TL (mm)	Ovary Weights (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
57	209	518	216	0	–
61	420	499	166	90	1.81
64	531	599	201	106	1.8
65	351	619	258	32	2.1
67	517	1061	398	52	2.0
67	610	567	196	113	2.0
68	493	850	301	82	1.88
68	715	889	392	89	2.1
69	533	674	236	128	1.81
72[5]	189	Numerous	115	12	1.3–1.6
73	795	1198	428	86	2.1

TN.* Ovary weights from TN populations average 16.1% of the total body weight.*

Sexual Maturity

Adults live to reach age 4,[5] maturity is attained by males at 11–13 months and 22–23 months by females; with all specimens greater than 50 mm SL capable of spawning.*[,9] Adult males from IN have testes that are 1.3% of the body weight in late May.* Nuptial male tuberculation is the most highly developed of all darters. Tubercles occur over much of the ventral surface of the body including belly and caudal peduncle scales as well as on rays of pelvic and anal fins and lower caudal fin rays[16]. Tubercles are present on males from March 10 to June 29.[16]

Spawning Act

The reproductive mode of *P. evides* is a burier.[14,17,*] Field observations from the Buffalo River (RM 79.7; G. D. Hickman, personal communication) and Tippecanoe River, IN, found that males occupy spawning riffles in areas with moderate current and gravel substrates. Females remain in deeper water until ready to spawn. No nest is established and males defend a weak territory that is around a female. Males are generally aggressive toward other males that enter within 0.3 m of their reproductive space. Males display intense coloration changes exhibiting black markings and a bright red-orange band in the first dorsal fin. Genital papillae of females are flat and elongate. Courtship includes a male approaching a female from behind and positions himself directly above (sometimes touching) the female. The male would move dorsally from one side of the female to the other "seemingly" touching and rubbing the female on each pass. The female selects the spawning sites in open fine gravel areas and begins to move her body forward in an upstream direction and terminates as she buries their bodies into the fine gravel. The female initiates the spawning by swimming into a depression in the gravel so that her genital papillae is buried about 10 mm beneath the substrate surface. Once the female comes to rest, a single male clasps the female by resting his pelvic fins on her nape. The pair assumes the classic spawning position with the male forming a serpentine position with his body so that his head is on one side and his tail on the other side of the female, which forces the female's vent into the substrate. The pair vibrates simultaneously and release as many as 3–5 eggs that are fertilized by the male in the gravel.* Eggs are buried in fine gravel and mixed gravel substrates in shallow shoal areas adjacent to water willow beds in areas with current. The spawning act lasts about 5 s. At the completion of the spawning act, the male abandons the clasping position and moves a few centimeters away. Spawning is repeated within 5–10 min. The female spawns individually with a single male but as she changes position on the spawning grounds she may mate with multiple males. No guarding is provided by either parent.*

EGGS

Description
Ovarian examination of Hiwassee River populations shows that ovoid latent, cream colored ova ranges from 0.62–0.66 mm, early maturing small spherical orange to light orange colored ova range from 1.0 to 1.11 mm, and large mature orange ova range between 1.81 and 2.14 mm. Eggs from the Powell River, TN, are spherical, average 1.85 mm in diameter (range: 1.7–2.0 mm); transparent; demersal; and nonadhesive. Eggs possess translucent, pale yellow yolk (mean = 1.6 mm in diameter; range: 1.6–1.7 mm); a single oil globule (mean = 0.26 mm); a moderate perivitelline space (mean = 0.15 mm); and a sculptured and unpigmented chorion.*

Incubation
Hatching occurs after 120–124 hr at an incubation temperature of 22ºC;[14] 384 h at an incubation temperature of 14.5–15ºC;* or 216 h at an incubation temperature of 22ºC based on aquarium culture.*

Development
Laboratory observations of embryonic development from the Powell River (RM 65 at 25 E bridge), shows that 50% of the ova are eyed by 168 h and hatched 2 days later at an incubation temperature of 22ºC; at temperatures of 14.5–15°C eyed stages are observed after 192 h.*

YOLK-SAC LARVAE

See Figure 171

Size Range
Populations from Hiwassee River, TN, hatch before 7.5 mm and yolk is absorbed by 9.2 mm.*

Myomeres
Predorsal 4; preanal 18 (30) or 19 (4) (N = 34, mean = 18.1), postanal 25 (N = 34), with total 43 (30) or 44 (4)(N = 34, mean = 43.1).*

Morphology
7.9–8.2 mm TL. Body laterally compressed; snout blunt; with well developed jaws; yolk sac large, triangular-shaped (33.8% TL), reaching maximum depth in the center of the yolk sac and tapering toward the anterior and posterior edges; yolk translucent clear to pale yellow, with a single anterior oil globule; a simple single vitelline vein occurs midventrally on yolk sac; head slightly deflected over the yolk sac; and eyes oval.*

8.8–9.2 mm TL. Digestive system functions before complete yolk absorption by 8.8 mm TL;* gills function (8.8–9.0 mm); yolk sac absorbed by 9.2 mm TL.*

Morphometry
See Table 187.*

Fin Development
7.9–8.2 mm TL. Pectoral fin present without incipient fin rays.*

Pigmentation
7.9–8.2 mm TL. Eyes pigmented; no melanophores present dorsally, laterally, or ventrally over the body or yolk sac.[15,*]

8.8–9.2 mm TL. No dorsal melanophores over the entire body. Melanophores continue along every postanal myosepta.*

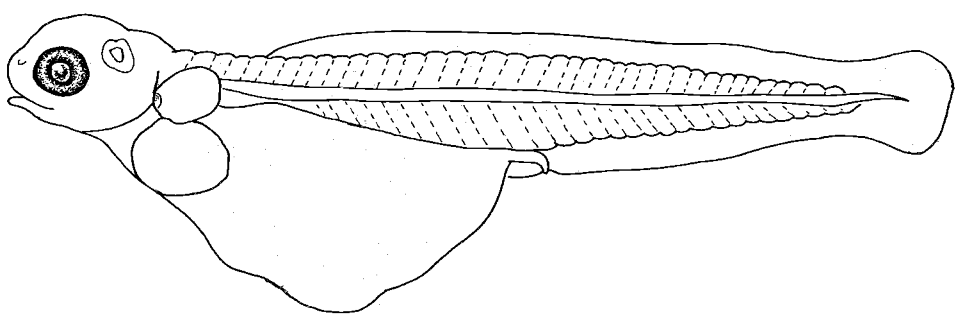

Figure 171 *Percina evides,* gilt darter, Powell River, Claiborne County, TN: yolk-sac larva, 7.5 mm TL; lateral view. (original illustration).

Table 187

Morphometric data expressed as percentage of TL for *P. evides* larvae and early juveniles from TN and MN.*

	TL Groupings		
Length Range (mm)	**7.9–8.2**	**8.3–10.1**	**23.5–33.8**
N	**34**	**9**	**23**
	Mean ± SD	**Mean ± SD**	**Mean ± SD**
As Percent TL			
SnL	3.8 ± 1.1	4.4 ± 0.9	4.7 ± 0.8
PEL	5.7 ± 0.6	6.2 ± 0.2	6.5 ± 0.3
OP1L	16.8 ± 1.2	18.5 ± 1.2	24.1 ± 0.8
ODL	30.1 ± 1.0	29.7 ± 1.1	29.3 ± 0.6
PVL	49.5 ± 1.2	49.3 ± 0.8	48.7 ± 0.8
MAXL-Y	38.4 ± 1.2		
P1L	8.1 ± 0.3	12.3 ± 0.8	20.8 ± 0.7
HD	7.4 ± 0.8	11.5 ± 0.7	15.2 ± 0.7
OP1D	17.4 ± 2.3	13.1 ± 1.0	13.5 ± 0.5
OD1D	27.5 ± 2.9	14.4 ± 0.7	13.7 ± 0.5
OD2D	—	14.2 ± 0.3	13.4 ± 0.4
BPVD	8.4 ± 1.1	9.3 ± 0.4	12.9 ± 0.5
MPMD	4.7 ± 0.8	6.8 ± 0.3	8.8 ± 0.2
AMPMD	3.9 ± 1.1	3.3 ± 0.7	7.8 ± 0.2
MAX-YD	26.4 ± 2.1		

POST YOLK-SAC LARVAE

Size Range
9.2 mm TL* to <23.5 mm TL.

Myomeres
Hiwassee River, TN, populations with predorsal 5; preanal 18 (5); postanal 24(2), 25 (4), or 26(3)(mean = 25.1), with total 42 (2), 43(4), or 44(3) (mean = 43.1)*.

Morphology
9.2 mm TL. Yolk sac absorbed.*

9.4–10.1 mm TL. Notochord flexion.

Morphometry
See Table 187.

Fin Development
9.2 mm TL. No incipient fin rays present.*

9.4–10.1 mm TL: Caudal fin rays form.*

Pigmentation
9.2–10.1 mm TL. Melanophores at every postanal myosepta occurring from the anus to the caudal peduncle.*

JUVENILES

Size Range
Unknown length, (smallest juvenile specimen from study area was 23.5 mm TL[6]) to 50 mm SL.[9]

Fin Development
23.5–33.8 mm TL. Complete adult fin ray counts in paired and median fins including pelvic fin ray; caudal fin rays with segmentation, fin is truncate; dorsal and anal finfolds completely differentiated.*

Larger Juveniles: Spinous dorsal fin (XI–XIII)–XIV; soft dorsal rays 10–(11–13); pectoral rays 12–(13–15)–16;

anal fin spines/rays II / 6–(8–9)–10; pelvic fin spines/rays I 5; and caudal fin rays 15–17 [1–7,*].

Morphology
23.5 mm TL. Lateral line formed. Squamation nearly complete, the only areas lacking scales are the cheeks, opercles, nape, and the anterior third of the body.*

24–28 mm TL. Some individuals with incomplete lateral lines. Specialized midventer squamation of males complete (25 mm); scales lacking only on the nape and most individuals have supratemporal canals (27–28 mm).*

33 mm SL. Scales present on nape.*

Larger juveniles. Cheeks naked; opercle and nape scaled; breast and belly naked with exception of modified mid-ventral scales in males; total vertebrae 37–42 including one urostylar element. Gill membranes barely connected or separate.[2–4]

Morphometry
See Table 187.*

Pigmentation
23.5 mm TL. Pigmentation similar to adult. Specimen possesses defined pre-, post, and suborbital bars; cranium with melanophores covering cerebellum and optic lobe. Dorsum from spinous dorsal fin origin to caudal peduncle with eight dorsal saddles, seven lateral blotches, and a distinct basicaudal hook at the base of hypural plate. Scales outlined with melanophores. Spinous dorsal with a medial stripe, soft dorsal fin with scattered melanophores outlining rays, anal fin with a single medial stripe, and three vertical stripes on caudal fin.[6]

25.1–35.5 mm TL. Body pigmentation straw colored with black dorsal saddles 7-8; dorsum of cranium with melanophores covering cerebellum and optic lobe. Eight large, lateral blotches form nonconnected bands that in later stages merge with the dorsal saddles. Median basicaudal spot small but prominent and becomes a blotch in later stages.*

TAXONOMIC DIAGNOSIS OF YOUNG GILT DARTER

Similar species: other members of subgenus *Alvordius. P. maculata* and *P. macrocephala.*[4]

The early life history stages of *P. evides* are unlike any other *Percina*. The large, triangular shaped yolk sac, large size at hatching (7.9 mm), few preanal (18) and large number of postanal myomeres (23–24), and absence of pigmentation separates *P. evides* from all other darter larvae.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 172)
Eggs. Percina evides eggs can be found in swift cobble runs;[13,14] or over gravel riffles in 0.3 m depths.[5] Eggs can be found over sand and gravel interspersed with cobble and boulder, in upper parts of riffles 0.3–0.6 m deep.[17] Our field observations confirmed eggs being laid near lateral areas in the head of riffles in depths of 0.3 m over gravel in moderate current.*

Yolk-sac larvae. Yolk-sac larvae are pelagic immediately after hatching.* The vitelline vein is simple and straight on the ventral yolk sac and is consistent with other *Percina* burier species.[16] Larvae are active and appear to be in constant motion without resting.*

Larvae. Larvae drift and are pelagic for most of the larval period. Larvae are pelagic for the first 3 weeks after hatching. Larvae settle out of the drift and become benthic, staying close to the substrate.*

Juveniles. Juveniles are often associated with slower current and smaller gravel.[9] Juveniles collected from the St. Croix River, Burnett County, WI, occur in shallow (0.3–0.6 m) lateral margins of riffles among cobble and large gravel. Juvenile density is 0.25 individuals/100 m^2.* By mid- to late August as many of 20 juvenile darters per Erickson haul were present in areas with moderate depth and swift to moderate current.[21]

Early Growth (Table 188)
Individuals do not exceed 4 years of age;[5,6] or 3 years.[14] During their first three months of life, growth rates of both sexes are equal, but by six months males become significantly larger, with the gap becoming greater at larger lengths.[13,14] Young darters attain 35–37 mm in July, 33–52 mm in August, 33–44 mm in September, and 30–52 mm by October in WI.[5] Age 0 individuals from VA were 34–40 mm within 90 days after hatching.[13] A regression equation shows that the length–weight relationship for WI is $\log W = -11.7037 + 2.9973 \log \mathrm{TL}$ (mm), when W weight in g;[5] while MN populations have

Figure 172 Distribution of gilt darter, *P. evides* from the Ohio River system (shaded area).

Log $W = -5.531 + 3.454 \log SL$ for ripe females, and $\log W = -5620 + 3.489 \log SL$ for males.[24] Hatch[21] reported that during the first 4 months of life, male *P. evides* attained lengths of 30.9, 39.8, 45.0, and 45.9 mm TL, while females attained lengths of 31.3, 38.6, 41.8, and 41.4 mm TL.[24]

Feeding Habits

Percina evides populations from French Creek, PA, have the most variety in its diet feeding on larger prey, more chironomids, and more fish eggs.[22] The main components of the diet (based on 2 fish) in WI include small dipteran larvae, caddisfly larvae, and small ephemeropteran nymphs;[5] midge larvae, blackflies, caddisflies, mayflies, and occasionally snails;[19,20] baetid nymphs, chironomid larvae, and hydropsychid larvae, although some individuals consume stonefly naiads and elmid beetle adults; young juvenile darters feed mainly on midge larvae.[7] Populations from MN consume immature mayflies (46%), midges (43%), and caddisflies (10%). Gilt darters are diurnal feeders and exhibit seasonal changes in feeding intensity.[14]

Table 188

Average calculated lengths (mm TL) of young gilt darter from several locations.

State	Age 1	2	3	4
Wisconsin (mean)[5]	52.9	68.6	73.0	75.5
Virginia[9]			67	
Tennessee[4]	45–50	60–70	80	

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Material Examined: TN: Claiborne Co: Powell River, 25 E bridge (5)(TVA 89–16); (23) (TV88-37); Hancock Co: Clinch River – Swan Island RM 123 (4 eggs) (TVA 88-39); Clinch River, Kyles Ford (12)(TV 761); Clinch River Spear Ferry (140 eggs; 12)(TV 2947); Hiwassee River (2 eggs); Hiwassee River (5)(TV1761). MN: Chisago Co: Sunrise River, lower 400 m, 2.4 km NNW Sunrise (4; UM 22119), (5; UM 22099), (1; UM 22116), (13; UM 22136).

* Original fecundity data for gilt darter from the Hiwassee River (Tennessee River drainage), Polk County, TN. Specimens curated at Northeast Louisiana University, Museum of Zoology, Monroe, LA. Early life history developmental series cultured from laboratory spawned specimens from TN and MN (see Table 187) are curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

LONGHEAD DARTER

Percina (*Alvordius*) *macrocephala* (Cope)

Percina: a small perch; *macrocephala*: long head.

RANGE

Percina macrocephala is widespread in the Ohio River drainage; however, nowhere is it common. It has been taken sporadically in the major southern tributaries of the lower Ohio River as well as various upstream tributaries in OH, WV, PA, and NY.[1–3]

HABITAT AND MOVEMENT

The longhead darter inhabits moderate-sized to large, clear streams[9] in pools or chutes of streams of moderate gradient.[2] Often associated with boulder and cobble-strewn flowing pools and the areas above and below deep, fast riffles underlain with cobble.[4] Inhabits deeper riffles and pools with current, of the mountain-torrent type of moderate- or large-sized Appalachian streams that normally have fairly clean waters and a clean bottom.[10] Common to abundant in gravel and boulder-bottomed riffles and pools,[10] or clean streams over gravel and cobble.[9] Requires streams with gradients of 1.6 m/km, and an average monthly discharge of 1,468 s/ft^3.[10] Rarely in pools or quiet waters avoiding silted areas. Occupies riffles and flowing pools of moderate currents in association with weed beds or exposed bedrock.[2] The longhead darter is intolerant of turbid waters and silt.[2,3,6] During winter, it moves into the deepest pool areas of the Little River, TN, and then migrates to shallow gravel shoal areas to spawn.[6] Found in low current velocities and commonly in silted areas. This species spends maximum time (61%) in the water column.[15]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

In KY, *P. macrocephala* is sporadic and rare in the upper Barren and upper Green Rivers. Most common in the upper Barren River and Kinniconick Creek;[5] apparently extirpated from the Cumberland and Kentucky Rivers;[4] also common in some years in localized portions of Little River, Blount Co., TN, extirpated in other tributaries to the Tennessee River and has not been collected from the Cumberland River since 1891; may rarely occur in the Barren River near the state line.[6] Collected only from the Elk River drainage in WV.[7] Extirpated from PA including the Youghiogheny River, French River, and Allegheny River at Foxburg, including the type locality due to acid mine pollution.[8,11,12] Occurs in the Allegheny River near Portville and Westons Mills, NY.[9] Collected from the Walhonding River, below Six Mile Dam, Coshocton Co., OH, in 1939; however, is considered extirpated since no additional specimens have been collected since.[10] It is known from only two tributaries in VA, Copper Creek and Little Rivers (Clinch River drainage) and in the North and Middle Forks of the Holston River. Since 1970, the longhead darter has only been collected in lower Copper Creek, and the North Fork Holston River above Saltville. It may have occurred in the South Fork Holston River before impoundment.[13]

SPAWNING

Location
Spawning occurs in shallow gravel shoal areas.[6]

Season
Spawning occurs during March to May in the Green River, KY;[3] spring in WV;[7] March in Little River, TN;[6] and March to May in VA.[13]

Temperature
Spawning begins at temperatures of 10°C in Little River, TN.[6]

Fecundity (Table 189)
Females from the Little River, Blount County, TN, in the size range from 88 to 95 mm TL have between 63 and 160 ova. Females from TN 88 mm TL were mature.*

Sexual Maturity
Specimens less than 50–66 mm SL did not have ripe gonads, showing that age 1 individuals were immature.[14] The sex ratio of Green River populations were 1.5:1.0 (males/females).[14]

Spawning Act
Unknown.

Table 189

Fecundity data for longhead darters from Little River, Blount County, TN.*

Date	TL (mm)	Ovary Weight (mg)	Number of Ova: Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
April 5	95	129	117	0	50	1.42
April 9	88	100	85	20	48	1.42
April 17	92	49.9	53	10	0	1.00[a]

[a] Egg diameter is based on mature oocytes instead of ripe oocytes diameters.

EGGS

Description
Spherical, demersal, slightly adhesive; average diameter 2.0 mm; yolk pale yellow in color, with a translucent smooth egg chorion.* Ripe oocytes are large with translucent light yellow to orange yolk.*

Incubation
27 days at 10°C.[6]

Development
Eggs develop slowly; after 8 days optic lobe evident, however, no somites were readily evident. After day 9 gastulation complete. At day 12 late gastrula stage, tail free from yolk; somites appear complete, and optic cups visible. After 14 days, tail free and thrashing periodically; head free ventrally; auditory structures visible; notochord visible; melanophores develope on the yolk-sac and concentrate ventrally on beneath the tail. Day 17, eyes pigmented; pectoral buds formed. At day 27 hatching occurs.*

YOLK-SAC LARVAE

See Figure 173

Size Range
10–12 mm TL* at hatching to unknown length >12 mm at complete yolk absorption.[6]

Myomeres
Total 43–49; predorsal 6–7; preanal 21; postanal 22–28.*

Morphology
10 mm TL. Body laterally compressed and elongate; eye oval and pigmented; jaws well developed; head not deflected over the yolk sac; yolk-sac small (25.4% TL) tapering posteriorly; a single mid-ventral vitelline vein present.*

12 mm TL. Oil globule and yolk sac mostly absorbed.*

Morphometry
See Table 190.

Fin Development
10–12 mm TL. Dorsal and anal finfolds complete; pectoral fins well developed; incipient fin rays 4–5 in pectoral fin; no incipient rays absent from all median and paired fins.*

Pigmentation
10 mm TL. Cranium with several stellate melanophores over cerebellum; a single stripe of melanophores along the dorsum from the nape occurring at every other myomere to midgut; concentrated cluster of melanophores occurring on the yolk sac, usually covering lower half of the yolk sac. A line of melanophores outline the dorsal edge of the gut.

12 mm TL. Little change apparent in pigmentation.*

POST YOLK-SAC LARVAE

Size Range
>12 mm TL to unknown lengths.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

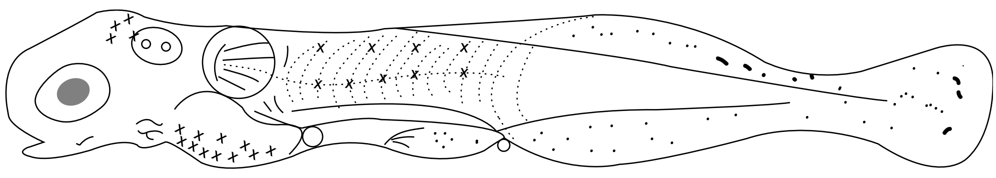

Figure 173 *Percina macrocephala*, longhead darter, Allegheny River, PA. yolk-sac larva, 10.0 mm TL, lateral view. (Original illustrations from W.C. Starnes laboratory notes.)

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
>12 mm TL to 88 mm TL.*

Fins
34.5 mm TL. Dorsal and anal finfolds completely absorbed; pectoral and anal fin rays completely formed; spinous dorsal and soft dorsal fin spines and rays not completely formed.*

Larger juveniles. Spinous dorsal IX–XII; soft dorsal 12–15; pectoral rays 14–15; anal rays II 10–11; pelvic rays I 5.[2,3,4,6] Caudal fin emarginate to slightly notched; principal and secondary caudal rays xv, 8 + 7, xii.*

Morphology
Lateral scales 48–59, complete; frenum present; gill membranes moderately connected. Branchiostegal membranes moderately or broadly united, rays 6, 6. The cheek may support exposed scales or only a few embedded scales; nape and opercle are scaled; breast and belly are naked.[2–4,6] Modified mid-ventral scales present in males.[4] Vertebrae 38–40.[2,3]

Morphometry
Table 190.

Pigmentation
34.5 mm TL. Preorbital and postorbital bands well formed; cerebellum covered with melanophores; lower half of the operculum concentrated with melanophores; a concentration of melanophores present on the lower cheek and at prepectoral base. A line of melanophores extends from the nape to the pectoral fin forming the first lateral blotch. Eight dorsal saddles and nine lateral blotches; concentrated pigmentation at interdigitation of anal fin rays with lepidiotrichia. Pigmentation on interstitial membranes of spinous and soft dorsal fin, anal with some pigment, forming a midband vertically on the caudal fin. Pectoral fin without pigment.*

Larger juveniles. Dorsum and upper sides olive, tan, or brown; markings brown to black; narrow straw or yellow stripe just above lateral blotches; lower side and venter yellow or white. Pale band of first dorsal fin lacks bright orange; other fins commonly pale yellow or olive. Spines and rays of dorsal fins tesselated with dark segments dusky to black.; pale segments pale yellow; lateral blotches pale green.[2,3,6,13,14]

TAXONOMIC DIAGNOSIS OF YOUNG LONGHEAD DARTERS

Similar species: similar to other members of subgenus *Alvordius*.

See diagnosis section in *P. maculata* species account.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 174)
Eggs. Laid in shallow margins of streams and buried in gravel.[12] Eggs difficult to determine whether alive or dead. The eggs never cloud over, however, debris tend to adhere to the egg chorion.*

Yolk-sac larvae. Yolk-sac larvae were collected from surface drift in the Little River, TN.* Larvae are phototaxic to light source.

Post yolk-larvae. Specimens were capable of swimming actively.*

Juveniles. Occurs in backwaters and pools that are flowing or, more frequently, sluggish; some fish are collected from long pools distant from riffles. The specimens were collected from areas close to stream banks during day and night, generally with slightly to heavily silted substrates that had detritus and sticks projecting above the substrate. Darters may use sunken brush and other materials to remain above the silt.[13]

Table 190

Morphometric data expressed as percentage of head length (HL) and total length (TL) for young longhead darters from the Little River, TN and Allegheny River, PA.*

	Total Length Groupings		
TL Range (mm)	**10.0–10.6**	**12.0–12.3**	**34.5**
N	**3**	**3**	**1**
Ratios	**Mean ± SD(Range)**	**Mean ± SD(Range)**	
As Percent HL			
SnL	24.2 ± 1.4	28.5 ± 3.1	34.8
	(23.4–25.2)	(27.3–32.5)	
ED	50.0 ± 2.2	46.4 ± 2.2	35.9
	(48.9–52.1)	(40.4–48.6)	
As Percent TL			
HL	18.2 ± 1.4	17.9 ± 1.1	17.7
	(17.2–19.5)	(16.4–20.4)	
HW	8.5 ± 1.7	11.8 ± 1.2	12.0
	(7.2–12.5)	(10.9–13.6)	
PreDFL	27.3 ± .3.9	28.5 ± .3.6	29.9
	(25.1–34.1)	(26.8–34.9)	
PreAFO	48.5 ± 1.2	51.1 ± 1.6	55.2
	(47.6–50.0)	(50.8–54.4)	
PreAL	48.5 ± 1.2	51.1 ± 1.6	55.2
	(47.6–50.0)	(50.8–54.4)	
PosAL	51.5 ± 1.1	48.9 ± 2.9	44.8
	(50.0–52.4)	(45.6–49.2)	
SL	90.9+0.6	90.4 ± 1.2	86.9
	(90.0–92.0)	(88.6–92.5)	
YSL	25.7 ± 3.4		
	(22.4–29.1)		
P1L	9.1 ± 1.4	11.2 ± 3.1	12.9
	(8.4–9.7)	(9.8–12.8)	
D1FL	72.7 ± 1.4	64.5 ± 6.7	13.5
	(65.9–74.9)	(63.1–77.2)	
D2FL			12.4
CFL	9.1 ± 1.4	9.6 ± 2.2	13.1
	(8.0–10.0)	(7.5–12.4)	
BDE	12.1 ± 1.3	9.7 ± 1.0	8.1
	(10.4–13.2)	(8.3–10.2)	
BDP1	9.1 ± 1.5	11.3 ± 1.3	12.2
	(8.9–14.2)	(9.2–13.0)	
BDA	6.8 ± 0.6	8.2 ± 0.9	14.2
	(6.0–7.3)	(7.6–8.4)	
MPosAD	5.3 ± 1.1	5.6 ± 0.5	13.1
	(4.5–6.2)	(5.0–6.1)	
CPD	2.3 ± 0.2	3.0 ± 1.0	7.2
	(2.1–2.9)	(2.2–3.5)	
YSD	7.5 ± 2.0		
	(7.0–10.1)		

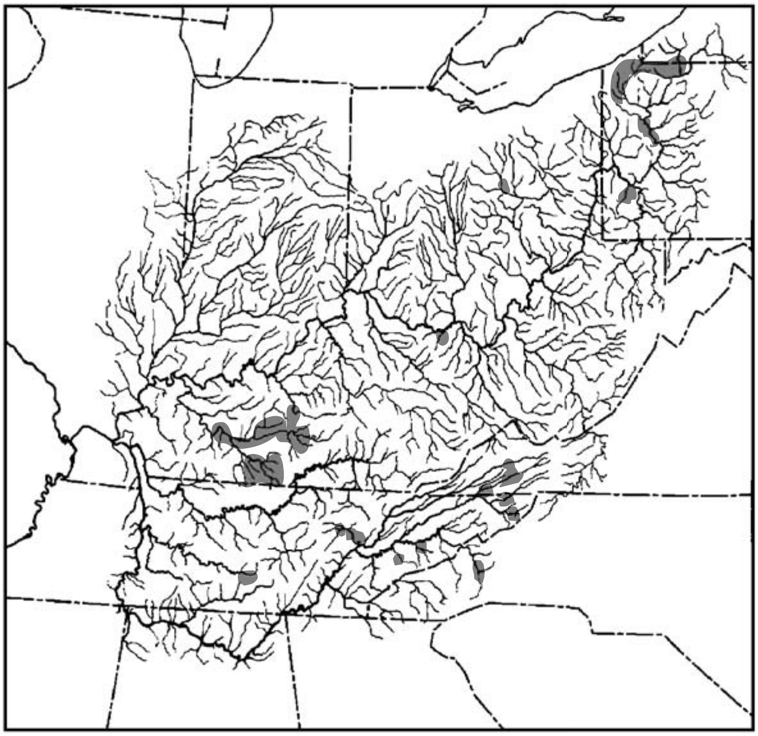

Figure 174 General distribution of longhead darters in the Ohio River system (shaded areas).

Early Growth (Table 191)
Young-of-the-year from VA were 50–66 mm TL after the first years growth in May.[13] Specimens from the Green River, KY, were 34–52 mm SL between May and October.[14] Age 0 specimens were 33–52 mm SL; specimens collected in May were age 1 and ranged between 50 and 66 mm SL[14].

Feeding Habits
After yolk absorption, larvae fed on microcrustaceans.[6] Juveniles and young adults eat mayflies and small crayfish.[14] Adults in the Little River, TN, were observed feeding in a delicate manner, deftly plucking food items from the surfaces of stones, and other underwater objects while swimming above the bottom.[6]

Table 191

Average calculated lengths (mm SL) of young longhead darters in Kentucky and Tennessee.

	Age			
State	**1**	**2**	**3**	**4**
Kentucky[14]	49–62	63–84	85–94	97–102
Tennessee[6]	50–60	75	90	

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* Original reproductive, early distribution, and growth information was obtained from notes provided by Wayne C. Starnes, North Carolina Museum of Natural History, Raleigh, NC from specimens collected from the Little River, Blount Co., TN during 1980. Developmental data are from a series obtained from the Allegheny River, PA, loaned by Joseph Kaskey, Geo-Marine, Plano, TX. Original fecundity data for longhead darter from Little River, Blount County, TN. Specimens are curated at Northeast Lousiana University Museum of Zoology, Monroe, LA.

BLACKSIDE DARTER

Percina (*Alvordius*) *maculata* (Girard)

Percina: a small perch, *maculata*: spotted.

RANGE

Percina maculata is widespread and found throughout the Mobile Basin, eastern and central portions of the Mississippi River drainage, Great Lakes basin, and portions of the Hudson Bay drainage.[1–5,17] The species occurs from the lower Mississippi River to MN and east into the Lake Ontario region.[1–5]

HABITAT AND MOVEMENT

Percina maculata occurs in a variety of habitats including medium- and large-sized streams.[1–5] It is a pelagic species depending on environment occupied and age group. It is most benthic in riffles and become increasingly pelagic with a decrease in water velocity, they were observed above the substrate 1.5 cm for more than 60% of the time.[16] It is almost always associated with vegetation or detritus.[20] Age 0 individuals are more pelagic than age 1+ in all environments. [16] It occurs in riffles usually in deeper places where the current decreased, occurrs also in pools, and is often found in brush and logs where the current is slow.[7] Preferred habitats include shallow, swift water over a hard bottom, often of rubble or rock;[7–10] to sluggish water over mud substrates.[11] It has been collected in habitats with current velocities less than 15 cm/s and in laboratory tests preferred current speeds of 5–10 cm/s.[12] It occurs in marginal coldwater and warmwater streams and rivers in clear to slightly turbid water at depths less than 1.5 m, often where considerable vegetation was present.[5] In streams, males enter the riffles during the reproductive period during mid-March,[7] and may exhibit movement from spawning riffles into silt covered pools,[13,14] while females remain in deeper water until ready to spawn.[5,13,14] *Percina maculata* shows longitudinal movement from upper stream reaches during the winter and spring into lower stream reaches during the summer.[7]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

The species is found in tributary streams of the upper Cumberland River drainage. It is of sporadic occurrence in small to medium streams in west TN, but is apparently absent from the Obion River system and is known in the Forked Deer River system based on a single specimen. This distribution pattern suggests that it crossed over into the headwaters of the Hatchie River of the Mississippi drainage, the Tombigbee River of the Mobile basin, and the southwestern tributaries of the lower Tennessee River.[6] The species is very rare in the upper Tennessee drainage, known only from the Emory and Powell River systems. It is common in the Big South Fork and upper Cumberland drainage.[1–5] The species occurs throughout the tributaries of the Wabash River drainage, IL and IN; throughout central and southwestern OH, and northern KY.[*,1–3]

SPAWNING

Location

Percina maculata uses pools and raceways to spawn where it lays eggs in coarse sand or fine gravel in shallow water at depths greater than 0.3 m;[13,14] or spawn over sand and gravel in shallow water (0.3 m) and of moderate current.[15]

Season

Spawning season occurs from April to June.[5,13–15]

Temperature

Spawning occurs at temperature of 16.5°C;[13] spawning occurs in the laboratory between 17and 22°C.*

Fecundity

Adult females collected in mid-March from the Kaskaskia River, IL, had ovaries that were 17% of the body weight, containing as many as 2000 enlarged ova, while age 1 females collected in mid-April had gonad weights ranging from 2 to 15% of total body weight and egg counts ranging from 630 to 860. The larger age 1 females probably spawned, but the small ones had very small eggs and would not have spawned at the end of their first year.[7] Egg numbers increase with age and size of individuals. Females from WI collected in April had ovaries that were 12.4% of the body weight and May females had ovaries that constituted 9.4% of the body weight.[5] Two age 2 females (56–68 mm TL) collected in May from WI held from 85 to 232 eggs, but these fish were almost spent, while an age 2 female (70 mm TL) collected in April from WI had 502 mature ova. Females from MN held 121 mature ova.[20] Female *P. maculata* showed statistically significant increasing fecundity (ANOVA, $F = 54.76$, $p > 0.0001$) with increasing length. Females between 63–89 mm collected in mid-April had 119–397 large mature ova Table 192.* Ovary weights averaged 14.8% of the total body weight.*

Sexual Maturity

Adults live to reach age 4,[7,18] maturity is suspected to be at age 2 with some larger age I females potentially spawning,[4] or all age 1 were mature.[20] Adult males from WI had testes that were 1.2% of the body weight in May.[5] Male tuberculation develops as tuberculate ridges on the rays and spines of the anal and pelvic fins and with exposed portion of modified midventral scales with hardened swellings.[4]

Spawning Act

The reproductive mode of *P. maculata* is a burier.[3] Males occupy spawning riffles in areas with moderate current, while females remain in deeper water until ready to spawn. No nest is established and males defend a weak territory that is around a female. Males are generally aggressive toward other males that entered within 40 cm of their reproductive space. Such moving territories are considered a pleisiomorphic behavioral trait. Males attack other conspecific males only. During an attack between two males, the pelvic, anal, and caudal fins are held erect in a challenging position. When an intense fight occurs, the head is often lowered and the erect caudal fin elevates the posterior portion of the body. Males do not really court females, rather once a male recognizes a female he follows her.

Table 192

Fecundity data for blackside darters from the Yellow River (Kankakee River drainage), Marshall County, IN; Terre Noir Creek, Clark Co., AR; Little Corney Creek, Union Parish, LA; Brusky Fork, Nevada Co., AR; Meridian Creek, Union Parish, LA.*

		Number of Ova			
TL (mm)	Ovary Weights (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
85	317.5	1344	378	397	1.63
67	218	912	221	119	1.65
66	215	728	159	181	1.58
63	219	798	182	163	1.58
63	221	610	379	162	1.18
66	184	958	347	123	1.25
67	300	1113	469	212	1.25
72	218	1030	223	189	1.65
72	438	1601	598	257	1.25
76	320	1145	288	230	1.65
77	456	1432	658	297	1.25
79	358	1481	419	186	1.25
80	212	1198	142	283	1.72
80	223	1249	267	241	1.65
83	395	1598	636	289	1.18
87	334	1494	412	386	1.73
89	417	1798	355	387	1.73
90	419	1780	801	0	—
92	466	1742	790	276	1.25
107	488	1391	758	0	—

This is considered the simplest type of courtship behavior. Males display intense coloration changes becoming intensely black. Females select spawning sites in open fine gravel areas and buried their bodies into the fine gravel. The female initiates the spawning by swimming to a depression in the sand or gravel. Once the female comes to rest, a single male clasps the female by resting his pelvic fins on her nape and stimulating her with the tuberculate mid-ventral scales and pelvic fins. The pair assume the spawning position with the male forming a serpentine position with his body that forces the female's vent into the substrate. The pair vibrates simultaneously and release as many as ten eggs into the gravel that were fertilized by the male; or if depositing into sand, a cloud of sand is disturbed. At the completion of the spawning act, the male abandons the clasping position and moves a few centimeters away. The pair exhibit laborious breathing and gasping and show relaxed dorsal and caudal fins. Spawning is repeated within 5 min to half an hour later. The female, usually spent within 2.5 days, spawns individually with multiple males as she changes position on the spawning grounds. No guarding is provided by either parent.[5,13–15] Only once was a supernumery male observed vibrating beside the spawning pair.[15]

EGGS

Description
Ovarian examination showed that ovoid latent ova ranged from 0.4 to 0.5 mm. Early maturing small spherical cream colored ova range from 0.83 to 1.0 mm, and large mature ova range between 1.58 and 1.73 mm.* Egg diameters from the Belle Branch of the River Rouge, MI, are 2.0 mm diameter, spherical, adhesive, and demersal.[15] Eggs from WI are colorless, transparent, and had a single, colorless oil globule.[5] Eggs from the Yellow River, IN are spherical, mean = 1.8 mm diameter (range: 1.7–1.9 mm); translucent; demersal; and nonadhesive. Eggs possess translucent, pale yellow yolk (mean = 1.6 mm diameter; range: 1.5–1.8 mm), a single oil globule (mean = 0.26 mm), a moderate perivitelline space (mean = 0.2 mm), and a sculptured and unpigmented chorion.*

Incubation
Hatching occurs after 142–144 h at an assumed incubation temperature of 16.5°C[15] hatching occurs in 148–168 h at an incubation temperature of 21–22°C.*

Development
Petravicz described the beat of the heart and blood flow.[15]

YOLK-SAC LARVAE

See Figure 175

Size Range
Michigan populations from Belle Branch Rouge River hatch at 5.75[15] and yolk is absorbed by 7.2 TL.[15]

Myomeres
Preanal 22–23 (*N* = 4); postanal 20–21 (*N* = 4); total 43.*

Morphology
5.75 mm TL. Newly hatched; body terete; snout blunt; simple stomodeum and nonfunctional jaws; yolk-sac elongated, large (38.9% TL), oval to rectangular, and tapering slightly posterior; yolk clear translucent to pale yellow, with a single oil globule; a simple single vitelline vein occurs mid-ventrally on yolk sac; head slightly deflected over the yolk sac; and eyes oval.*

7.2 mm TL. Digestive system functions before complete yolk absorption by 6.8 mm TL;* yolk sac absorbed by 7.2 mm TL; gills functional.*

Morphometry
See Table 193.*

Fin Development
See Table 194.*

5.75 mm TL. Pectoral fin bud present.*

6.8–7.2 mm TL. Pectoral fin forms without incipient rays present.*

Pigmentation
5.75 mm TL (*newly hatched*). Eyes pigmented; no melanophores found dorsally over the body. No pigment present dorsally over the yolk sac, however, several punctate melanophores occur posterior to the yolk sac over the gut. Melanophores distributed laterally over the oil globule and at every postanal myosepta along the mid-ventral.[15,*]

6.8–7.2 mm TL. No dorsal melanophores present over the entire body. Melanophores present from the pectoral fin base to the anus over the gut, outlining the anus, and continuing along every postanal myosepta.[15,*]

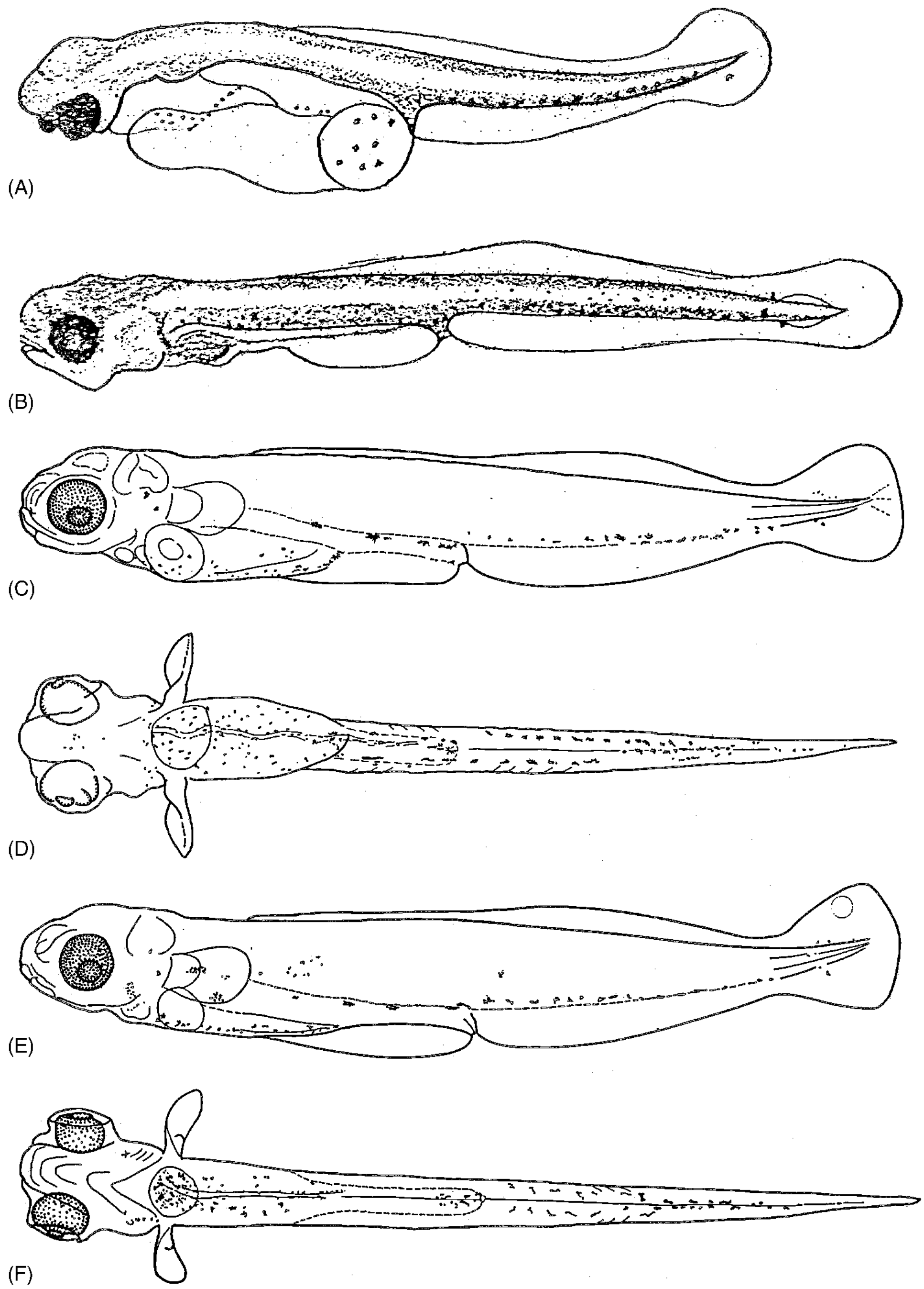

Figure 175 *Percina maculata,* blackside darter, Yellow River, Marshall County, IN. (A) yolk-sac larva, 5.75 mm TL, lateral view; (B) yolk-sac larva, 7.2 mm TL, lateral views; (C-D) yolk-sac larva, 7.6 mm TL, lateral and ventral view; (E-F) yolk-sac larva, 8.3 mm TL, lateral and ventral view. (A-B redrawn from reference 15; C-F original drawings.)

LARVAE

See Figure 176

Size Range

7.2–15.5 mm TL.*

Myomeres

Preanal 22 (8), 23 (9), or 24 (4) (*N* = 21, mean = 22.8), postanal 20 (14) or 21 (6) (*N* = 21, mean = 19.3), total 42 (8), 43 (9), or 44 (4) (*N* = 21, mean = 42.8).*

Morphology

7.2–7.4 mm TL. Yolk absorbed.*

7.6–8.1 mm TL. Operculum and gill arches function and premaxilla and mandible form.*

8.2 10.1 mm TL. Neuromast development occurs midlaterally from the anterior trunk posteriad.

Table 193

Morphometric data expressed as percentage of TL for young *Percina maculata* from Indiana.*,15

	TL Groupings				
Length Range (mm)	**5.75–7.2**	**7.3–10.4**	**10.6–14.0**	**14.2–18.2**	**18.4–35.0**
N	**4**	**21**	**10**	**5**	**4**
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
As Percent TL					
SnL	3.4 ± 1.1	4.5 ± 0.9	4.3 ± 0.4	4.1 ± 0.3	4.5 ± 0.2
PEL	11.6 ± 1.6	6.2 ± 0.5	6.6 ± 0.7	6.1 ± 0.4	6.1 ± 0.5
OP1L	14.5 ± 1.3	18.4 ± 0.8	19.1 ± 0.9	19.2 ± 1.0	20.4 ± 0.8
ODL	34.8 ± 2.8	26.9 ± 1.7	25.3 ± 1.3	26.9 ± 0.9	28.2 ± 0.7
PVL	54.7 ± 2.1	53.8 ± 0.8	51.0 ± 0.9	50.2 ± 0.7	51.0 ± 0.4
MAXL-Y	38.4 ± 1.2				
P1L	—	10.6 ± 0.6	13.6 ± 0.8	17.6 ± 0.7	18.0 ± 0.4
HD	7.0 ± 0.9	13.6 ± 0.1	12.1 ± 0.5	12.2 ± 0.7	11.4 ± 0.7
OP1D	17.4 ± 2.3	13.1 ± 1.0	13.6 ± 0.8	14.3 ± 0.6	13.9 ± 0.6
OD1D	20.9 ± 2.7	14.8 ± 0.2	13.6 ± 0.7	14.3 ± 0.6	13.9 ± 0.4
OD2D	—	14.4 ± 0.3	14.8 ± 0.8	13.9 ± 0.4	12.2 ± 0.1
BPVD	8.1 ± 1.5	9.1 ± 0.1	13.2 ± 0.4	13.5 ± 0.2	14.5 ± 0.5
MPMD	4.7 ± 0.7	6.7 ± 0.1	5.1 ± 0.3	9.0 ± 0.2	8.6 ± 0.2
AMPMD	3.5 ± 1.5	2.9 ± 0.1	7.4 ± 0.2	6.9 ± 0.3	7.3 ± 0.2
MAX-YD	17.4 ± 2.2				

Swim bladder formed (9.4–10.1 mm); gut straight, with striations (9.8–10.1 mm).*

Morphometry
See Table 193.*

Fin Development
See Table 194.*

8.2–10.1 mm TL. Notochord flexion preceding caudal fin ray development by 9.4 mm; anal fin rays form between 9.7 and 10.4 mm; soft dorsal fin rays form 9.4–10.6 mm; pectoral fin rays form by 10.1 mm TL.*

8.4–8.6 mm TL. First rays form in caudal fin; soft dorsal fin rays and branchiostegal rays form.*

13.0 mm TL. Pelvic fin buds form anterior to dorsal fin origin.*

10.2–14.7 mm TL. Soft dorsal fin rays form between 12.2 and 12.7 mm; first pelvic fin ray form by 14.7 mm; spinous dorsal rays form 12.0–12.9 mm. Dorsal and anal finfold partially differentiated between 12.2 and 12.5 mm. Spinous dorsal fin origin situated over preanal myomere 6; soft dorsal origins over preanal myomere 22;* both finfolds completely differentiate by 14.5 mm TL.*

Pigmentation
7.2–7.6 mm TL. No dorsal pigmentation; several punctate melanophores over the otic capsule and operculum; a few scattered melanophores interopercle and base of pectoral fin girdle. Lateral pigmentation present dorsally over the stomach and gut. Ventral pigmentation consists of single mid–ventral melanophores scattered from the breast to the anal finfold, concentrated at the oil globule and anus, and staggered. Paired melanophores from the anus to the base of the anal fin, extending to base of caudal peduncle.*

8.1–10.2 mm TL. Dorsum of body without pigment, with exception of a patch of pigment at base of soft dorsal fin insertion. Several melanophores present on the operulum and at base of maxilla; laterally a single series of melanophores from gut to anus, no other melanophores laterally along the midline. Ventral pigmentation includes a series of melanophores midventrally concentrated near

Table 194

Meristic counts and size (mm TL) at the apparent onset of development for *P. maculata*.*

Attribute/event	*P. maculata*	Literature
Branchiostegal Rays	6,6	6,6[2–5]
Dorsal Fin Spines/Rays	XIII–XV/12–13	XII–XVII/10–15[2–5]
First spines formed	12.0–12.9	
Adult complement formed	17.0–17.6	
First soft rays formed	9.4–10.6	
Adult complement formed	12.2–12.7	
Pectoral Fin Rays	13–14	11–16[2–5]
First rays formed	10.1	
Adult complement formed	17.0–17.6	
Pelvic Fin Spines/Rays	I/5	I/5[2–5]
First rays formed	10.2	
Adult complement formed	17.1	
Anal Fin Spines/Rays	II/8–9	II/7–13[2–5]
First rays formed	9.7–10.4	
Adult complement formed	17.0–17.6	
Caudal Fin Rays	vii–xi, 7–9 + 7–8, viii–xi	14–17[4]
First rays formed	9.4	
Adult complement formed	17.0–17.6	
Lateral Line Scales	60–71	53–81[2–5]
Myomeres/Vertebrae	42–43/38–42	Unknown/40–44[2,3,5]
Preanal myomeres	20–22	
Postanal myomeres	20–21	

the isthmus and from the breast to the anus; several radiating melanophores outline the first eight postanal myosepta over the area of the future anal fin; two clusters of midventral postanal melanophores beginning at base of anal fin anlagen and rays along postanal myomeres forming a single, stellate melanophores at each midventral postanal myosepta.*

10.4–13.0 mm TL. Several melanophores form a cluster at base of soft dorsal fin insertion, forming dorsal saddles from the spinous dorsal fin origin to midsoft dorsal fin. Lateral melanophores form over the operculum; laterally form over the anus and extending ventrally from the breast to the gut; extending posteriorly from the anus to the caudal peduncle. Ventral pigmentation consists of a single series of melanophores vertically at the base of the caudal peduncle, forming a line of melanophores along each hypual plates.*

JUVENILES

See Figure 176

Size Range
16.9 mm TL* to 54 mm TL.[5,13–14]

Fins
See Table 195.*

15.5–17.6 mm. Complete adult fin ray counts in median fins; first pelvic fin ray forms by 15.5 mm; caudal fin rays with segmentation, fin is truncate; dorsal and anal finfolds completely differentiated (16.5 mm).*

Larger Juveniles: Spinous dorsal fin XII–(XIII–XV)–XVII; soft dorsal rays 10–(12–13)–15; pectoral

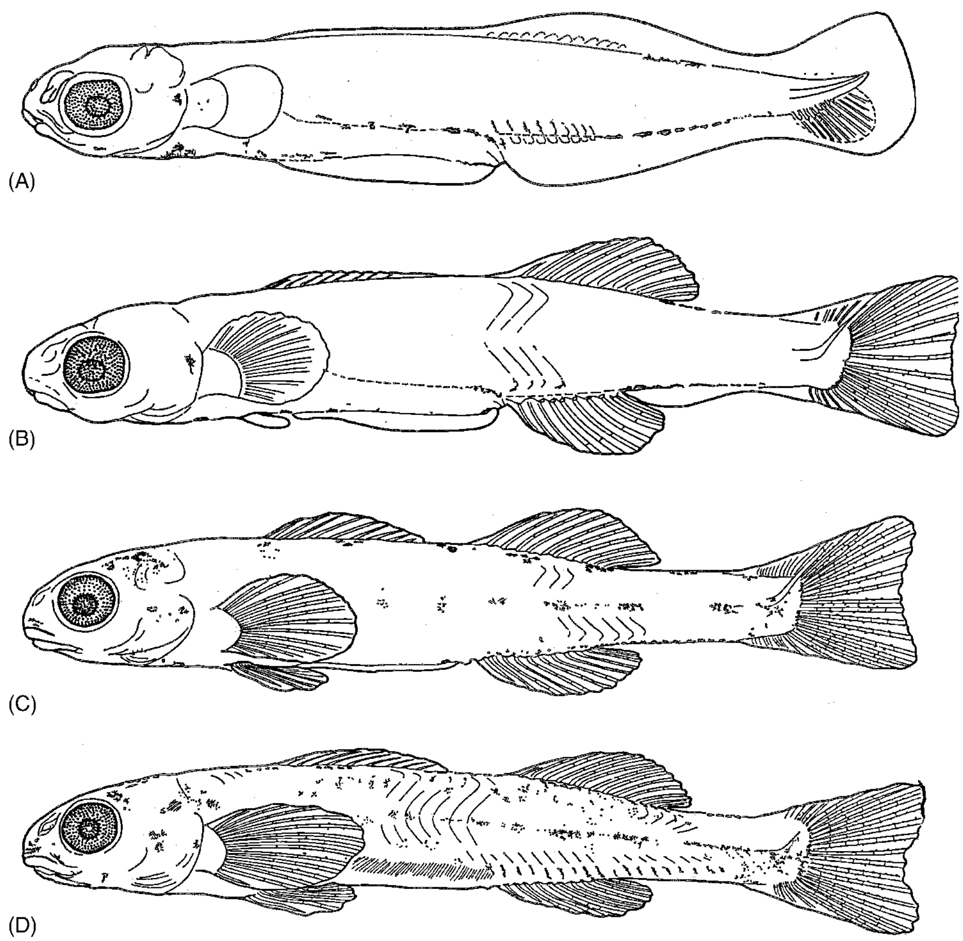

Figure 176 *Percina maculata,* blackside darter, Yellow River, IN. (A-C) post yolk-sac larvae, (A) 9.4 mm TL, (B) 13.0 mm TL, (C) 15.5 mm TL; (D) early juvenile, 16.5 mm TL. (Original drawings.)

rays 11–(13–14)–16; anal fin spines/rays II/ 7–(8–9)–13; pelvic fin spines/rays I 5; caudal fin rays 14–17.[1–5]

Morphology

17.2–18.0 mm TL. Lateral line forms; squamation intiated at 17.7 mm.*

19.8–21.1 mm TL. Squamation complete; cheek with at least a few scales posterior to the eye; nape, opercles, and belly variable with either complete scalation or naked; breast and prepectoral area naked; total vertebrae count 40–44, including one urostylar element. Gill membranes narrowly either barely connected or separate, frenum present.[2–4]

Morphometry (*See Table 193.*)

18.0–22.9 mm TL. Average predorsal length 27.7% TL.

Pigmentation

15.5–16.0 mm. Cranium with melanophores concentrated over cerebellum, forming six dorsal saddles along dorsal midline. Preorbital and postorbital bars form; a few malnophores form eight mid-lateral blotches. Ventrally a cluster of melanophores on breast, just anterior to anus, and form a mid-ventral stripe from the anal fin insertion to the caudal peduncle base. Subdermal melanophores form over anal fin. Hypural plate outlined.*

16.5–23.6 mm TL. Postorbital bar begin to form teardrop (16.5 mm). Radiating melanophores form over anal fin and continue to caudal peduncle. Melanophores form blotches along midlateral. Outline of cerebellum and optic lobe covered with melanophores; seven dorsal saddles become apparent, on nape, anterior spinous dorsal fin origin, mid-spinous dorsal fin, anterior spinous dorsal fin insertion, immediately posterior to soft dorsal fin origin, soft dorsal fin insertion, and over the caudal peduncle. Lateral pigmentation includes the beginning of the weak preorbital bar formation; pigment in the hypaxial portion of the operculum; and beginning of 8–9 elliptical mid-lateral clusters of melanophores. Ventral pigmentation forms a series of melanophores between the anal fins, extending to caudal peduncle; two clusters of postanal pigmentation at mid-anal fin and at the mid-caudal peduncle. Scattered melanophores outline the caudal fin rays; a single stripe on the spinous dorsal and anal fins; and a few melanophores in the epaxial portion of the pectoral fin.*

25.1–35.5 mm TL. Preorbital, postorbital, and suborbital bar present; cerebellum and optic lobe pigmentation dense; 6 to 11 dorsal saddles from the nape to the caudal peduncle. Six to eight longitudinal blotches along mid-lateral, with a black caudal spot present. Spinous dorsal fin membranes with black pigment on proximal half, becoming less intense posteriad; soft dorsal fin and caudal fins with 4–5 stripes forming; pectoral, pelvic, and anal fins lightly pigmented.*

TAXONOMIC DIAGNOSIS OF YOUNG BLACKSIDE DARTER

Similar species: members of subgenus *Alvodius*[3] and *Hadropterus.*

Adult. *Percina maculata* is similar to *P. sciera.* The two species differ in the absence of the suborbital bar in *P. sciera* and the presence of three basicaudal spots. The dorsal vemiculations are continuous in *P. maeulata* and distinct and isolated in *P. sciera.** *Percina maculata* differs from *P. macrocephala* in possessing completely scaled cheeks and a strong suborbital bar, which are not present in *P. macrocephala.*[4]

Larva. The early life history of *P. maculata* is similar to *P. sciera* and *P. macocephala*. The three species can be differentiated by their pigmentation and differences in myomere counts. *Percina maculata* possesses higher preanal (20–22) and higher postanal myomeres (20–21) than *Percina sciera,* which possesses 18 preanal and 22–24 postanal myomeres. *Percina macrocephala* possesses 21 preanal and 22–28 postanal myomeres.* Thus, preanal myomere number will separate *P. maculata* from *P. sciera*, and postanal myomeres are diagnostic between *P. maculata* and *P. macrocephala*.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 177)

Eggs. Percina maculata use pools and raceways to spawn where it lays eggs in coarse sand or fine

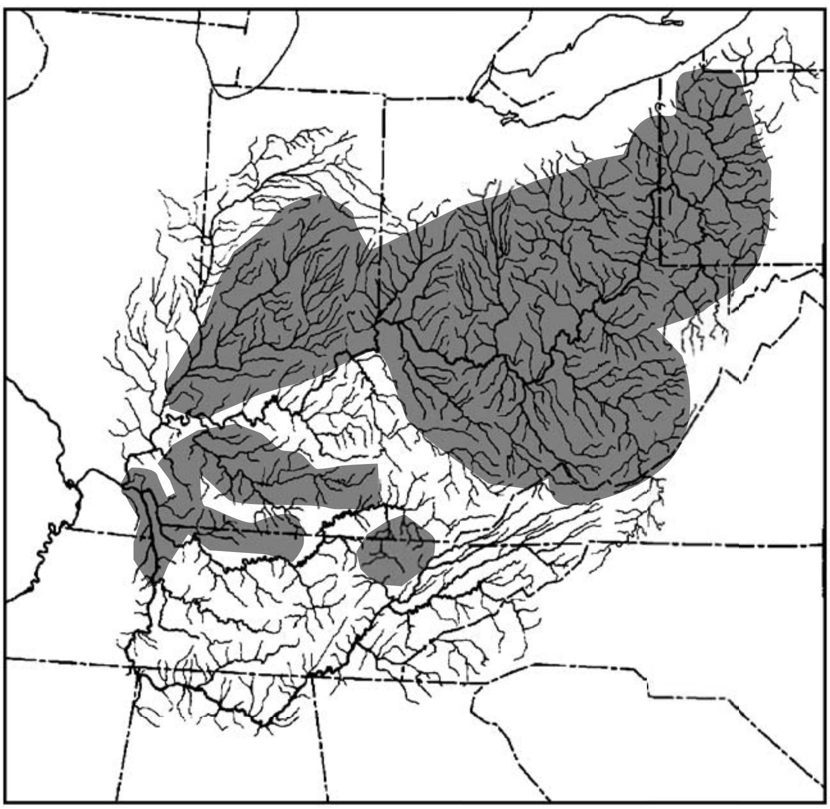

Figure 177 Distribution of blackside darter, *Percina maculata* from the Ohio River system (shaded area).

gravel in shallow water at depths greater than 0.3 m,[13,14] or spawns over sand and gravel in shallow water (0.3 m) and of moderate current.[15]

Yolk-sac larvae. Yolk-sac larvae are pelagic immediately after hatching for the first 3 weeks and then become benthic.* The vitelline vein plexus on the ventral yolk sac is consistent with other *Percina* burier species.[16]

Post yolk-sac larvae. Larvae are benthic and stay in close association with the substrate. The late development of fin rays in the paired and median fins enables the species to inhabit the drift and maximize the slower flowing margins of natal habitats along the edges of riffles or flowing pools in spring habitats.*

Juveniles. Early juveniles utilize the downstream pools and run and riffle margins of areas adjacent to spawning areas as nursery habitats.*

Early Growth (Table 195)
Apparently individuals do not exceed 4 years of age.[4] During their first year of life young darters attained 48 to 62 mm TL in WI.[5] Blackside darters from Yellow River, Marshall County, IN, attained 38–42 mm TL during their first year of life*. A regression equation shows that the length–weight relationship for southern WI is $W = -13.0513 + 3.3825 \log TL$ when W is the weight in g;[5] MN is $\log W = -5.973 + 3.468\ TL$;[20] central IA was $TL = 17.06 + 0.92788R$, where R is the MN anterior scale radius.[18] Young darters in central WI are to 29–47 mm TL in July and 34–60 mm in September .[5] Average growth of age 0 juveniles during their first 4 months is 38.9, 42.8, 51.1 and 60.8 mm[20].

Feeding Habits
The main components of the juvenile diet in IL include microcrustaceans, with a rapid change to insect larvae. In central WI, mostly mayfly larvae were consumed, lesser quantities of dipteran larvae, and small incidental amounts of plant material are consumed.[5] In IL, young darters ate midges (92.9% occurrence), Baetid mayfy nymphs (78.6% occurrence), and Hydopsychidae (64.3% occurrence).[7,19] Blackside darter have large mouths that are positioned terminally and directed anteriorly when opened. The premaxilla is not protrusible.[16]

Table 195

Average calculated lengths (mm TL) of young blackside darters from several locations.

State	Age			
	1	2	3	4
Wisconsin (mean)[5]	58.5	70.9	78.54	94.0
Minnesota[20]	59.9	73		
Iowa (mean)[18]	34.7	49.6	67.3	76.0
Illinois (Kaskaskia River)[7]	50.9	63.3	69.4	78.7
Indiana (Yellow River)*	37–42	50–54	62–65	70–74
Tennessee[4]	40	65	75	80+

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Material Examined: IN: Marshall County: Yellow River, Olive Street bridge (LRRC uncatalogued)(44).

* Original fecundity data for blackside darter from the Yellow River (Kankakee River drainage), Marshall County, IN, Terre Noir Creek, Clark Co., AR, Little Corney Creek, Union Parish, LA, Brusky Fork, Nevada Co., AR, Meridian Creek, Union Parish, LA. Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe, LA. Early life history developmental series cultured from laboratory spawned specimens from Yellow River, Kankakee River, Marshall County, IN. Specimens curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

SHARPNOSE DARTER

Percina (*Swainia*) *oxyrhynchus* (Hubbs and Raney)

Percina: a small perch; *oxyrhynchus*: sharp-nosed.

RANGE

Percina oxyrhyncha occurs along the southern tributaries of the Ohio River from the Monongahela River, PA; southwest including the Kanawha, New, and Guyandot Rivers, WV; Big Sandy, Licking, Kentucky, and Green Rivers, KY.[1–4]

HABITAT AND MOVEMENT

Percina oxyrhyncha inhabits large creeks to large river with moderate to fast current.[3] Substrates reported to be primarily gravel or rubble, often near boulders.[1–3] In WV the species has been collected from deep, fast flowing riffles or runs.[5,7] Occurs in moderate-gradient streams and rivers in VA.[4,6,7] Reported to prefer fast velocities[9] and coarse substrates clear of debris and silt, however reported to occur over silty substrates in the Russell Fork of the Big Sandy River system;[6] collected among boulders in swift water 0.45–0.65 m deep.[7] Found in cool and warm streams and frequently occurred in a heated discharge of 35ºC.[8]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Sporadic and uncommon in the Kentucky River from the Red River upstream. Occasional and common in the main channels of the Licking and Big Sandy Rivers, KY.[9,10] Occur in the New and Big Sandy Rivers of VA.[6] Widely distributed in WV, the lower Kanawha and New Rivers supporting the largest populations.[5] Extirpated from its only reported site in PA probably in the early 1900s when acid water from coal mining decimated almost the entire fish fauna of the main channel of the Monongehela River.[11]

SPAWNING

Location

Over gravel and cobble substrates in moderate current in shallow riffles.*

Season

Spawning occurs during late April to early June,[4,5] spawn in spring in PA;[11] reproductive season heightened in May, however, from April to early June; late April to late June in VA.[6]

Temperature

15–18°C in VA.*

Fecundity

Females ranging between 69 and 80 mm TL had 476–557 oocyctes from the Monongahela River drainage, WV* (Table 196).

Sexual Maturity

Unknown. Mature males have a short, flattened, and longitudinally grooved genital papilla. Females have a broad and flattened genital papilla or short nearly round tube.[2,3]

Spawning Act

Similar to *P. phoxocephala* in that either a single male mates with a single female remaining in close contact, while the female partially buries in gravel. Reproductive guild is the nonguarding, open substrate spawning lithophil guild.* Breeding males are overall dusky while females are pigmented same as the nonbreeding females.

EGGS

Description

Spherical, demersal, nonadhesive; average 1.2 mm in diameter; yolk pale yellow to amber, a single oil globule, narrow perivitelline space, and a smooth chorion.* Ripe oocytes were large and orange, while mature oocytes were light orange to orange. *

Incubation

Unknown.

Development

Unknown.

Table 196

Fecundity data for sharphead darter from Shaver's Fork (Monongahela River), Ranolph County, WV.*

			Number of Ova			
Date	TL (mm)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
April 21	69	77.2	281	120	75	1.0
	80	221	349	62	146	1.25

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Larger juveniles. Spinous dorsal XIII–XIV; soft dorsal 11–14; pectoral rays 13–15; anal rays II 8–9; pelvic rays I 5.[2,3] Caudal fin emarginate (notched) to slightly forked.

Morphology
Lateral scales 66–82; complete; body almost completely scaled. Branchiostegal membranes moderately or broadly united, rays 6, 6. The cheek, nape, prepectoral, belly, and opercle are fully scaled, breast naked or possibly half scaled.[2–6] Modified mid-ventral scales present in both sexes.[9] Vertebrae 40–43.[2,3]

Morphometry
Unknown.

Pigmentation
Larger juveniles. Preorbital bar usually wraps around maxillary; postorbital bar is narrow on cheek; broadening on opercle. Suborbital bar is weakly developed. The chin, throat, and breast are pale. Dorsum possesses 16 narrow bands, which may be interrupted at the midline and may connect to diagonal markings on upper side to form a reticulated pattern. Eleven to 14 lateral blotches vary from vertically elongated to almost square on the caudal peduncle; elongate blotches are connected by a dull mid-lateral band; upper side appears finely cross-hatched, while lower side and belly are pale. Humeral bar is long and very distinct.[2,3,6]

TAXONOMIC DIAGNOSIS OF YOUNG SHARPNOSE DARTERS

Similar species: unknown.

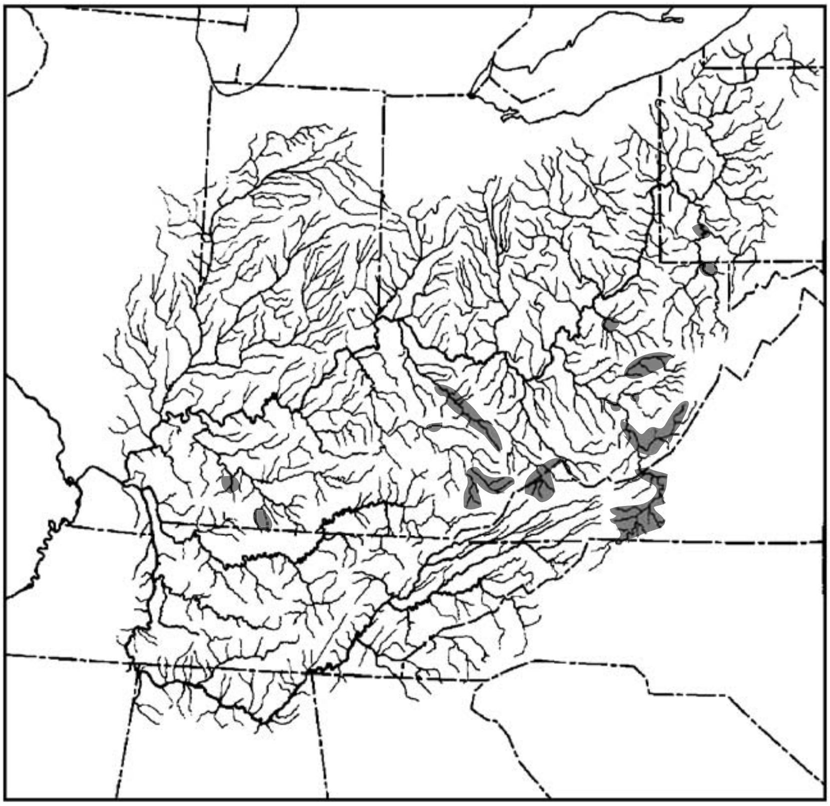

Figure 178 General distribution of sharpnose darter *P. oxyrhyncha* in the Ohio River system (shaded areas).

No descriptive information is available for young sharpnose darter.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 178)
Eggs. Deposited in gravel and cobble substrates as *P. phoxocephala*. No parental guarding is provided. Embryos develop in the darkness of interstitial spaces of cobble and coarse gravel.*

Yolk-sac larvae. Unknown.

Post yolk-sac larvae. Unknown.

Juveniles. Occurs in shallows of moderate to large creeks and rivers, usually over substrates of sand and gravel in slow current.[1,6]

Early Growth
Unknown.

Feeding Habits
Juveniles and young adults feed on the immature stages of aquatic insects.[11] VA specimens feed mostly on mayflies and caddisfly larvae; midge and blackfly larvae are also consumed.[6,12]

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* Original fecundity information from specimens collected from Shaver's Fork (Monongahela River), Ranolph County, WV and curated at Northeast Louisiana University, Museum of Zoology, Monroe, LA.

SLENDERHEAD DARTER

Percina (*Swainia*) *phoxocephala* (Nelson)

Percina: a small perch; *phoxocephala*: tapering head.

RANGE

Percina phoxocephala is widespread in the upper and middle portions of the Mississippi River drainage from MN south through the Tennessee River and Red River, OK, and TX. Several records from the Great Lakes drainage of Lake Michigan include locations (Lake Winnebago) in the Fox River system. A questionable record exists from the Yazoo River system of northwest MS.[1–5]

HABITAT AND MOVEMENT

Percina phoxocephala occurs in moderate to large streams (>8 m wide to the largest rivers) with moderate to swift runs,[1–7,11,20] and occasionally in small-stream riffles, large-rocky riffles, and even sand pools of large rivers.[6] It is collected in clear water, but more frequently it appears in slightly turbid to turbid waters.[5] It occurs at depths more than 0.6 m, although in smaller streams it has been taken from shallow riffles 0.1–0.25 m deep.[5] Substrates include gravel, sand, and rubble.[5] In streams, males moved in mass into the spawning territory but did not exert any territoriality, while females remained in deeper water until ready to spawn.[6] *Percina maculata* shows longitudinal movement from riffles and gravel runs into deeper pools, although the actual winter habitat has not been determined.[6]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Percina phoxocephala is found in the Duck River (Tennessee River drainage), and the Stones, Harpeth, and Red rivers of the Cumberland drainage. It is sporadically collected from the main channel of the Tennessee and Cumberland Rivers, TN.[4] It is found in the Bear and Yellow Creek systems, MS and AL,[9,10] and in the lower Cumberland east to the lower Kentucky River (Eagle Creek) in KY[8] The species occurs throughout tributaries of the Wabash River drainage, IL and IN,[12,13] and in the Scioto, Greater Miami, and lower Muskingum Rivers in southern OH.[1–3,8,*]

SPAWNING

Location

Percina phoxocephala occurs in swift riffles over coarse gravel and rubble, at depths of 0.15–0.60 m.[6,7]

Season

Spawning season occurs from April to June with the peak spawning period being in May and June. [5–7,14,16]

Temperature

Spawning occurs at temperature of 21.1°C[15] spawning occurs in the laboratory at 18–22°C.[14]

Fecundity (Table 197)

Adult females collected from IL in mid-August from the Kaskaskia River had ovaries that were 6% of the body weight,[7] while females from the Embarras River had ovaries that represented 12.0–20.1% body weight between April and early June.[6] Egg production increases with age and size of individuals. Six females from central IA held between 186 and 365 ova with an average of 288 ova;[17] while MN populations had 22 mature ova. [21] Females from WI, collected in June, had ovaries that were 6–11% of the body weight.[5] An age 2 female collected in June from WI held 407 mature ova.[5] Females from IL held 500–2000 mature eggs prior to spawning, of which 50–1000 ova were laid during the spawning period.[6] Female *P. phoxocephala* from the Duck River did not show statistically significant increasing fecundity based on mature ova (ANOVA, $F = 4.485$, $p = 0.059$) with increasing length, but were significant for total ova (ANOVA, $F = 30.439$, $p = 0.001$). Females between 52 and 76 mm collected from early April to early May had 71–289 large mature ova (Table 175).* Ovary weights from TN averaged 9.6% of the total body weight.*

Sexual Maturity

Adults live to reach age 4,[7,18] maturity is attained at age 1 with all specimens greater than 42 mm capable of spawning.[5,6] Adult males from WI had testes that were 1.2% of the body weight in May.[5] Nuptial male tuberculation is weakly developed with weak tuberculate ridges on anal spines, distal half of anal

Table 197

Fecundity data for slenderhead darters from the Duck River (Tennessee River drainage), Maury and Marshall Counties, TN.*

		Number of Ova			
TL (mm)	Ovary Weights (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
52	87.2	478	134	71	1.11
53	23.5	636	99	0	0.77
54	147	521	211	128	1.11
56	93.2	591	288	0	0.77
63	120	815	255	1	1.25
64	273	708	285	208	1.11
64	169	1273	286	181	1.00
67	366	812	313	289	1.17
71	169	1273	286	181	1.00
76	220	923	271	172	1.11

rays, and on the pelvic spine and adjacent one or two pelvic rays.[4]

Spawning Act

The reproductive mode of *P. phoxocephala* is a burier.[14] Males occupy spawning riffles in areas with moderate current, while females remain in deeper water until ready to spawn. No nest is established and males defend a weak territory that is around a female. Males were generally aggressive toward other males that entered within 40 cm of their reproductive space. Such moving territories are considered a pleisiomorphic behavioral trait.[6] During reproduction males outnumber the females 11:2 and after reproducing adults returned to deeper water. Males display intense coloration changes exhibiting black markings and a bright red-orange band in the first dorsal fin.[14] Genital papillae of females are relatively long. Females select spawning sites in open fine gravel areas and buried their bodies into the fine gravel. The female initiates the spawning by swimming into a depression in the gravel-sand or gravel so that her genital papillae is buried about 10 mm beneath the substrate surface. Once the female comes to rest, a single male clasps the female by resting his pelvic fins on her nape. The pair assume the spawning position with the male forming a serpentine position with his body so that his head is on one side and his tail on the other side of the female, which forced the female's vent into the substrate. The pair vibrate simultaneously and release as many as 8 eggs that are fertilized by the male in the gravel.[14] Eggs are buried in mixed gravel and sand behind large rocks and areas with current. The spawning act lasted about 4 s.[14] At the completion of the spawning act, the male abandons the clasping position and moves a few centimeters away.[14] Spawning is repeated within 5 min to a half an hour later. The female spawns individually with multiple males as she changes position on the spawning grounds. No guarding is provided by either parent.[14] No observations were made with a supernumery male vibrating beside the spawning pair.[14]

EGGS

Description

Ovarian examination of Duck River populations showed that ovoid latent, cream-colored ova range from 0.35 to 0.4 mm, early maturing small spherical orange to light orange colored ova range from 0.71 to 0.83 mm, and large mature orange ova range between 1.1 and 1.6 mm. Ova from the Embarras River population were divided into three categories ranging from 0.1 to 0.5, 0.6 to 1.0, and 1.1 to 1.3 mm.[6] Eggs stripped from females from the Embarras River, IL, were 1.3 mm diameter, transparent, adhesive, and contained a single oil globule.[6] Eggs from the Embarras River were spherical; averaged 1.7 mm diameter (range: 1.7–1.8 mm); transparent; demersal; non-adhesive; possessed translucent, pale yellow yolk (mean = 1.6 mm diameter; range: 1.6–1.7 mm); a single oil globule (mean = 0.26 mm); a moderate perivitelline space (mean = 0.15 mm); and a sculptured and unpigmented chorion.[*,14]

Incubation
Hatching occurs after 120–124 h at an incubation temperature of 22°C.[14]

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Populations from Embarras River, IL, hatch at 5.0,* absorb yolk by 8.2 mm TL.*

Myomeres
Predorsal 4; preanal 22 (N = 4); postanal 21 (N = 4); total 43.*

Morphology
5.0 mm TL (newly hatched). Body terete; snout blunt, with simple stomodeum and nonfunctional jaws; yolk sac elongate, moderate (33.8% TL), oval to rectangular and tapering slightly posteriorly; yolk translucent pale yellow, with a single oil globule; a simple single vitelline veins occurs mid-ventrally on yolk sac; head slightly deflected over the yolk sac; eyes oval.*

6.8–8.2 mm TL. Digestive system functions before complete yolk absorption by 6.8 mm TL,* yolk sac absorbed by 8.2 mm TL; gills functional.*

Morphometry
See Table 198.*

Fin Development
5.0 mm TL. Pectoral fin bud present.*

5.6–7.2 mm TL. Pectoral fin forms without incipient rays present.*

Pigmentation
5.0 mm TL (*newly hatched*). Eyes pigmented; no melanophores dorsally over the body. No pigment dorsally over the yolk sac; several punctate melanophores occur posterior the yolk sac over the gut. Melanophores at every postanal myosepta along the mid-ventral.[15,*]

6.8–7.2 mm. No dorsal melanophores over the entire body, melanophores continuing along every postanal myosepta.[15,*]

POST YOLK-SAC LARVAE

Size Range
8.2 mm* to unknown lengths.

Myomeres
Predorsal 4; preanal 22; postanal 21; total 43.*

Morphology
8.2 mm TL. Yolk sac absorbed.*

Morphometry
See Table 198.

Fin Development
8.2 mm TL. No incipient fin rays present.*

Pigmentation
8.2 mm TL. Melanophores at every postanal myosepta occurring from the anus to the caudal peduncle.*

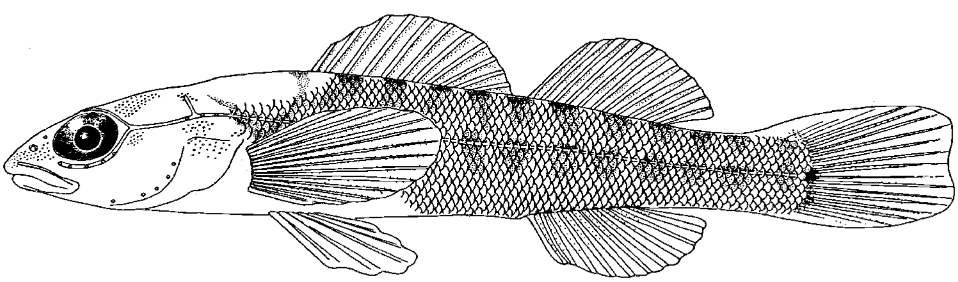

Figure 179 *Percina phoxocephala,* slenderhead darter, Embarras River, Cumberland County, IL. Juvenile, 19.0 mm, lateral view. (From reference 6, with permission.)

Table 198

Morphometric data expressed as percentage of TL for young *P. phoxocephala* from Illinois.*

	TL Groupings		
Length Range (mm)	**5.0–7.2**	**7.3–8.2**	**22.3–33**
N	3	2	(9)
	Mean ± SD	**Mean ± SD**	**Mean ± SD**
As Percent TL			
SnL	3.3 ± 1.1	4.3 ± 0.9	4.7 ± 0.8
PEL	5.6 ± 0.6	6.0 ± 0.2	7.1 ± 0.3
OP1L	15.6 ± 1.0	17.3 ± 1.0	25.3 ± 0.8
ODL	32.6 ± 1.2	27.9 ± 1.1	25.9 ± 0.5
PVL	53.4 ± 1.2	53.1 ± 0.8	52.9 ± 0.6
MAXL-Y	28.4 ± 1.2		
P1L	8.3 ± 0.4	10.6 ± 0.6	22.4 ± 0.3
HD	7.0 ± 0.9	10.3 ± 0.4	11.2 ± 0.2
OP1D	17.4 ± 2.3	13.1 ± 1.0	16.5 ± 0.5
OD1D	20.9 ± 2.7	14.8 ± 0.2	15.3 ± 0.4
OD2D	—	14.4 ± 0.3	12.9 ± 0.5
BPVD	8.3 ± 1.5	9.1 ± 0.1	12.9 ± 0.5
MPMD	4.5 ± 0.5	6.8 ± 0.1	8.8 ± 0.2
AMPMD	3.6 ± 1.5	3.3 ± 0.1	7.1 ± 0.2
MAX-YD	18.3 ± 2.1		

JUVENILES

See Figure 179

Size Range
Unknown length (smallest specimen examined was 22.4)[6] to 42 mm TL.[5,6]

Fin Development
22.4 mm TL. Complete adult fin ray counts in median fins including pelvic fin ray; caudal fin rays with segmentation, fin is truncate; dorsal and anal finfolds completely differentiated.[6]

Larger Juveniles. Spinous dorsal fin X–(XII–XIII)–XIV; soft dorsal rays 10–(12–14)–14; pectoral rays 12–(13–15)–15; anal fin spines/rays II/7–(9–10)–11; pelvic fin spines/rays I 5; and caudal fin rays 15–17.[1–5]

Morphology
22.4 mm TL. Lateral line formed. Squamation nearly complete, the only areas lacking scales are the cheeks, opercles, nape, and the anterior two-third of the belly.[6]

21–23 mm SL. Some individuals with incomplete lateral lines. Specialized midventeral squamation of males complete by 23 mm SL.[6]

27–28 mm SL. Scales lack only on the nape and most individuals had supratemporal canals.[6]

33 mm SL. Scales present on nape.[6]

Cheeks, opercle, and nape scaled; belly with naked areas anteriad, and breast with modified midventral scale, otherwise naked or possessing embedded scales posteriad or near base of pectoral fin; total vertebrae count 39–41 including one urostylar element. Gill membranes moderately connected.[2–4]

Morphometry
Head and eyes are large in relation to body size, Head length 32% SL.[6]

Pigmentation
22.4 mm TL. Pigmentation similar to adult. Specimen possesses dorsal spots; lateral blotches; a band

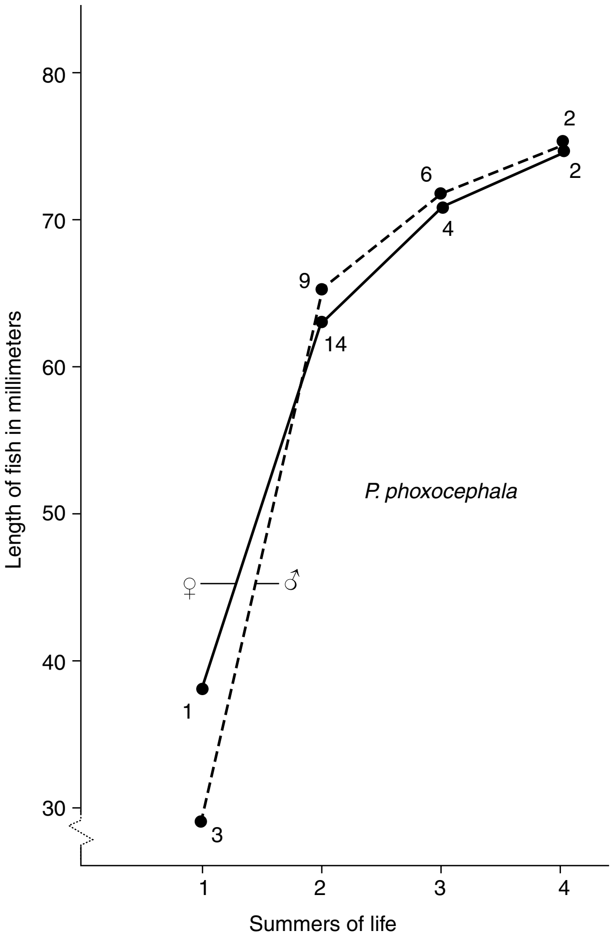

Figure 180 Growth trends for age classes of *P. phoxocephala* based on annual mean total lengths for populations from Kaskaskia River, near Sullivan, IL. (After reference 7.)

around the cranium. Yellow pigment in the spinous dorsal fin forming the orange band.[6]

25 mm SL. Orange band present in spinous dorsal fin.[6]

25.1–35.5 mm TL. Body pigmentation straw colored with brown vermiculations. Median caudal spot small but prominent. Suborbital bar lacking. About 14 lateral spots range from vague to distinct.*

TAXONOMIC DIAGNOSIS OF YOUNG SLENDERHEAD DARTER

Similar species: members of subgenus *Alvodius*.[3] and *Hadropterus.*

Adult. *Percina phoxocephala* is not similar to any other *Percina* species.[4]

Larva. The early life history stages of *P. phoxocephala* are not similar to any other *Percina*.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 181)
Eggs. Percina phoxocephala use pools and raceways to spawn, where it lays eggs in coarse sand or fine gravel in shallow water at depths greater than 0.3 m,[13,14] or spawn over sand and gravel in shallow water (0.3 m) and of moderate current.[15]

Yolk-sac larvae. Yolk-sac larvae are pelagic immediately after hatching for the first 4 weeks and then become benthic.[*,6] The vitelline vein is a simple and straight on the ventral yolk sac and is consistent with other *Percina* burier species.[16]

Post yolk-sac larvae. Larvae drift and are pelagic for most of the larval period. Once larvae settle out of the drift they become benthic and stay in close association with the substrate.* The late development of fin rays in the paired and median fins enables the species able to inhabit the drift and maximize the slower flowing margins of natal habitats along the edges of riffles or flowing pools in spring habitats.*

Juveniles. Early juveniles (19–27 mm) remain in the spawning habitat for 2–4 weeks after hatching.[6] It seems that Page and Smith[6] are referring to age 0+ individuals rather than that same years young. Larvae do not transform to juveniles in 2 to 4 weeks. These age 0+ fish were collected from shallow water (0.15–0.3 m) along a gravel bar.[6] These areas were adjacent to spawning areas used as nursery habitats.*

Early Growth (Figure 180 and Table 199)
Apparently individuals do not exceed 4 years of age.[5,6] During their first year of life, young darters attained 48 to 62 mm TL in WI.[5] Larvae reach 20 mm by 2–3 weeks of age.[6] A regression equation showed that the length–weight relationship for northern and central WI is $W = -12.3845 + 2.1667 \log TL$ (mm), when W is weight in g;[5] northeastern MN was $\log W = -6.407 + 3.766 \log TL$;[21] central IA was $W = -4.40476 + 3.19153 \log TL$ (mm), where W is weight in g.[18] Young darters in central WI were 28 mm TL in late June and 45 mm in October.[5] The average size of 12-month-old *P. phoxocephala* was 46 mm in IL. Page and Smith reported that young fish attained almost half of their

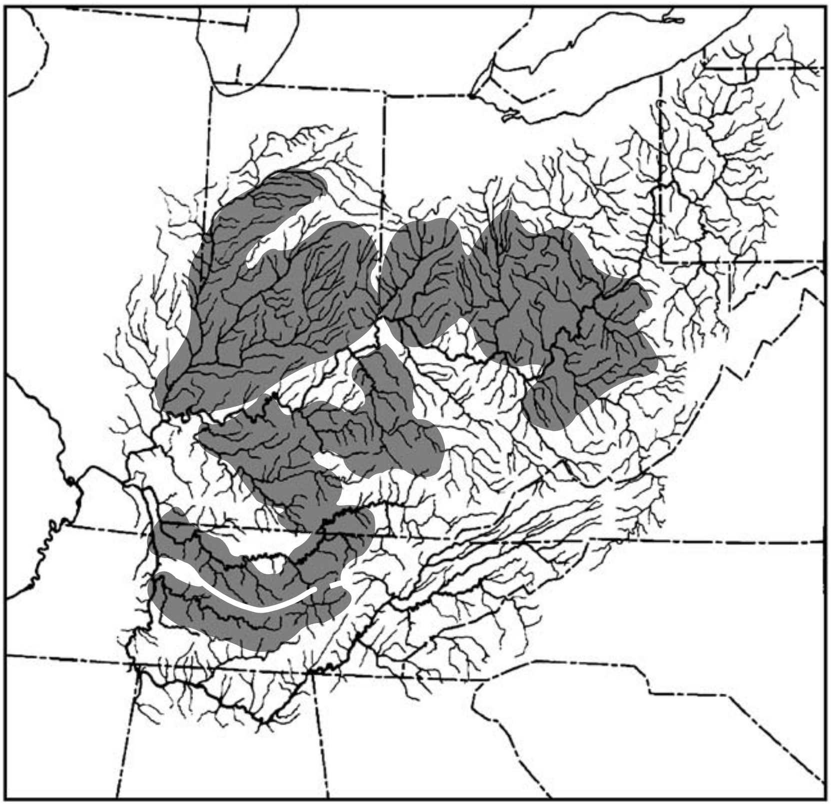

Figure 181 Distribution of slenderhead darter, *P. phoxocephala* from the Ohio River system (shaded area).

first year's growth in about 2 weeks.[6] Our observations suggest that this is an erroneous statement and that larvae attain half of the first years growth in 60 days;* while Sunrise River, MN, populations were 41.2 mm (third month of life) and 50.6 mm (fourth month of life).[21]

Feeding Habits
The main components of the diet in IL include baetid nymphs, chironomid larvae, and hydropsychid larvae, although some individuals consume stonefly naiads and elmid beetle adults; young juvenile darters feed mainly on midge larvae.[7] Adults from the Embarras River feed predominantly (99%) on midge larva and pupae, black fly larvae, caddisfly larvae, and mayfly naiads microcrustaceans.[6] Less frequently consume items including amphipods, fish eggs, and terrestrial insects, as well as, dragonfly naiads and water boatmen. Feeding occurs throughout the daytime. The heaviest feeding occurs prior to spawning (May).[6,7]

Table 199

Average calculated TL (mm) of young slenderhead darters from several locations.

State	Age			
	1	2	3	4
Wisconsin (mean)[5]	49.5	62.3	72.3	77.7
Minnesota[21]	48.6	66.6	73.2	78.9
Iowa (mean)[18]	34.1	43.3	51.9	62.9
Illinois				
(Kaskaskia River)[7]	45.3	60.6	76.7	
(Embarras River)[6]	45.7	58		
Tennessee[4]	45–50	60	68	92

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Material Examined. IL: Cumberland County: Embarras River, 0.5 miles N Greenup (LRRC uncatalogued)(14).

* Original fecundity data for slenderhead darter from the Duck River (Tennessee River drainage), Maury and Marshall Counties, TN Specimens curated at Northeast Lousiana University, Museum of Zoology, Monroe, LA. Early life history developmental series cultured from laboratory spawned specimens from Embarras River (Wabash River drainage), Cumberland County, IL. Specimens curated at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, IN.

ROANOKE DARTER

Percina (*Alvordius*) *roanoka* (Jordan and Jenkins)

Percina: a small perch; *roanoka*: referring to the species type locality, the Roanoke River.

RANGE

Percina roanoka is widespread in the James to the Neuse River drainages and the lower New River drainage, NC and WV. The populations in the James and New River drainages are probably introduced.[1–4,12]

HABITAT AND MOVEMENT

The Roanoke darter inhabits moderate gradient, generally clear creeks, streams, and rivers.[4] In montane areas, the species inhabits gravel, rubble, and boulder substrates in runs and riffles. It inhabits gentle currents and sand and gravel bottoms on the Coastal Plain, but morphologically is adapted to the fast water[10] of upland rivers, where it resides in boulder and bedrock chutes having moderate to torrential current.[3] Substrates reported to be primarily gravel or rubble, often near boulders.[1–3] Reported to prefer fast velocities or the deeper downstream portions of gravel riffles in streams of moderate gradient.[2]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Percina roanoka is most likely an introduced species in the New River drainage.[1–4] It was first found during 1963 from an area that is now beneath the center of Claytor Dam to the tailwaters of Bluestone Reservoir.[5,6] Records from 1968 to 1972 show that the species was abundant at some sites.[5,6] It was captured in 1970 from the mouth of the Greenbrier River, WV, just below Bluestone Dam.[7] It is now one of the most abundant darters in the New River from the dam to some 20 km downstream.[8,9] The species is expanding into New River tributaries.[4]

SPAWNING

Location
Spawning occurs in deep riffles on sand-gravel substrates among large rubble and small boulders.[4]

Season
Spawning occurs during late May to early June, based on sexual condition of adults.[11] Adults are observed spawning in Craig Creek, VA in late April.[4] Spawning probably starts in early April on the Coastal Plain and extends to early June in the mountains.[4]

Temperature
Spawning begins at temperatures of 12°C.[4]

Fecundity
Unknown.

Sexual Maturity
Age 1 specimens are sexually mature.[11]

Spawning Act
Percina roanoka is an egg-burier. The male mounts the female in classic burier manner and deposits eggs in deep riffles among large rubble and small boulders.[4]

EGGS

Description
Unknown.

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomers
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Larger juveniles. Spinous dorsal IX–(X–XI)–XII; soft dorsal 9–(10–11)–12; pectoral rays 12–(13–14)–15; anal rays II 7–(8–9)–10; pelvic rays I 5.[2–4] Caudal fin slightly emarginate. [4]

Morphology
Lateral scales 38–(42–50)–54, complete; cheek and breast uscaled (except for breast scute), opercle scaled or unscaled; nape usually scaled except anteriorly or medially; premaxillary frenum present; gill membranes moderately connected. Branchiostegal membranes moderately or broadly united, rays 6,6. Modified midventral scales present in males.[4] Vertebrae 42–45.[2,3]

Morphometry
Unknown.

Pigmentation
Larger juveniles. Body color usually with dorsal markings that are usually brown or olive brown; dorsolateral stripe tan or orange. [2–4] Laterally 8-14 dark, vertically elongate or oval blotches that often extend to venter, particularly on anterior two-thirds of body. Blotches elongate or oval in juveniles, moderately interconnected mid-laterally by smaller dark areas. Dorsolateral area pale to dusky, sometimes with small flecks, sometimes with a pale stripe above blotches. Dorsum with 6–9 generally square dark saddles occasionally interconnected by short lines; predorsal saddles sometimes connected to dorsal fin. Belly pale, uniformly dusky, or with blotches. Breast and underside of head pale, dusky, or dark. Preorbital bar extends onto upper lip, suborbital bar present, usually somewhat diffuse; postorbital bar often divided by pale streak; supraocular marks present. Prepectoral area mostly dusky or with a dark blotch. Median and paired fins dusky. [4]

TAXONOMIC DIAGNOSIS OF YOUNG ROANOKE DARTER

Similar species: unknown.

No early life history information is available for young roanoke darter.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 182)
Eggs. Deposited in gravel riffles and runs among large cobble and boulders.[4]

Yolk-sac larvae. Unknown.

Post yolk-sac larvae. Unknown.

Juveniles. Juveniles are most often collected from pools, slow runs, and riffle margins.[4]

Early Growth
Maximum life span is 3 years. [4]

Feeding Habits
Juveniles and young adults feed primarily on mayfly, blackfly, and midge larvae.[4]

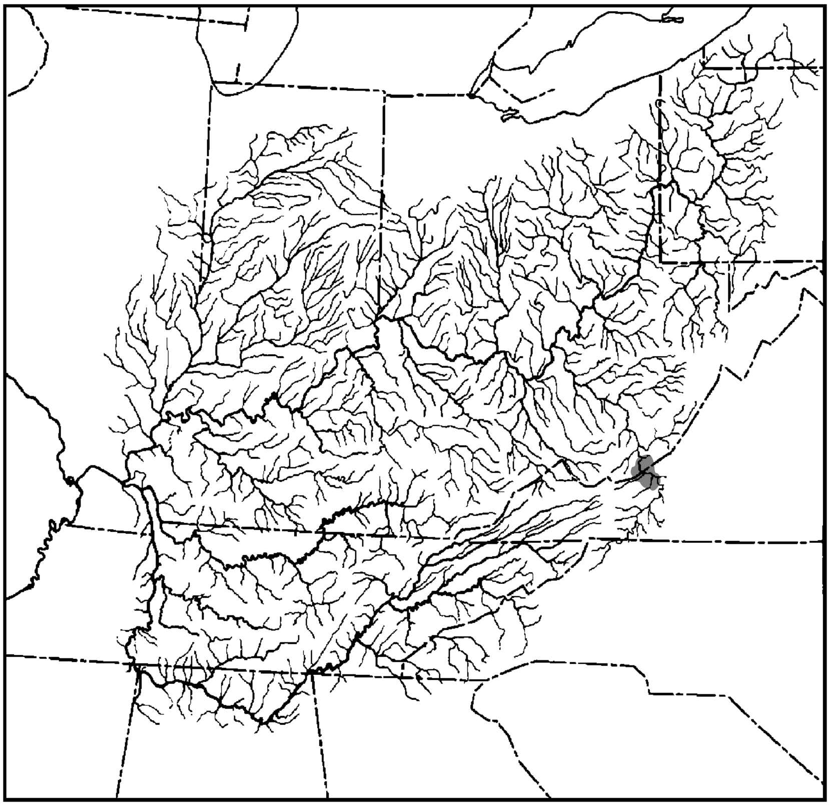

Figure 182 General distribution of Roanoke darter in the Ohio River system (shaded areas).

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OLIVE DARTER

Percina (*Swainia*) *squamata* (Gilbert and Swain)

Percina: a small perch; *squamata*: scaly.

RANGE

Percina squamata is confined to the headwaters of the upper Tennessee River and Cumberland River drainages below the Falls, primarily in the Rockcastle River, KY, and Big South Fork, TN. Within the Tennessee River drainage, it has been collected from the French Broad, Watauga, Nolichucky, Hiwassee, and Emory Rivers in TN, NC, and GA.[1–3]

HABITAT AND MOVEMENT

The olive darter inhabits higher gradient upland rivers where it resides in boulder and bedrock chutes having moderate to torrential current.[3] Substrates reported to be primarily gravel or rubble, often near boulders.[1–3] Reported to prefer fast velocities or the deeper downstream portions of gravel riffles in streams of moderate gradient.[2]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Percina squamata is most likely a relict species that formerly possessed a much larger distribution. Often it is very abundant and successful in localized situations. Cumberland drainage records are available from the Rockcastle River, Kentucky, and the Big South Fork River, TN. Currently, it exists from the Holston River system (Watauga River) downstream through the Hiwassee River system. The species range has probably been reduced considerably by storage reservoirs, especially in the Tennessee River.[4] Sporadic and uncommon in the Rockcastle River and Big South Fork, KY, in the middle Cumberland River drainage (below the Falls).[5]

SPAWNING

Location
Unknown.

Season
Spawning occurs during mid-May through mid- or late July, based on the sexual condition of adults and seasonal occurrence of very small young-of-the year specimens.[4,6]

Temperature
Unknown.

Fecundity
Unknown.

Sexual Maturity
Unknown.

Spawning Act
Unknown.

EGGS

Description
Unknown.

Incubation
Unknown.

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown.

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fins
Larger juveniles: Spinous dorsal XII–XV; soft dorsal 11–14; pectoral rays 12–15; anal rays II 7–9; pelvic rays I 5.[2–4,6] Caudal fin truncate to slightly emarginate.

Morphology
Lateral scales 71–86, complete; body almost completely scaled. Premaxillary frenum present; gill membranes moderately connected. Branchiostegal membranes moderately or broadly united, rays 6, 6. The cheek, nape, opercle, and prepectoral area, breast, and belly are fully scaled.[2–4,6] Modified midventral scales present in males.[4] Vertebrae 42–45.[2,3]

Morphometry
Unknown.

Pigmentation
Larger juveniles. Body color is usually olive brown with brown vermiculations on the upper side and dorsum. Dorsum possesses 13–15 small dark crossbars and on the side is a mid lateral row of 10–12 dark oblong and often confluent blotches followed by a black round basicaudal spot. The ventral is white or yellow. The first dorsal fin has a dusky green base, an orange submarginal band, and a dusky margin. The second dorsal, pectoral, and

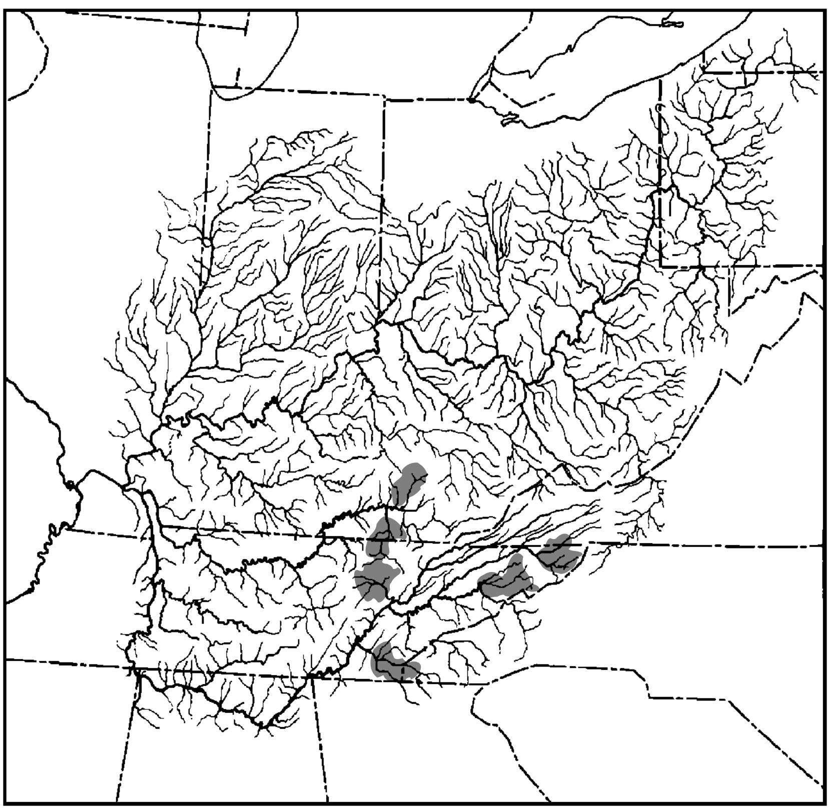

Figure 183 General distribution of olive darter *P. squamata* in the Ohio River system (shaded areas).

caudal fins are banded with light brown. All other median and paired fins are clear. A distinct preorbital bar extends around the snout nearly joining the bar from the other side. Preorbital bar usually wraps aound maxillary, postorbital bar is narrow on cheek, broadening on opercle.[2,4]

TAXONOMIC DIAGNOSIS OF YOUNG OLIVE DARTER

Similar species: unknown.

No identification information is available for young olive darters.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 183)
Eggs. Unknown.

Yolk-sac larvae. Unknown.

Post yolk-sac larvae. Unknown.

Juveniles. Occur in a moderate-sized creeks; only one juvenile captured outside a principal river. [2–4]

Early Growth
Young-of-the-year from the Big South Fork, TN, are 46–49 mm TL in July; age 0 specimens attain lengths of 50 mm during the first summer; age 1 specimens average 80 mm TL, age 2 specimens 100 mm TL, and age 3 specimens were 115 mm TL.[4]

Feeding Habits
Juveniles and young adults feed on the immature stages of aquatic insects.[1–3] Big South Fork, TN, specimens feed mostly on hydropsychid caddisfly larvae and heptageniid mayfly nymphs. [4]

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DUSKY DARTER

Percina (Hadropterus) sciera (Swain)

Percina: a small perch; *sciera*: dusky.

RANGE

Percina sciera is widespread and found in the Elk River, WV, Tennessee River drainage, TN and KY, and the Black Warrior-Tombigbee drainage, AL, south to the Gulf Coast and west through MS and LA to central TX, southeastern OK, and southeastern MO. Its range extends north to eastern IL, and throughout most of IN and into the Scioto River drainage in south-central OH.[1–11]

HABITAT AND MOVEMENT

Percina sciera inhabits large streams and rivers usually along the main channel borders with moderate current and is associated with woody debris, undercut banks, and vegetation.[1–11,17] It is moderately a pelagic species depending on environment occupied and age group. It is almost always associated with gravel substrates, rapid or moderately rapid current velocities, and a minimum depth of 0.3 m, and never found in quiet pools or shallow water;[10] prefers rooted plants,[8] and woody debris and root mats.[2–7] Seasonal migrations occur with winter movement out of the river channel and spring immigration into them, followed by fall emigrations from tributaries.[10]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Percina sciera is restricted to the Ohio River drainage in northern portions of its range in IL, IN, and OH.[8–11] It is found in the Bear Creek system, MS,[5] and in many tributaries of the Tennessee River, AL.[6] The species is widespread in TN and can be found in more sluggish tributaries to the Tennessee River, yet only two specimens have been collected from the Cumberland River.[4] It is confined to the Clinch and Powell Rivers and lower Copper Creek, VA.[7]

SPAWNING

Location
Percina sciera uses sand and gravel bars to spawn where it lays eggs in fine gravel in water at depths greater than 0.3 m;[10,18] or over gravel riffles at depths from 0.15 to 0.6 m.[13]

Season
Spawning season occurs from May to early July.[2,3,7,10,13]

Temperature
Spawning occurs at temperatures of 23°C, with ranges between 22 and 25°C.[13]

Fecundity (Table 200)
The number of eggs produced correlates inversely with intraspecific population density and interspecific density of *P. caprodes.*[16] Adult females (73–76 mm TL) collected in early June from the San Marcos River, TX, had ovaries that held 443–656 enlarged ova.[13] A 76 mm female had two size classes of eggs ranging from 0.5 to 1.5 mm diameter.[13] A comparison of two populations from San Marcos and Austin, TX, showed that females between 51 and 67 mm held about 20–160 mature ova from the Austin population, while females 50–69 mm held about 35–140 mature ova.[16] The ovaries of the dusky darter gradually increase in size from 17% of SL in September, 21% of SL in March, 27% SL in April, 35% SL in May, and 34% SL in June.[10] A relationship exists between the size of the female and the number of eggs produced, with larger females producing more eggs.[10] Mature ova are concentrated near the center of the ovary. [10] Female *P. sciera* from the Buffalo River, TN, shows statistically significant increasing fecundity (ANOVA, F = 125.471, p>0.0001) with increasing length (Table 201). Females between 53 and 101 mm collected between early April and early May have 23–661 large mature ova (Table 200).* Ovary weights average 9.1% of the total body weight.*

Sexual Maturity
Adults live to reach age 4,[7,18] maturity is suspected to be at age 1[10] at lengths of 55 mm SL for males and

Table 200

Fecundity data for dusky darter from the Buffalo River (Duck River Drainage), Marshall and Lewis Counties, TN.*

		Number of Ova			
TL (mm)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
53	27.3	312	61	0	—
56	30.1	343	77	0	—
57	89.8	426	144	0	—
57	130	480	115	23	1.17
58	130	463	128	70	1.17
58	51.8	459	110	0	—
75	168	508	217	164	1.11
82	364	972	368	249	1.17
84	509	1249	516	338	1.25
101	750	1154	851	661	1.18

Table 201

Morphometric data expressed as percentage of TL for young *P. sciera* from Illinois.*

	TL Groupings			
Length Range (mm)	5.7–7.6	8.0–8.75	16.0–24.4	25.7–35.3
N	4	3	8	4
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
As Percent TL				
SnL	3.0 ± 0.2	3.7 ± 0.9	4.2 ± 0.6	4.9 ± 0.3
PEL	6.1 ± 0.6	6.2 ± 0.5	6.3 ± 0.6	4.9 ± 0.4
OP1L	15.9 ± 0.5	16.0 ± 0.9	24.0 ± 0.8	23.2 ± 0.4
ODL	27.4 ± 0.8	32.1 ± 1.5	31.3 ± 1.6	30.5 ± 0.7
PVL	53.0 ± 1.0	54.3 ± 0.8	53.1 ± 0.9	54.8 ± 0.5
MAXL-Y	33.3 ± 1.1			
P1L	—	6.7 ± 1.6	17.7 ± 0.6	15.9 ± 0.4
HD	12.6 ± 0.6	13.6 ± 0.5	12.0 ± 0.7	11.0 ± 0.6
OP1D	19.7 ± 1.4	13.6 ± 0.3	13.5 ± 0.4	13.4 ± 0.7
OD1D	21.9 ± 2.2	11.1 ± 0.4	12.5 ± 0.6	13.4 ± 0.6
OD2D	—	7.7 ± 0.3	10.4 ± 0.6	12.2 ± 0.3
BPVD	9.1 ± 1.2	7.5 ± 0.2	12.5 ± 0.5	12.5 ± 0.2
MPMD	6.8 ± 0.3	5.6 ± 0.2	6.8 ± 0.3	7.9 ± 0.2
AMPMD	3.8 ± 0.4	2.5 ± 0.1	8.3 ± 0.2	7.3 ± 0.1
MAX-YD	15.5 ± 2.0			

40 mm SL for females.[10] Males show pronounced breeding coloration as early as late April,[10] and increasing size of testes from September until June, with a drastic reduction in July.[10] Although adult males are reported not to have tuberculation,[10,19] a thickening on the middle portion of the anal fin rays

of males occurs and less prominently on the anal fin spines and pelvic fin spine and adjacent rays.[4]

Spawning Act
The reproductive mode of *P. sciera* is a burier.[10,13,*] Males occupy spawning riffles in shallow areas (0.15–0.6 m) with moderate current, while females remain in deeper water until ready to spawn. No nest is established and males defend a weak territory around a female. Males are generally aggressive toward other males and establish moving territories. Males do not court females, rather once a male recognizes a female he follows her. Males display intense color changes by becoming intensely black. Females select spawning sites in open fine gravel areas and bury their bodies into the fine gravel. The female initiates the spawning by swimming to a depression in the sand or gravel. Once the female comes to rest, a single male clasps the female by resting his pelvic fins on her nape and stimulating her with the tuberculate anal and pelvic fins. The pair assume the classic spawning position with the male forming a serpentine position with his body that forces the female's vent into the substrate. The pair vibrates simultaneously and release an undetermined number of eggs that are fertilized by the male into the gravel. At the completion of the spawning act, the male abandons the clasping position and moves a few centimeters away. Spawning is repeated and the male and female spawn individually with multiple partners as females change position on the spawning grounds. No guarding is provided by either parents.*

EGGS

Description
Ovarian examination of Duck River, TN, specimens showed that ovoid latent ova ranged from 0.38 to 0.42 mm, early maturing small spherical cream-colored ova range from 0.80 to 0.86 mm, and large mature ova range between 1.11 and 1.25 mm.* Ova diameters from Embarras River females were white and ranged from 0.1 to 0.5 mm, the intermediate yellow ova were 0.6–1.0 mm, and the largest orange ova were 1.1–1.5 mm.[10] Egg diameters from the Embarras River, IL, were 1.5 mm spherical, adhesive, and demersal.[10] Eggs from the San Marcos River were adhesive, demersal, and were 1.5 mm in diameter;[13] while eggs from two populations averaged 1.64 mm from San Marcos and 1.78 mm in diameter from Austin, TX.[16]

Incubation
Eggs have a narrow range of thermal survival, with temperatures less than 20°C showing no survivorship, and temperatures ranging from 22 to 27°C show the best survivorship.[12] Hatching occurs from 90 to 108 h at an incubation temperature of 74–78°F.[10]

Development
Embryonic development from 36 h postfertilization to 108 h is described, including the formation of the brain, somites, and circulation.[10]

YOLK-SAC LARVAE

See Figure 184

Size Range
IL populations from the Embarras River hatch at 5.5 mm SL[10] and phase continues until day 5 posthatching and SL >7.2 mm (about 8.75 mm TL).*

Myomeres
Predorsal 4–7; preanal 19–21 (N = 2), postanal 21–22 (N = 2); total 41–42.*

Morphology
5.5 mm SL. Newly hatched; body laterally compressed; snout rounded, with simple stomodeum and nonfunctional jaws; yolk-sac elongate, large (33.3% TL), oval, and tapering slightly posteriorly; yolk translucent clear to pale yellow, with a single, anterior oil globule; a simple single vitelline veins occurs midventrally on yolk-sac; head slightly deflected over the yolk sac; eyes spherical.[*,10]

6.8–7.2 mm SL. Digestive system functions; yolk-sac reduced but not absorbed; gills functional; jaws well developed.[*,10]

Morphometry
See Table 201.*

Fin Development

5.5 mm SL. Pectoral fin bud present.[*,10]

6.8–7.2 mm SL. Pectoral fin forms with incipient rays present.[*,10]

Pigmentation
5.5 mm SL (*newly hatched*). Eyes pigmented; no melanophores dorsally over the body. No pigment dorsally over the yolk sac or over the gut. Melanophores distributed ventrally, a paired series of from the anterior oil globule to the posterior portion of the yolk-sac; at every other postanal myosepta along the midventral.[10,*]

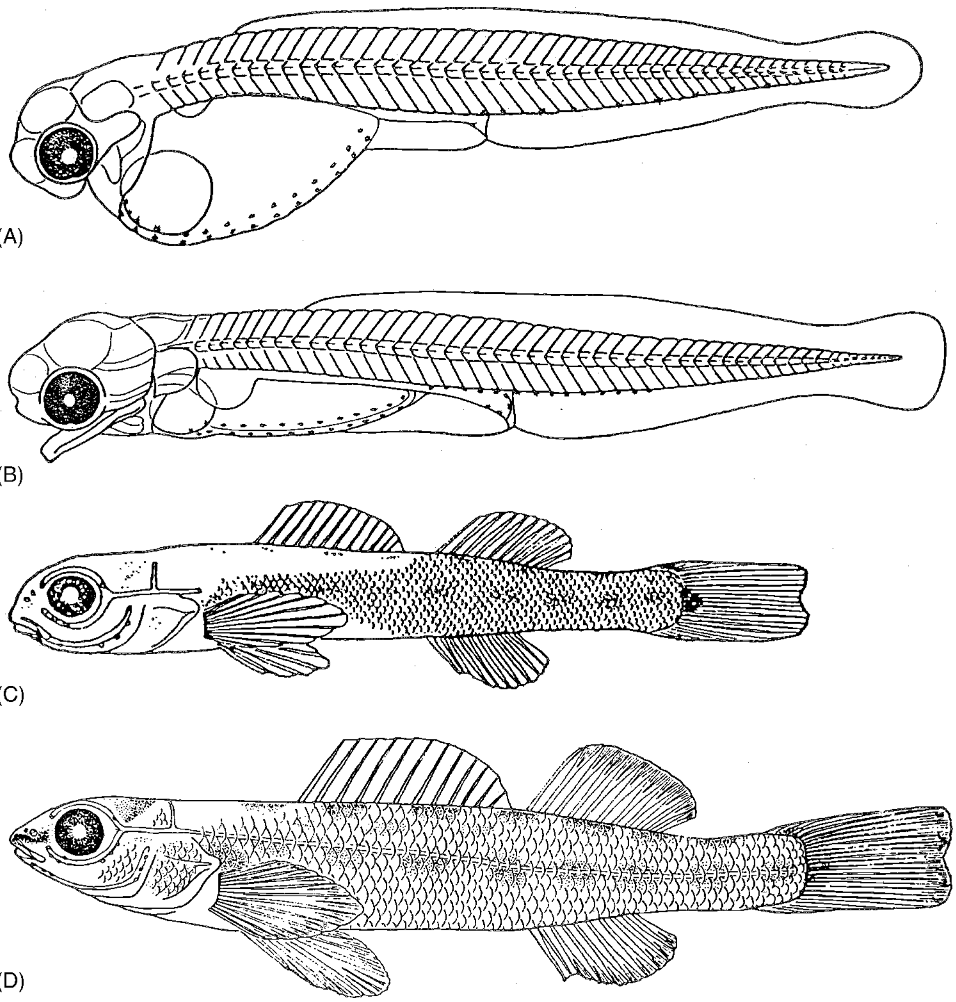

Figure 184 *Percina sciera*, dusky darter, Embarras River, Cumberland Co., IL: (A) yolk-sac larva, 5.5 mm SL, lateral view; (B) yolk-sac larva, 7.2 mm SL, lateral view; (C) early juvenile, 16.0 mm SL, lateral view; (D) juvenile, 26.0 mm SL, lateral view. (A-D from reference 10, with author's permission.)

6.8–7.2 mm SL. No dorsal melanophores over the entire body. Melanophores present from posterior edge of the yolk sac to the anus over the gut. Ventrally, melanophores distributed from the posterior edge of the oil globule along the single, mid-ventral vitelline vein to the posterior edge of the yolk-sac; melanophores outline the anus; melanophores occur from postanal myomere 1–9 at every postanal myosepta.[10,*]

POST YOLK-SAC LARVAE

Size Range
>7.2 mm SL[10] (about 8.75 mm TL) until <16 mm TL.*

Myomeres
Predorsal 4–7; preanal 19–21, postanal 21–22, with total 41–42.*

Morphology
Day 8 posthatch (estimated at 8.75 mm TL): Yolk absorbed.*

Morphometry
See Table 201.*

Fin Development
8.75 mm TL. Notochord flexion occurs simultaneously with caudal fin ray development.*

Pigmentation
8.75 mm TL. No dorsal pigmentation. Ventral pigmentation consists of single mid-ventral melanophores scattered from the breast to the anal finfold, gut, and around anus; staggered, melanophores from the anus to the base of the caudal peduncle.[*,10]

JUVENILES

See Figure 184

Size Range
<16 mm TL* to 40–55 mm SL.[10]

Fin Development
16.0–18.6 mm SL. Complete adult fin ray counts in median and paired fins; caudal fin rays with segmentation, fin is slightly emarginate; dorsal and anal finfolds completely differentiated.*[,10]

Larger Juveniles. Spinous dorsal fin X–(XII–XIII)–XIV; soft dorsal rays 10–(12–14); pectoral rays 12–(13–15); anal fin spines/rays II / 7–(9–10)–11; pelvic fin spines/rays I 5; caudal fin rays 15-17.[1–9,15,20]

Morphology
16.0–18.6 mm SL. Lateral line forming with a short segment in the region above the operculum, supratemporal canal forms. Head canals interrupted; anterior portions of the supraorbital canal present with three pores. Squamation intiated from posterior to the pectoral fin, not covering nape, opercle, prepectoral base, breast, or belly.*[,10]

19.8–26.0 mm TL. Squamation complete except on the nape; cheek and opercle with scales posterior to the eye; nape unscaled, and belly scaled; breast and prepectoral area naked. Lateral line complete; head canals complete and fully pored, specialized scales present mid-ventral (26.0 mm SL). Total vertebrae count 39–42 including one urostylar element. Gill membranes moderately connected, frenum present.*[,10]

31–35 mm SL. Scales present on the nape.*[,10]

Morphometry
See Table 201.*

18.0–22.9 mm SL. Average predorsal length 34.1% SL.*[,10]

Pigmentation
16.0–18.6 mm SL. Pigmentation poorly developed, but the eight lateral blotches, the preorbital band around the snout, and spots of color in the fins are present.*[,10] Distinct basicaudal spot present.*

20.6–28.3 mm SL. Postorbital bar beginning to form (26.5 mm). Melanophores over the cranium forming a chevron that extends posterior to the eye; 7–8 dorsal saddles forming from anterior of the dorsal fin origin to the caudal peduncle. Eight midlateral melanophores forming from the pectoral fin base to the caudal peduncle base. Melanophores form at the distal edge of the soft dorsal fin and distal edge of the anal fin. Caudal fin with a distinct medial spot and the distal edge of the caudal fin.*

25.1–40 mm TL. Preorbital and postorbital bar present; cerebellum and optic lobe pigmentation dense; 7–9 dorsal saddles, which have discrete vermiculations that are separated between the blotches and dorsal saddles. Eight to nine longitudinal blotches along mid-lateral, surface and three vertically arranged basicaudal spots are present. Median fin membranes speckled forming vertical stripes on the caudal fin.*

TAXONOMIC DIAGNOSIS OF YOUNG DUSKY DARTER

Similar species: members of subgenus *Alvordius*[3] and *Hadropterus.*

Adult. Percina maculata is similar to *P. sciera.* The two species differ in the absence of the suborbital bar in *P. sciera* and the presence of three basicaudal spots. The dorsal vermiculations are continuous in *P. maculata* and distinct and isolated in *P. sciera.* *Percina maculata* differs from *P. macrocephala* in possessing completely scaled cheeks and a strong suborbital bar, which are not present in *P. macrocephala.*[4]

Larva. The early life history of *P. maculata* is similar to *P. sciera* and *P. macocephala*. The three species can be differentiated by their pigmentation and differences in myomere counts. *Percina maculata* possesses 20–22 preanal and 20–21 postanal myomeres. *Percina sciera,* possesses 18 preanal and 22–24 postanal myomeres. *P. macrocephala* possesses 21 preanal and 22–28 postanal myomeres.* Thus, preanal myomere number will separate *P. maculata* from *P. sciera*, and postanal myomeres is diagnostic between *P. maculata* and *P. macrocephala*.*

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 185)
Eggs. Percina sciera spawned in riffles and raceways where it laid eggs in fine gravel in shallow water usually <0.6 m.[10,13]

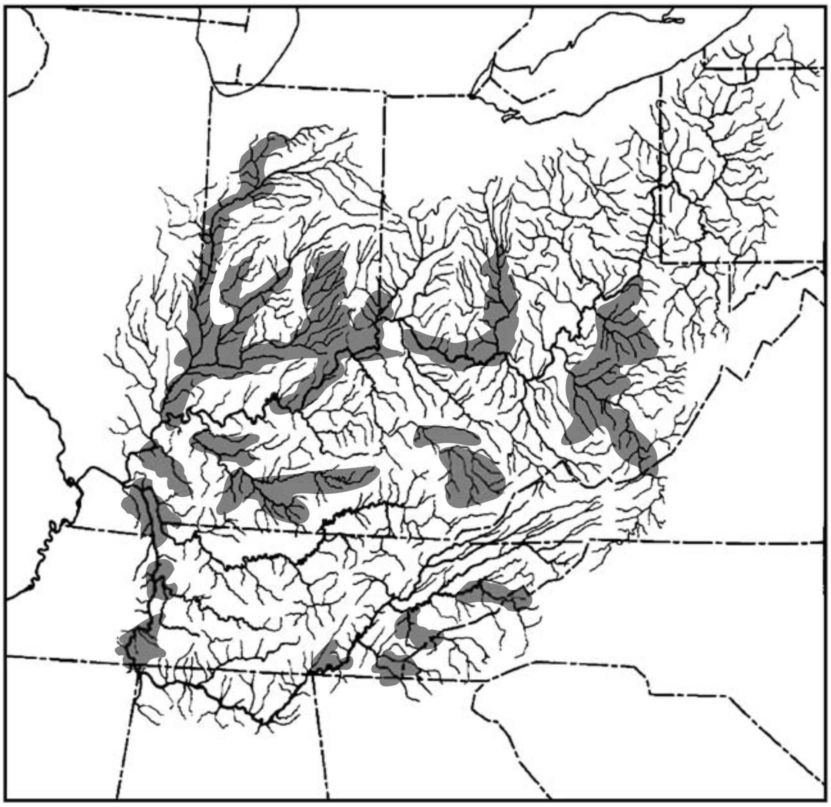

Figure 185 Distribution of dusky darter, *P. sciera* from the Ohio River system (shaded areas).

Yolk-sac larvae. Yolk-sac larvae are pelagic immediately after hatching.* The vitelline vein consists of a single midventral trunk on the ventral yolk-sac, which is consistent with other *Percina* burier species.*

Post yolk-sac larvae. Larvae are pelagic and are part of the drift during most of the larval stage.

Juveniles. Early juveniles are predominantly pelagic and are active most of the time and rarely rest on the bottom.[10] Juveniles use smaller diameter woody debris than adults and occur in shallow water (<0.3 m).* Embarras River populations are estimated at 6.3 individuals per square yard, about 5.4 of those individuals per square yard are age 0 fish. *

Early Growth (Table 202)

Apparently, individuals do not exceed 4 years of age, however, a few darters live past age 3.[10] Early growth is estimated to be 1.75 mm per day based on laboratory-raised specimens.*[,10] During their first year of life, young darters attained 31 mm SL within 5 weeks,[10] 38 mm SL by 7–9 weeks,[10] and 45 mm SL by 14 weeks.[10]

Table 202

Average calculated lengths (mm SL) of young dusky darter from several locations.

	Age			
State	1	2	3	4
Illinois (Embarras River)[10]	60	72	82	100
Virginia[7]	—	62–73	84	
Tennessee[4]	70	82	94	110

Feeding Habits

The main components of the diet in IL include current dwelling immature insects. Diet is primarily midge larvae, caddisfly larvae, black flies, snipe flies, mayfly naids, and stone flies.[10] Adult darters consume larger prey items, which are correlated with size.[14] Dusky darters feed the most during May, just before the spawning period.[10]

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Material Examined: IL: Cumberland County: Embarras River, near Greenup (INHS uncatalogued)(19).

*Original fecundity data for dusky darter from the Buffalo River (Duck River drainage), Marshall and Lewis Counties, TN. Specimens curated at Northeast Louisiana University, Museum of Zoology, Monroe, LA. Early life history developmental series cultured from laboratory spawned specimens from Embarras River, Cumberland County, IL. Specimens curated at the Center for Biodiversity, Illinois Natural History Survey, Champaign, IL.

RIVER DARTER

Percina (Imostoma) shumardi (Girard)

Percina: a small perch; *shumardi*: named after George C. Shumard, surgeon of the U.S. Pacific Railroad Survey.

RANGE

Percina shumardi occurs in the Gulf Coast including the Mobile basin of AL to the Guadalupe River, TX; north through the Mississippi River drainage including most major tributaries; east into the Lakes Erie and Huron basins including Manitoba and eastern ON. Disjunct populations exist in the San Antonio Bay drainage, TX, and the Sabine River, TX and LA.[1,2]

HABITAT AND MOVEMENT

The river darter is typically found in deep chutes and riffles with swift current and substrates of coarse gravel or rock; confined to large rivers and the lower parts of major tributaries.[2,3,9–11] it is more tolerant of turbidity than most other darters.[2,6] Spawning or spent adults have been captured in moderate currents over gravel and sand in association with growths of pondweeds and the species may be amenable to environmental conditions of some reservoirs.[3] Spring migration of adults occurred into flooded fields adjacent to the Scioto River.[6] The species is frequently collected in turbid water at depths from 1 m;[8] over substrates of sand (33%), gravel (45%), boulders (16%), and rubble (6%).*

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Percina shumardi is sporadic and uncommon in the main channel of the Ohio River and Bayou du Chien, lower Tennessee, upper Green, upper Kentucky, middle Licking, and lower Little Sandy Rivers, KY;[3] rare to sporadic in the middle and lower Wabash River, IN;[4,5,*] collected from the lower Scioto River, OH;[6] found in Rough Creek near Hartford, Cumberland River near Kuttawa, and the Obion River;[7] and the Ohio River, Mason Co., WV;[19,20] and occurs throughout the Tennessee River and its tributaries to the area surrounding Knoxville.[21]

SPAWNING

Location

Spawning occurs over exposed bedrock, gravel, and larger cobble at depths of 0.6 m only in strong, deep currents near shore;[8, 22] Spawning adults in the Black River, WI, were collected downstream of a spillway in water less than 1.0 m over coarse sand-gravel and cobble in moderate eddy currents.[1] Eggs were found in shallow littoral zones buried in sand or gravel in areas of minimal current.[1]

Season

Spawning occurs during January to mid-April in TX;[23] April to May in IL;[13] April to May in MN;[12] April in KS;[22] between April and May in the upper Mississippi River, WI,[1] or as late as June,[8] possibly as early as February to March in TN;[14,21,23] and late February and early March in MS.* Spawning occurred from late April to mid-May in the Tippecanoe River, IN;* June or July in Manitoba and ON.[15] Female ovaries show differential stages of ova development during early June in WI.[8] Females from the Tippecanoe River, IN, were spent by late May with no ripe ova found after the first week of July.* Spawning in laboratory aquaria occurred from early March to mid-May.*

Temperature

10°C during field observations from the upper Mississippi River, WI;[1] eggs were able to tolerate temperatures of 13–26°C.[16]

Fecundity (Table 203)

A female collected in early June from WI have ovaries 2.2% of the body weight.[8] Ovaries from specimens collected from the Black River, WI, have three size classes of ova. Immature ova are ovoid, opaque, white in color, and contain an oil globule center. Early maturing ova are spherical, are generally pale yellow, and do not possess a perivitelline space. Ripe eggs are large, demersal, and unpigmented with a pale yellow yolk and smooth chorion.[1] Females 53–64 mm TL from the Ouachita River have between 1706 and 3270 oocytes.*

Sexual Maturity

Adults live to reach age 2;[8,*] however, maturity is generally at age 1.* Males exhibit sexually dimorphic

Table 203

Fecundity data for river darter from Ouachita River, Caldwell Parish, LA.*

			Number of Ova			
Date	TL (mm)	Ovary Weight (mg)	Ripening Oocytes (LA)	Mature Oocytes (EM, MA ,LM)	Ripe Eggs (MR, RE)	Egg Diameter (mm)
February 12	95	158	2091	617	479	0.769
March 12	53	120	1694	370	168	0.952
	54	89.6	1268	239	199	0.833
	54	136	1380	329	301	0.833
	58	75.4	1863	391	0	—
	58	181	1648	403	234	1.05
	58	198	1661	425	344	0.952
	59	175	1625	324	260	1.0
	63	162	1931	320	278	0.952
	63	123	2017	287	88	1.0
	64	451	2210	577	483	1.11

traits during the reproductive season with the development of a line of modified scales extending from anus to midpoint between pelvic fins, thickened membranes occur on the anterior edge of the pelvic fins, the anal fin is enlarged, and the anal, pectoral, and pelvic fins are more pigmented than females. Males have a shorter and broadly conical genital papillae shaped to a sharp or blunt end, while females have distended abdomens, an unscaled breast, shorter anal fins, and a digitiform, more elongate and flaccid, and comparatively flattened tube that touches the base of the anal fin.*

Spawning Act

Percina shumardi is an egg burier. The river darter is thought to spawn similar to the blackside darter *P. maculata* or channel darter *P. copelandi*.[15] Aquarium observations of captive river darters from the Black River, LaCrosse County, WI, showed that spawning occurred from early morning to early evening but did not occur at night.* The river darter is an intermittent or fractional spawner with the females spawning many times during the season depositing eggs daily.[1] Field observations from the Black River, WI, found eggs buried in fine gravel and sand downstream from a spillway at depths less than 1.0 m over coarse sand-gravel and cobble. Current velocities were moderate and formed an eddy.[1] Aquarium observations of reproduction behavior was based on specimens from the Black River, WI.* Males form groups that attempt to court females by displaying laterally in a head-to-tail orientation. Males maintain a head down orientation toward the female while displaying in the water column. Females held position while males rotated around the female swimming backwards and forwards such that the head of the female was always between the pectoral fin and the caudal fin. The male often curves his body around the head of the female and often changed coloration becoming extremely dark and expanding lateral blotches and intermembrane pigment. A female chooses the male she wants to spawn with by moving toward a gravel area in the aquarium near the corner with fine to large gravel substrates. If the female chooses not to spawn with the male, she often swims away, although repeated advances can occur. Group formation is needed to keep and maintain males in a heightened reproductive state. Males protected a "moving territory" by immediately surrounding a female that has entered the breeding grounds.* The choice of the female seems to be based on the heightened coloration of the males, fluttering and twitching of the male's body, and does not involve the size of the male. Females choose the spawning location and swim to the desired location followed by the male. She settles to the bottom and a single male takes a position over the female with his pelvic fins clasping her head and his tail alongside hers. Multiple male spawning was not observed. The female releases 5–8 eggs during each spawning act as the pair become almost completely buried by the swirling gravel when vibrating. After spawning the female swims out from under the male either to spawn again with the same male or to return to another portion of the aquarium to rest. Neither the male or female provide any parental care to either the eggs or larvae.*

EGGS

Description

Spherical, demersal, slightly adhesive;[1] range from 1.0 to 1.3 mm in diameter from upper Mississippi River, WI and MN;[1] 1.2 mm in WI;[8] 1.67 mm in the Guadalupe River, TX.[16] Yolk pale yellow in color, with a single oil globule, a moderate perivitelline space, and a translucent smooth egg chorion.[1,*] Fertilized eggs are translucent, spherical, and slightly adhesive, averaging 1.4 mm in diameter (range: 1.1–1.7 mm).[16] Latent ova are ovoid ranging between 0.2 and 0.22 mm in diameter, early maturing and late maturing ova were 0.82–0.94 mm, and mean ripe ova were 1.1 mm in diameter.[1] Three size classes of ova are observed in females from the upper Mississippi River, WI and MN, the smallest or immature ova are usually faceted and translucent to clear with no yolk development and a visible nucleus, mature ova are smaller and opaque white or light yellow ova, and ripe ova were golden to translucent yellow and average 1.1 mm.[1,*]

Incubation

Hatching occurs in 144–168 h and averaged 156 h at 22°C.[1]

Development

Unknown.

YOLK-SAC LARVAE

See Figure 186

Size Range

3.6–4.0 mm[1] at hatching, yolk absorption complete by 5.5–6.2 mm TL.[1]

Myomeres

Total 40–44; predorsal 5–6; preanal 18–19; postanal 22–26.[1]

Morphology

3.6–4.0 mm TL. Body elongate, laterally compressed; stomodeum present with no functional mouth parts; head slightly deflected over the yolk sac; pale yellow translucent yolk; yolk-sac oval, tapering posteriorly; a single anterior oil globule; a single mid-ventral vitelline vein is present.[1]

4.8–5.4 mm TL. Eyes oblong; jaws developed.[1]

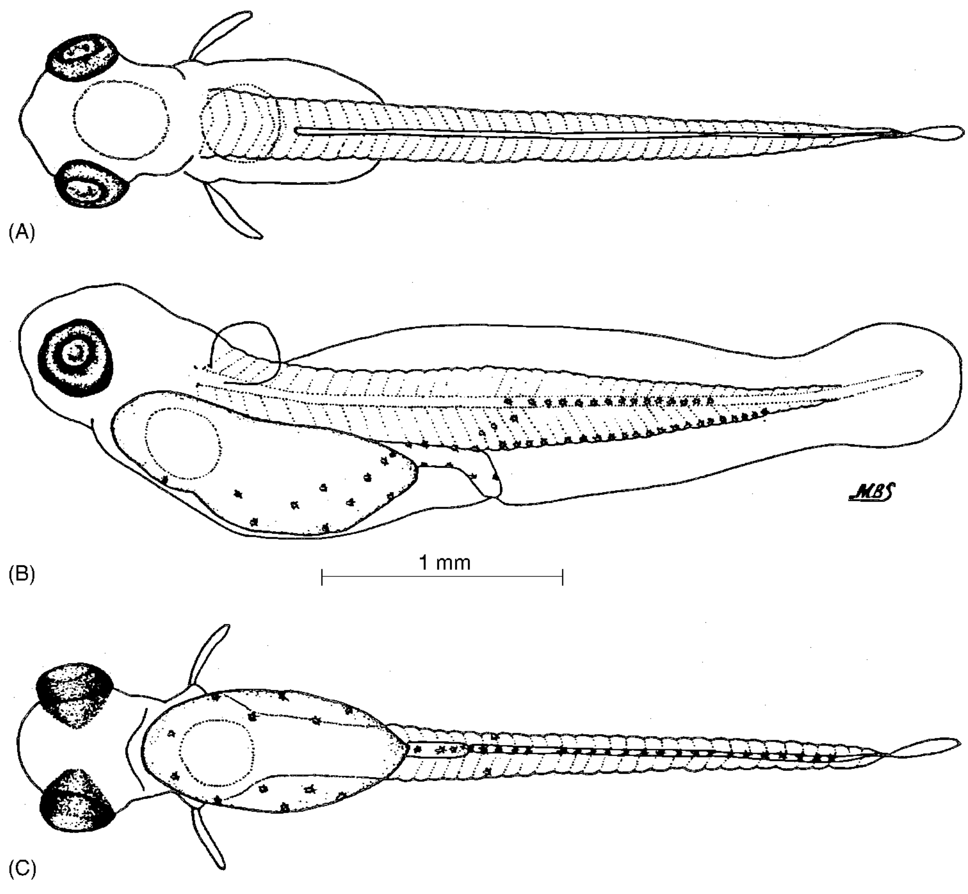


Figure 186 Development of *P. shumardi*, river darter, Black River, La Crosse County, WI, yolk-sac larvae, 4 mm TL: (A) dorsal, (B) lateral, and (C) ventral views. (A-C from reference 1, with author's permission.)

5.5–6.2 mm TL. Complete yolk absorption occurs; swim bladder evident after yolk absorption.[1]

Morphometry
See Table 206.

Fin Development (Table 205)
3.6–5.5 mm TL. Dorsal and anal finfolds complete, small pectoral buds; incipient rays absent from all median and paired fins.[1]

5.8–6.1 mm TL. First rays formed in pectoral, anal, and soft dorsal fins.[1]

Pigmentation
3.6–4.0 mm TL. Eyes pigmented with melanophores; sparce pigmentation, pigmentation absent on cranium and dorsal surface. Lateral pigmentation with two parallel lines of melanophores at almost every mid-lateral and ventral postanal myoseptum, with mid-lateral line extending only from anus to about the middle of the postanal length. Scattered melanophores limited to ventral half of horizontally bissected yolk sac with greatest concentration at the mid-ventral surface. Pigment outlining dorsal and ventral position of the gut posterior of yolk sac; ventral yolk-sac pigmentation extending obliquely to dorsal surface of gut.[1]

4.8–5.9 mm TL. Cranium and dorsal surface without pigmentation; several stellate melanophores present at cleithra; a few scattered melanophores on dorsal half of yolk-sac, concentrated more heavily at mid-ventrals. Lateral pigmentation forming an inverted v-pattern above the anus extending dorsally to mid-body; an oblique mid-lateral stripe of melanophores at postanal myosepta apex extending posterior from anus to the middle of postanal length. Ventral pigmentation at almost every postanal myosepta; melanophores encircle anus.[1]

POST YOLK-SAC LARVAE

See Figure 187

Size Range
6.2 –20.7 mm TL.[1]

Myomeres
Total 39–41; predorsal 6–10; preanal 18–19; postanal 22–26.[1]

Morphology
6.8–10.8 mm TL. Notochord flexion occurs at 6.8 mm TL; maxillary extending slightly anterior to mandible at lengths less than 8.0 mm TL, of equal length greater than 10.8 mm TL; gut slightly curved at 10.8 mm TL.[1]

13.6 mm TL. Scales present.[1]

16.7–18.5 mm TL. Squamation complete.[1]

Morphometry
See Table 204.

Fin Development (Table 205)
5.8–6.6 mm TL. Fin rays formed in caudal fins.[1]

6.7–7.1 mm TL. First pectoral fin rays formed at 6.7 mm TL; incipient dorsal fin margin partially differentiated at 7.1 mm TL.[1]

7.5–8.0 mm TL. Pelvic fin buds formed anterior to dorsal fin origin at 7.5 mm TL; first anal fin rays formed at 8.0 mm TL; incipient dorsal fin margin completely differentiated at lengths greater than 8.0 mm TL; incipient anal fin margin partially differentiated at lengths greater than 8.0 mm TL.[1]

10.8–12.3 mm TL. Entire finfold absorbed at 10.8 mm TL; first pelvic and caudal fin rays formed at 12.3 mm TL; caudal fin emarginate at 12.3 mm TL.

13.2–13.6 mm TL. Complete adult complement of fin rays formed in dorsal fin by 13.2 mm TL; scales present at 13.6 mm TL.[1]

16.7–18.5 mm TL. Squamation complete.[1]

Pigmentation
6.1–7.5 mm TL. Several melanophores below mandible; melanophores forming postorbital chevron; melanophores outline the dorsal and ventral portion of the gut; oblique melanophores at mid-lateral apex of postanal myosepta parallel to ventral surface. Dorsally, posterior portion of optic lobe outlined on cranium; notochord tip near caudal fin with several single melanophores. Ventral pigmentation at isthmus at the margin of operculum and at every postanal myoseptum from the anus to the tip of the notochord.[1]

8.0 mm TL. Dorsal pigmentation on cranium concentrated only on optic lobe; four small clusters of melanophores forming dorsal blotches, present on nape, just behind incipient spinous dorsal, posterior of incipient soft dorsal, and near caudal peduncle; a single line of melanophores at tip of notochord. Laterally, postorbital tear drop chevron shaped; margin of operculum with pigment extending over dorsal portion of anterior gut; pigment near anus becoming subdermal. Ventral pigment clustered near isthmus of operculum extending posterior at mid-ventral; melanophores present at every postanal myosepta extending to tip of notochord.[1]

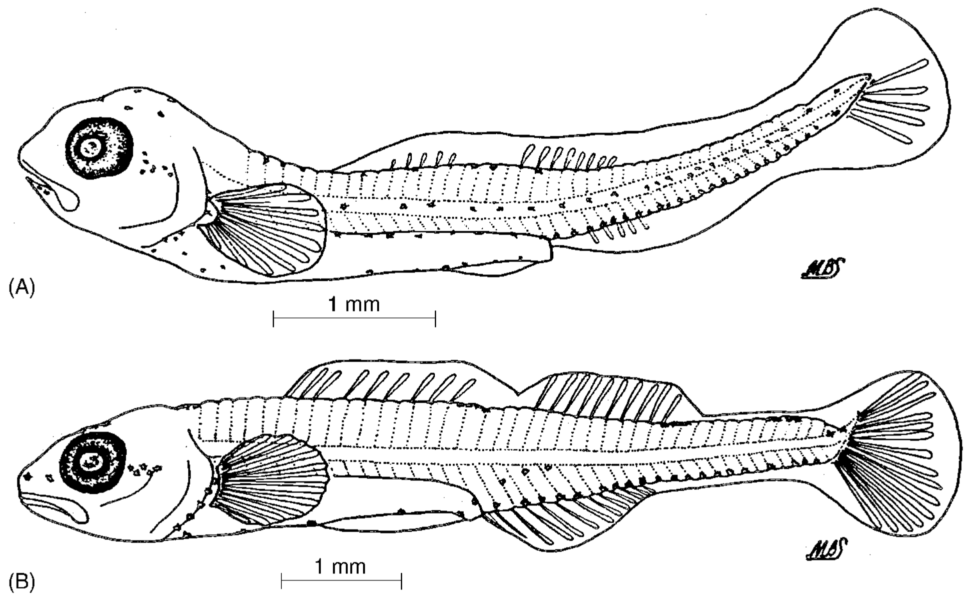


Figure 187 Development of *P. shumardi,* river darter, Upper Mississippi River, Pool 5, WI: (A) Post yolk-sac larva, 6.2 mm TL, (B) Post yolk-sac larva, 8.0 mm TL. (A-B original drawings.)

10.8–12.3 mm TL. Cranium with melanophores concentrated dorsally over the optic lobe and cerebrum; snout with pigment posterior to maxillary; five elliptical clusters of melanophores from nape to caudal peduncle; several melanophores near postflexion notochord. Cranium with forming preorbital, and formed postorbital bars; preopercle with stellate melanophores; margin of opercle with pigment at apex. Dorsal gut pigmentation subdermal; several stellate melanophores present ventrally; a single midlateral line of pigment present from the cleithrum to the tip of the notochord. An oval cluster of melanophores present near caudal peduncle; oblique line of melanophores from anus to caudal peduncle clusters. Melanophores at base of caudal peduncle forming a hook-shaped vertical line on the lower half of the caudal fin; caudal fin with a few scattered melanophores on rays. Ventrally, margin of opercle outlined; pigment extending between pelvic fin posterior to sides of anus; postanal pigment present from anus to the end of the caudal peduncle at mid-ventral.[1]

13.6–15.5 mm TL. Cranium with concentrated melanophores present dorsally as described for 10.8–12.3 mm TL interval; preopercle and interopercle outlined with melanophores; developed preorbital and postorbital tear drops; 7–8 dorsal blotches not extending to notochord. Posterior to opercle, pigment surrounding air bladder and incorporating an oval melanophore cluster; four additional oval clusters to caudal peduncle. Vertical hook at caudal peduncle base darkening. Additional pigmentation present on rays of caudal fins; few melanophores present on spines and rays of dorsal fins. Ventral pigmentation remains as in previous condition.[1]

16.5–20.7 mm TL. Dorsal pigmentation with melanophores concentrated over the optic lobe, and cerebellum extending into upper sections of the operculum; from nape to base of caudal peduncle are 6–8 oval dorsal clusters; U-shaped cluster of melanophores posterior to maxillary. Lateral pigmentation includes 7–9 oval clusters, formed preorbital, postorbital, and a weakly defined line of melanophores; cluster of melanophores on cleithrum; pigment present on pectoral, caudal, and spinous and soft dorsal fin rays; black diamond-shaped spot present at the base of caudal peduncle with a vertical extension forming a hook. Ventral pigment from anus posteriorly to the base of caudal peduncle.[1]

JUVENILES

See Figures 188 and 189

Size Range
20.7–27.8 to 54 mm TL.[8]

Fin Development
21.4 mm TL. All median and paired fin rays distinct and with fully developed of fin spines and rays. Finfolds completely differentiated, caudal fin truncate to slightly notched.*

Larger juveniles. Spinous dorsal VIII–XI; soft dorsal 12–14; pectoral rays 13–14; anal rays II 10–12; pelvic rays I 5; caudal rays ix–xiv, 8 + 7, x–xii.[1,6,8,10,11]

Table 204

Morphometric data expressed as percentage of total length (TL) with range of actual measurements in parentheses for young *P. shumardi* from the upper Mississippi River, WI, and MN.[1,*]

	Total Length Groupings				
TL Range (mm)	4.0–6.7	7.1–10.8	12.3–16.7	17.0–24.1	25.2–27.8
N	51	5	13	20	4
Ratios	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)
SnL	3.4 ± 2.3	4.3 ± 2.0	5.2 ± 1..2	5.4 ± 2.1	5.5 ± 0.8
	(0.9–0.22)	(0.22–0.45)	(0.6–0.90)	(0.8–1.2)	(1.3–1.8)
ED	6.7 ± 2.8	6.5 ± 0.2	6.5 ± 1.6	6.3 ± 1.3	7.0 ± 0.2
	(0.23–0.60)	(0.46–0.65)	(0.8–1.2)	(0.9–1.7)	(1.8–2.0)
HL	16.9 ± 1.3	19.4 ± 2.3	21.0 ± 1.3	23.5 ± 0.8	24.8 ± 1.2
	(0.50–1.2)	(1.2–2.2)	(3.1–4.2)	(4.0–5.4)	(5.8–7.5)
PreAL	53.0 ± 0.7	52.8 ± 1.6	52.6 ± 1.7	52.0 ± 0.4	50.1 ± 2.8
	(2.0–3.5)	(3.7–5.6)	(6.6–9.1)	(9.0–12.8)	(12.0–14.0)
PosAL	47.0 ± 0.7	47.2 ± 1.5	47.4 ± 1.9	48.0 ± 0.5	49.9 ± 0.5
	(2.0–3.2)	(3.4–5.2)	(5.7–7.6)	(8.0–12.3)	(13.2–13.8)
SL	97.3 + 0.8	92.6 ± 1.1	88.0 ± 1.3	85.3 ± 1.3	85.8 ± 1.0
	(3.7–6.4)	(6.8–9.3)	(10.8–14.7)	(14.3–20.1)	(21.3–23.5)
YSL	33.6 ± 4.2				
	(0.30–1.34)				
BDP1	9.7 ± 1.5	10.8 ± 1.1	16.8 ± 2.1	16.7 ± 1.1	15.5 ± 1.1
	(0.56–0.90)	(9.2–13.0)	(1.8–3.0)	(2.6–3.8)	(3.9–4.3)
BDA	7.2 ± 0.2	8.6 ± 0.7	11.4 ± 0.6	13.4 ± 0.5	15.0 ± 2.8
	(0.2–0.6)	(0.5–1.0)	(1.4–2.0)	(2.0–3.8)	(3.8–4.2)
CPD	3.1 ± 0.2	3.7 ± 0.4	7.5 ± 0.6	7.8 ± 0.3	8.6 ± 0.2
	(0.08–0.26)	(0.22–0.5)	(0.9–1.3)	(1.2–1.8)	(2.0–2.5)
YSD	12.1 ± 2.0				
	(0.08–0.48)				

Morphology

20.8–23.3 mm TL. Preoperculomandibular, supratemporal, and lateral line canals formed by 20.8 mm TL, lateral line formed by 22.0 mm TL; supraorbital and infraorbital head canals formed by 23.3 mm TL. Mandible of equal length as maxillary.[1]

24.1–27.8 mm TL. Supraorbital, infraorbital, preoperculomandibular, and lateral head canals formed. Scales beginning to form on opercle by 24.1 mm TL and completely formed by 26.0 mm TL. Scales formed on cheeks by 27.8 mm.[1]

Lateral scales 46–57; total vertebrae 39–41; Branchiostegal rays 5, 5. The cheek and opercle are scaled; breast is unscaled.[1] Cephalic sensory canals complete, lateral canal pores 5, supratemporal canal pores 3, supraorbital canal pores 4, coronal pore present; infraorbital canal pores 8; preoperculomandibular canal pores usually ten, ranging between 9 and 11.* Vertebrae 39–41.[1]

Morphometry

See Table 204.

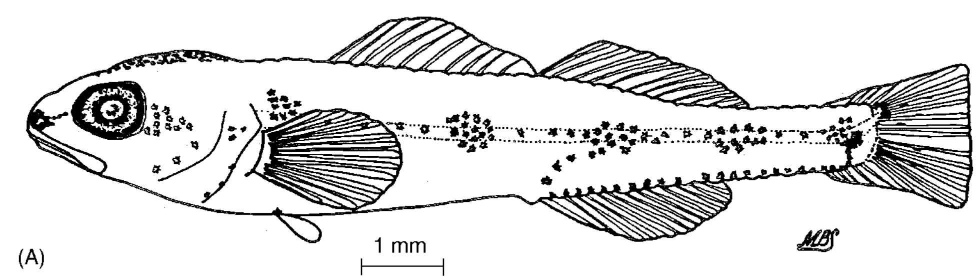
Pigmentation

21.4–27.8 mm TL. Dorsum cranium pigmentation consisting of concentrated melanophores covering the cerebellum and optic lobe; U-shaped preorbital bar (when viewed from dorsum) posterior to maxillary; pigment extending from posterior of optic lobe onto operculum; either 7 or 8 oval-shaped clusters of melanophores evenly spaced, extending from nape to the base of the caudal peduncle. Head pigmentation with evident preorbital and postorbital chevron-shaped tear drops and a weakly formed postorbital bar; pigment clustered into the form of a triangle on the lower half of the operculum; pigment initiating

Table 205

Meristic counts and size (mm TL) at the apparent onset of development for *P. shumardi.*

Attribute/Event	*P. shumardi*[1]	Literature
Branchiostegal Rays	5,5[1]	5,5[6,9–12,27,28]
Dorsal Fin Spines/Rays	VIII–(X)–XI/12–(13–14)[1]	VIII–XI/10–13[6,9–12,27,28]
First spines formed	5.9[1]	
Adult complement formed	13.2[1]	
First soft rays formed	5.9[1]	
Adult complement formed	13.2[1]	
Pectoral Fin Rays	(13)–14[1]	12–13[10,11,27]
First rays formed	5.9[1]	
Adult complement formed	6.7[1]	
Pelvic Fin Spines/Rays	I/5[1]	
First rays formed	8.8-9.2[1]	
Adult complement formed	8.8–9.2[1]	
Anal Fin Spines/Rays	II/8–(10–11)–12[1]	II/9–11[6,9–12,27,28]
First rays formed	5.8[1]	
Adult complement formed	8.0[1]	
Caudal Fin Rays	ix–xiv, 8 + 7, x–xii[1]	14–17[4]
First rays formed	5.8[1]	
Adult complement formed	12.3[1]	
Lateral Line Scales	46–(48)–57[1]	46–62[6,7,9–12,25–28]
Myomeres/Vertebrae	40–(41)–44/39–(40)–41[1]	Unknown/37–38–40 [10,11,26,27]
Preanal myomeres	(18)–19[1]	
Postanal myomeres	22–(23)–26[1]	



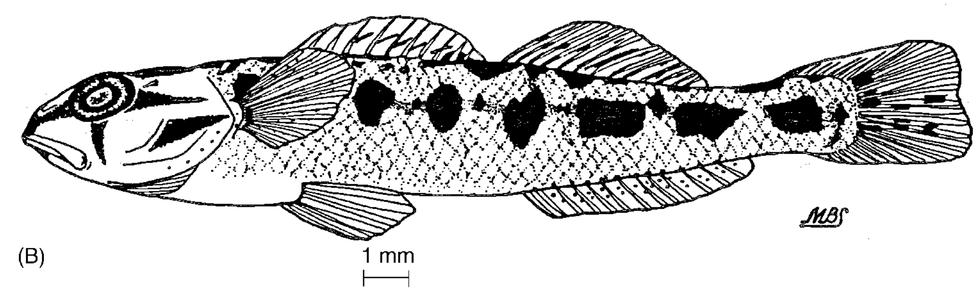


Figure 188 Development of *P. shumardi,* river darter, upper Mississippi River, Pool 5, WI: (A) early juvenile, 12.3 mm TL; (B) juvenile, 24.1 mm TL. (A-B from reference 1, with authors' permission.)

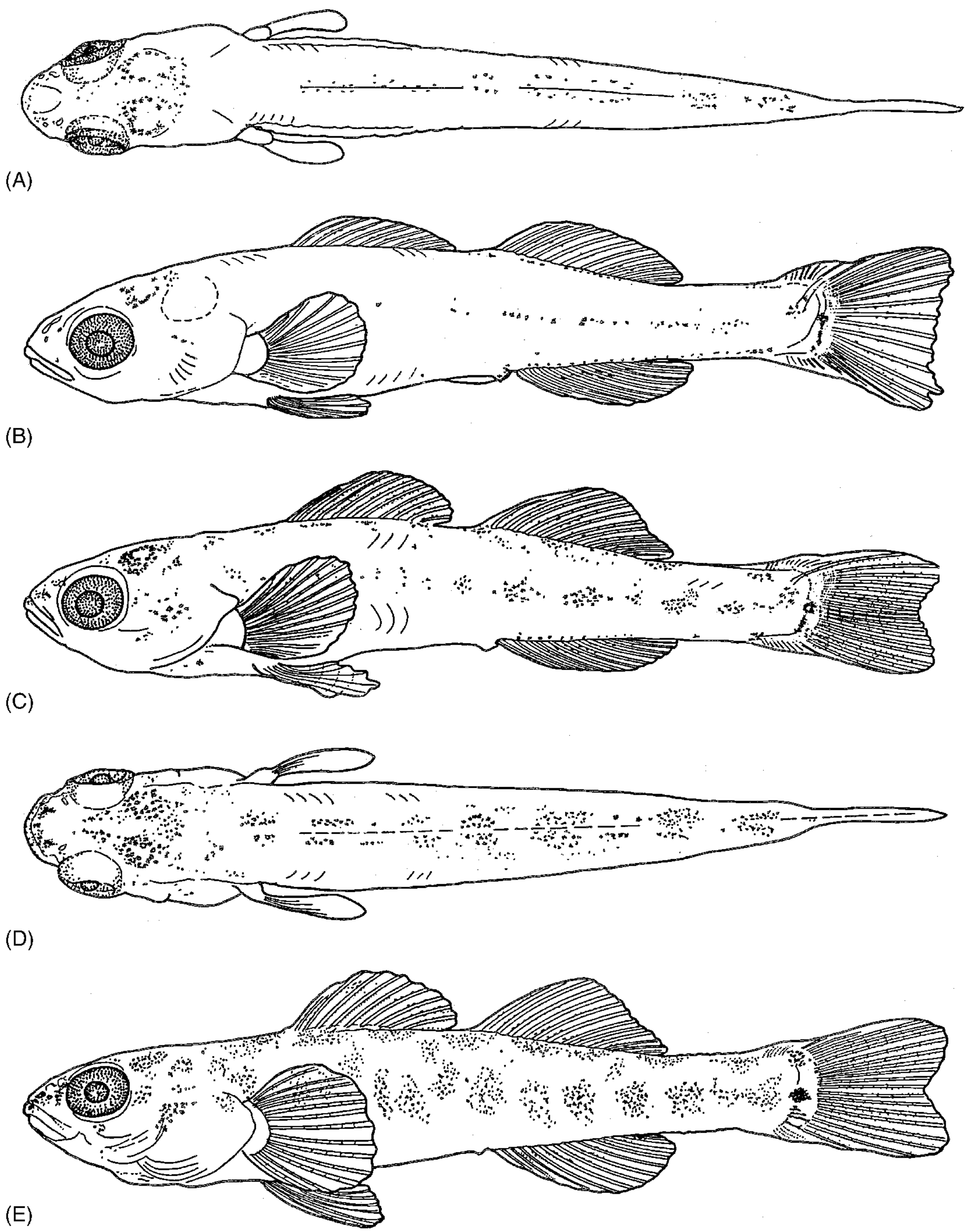


Figure 189 *Percina shumardi*, river darter, upper Mississippi River, Pool 5, WI. (A–B) Early juvenile 16.0 mm TL dorsal and lateral views; (C–D) juvenile, 18.5 mm TL, lateral and dorsal views; (E) juvenile, 23.0 mm TL. (A–E original illustrations.)

on chin below mandible and posterior of maxillary. Cleithra and margin of operculum with a few scattered melanophores; lateral oval blotches numbering either 7 or 8 situated at midbody; evident black-diamond-shaped cluster at the base of caudal peduncle extending vertically into hypaxial portion of caudal fin. Principal rays of caudal fin with scattered melanophores on rays; anal, pectoral, and soft dorsal rays pigmented; pelvic fin without pigmentation; spinous dorsal with dense clusters of melanophores at anterior and posterior base, with flecks of melanophores on individual rays. Ventral pigment limited to a few melanophores beneath operculum, and a series of single melanophores from insertion of first anal fin spine posterior to caudal peduncle.[1]

Larger juveniles. Dorsum yellow to dark olive; sides lighter, and bell white; 15–25 dark olive to black narrow zebra-like bands crossing over the back and vertically down the sides; bands alternating in length, with the shorter bands barely reaching the lateral line. Dorsal and caudal fins lightly barred;

remaining fins clear to lightly pigmented, especially along fin rays. Fin rays yellow in life. Suborbital bar distinct to vague. Black caudal spot about the size of pupil of eye.[17,23]

TAXONOMIC DIAGNOSIS OF YOUNG RIVER DARTER

Similar species: other members of subgenus *Imostoma*.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 190)
Eggs. Eggs are buried in coarse sand and gravel substrates in moderate current of riffles and runs;[1] adults do not provide any protection or guard eggs after spawning.[1] Embryos develop in the darkness of interstitial spaces of clean sand.*

Yolk-sac larvae. Yolk-sac larvae are photophobic and remain buried in the gravel during daylight hours.[1] Yolk-sac larvae are observed in drift collections when water temperatures approached 11ºC. Collections in the Black River, WI, showed a tendency toward surface drift.[20] Specimens from MN were collected from backwater habitats from surface drift.* Yolk-sac larvae are more restricted to shallow water than larvae.* They are significantly more abundant in surface drift collections from the main channel of the upper Mississippi River than at mid- and bottom depths.* The largest proportion of larvae were collected during drift collections in May.*

Post yolk-sac larvae. River darter larvae were collected in drift samples at 11.0ºC. Specimens tended to be surface portions of the water column in WI, and in surface and middepth drift samples in the main channel of the Ohio River.[18] A nursery area in McAlpine Pool had densities of 0.023 fish/m^3 in May.[18] Larvae seldom taken at bottom, more abundant in open waters; frees wimming for over 30 days.[18] Larvae make diurnal migrations vertically, bottom during daytime, surface at night.*

Juveniles. Early juveniles were collected from nearshore habitats, ranging from channel border habitat with sand and gravel bottoms to backwaters with sand substrates with slight current.*

Early Growth (Table 206)
River darter ranges between 36 and 54 mm TL in August; southern WI specimens ranges from 42 to 56 mm in August; young-of-the-year in IL were 36–43 mm TL in June.[13] Young of one year reach 63.8% of total growth during first year of life and 86.1% by the

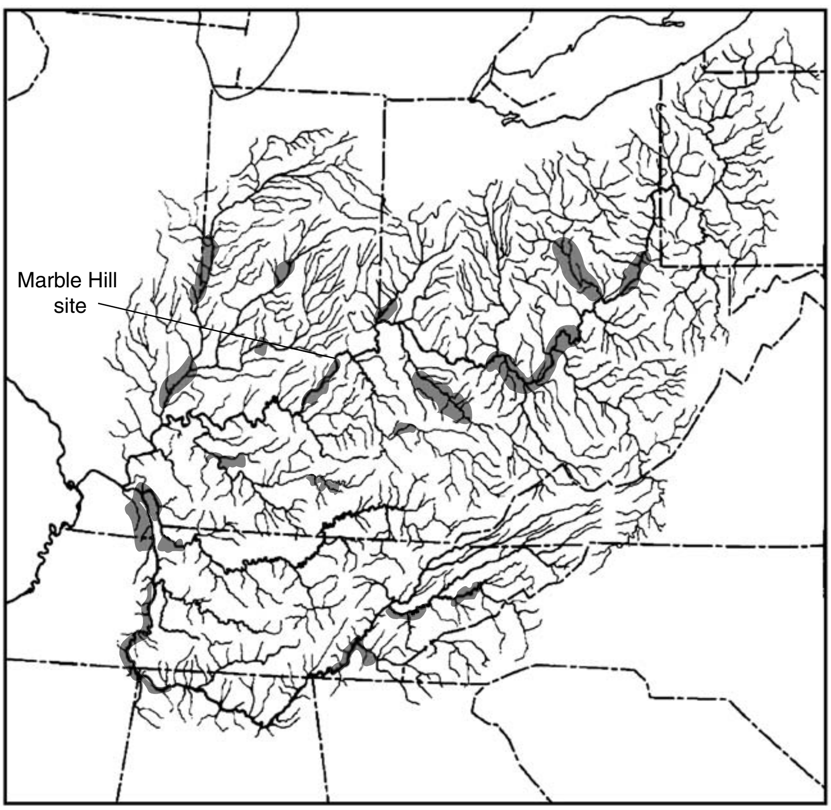


Figure 190 General distribution of river darter in the Ohio River system (shaded area).

Table 206

Average calculated lengths (mm SL) of young river darters in several states.

State	Age 1	2	3
Illinois[13]	48	62	72
Wisconsin[24]			
Central	46–62		
Southern	45–70	68–80	
Indiana*	44	66	71

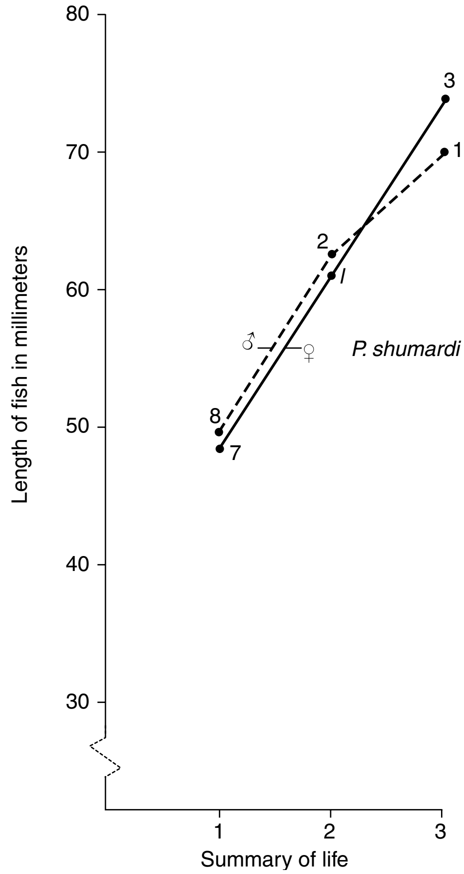


Figure 191 Growth trends for age classes of *P. shumardi* based on annual mean total lengths for populations from Kaskaskia River, near Sullivan, IL. (After reference 13.)

second year of life (see Figure 191).[13,*] Specimens collected from Kaskaskia River, IL, range between 36–43 mm during June, while southern WI specimens are 28 mm TL, by July specimen was 40 mm TL, 42–56 mm during August in southern WI, and 37–52 mm during September,[24] and Ohio specimens are 27–50 mm TL.[6] Young of one year collected during September 1983 were 35–46 mm TL in the upper Mississippi River, WI and MN.* The length–weight relationships of river darters from the Kaskaskia River, IL, was $\log W = -5.6099 + 3.3701 \log L$, while darters from southern WI are $-12.9628 + 3.3473 \log L$, where W is the weight is in g and total length is in millimeter.[13,24]

Feeding Habits

River darters feed throughout the daylight hours.*[,8] Juveniles and young feed primarily on microcrustaceans,[8] the predominant food items in the Kaskaskia River were midges and caddisflies,[13] some populations feed heavily on gastropods.[17] River darters feed on chironomids and Simulidae, Hydropsychidae, and copepods and cladocerans.[8] Larvae and juvenile river darters consume cladocerans and copepods.*

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* Original reproductive, early distribution, and growth information was obtained from adult and ichthyoplankton data collected by Large Rivers Research Station in the upper Mississippi River, Pool 7, WI, and Black River, WI, during 1981 to 1984. Developmental data are from a series obtained from the upper Mississippi River, WI (LRRC larval fish reference collection numbers). Original fecundity data are from specimens from the Ouchita River, Caldwell Parish, LA. These specimens are curated at Northeast Louisiana University, Museum of Zoology, Monroe, LA.

FRECKLEBELLY DARTER

Percina (Odontopholis) stictogaster Burr and Page

Percina: a small perch; *stictogaster*: black fin.

RANGE

Percina stictogaster is restricted to the middle and upper Green River system and portions of the upper Kentucky River system. In TN, the species is restricted to the Barren River system.[1–5]

HABITAT AND MOVEMENT

The blackfin darter occurs in upland streams of the Cumberland Plateau and central portions of the Highland Rim.[1–7] The species inhabits clear, rocky, silt-free flowing pools, back eddies, or riffle margins; often associated with beds of water willow tree roots, woody debris, or undercut banks.[5] In TN, it occurs in small rivers and larger creeks where it generally frequents pool areas with moderate to sluggish creeks and vegetation cover, such as water willow and riverweed, steep banks with brush and roots, and submerged leaf litter. It spends most of its time in the water column, hovering among current-swept vegetation or perched on suspended roots and woody debris.[5]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Percina stictogaster is generally distributed in the upper Barren, upper Green, and upper Kentucky Rivers from Red River upstream and including the South Fork. [1–5] There is one record for Rock Creek, Grayson County, KY. In TN, it is rarely collected occurring with records from West Fork Drakes Creek, Sumner County, and Salt Lick Creek, Macon County.[6,7]

SPAWNING

Location
Spawning occurs in fine gravel substrates.[4]

Season
Spawning occurs from mid-March to mid-April.[6]

Temperature
Spawning begins at temperatures of 12ºC.[4]

Fecundity
Females contain about 100–300 mature ova depending on their size.[5]

Sexual Maturity
Age 1 specimens are sexually mature. [11]

Spawning Act
Percina stictogaster is an egg burier. The male mounts the female in a classic burier manner and deposits eggs in deep depressions created by receptive females.[5]

EGGS

Description
Unknown.

Incubation
Eggs hatch in 240 h at undisclosed temperatures.[5]

Development
Unknown.

YOLK-SAC LARVAE

Size Range
Yolk-sac larvae hatch at 8.5 mm TL.[5]

Myomeres
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

POST YOLK-SAC LARVAE

Size Range
Unknown

Myomeres
Unknown

Morphology
Unknown

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown.

Fin Development
Larger juveniles. Spinous dorsal XI–XV; soft dorsal rays 11–13; pectoral rays 10–13; anal rays II 8–11; pelvic rays I 5; caudal fin rays 15–16.[2–4] Caudal fin slightly truncate.[4]

Morphology
Lateral scales 56–71, complete; cheek, nape, opercles, prepectoral area, and breast scaled. Modified mid-ventral scales lacking except for 1 or 2 between the pelvic fin bases. Premaxillary frenum present; gill membranes barely connected or separate. Vertebrae 42–45.[2–4]

Morphometry
Unknown.

Pigmentation
Larger juveniles. Dorsum of body brown with about 11 small saddles; anterior saddles form a continuous predorsal streak. Dorsolateral area with a vermiculate tan stripe. Lateral line lightly colored against nine large, wide, midlateral, interconnected black blotches. Lower head and body with brown mottlings which may form irregular horizontal stripes along belly. Suborbital bar weakly to moderately developed. Single midlateral caudal spot that is prominent and more darkly pigmented than the lateral band. Spinous dorsal fin with medial and distal black band, soft dorsal with three stripes that form in the median fin, and three stripes in the anal and caudal fins, pelvic fins with darkly spotted melanophores along the spine and scattered on membranes of rays.[2–4]

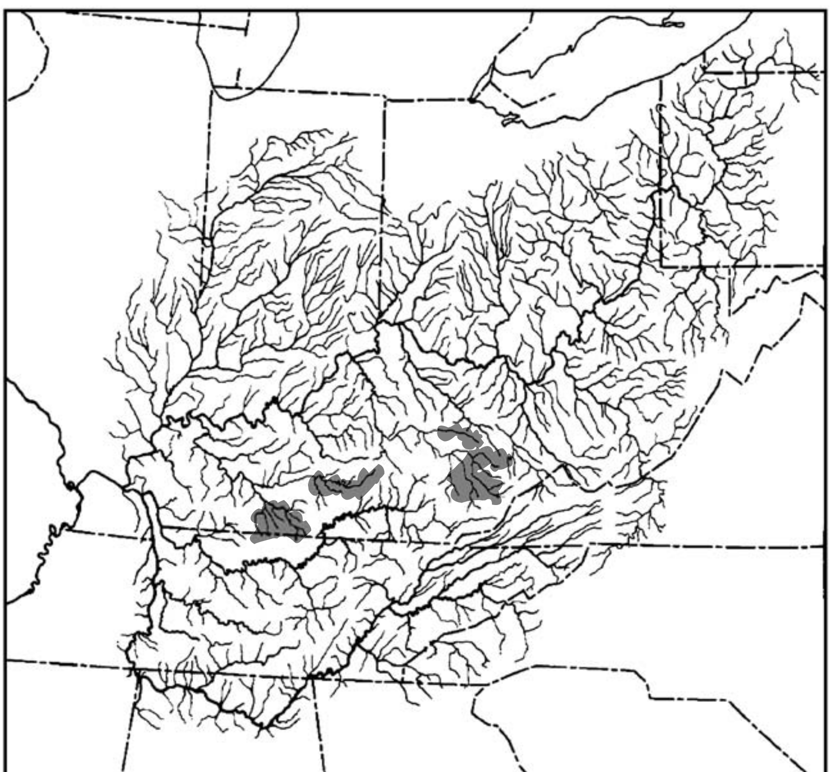

Figure 192 General distribution of freckleberry darter in the Ohio River system (shaded areas).

TAXONOMIC DIAGNOSIS OF YOUNG FRECKLEBELLY DARTER

Similar species: similar to *P. macrocephala*.

Adult. The blackfin darter differs from longhead darter by the presence of a complete covering of exposed scales on the gill cover, breast, and belly, which is absent in *P. macrocephala*.[4]

No information is available for young frecklebelly darter.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 192)
Eggs. Deposited in fine gravel.[4]

Yolk-sac larvae. Unknown.

Post yolk-sac larvae. Unknown.

Juveniles. Unknown.

Early Growth (Table 207)
Maximum life span is 4 years.[4]

Feeding Habits
Primarily diet includes midge larvae, mayfly, and stonefly nymphs, microcrustaceans, and amphipods.[4]

Table 207

Average calculated lengths (mm SL) of young frecklebelly darter in Tennessee.[4]

	Age			
State	**1**	**2**	**3**	**4**
Tennessee [4]	45	63	68	72

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SNAIL DARTER

Percina (Imostoma) tanasi Etnier

Percina: a small perch; *tanasi*: is the former capital of the Cherokee Nation which was located on the Little Tennessee River, which is the type locality. A derivation of this Cherokee place name is "Tennessee."

RANGE

Percina tanasi occurred in the main channel of the upper Tennessee River and lower reaches of major tributaries in TN.[1–7] The known distribution was the lower 24 km of the Little Tennessee River[5] and the main channel of the Tennessee River in upper Watts Bar Reservoir.[6]

HABITAT AND MOVEMENT

Percina tanasi is typically an inhabitant of large creeks where it frequents sand and gravel shoal areas and in deeper portions of rivers and reservoirs where current is present;[1–3] it only occurred to a limited extent in rubble habitats.[5,6] Current velocities ranged from 0.25 to 0.5 m/s at depths ranging from 0.2 to 1.5 m.[6] The snail darter is intolerant of siltation.[6] Migration is an important component of the snail darter life history with individuals known to move 27 km during the period of late June until late October.[5,6] Spawning migrations occur in early February with adult males moving from deeper areas of riffles to silt-free shallow areas; females follow a few days later and actually outnumber males on the spawning shoals.[6]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Impoundments fragmented the original range and restricted the snail darter population into adjacent headwaters of Watts Bar Reservoir below Fort Loudon Dam.[1–7] It was transplanted during 1976 into the lower Hiwassee River in attempts to preserve the species prior to impoundment of the Little Tennessee River by Tellico Dam, which occurred in 1979.[6] Another smaller transplant occurred in the Nolichucky River in 1975, but was abandoned when *Etheostoma acuticeps* was discovered.[6] New populations were found in 1981, which were represented by a few individuals that have been found in the Sequatchie River, Marion County, Little River, Blount County, lower French Broad River, Sevier County, and lower Paint Rock River, Madison County, AL.[3,7,8] A substantial population was found in the lower portion of Big Sewee Creek, Meigs Co., TN.[3,7,8]

SPAWNING

Location

Spawning occurs on shallow swift shoal areas consisting of sand and small gravel substrates; or at depths of 6 m; over silt-free sand interspersed with gravel with current velocities of 0.1–0.4 m/s.[5,6]

Season

Spawning occurs from February until mid-April, with eggs released with slight pressure in mid-February.[3,5,6]

Temperature

Spawning begins or occurs at temperatures of 6.5–11°C.[6]

Fecundity

Females contain an average of 600 mature ova.[3,5] Ovaries increase in size from 1.5 to 3.2 mm by October and attain sizes as much as 7 mm in diameter.[5] Five females held at the Morristown State Fish Hatchery spawned 1075 eggs in mid-March with about 51.9% being of questionable viability. Two females spawned between 173 and 524 eggs, and a female from the Hiwassee River (RM 36.9) spawned 110 eggs.*

Sexual Maturity

Adults live to reach age 3,[3,5,6] however, maturity is attained by age 1 at lengths between 50 and 55 mm

SL.[5,6] Males exhibit sexually dimorphic traits during the reproductive season with the development of an elongate anal fin with tubercles on each fin ray. Tubercles are also well developed on the cheek, breast, pelvic fin rays, lower caudal fin rays, and on the branchiostegals; additionally, scales of the cheeks, breast, and ventral portion of the body also bear tubercles.[3–6] Males undergo small changes in coloration developing green along the sides and iridescent turquoise blue patches in the branchiostegal region with yellow at the base of the pectoral, pelvic, and caudal fins. The dorsal saddle tends to darken during spawning and gold coloration is more interspersed on the back.[6] Males have a shorter and broadly conical genital papillae shape coming to a sharp or blunt point, while females have distended abdomens, an unscaled breast, a shorter anal fin, and a digitiform, more elongate and flaccid, and comparitively flattened tube that touches the base of the anal fin.*

Spawning Act

Percina tanasi is a burier.[5,6] Males moved to shoal areas and were joined by more females as the season progressed. Male courtship involves the following of females along the bottom and butting them on the caudal peduncle with their heads and stroking the females' backs with their pectoral fins.[3] Males were observed around cobble slightly elevated at one edge and situated over sand or sand-gravel. The male pushed his head beneath the rock edge and swam vigorously creating a small depression, which was then abandoned. These prespawning activities may be in preparation for female arrival on the spawning grounds.* The snail darter is an intermittent or fractional spawner with the females spawning many times during the season depositing eggs daily.* Field observations showed that a male and female were observed to lay parallel to each other facing the current. The male stroked the sides of the female's caudal peduncle with his pectoral fin. The female then vibrated, then was joined by the male which vibrated beside the female. The pair swam upstream stopping 4 to 5 times to repeat this act. Neither the male or female provide any parental care to either the eggs or larvae.[3,5,6,*]

EGGS

Description

Average egg diameters are 1.63 mm.[6] Yolk pale yellow in color, with a single oil globule, a moderate perivitelline space, and a translucent smooth egg chorion.[5] Fertilized eggs are translucent, spherical, and slightly adhesive, averaging 1.6 mm in diameter (range: 1.4–1.7 mm).[6] Three size classes of ova are observed in females including latent ova are ovoid, ranging between 0.2 and 0.22 mm in diameter, early maturing and late maturing ova were 0.82–0.94 mm, and mean ripe ova are 1.1 mm in diameter.*

Incubation

Hatching occurs in 320 h at incubation temperature between 5.5 and 14ºC;[*,6] or in 220 h at temperatures of 23ºC.[5]

Development

The blastodisc formation, embryonic axis formation, development of the somites, brain, and circulatory system was described.[5] Additional information was provided at different incubation temperatures. [6]

YOLK-SAC LARVAE

See Figure 193

Size Range

5.0–6.1 mm[6] at hatching, yolk absorption complete by eighth day posthatching (estimated as 8.0 mm).*

Myomeres

Predorsal myomeres 4; preanal 16 (7) or 17 (4) (mean = 16.5, N = 11); postanal 19 (3), 20 (5), or 21 (3) (mean = 19.9, N = 11); total 35 (1), 36 (7), 37 (1), or 38 (2) (mean = 36.4, N = 11).[6,*]

Morphology

5.0–6.1 mm TL. Body elongate, laterally compressed; stomodeum present with no functional mouth parts; head slightly deflected over the yolk sac; pale yellow translucent yolk; yolk-sac oval, tapering posteriorly; a single anterior oil globule; a single midventral vitelline vein is present; eyes spherical.[*,5,6]

6.8–7.4 mm TL. Eyes oblong; jaws developed.*

8.0 mm TL. Complete yolk absorption occurred.*

Morphometry

See Table 208.

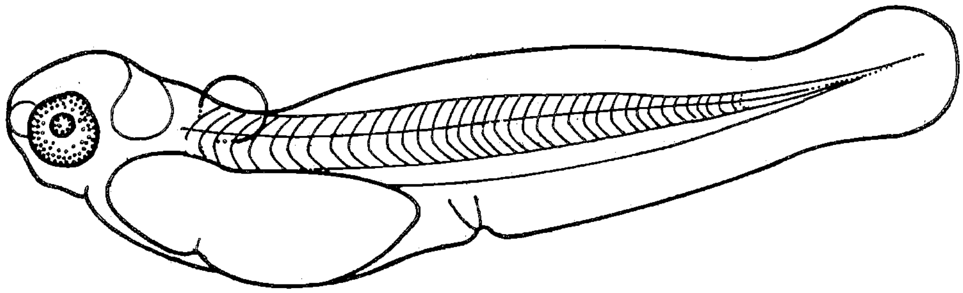

Figure 193 *Percina tanasi*, snail darter, 5.5 mm TL, yolk-sac larvae, lateral view. Little Tennessee River, TN, (From reference 6, U.S. TVA).

Fin Development
5.0–6.1 mm TL. Dorsal and anal finfolds complete, small pectoral buds; incipient rays absent from all median and paired fins.*[,5,6]

Pigmentation
5.0–6.1 mm TL. Eyes pigmented; sparse pigmentation scattered over ventral yolk sac. Chromatophores may be extending anteriorly on the heart region or posteriorly onto the finfold between the yolk sac and anus.

6.8–7.4 mm TL: Several large melanophores along the dorsal margin of the gut posterior to the yolk sac. Scattered stripe of melanophores from the anus to the base of the caudal fin.

POST YOLK-SAC LARVAE

Size Range
8.0 mm TL* to unknown length.[3,5,6]

Myomeres
Predorsal 4; preanal 16; postanal 20; 37 total myomeres.*

Morphology
8.0 mm TL. Yolk-sac absorbed.*

Morphometry
See Table 208.

Fin Development
8.0 mm TL. Incipient fin rays form in pectoral fin.*

Table 208

Morphometric data expressed as percentage of total length (TL) for young snail darters from the Little Tennessee River, TN.[6,*]

	Total length groupings	
TL Range (mm)	**5.5–7.2**	**8.0–8.2**
N	**11**	**5**
Ratios	**Mean ± SD**	**Mean ± SD**
SnL	3.1 ± 0.7	3.5 ± 0.7
ED	5.8 ± 0.5	5.7 ± 0.2
HL	16.4 ± 1.1	18.4 ± 1.4
HW	12.4 ± 1.0	12.8 ± 1.0
PreAL	49.7 ± 0.4	49.5 ± 0.6
PosAL	50.3 ± 0.4	50.5 ± 0.6
SL	97.6 + 1.0	94.8 ± 1.2
YSL	29.5 ± 0.9	
BDP1	20.7 ± 0.5	16.3 ± .0.3
BDA	6.7 ± 0.3	8.2 ± 0.9
MPosAD	5.3 ± 1.1	6.2 ± 0.4
CPD	3.4 ± 0.2	3.0 ± .0.3
YSD	15.4 ± 1.3	

Pigmentation
8.0 mm TL. Dorsal pigmentation consists of two chromatophores on cranium concentrated on optic lobe; scattered row of melanophores from the anus to the base of the caudal fin.*

JUVENILES

Size Range
Unknown length to 50–55 mm SL.[5,6,8]

Fin Development

Larger juveniles. Spinous dorsal VIII–XI; soft dorsal 12–14; pectoral rays 13–14; anal rays II 10–12; pelvic rays I 5; caudal rays ix–xiv, 8 + 7, x–xii.[1,6,8]

Morphology

Lateral scales 48–56; total vertebrae 39–41; branchiostegal rays 5.[5] Gill membranes separate. Opercles and nape fully scaled; cheeks typically with a few scales but ranging from naked to almost fully scaled. Breast and prepectoral area naked, but these areas with embedded scales in adults and occasionally with exposed scales.[3,4]

Morphometry

Unknown.

Pigmentation

Larger juveniles. Dorsum brown to brownish gray with traces of green. Back with four distinct dark brown saddles, which extends down and forward to contact the series of ten or more lateral blotches along the lateral line. Dark suborbital bar prominent. Rays of all fins are usually speckled, but pelvic and anal fins are occasionally clean.[3]

TAXONOMIC DIAGNOSIS OF YOUNG SNAIL DARTER

Similar species: other members of subgenus *Imostoma*.

Adult: Percina tanasi is similar to *P. vigil* and *E. blennius*. *Percina vigil* has a posterior border of the fourth dorsal saddle in advance of the anterior dorsal insertion of the caudal fin, *P. tanasi* has the posterior border which makes contact with the caudal fin. *Etheostoma blennius* has broadly connected gill membranes, a completely scaled belly covered with unmodified scales, and the most anterior dorsal saddle is in front of the dorsal fin. [3]

Larvae: Limited larval information is available for *P. vigil* and none for *E. blennius*.

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 194)

Eggs. Percina tanasi eggs are buried in coarse sand and gravel substrates in moderate current of riffles and runs.[3,5,6] Adults do not provide any protection or guard eggs after spawning.[1] Embryos develop in the darkness of interstitial spaces of clean sand. Survivorship from 1075 spawned eggs was 31 (2.4%).*

Yolk-sac larvae. Yolk-sac larvae are phototaxic, which is contrary to other members of the *Imostoma* subgenus. Yolk-sac larvae were observed in drift collections when water temperatures approached 11ºC. Yolk-sac larvae were more abundant in surface drift collections from the main channel of the Little Tennessee River than at mid- and bottom depths.* The largest proportion of larvae were collected during drift collections in March.*

Post yolk-sac larvae. Snail darter larvae were collected in drift samples from late February until late March.* Individuals drift downstream from the spawning shoals for considerable distances before becoming benthic. Larvae swim into the water column and drift several kilometers downstream into Watts Bar Reservoir where they spend their postlarval nursery period. A single snail darter was collected from an area about 16 km below Tellico Dam at the Harrison Island area (TRM 591) in Watts Bar Reservoir.[5,6]

Juveniles. Early juveniles begin to migrate back upstream toward the spawning shoal areas in the Little Tennessee River; however, upstream migration is now prevented by the closure of the Tellico Dam.[6] Average density of snail darters is 1.4 individuals/ m^2 in preferred habitats.[6]

Early Growth

Percina tanasi survives to age 3 with a few individuals reaching age 4.[3] Snail darters attain lengths of 40 mm by late summer and begin to migrate upstream to the spawning grounds.[5,6] The length–weight relationships of snail darters from the Little Tennessee River was, log $W = + 5.9148 + 3.5134$ log TL.[6]

Feeding Habits

Snail darter feed throughout the daylight hours.[5,6] The diet is primarily gastropods (66%) with *Anculosa*

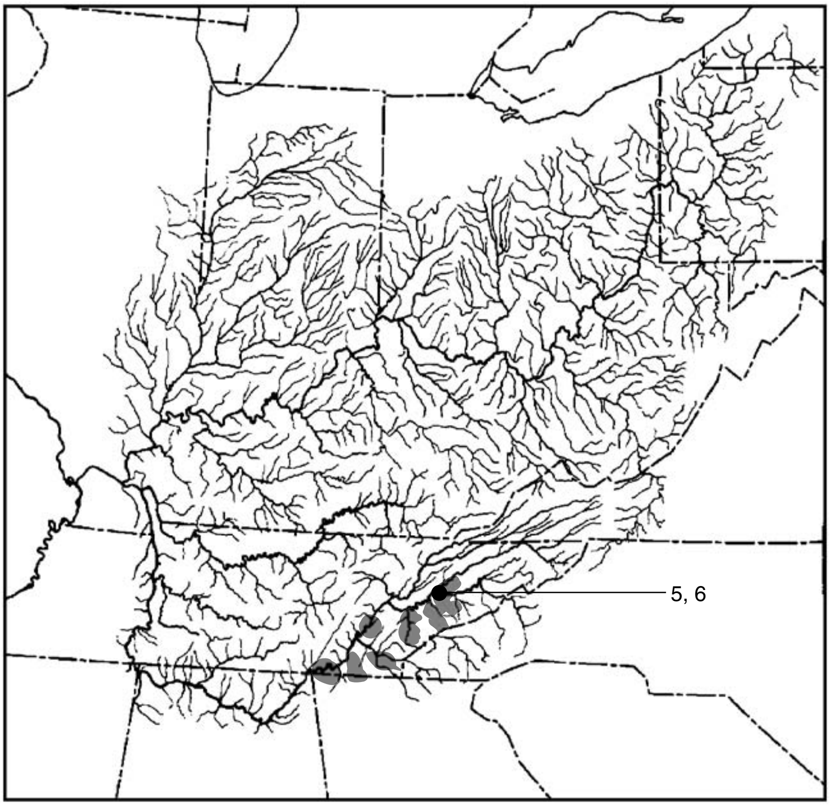

Figure 194 General distribution of snail darter in the Ohio River system (shaded areas) and areas where early life history information has been collected (circles). Numbers indicate appropriate reference.

Table 209

Average calculated lengths (mm SL) of young snail darters in Tennessee.[3]

	Age		
State	**1**	**2**	**3**
Tennessee[3]	55	65–70	80 +

and *Physa* being of greatest importance, midges mostly chironomid and *Simulium* (23%), and caddisflies (8%), and fish eggs (2%).[3,5,6] Additional food items include mayfly naiads and coleopterans.[6] Juveniles and young feeding preferences could not be determined.[5,6]

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* Original reproductive, early distribution, and growth information was obtained from adult and ichthyoplankton data collected by Tennessee Valley Authority in the lower Little Tennessee River above Watts Bar Reservoir, during 1976–1981. Developmental data are from a series obtained from the Little Tennessee River, TN (TVA larval fish reference collection).

SADDLEBACK DARTER

Percina (Imostoma) vigil (Hay)

Percina: a small perch; *vigil:* wide awake.

RANGE

Gulf slope from Escambia River, FL and AL; west to Lake Pontchartrain, LA; north on east side of Mississippi River to central Tennessee River and small Mississippi River tributaries in western KY; west of the Mississippi River from lowland ditches in southeast MO; south to Red River system in northern LA; North to the Green River, KY, and Wabash River, IN.[1–3]

HABITAT AND MOVEMENT

The saddleback darter inhabits larger streams and rivers having moderate current.[1,*] Common to abundant in gravel and sand-gravel bottomed riffles and runs. Rarely found in pools or quiet waters and avoids silted areas. Substrates reported to be primarily gravels or rubbles, often near boulders.[1–3] Occupies riffles and shoals of moderate to rapid currents in association with gravel-strewn clay, sand mixed with gravels, or gravel substrates.[5] The saddleback darter is tolerant of turbid waters;[2,7] but not tolerant of silt.[9]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Occasional and locally common in KY from the Obion Creek, Bayou du Chien, Clarks River, and Blood River. Occasional to sporadic and locally common in the main channels of the Green and Mud rivers. Considered extirpated from the Green River, KY. A single preimpoundment record is available from Jonathan Creek, Marshall Co., KY; reported from 1892 from the Rough River, Ohio Co., KY.[5] In TN, they are widespread and fairly common in suitable habitats in lower Tennessee River tributaries.[6] Extirpated from the Wabash River, IN and IL;* but collected from extreme southern IN from the Wabash River near New Harmony, Posey Co., and Vincennes, Knox Co., IN, in the late 1890s.[*,7] Collected from the Tennessee River drainage of AL.[12]

SPAWNING

Location
Deposited in sand and gravel shoals in Little Escambia Creek, AL.[12]

Season
Spawning occurs during early February based on the presence of breeding tubercles in Pearl River, MS;[4] February in AR;[11] in the Homochitto River, MS, and Little Escambia Creek, AL, from February to April;[8,10] extends into April in TN;[6] postulated breeding season from April to June.[9]

Temperature
12–22°C.[8]

Fecundity (see Table 210)
Relative clutch mass is not correlated with standard length of females in MS.[8] Females 41.3–54.7 mm SL averaged clutch sizes of 142 ova in March and 194 ova in April from the Homochitto River near Union Church, and 296 ova in February from the Homochitto River near Bude, MS.[8] Mature females from the Homochitto River, MS, had ovaries that were 9.1% of the body weight. Clutch sizes ranged between 142 and 296 ova in MS. Females having more ova or attaining larger sizes bore more mature ova.[8] Total fecundity of females ranged between 45 and 65 mm TL from Trout Creek (Ouchita River drainage), La Salle Parish, LA, were 1212–2146 oocytes.*

Sexual Maturity
Specimens in TN are 35–50 mm TL at age 1 and many of these are sexually mature.[6] The smallest adult male that is sexually mature is 42.6 mm SL; the smallest adult female was 41.3 mm SL. Two females attained lengths of 42.6 and 48.2 mm SL in their first year of life but were immature. Almost all *P. vigil* spawn during the reproductive season following hatching.[8] Males develop elongate anal fin lengths[6,8] and nuptial tubercles over the entire body.[8] Males remain tuberculate from October to April and have large elongate anal fins. During peak development in February and March, tubercles are so widespread as to be exceeded by only

TABLE 210

Ovarian and fecundity data for saddleback darters from the Homochitto River, MS.[8]

Date	*N*	Percent Occurrence of Ova: Ripening Oocytes (LA)	Mature Oocytes (EM, MA, LM)	Ripe Eggs (MR, RE)	Average Egg Diameter (mm)
October	87	100	—	—	0.18
November	81	72	28	—	0.26
December	66	0	100	—	0.33
January	15	0	100	—	0.40
February	5	0	100	—	0.60
March	39	0	90	10	0.76
April	14	0	100	0	0.74
May	15	100	0	0	0.15
June	29	100	0	0	0.12

P. evides among all darters. Tubercles are present on every ventral body scale, on lower half to three quarters of each anal fin ray, and on ventral surface of each pelvic ray and pelvic spine. Ventral caudal fin rays are tuberculate, as are ventral 2–5 pectoral rays. Additional tubercles occur on breast, infraorbital and preoperculomandibular canals, cheek, opercle, lower jaw and branchiostegal rays.[2,11] Male genital papillae is a short flattened tube with lateral grooves and terminal papillae. Breeding females have enlarged abdomens, smaller anal fin lengths, and an elongate genital papillae tube.[2]

Spawning Act
Unknown. Assumed to be similar to *P. shumardi*. The sex ratio was 1:1 in the Homochitto River, MS.[8]

EGGS

Description
Large mature oocytes are spherical, with glossy tangerine orange yolk. Ripe oocyctes range between 0.76 and 1.0 mm in diameter.*

Incubation
Unknown.

Development
Unknown.

YOLK–SAC LARVAE

See Figure 195

Size Range
Tallapoosa River, AL, yolk-sac specimens are 6.2–7.1 mm TL, while in Cahaba River, AL, yolk-sac larval specimens were 6.0–6.8 mm TL.[13]

Myomeres
Preanal 18–19, postanal 21–22, total 21–22.[13]

Morphology
6.2–7.1 mm TL. Weakly developed stomodeum.*

Morphometry
6.2–7.1 mm TL. Snout length/HL: 16.7%; eye diameter/HL: 41.7%; head length/TL: 17.2% ; preanal length/TL: 51.7%; postanal length/TL: 48.3%; standard length/TL: 96.1%; pectoral fin length/TL: 7.4%; head depth/TL: 15.7%; anal depth/TL: 8.3%; mid-postanal depth/TL: 5.9%; and caudal peduncle depth/TL: 2.9%.[13,*]

Fin Development
6.2–7.1 mm TL. Median finfolds present with weakly developed pectoral fin.*

Pigmentation
6.2–7.1 mm TL. Pigmentation is present as scattered melanophores on the oil globule and ventral yolk

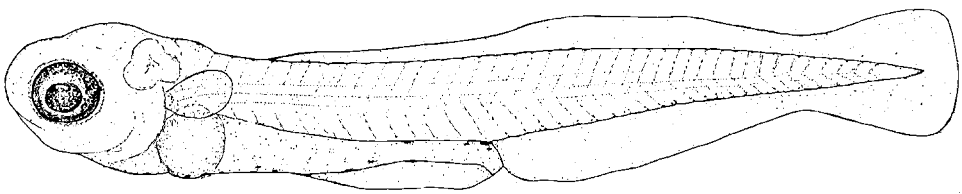

Figure 195 *Percina vigil*, saddleback darter, Tallapoosa River, AL. Yolk-sac larva, 7.1 mm TL, lateral view. (Redrawn from reference 13, with author's permission.)

sac. There are several small melanophores on the dorsal gut, and large stellate melanophores on the dorsal anus. A row of melanophores extends ventrally from the anus to the caudal peduncle.[13]

POST YOLK-SAC LARVAE

Size Range
Unknown.

Mymers
Unknown.

Morphology
Unknown.

Morphometry
Unknown.

Fin Development
Unknown.

Pigmentation
Unknown.

JUVENILES

Size Range
Unknown length to 35–50 mm TL.[6]

Fins
Larger juveniles. Spinous dorsal IX-XII; soft dorsal 12–15; pectoral rays 14–15; anal rays II 10–11; pelvic rays I 5.[2–4,6] Caudal fin emarginate to slightly notched.

Morphology
Lateral scales 48–59, complete; frenum present; gill membranes moderately connected. Branchiostegal membranes moderately or broadly united, 6,6. The cheek may support exposed scales or only a few embedded scales; nape and opercle are scaled; breast and belly are naked.[2–4,6] Modified mid-ventral scales present in males.[4] Vertebrae 38–40.[2,3]

Morphometry
Unknown.

Pigmentation
Larger juveniles. Suborbital and preorbital bar well developed. Dorsum of body is straw colored with four broad dark saddles that are often indistinct. Eight or nine blotches occur along the mid-lateral and are connected by a mid-lateral stripe. Spinous dorsal fin with narrow dark marginal and broader basal dark bands separated by a clear area. Soft dorsal and caudal fins with brown markings on rays, all other fins clear.[2,3,6]

TAXONOMIC DIAGNOSIS OF YOUNG SADDLEBACK DARTERS

Similar species: similar to other members of subgenus *Imostoma*.

Percina vigil differs from *P. shumardi* by lacking the presence of the obliquely rising melanophore stripe in the postanal myomeres. *Percina vigil* has the same number of preanal myomeres (18–19) as *P. shumardi*, but has fewer (21–22) postanal myomeres than *P. shumardi* (22–26). Similarly, it differs from *P. tanasi* by the presence of postanal melanophores along every postanal myoseptum, which *Percina tanasi* does not possess. *Percina vigil* has a greater number of preanal myomeres (18–19) than *P.tanasi* (16–17), and usually fewer postanal myomeres (21–22) than *P. tanasi* (19–21).*

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 196)

Eggs. Laid in shallow margins of streams and buried in gravel.[12]

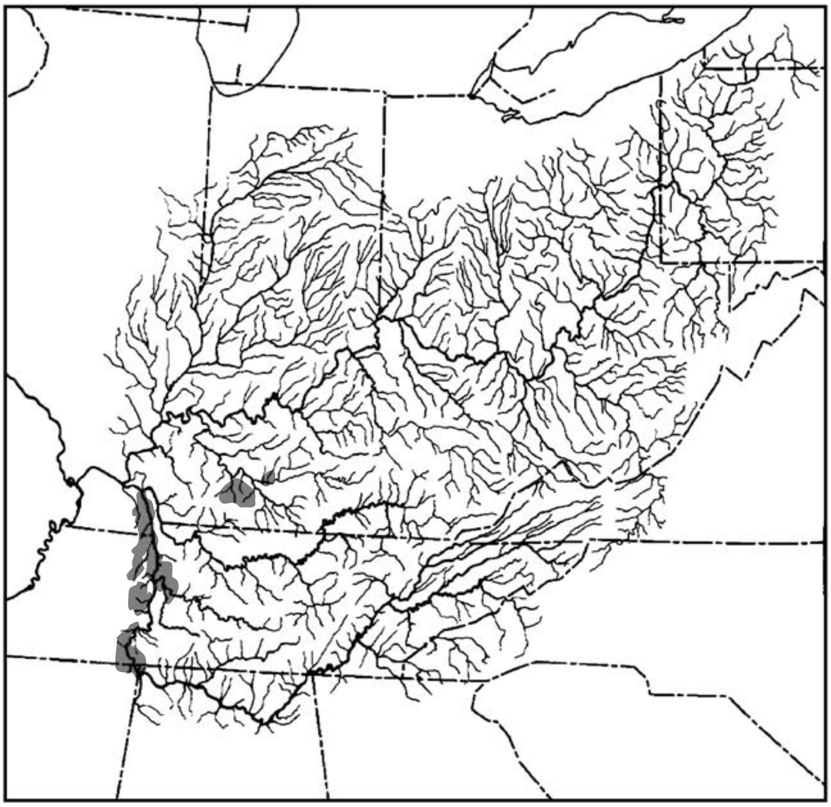

Figure 196 General distribution of saddleback darter in the Ohio River system (shaded areas).

Yolk-sac larvae. Yolk-sac larvae were collected from surface drift in the Cache River, Black Swamp Wildlife Management Area, AR.* They were collected from drift samples from mid- to late March in the Cahaba River and Tallapoosa River, AL.[13]

Post yolk-sac larvae. Larvae were collected from surface drift in the Cache River, Black Swamp Wildlife Management Area, AR.* Specimens were capable of swimming actively.*

Juveniles. Occur in moderate-sized creeks, the only juvenile captured outside a principal river.[2]

Early Growth

Young-of-the-year from TN are 35–50 mm TL after the first years growth and reaches 55–60 mm TL at age 2 (Table 211).[6] In the Homochitto River, MS, specimens captured in July averaged 36.5 mm SL, September averaged 41.2 mm SL, at age 1 specimens were 46.2 mm SL, and at age 2 they were 47.9 mm SL.[8] At the onset of maturation, male saddleback darters grew faster than females probably as a result of more energy expenditure being targeted toward production of ova.[8] Length–weight relationships of saddleback darters are log $W = -12.141 + 3.174$ log (SL) for males, log $W = -10.179 + 2.629$ log (SL) for females, and log $W = -12.045 + 3.149$ log (SL) for juveniles, where weight is in g and standard length is in mm.[8]

Table 211

Average calculated lengths (mm) of young saddleback darters in Mississippi and Tennessee.

	Age	
State	**1**	**2**
Mississippi[8] (SL)	46.2 (46–52)	47.9 (52–60)
Tennessee[4] (TL)	35–50	55–60

Feeding Habits

Juveniles and young adults from the Current River, AR, feed on the immature stages of aquatic insects and microcrustaceans, but other populations feed on limpets and snails.[13] In OK, it is reported that they consumed primarily hydropsychids, simuliids, chironomids, and baetid mayfly nymphs.

Crustaceans are rarely consumed. In Escambia Creek, AL, fall diets are almost exclusively caddisfly larvae (*Cheumatopsyche* and *Oxyethira*), while summer diets include beetles, mayflies, and stoneflies.[12] Duck River, TN, specimens feed mostly on pleurocerid river snails. In addition, a variety of aquatic insects included in the diet are hydropsychid caddisflies larvae, midge larvae, and baetid mayfly nymphs.[6]

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* Original reproductive, early distribution, and growth information was obtained from ichthyoplankton data collected by Robert Wallus and the U.S. Army Corps of Engineers in the Cache River, Black Swamp Wildlife Management Area, AR during 1993–1994. Developmental data are from a series obtained from the Cache River, AR (LRRC larval fish reference collection). Original fecundity data from Trout Creek, La Salle Parish, LA is from specimens curated by Northeast Louisiana University, Museum of Zoology, Monroe, LA.

GENUS
Perca Linnaeus

Robert Wallus

The genus *Perca* is circumpolar in distribution and comprises three extant species: *P. fluviatilis*, *P. schrenki*, and *P. flavescens* (Collette and Banarescu, 1977). Yellow perch *P. flavescens* occur over the same latitudinal range as the Eurasian *P. fluviatilis*. These two species combined have an almost circumpolar distribution in the freshwaters (and rarely in brackish waters) of the northern hemisphere. The native distribution of yellow perch in North America includes waters of the Ohio River drainage.

Svetovidov and Dorofeeva (1963) considered the Eurasian and North American perches to be conspecific. Mansueti (1964) compared the ontogenetic development of larval and juvenile stages of *P. fluviatilis* (Konstantinov, 1957) and *P. flavescens* based on descriptions and illustrations and concluded that the similarities through all stages, both in morphometry and size, overwhelmingly supports the theory that the two may be conspecific. After reviewing published morphological data and comparing biological characteristics, such as time of spawning, temperature at spawning, fecundity, and growth, Thorpe (1977) concluded that there are no biological reasons to maintain *P. flavescens* and *P. fluviatilis* as separate species. Collette and Banarescu (1977) disagreed with this conclusion and suggested that differences in dorsal fin skeletal structure and characters proposed by other researchers are evidences that *P. flavescens* must be maintained as a separate and valid species.

Yellow perch inhabit a large geographic area, a wide variety of habitats, are schooling fish, and congregate near the shores in the spring. All these factors make them readily available to fishermen, both to commercial and recreational. They are active feeders year-round, so they can be angled during summer and winter. Their flesh is white, flaky, delicious, and popular, especially in northern areas of their distribution (Scott and Crossman, 1973; Emery, 1976). This species also serves a valuable ecological function as an important converter of invertebrate foods into a form suitable for ingestion by terminal predators, such as sauger, walleye, and pike. Parallel fluctuations of yellow perch and their predators have been reported (Thorpe, 1977).

Adult characteristics of this genus are a rather deep, slab-sided (nearly sunfish-shaped) body; two separate dorsal fins, the first with 11–15 spines, the second with 1–2 spines and 12–16 rays; a moderately large, terminal mouth, the upper jaw extending posteriorly to about the middle of the eye; jaws and roof of mouth with teeth, small and inconspicuous; opercular spine present; rear margin of the preopercle saw-toothed (serrate); anal fin with two spines and 6–8 soft rays; principal caudal rays 17; branchiostegal rays 7 (6–8); gill rakers about 20, length of the longest rakers about 6 to 8 times their basal width; exposed scales cover the body, including breast, belly, nape, cheeks, and dorsal portions of opercles. A prominent blotch is usually present in the posterior membranes of the spinous dorsal fin and distinctive dark bands of pigment (6–8) are regularly spaced across the back and laterally onto the sides (Etnier and Starnes, 1993; Jenkins and Burkhead, 1994; Pflieger, 1975).

YELLOW PERCH

Perca flavescens (Mitchill)

Perca: a perch; *flavescens*: yellowish.

RANGE

Yellow perch occur in North America from Nova Scotia, south along the Atlantic coast apparently to the FL panhandle and AL; west on the west side of the Appalachian Mountains from PA to upper MO; from eastern KS northwest to MT; north to Great Slave Lake; southeast to James Bay, Quebec, and New Brunswick.[1,2,4] Mountain ranges prevent natural range extension westward in North America.[3]

Yellow perch, like all percids, are temperate mesothermal fish. This physiological characteristic together with osmoregulatory capacity and swimming performance is shown to limit their range.[5,6] However, their range continues to expand in North America.[1,2,4] This species has been introduced into almost all the states to the west and south of its natural range,[1] and in 1978, the distribution of yellow perch as a percentage of total freshwater area in North America was 26%.[4] The 1978 report also indicated that in the previous 20 years yellow perch range had been expanding in the northeastern states, especially northward in ME.[4]

HABITAT AND MOVEMENT

Yellow perch are adaptable and able to utilize a wide variety of warm and cool water habitats.[1,7–9] They inhabit streams, lakes (big and small), reservoirs, ponds, and swamps.[1,2,8,10–12] In flowing water they are encountered in slow, medium, and fast current.[9] However, they reportedly prefer quiet water habitats such as backwaters, sloughs, embayments, and clear pools of rivers and streams.[7–9,12–15] In northern states they are reported as not being abundant in small streams.[9] They are most abundant in the open, clear waters of lakes, including deep areas and inshore shallow areas.[1,10,13,16,17]

Abundance of yellow perch was low in the Missouri River before impoundments, but as reservoirs filled, ideal spawning conditions were created, and strong year-classes were produced. After the reservoirs were filled, spawning habitat deteriorated and strong year-classes were produced only in the years of high water. They eventually became most abundant in sections of the reservoirs that tended to be shallow and productive and least abundant in those areas that were deep and less productive or river-like.[11]

Yellow perch are often associated with shallow or deep rooted aquatic vegetation[1,2,7–10,12,14,16,17] over bottoms of muck, sand, gravel, organic debris, or mixes thereof.[1,10] Their number decreases in a body of water in which vegetation decreases.[1,10]

Yellow perch are considered a shallow-water species.[1,10,17] They are usually not reported below 9.2 m (30 ft), but have been captured as deep as 45.7 m (150 ft).[1] They are reported common throughout the Great Lakes to depths at least as great as 25 fathoms.[18] They concentrate in open water 2 to 5 m deep in early summer, and in weedy, shallow areas in late summer, but they are thinly dispersed along the shoreline at all times.[16] Schools or small groups roam in shallow areas among vegetation and other cover during warm months; in winter, they retreat to deep, more open areas.[8] Yellow perch in lakes are mainly demersal, although some occupy midlevels in the summer. They often concentrate in a relatively small interval within the depth ranges reported, and depths of greatest abundance may shift rapidly as bottom temperatures fluctuate.[20] In WI, during summer daylight hours, yellow perch swim in large schools at depths between 8 and 11 m below the surface. At sundown they move inshore and swim along the 6-m contour until sunset. The school then disperses and the fish settle to the sandy bottom and become motionless after dark. At daybreak, they rise, congregate back into schools, and, shortly after sunrise, move back into deeper water. In winter, they often inhabit the deepest parts of the lake.[9] Large individuals are typically found in deeper water and will move into anoxic water to feed.[12] Expanded range in littoral areas may result from food availability, preferred light, or population pressure.[19]

Temperature determines the depths to which yellow perch will go. In Lake Huron, they commonly range down to the thermocline, going deepest in warm years and in the fall during turnover.[21] Their habitat extends throughout in the rivers and lakes that are not strongly stratified in summer; large surface area has little constraint on distribution. In thermally stratified lakes, habitat may be bound by the intersection of the thermocline and the substrate.[22]

Yellow perch are classified as temperate-zone mesotherms.[23,24] Their particular cool-water niche segregates them in space from many other species and results in reduced species interactions.[23] In nature, they are usually found in water temperatures of 19 to 21°C.[1] The reported natural temperature range is 6.7 to 25°C.[12] In WI, they are generally reported from water temperatures between 11 and 22°C.[9] Seasonal vertical movements suggest that they move to follow the 20°C isotherm.[1] Temperature preferences have been experimentally determined at 21–24°C,[1] 19.7–21.2°C for northern populations,[25] and 19.7–29°C,[26] with laboratory reports of 7–14°C in winter, 13–16°C in spring, 21–27°C in summer, and 19.9–25°C in fall.[25] Physiological optima is 25°C. They produce viable ova at temperatures between 3.9 and 18.6°C, but a winter minimum of 10°C is near the upper limit for maturation of gonads.[26] The upper thermal limit is reported between 26.5 and 33°C.[6,12]

Although yellow perch are reported to prefer clear water,[1,7,10] they occupy waters which vary considerably in color, turbidity, pH, and productivity.[8] They are reported from water of moderate fertility.[9,14] They are also reported intolerant of turbidity and siltation. In the upper Mississippi River, yellow perch are found in backwater areas where turbidity is low and current reduced.[15] Their number decreases in a body of water in which turbidity increases.[1,10] They are thought to be more tolerant of the detrimental effects of eutrophication than sauger and walleye.[19] They are tolerant of low dissolved oxygen levels.[9] The limiting concentration of dissolved oxygen for survival is reported to be 0.4–0.9 ppm at 15.5°C and 2.25 ppm at 20–25°C.[3]

Yellow perch is considered a freshwater species, but it enters brackish water along the Eastern Seaboard,[1–3,8,12,27,31–33] and is reported from saline lakes in the Prairies (to 10,300 ppm total dissolved solid).[1] There are records of captures from salinities as high as 6.3 ppt in the shore zone of the Delaware estuary. They have been found at salinities up to 10 ppt in the tidal creeks of the lower Delaware River[27] and at 12.94 ppt in the Chesapeake Bay area.[12]

Yellow perch are active fish. There are migratory movements in the spring, movements inshore and out, up and down over the day, and seasonal movements out of and into deeper water in response to temperature and, probably, to the distribution of food. They are active all through the winter under ice, in shallow water or deeper water.[1]

Seasonal migration from deep-water areas to shallow-water spawning areas in spring is characteristic.[3] Migrations into shallows of lakes and into tributary rivers to spawn are reported.[1,3,12,28,34,35] They are documented moving as far as 40 km out of a lake and up a river to spawn.[28] In the Fox River, a tributary to Lake Winnebago, WI, migrations started in late March or early April, beginning, in three out of 6 years of study, before the ice broke up on the lake.[28] No pronounced downstream migration was observed after spawning in the Fox River. Most fish tagged were recaptured within a few km of the tagging area, however a few fish traveled as far as 64–81 km.[28] Homing to an upriver site on the Fox River was suggested by a high proportion of yellow perch marked and recaptured in subsequent years. The recapture rate was as high as 85%. Another study on Oneida Lake, NY also found strong homing tendencies among spawning perch.[28] Coastal populations move up the tidal and nontidal tributaries to spawn.[8,27,32,33]

Seasonal movements other than spawning migrations are reported. Seasonal vertical movements suggest that yellow perch move to follow the 20°C isotherm.[1] There is a general tendency for them to move to deeper water in winter, but they remain active under the ice.[1] In winter, schools are less compact than in summer.[1,12] In winter they often inhabit the deepest parts of lakes.[9]

Diurnal movements of yellow perch are reported, with schools moving both upward and inshore at night.[1,3,12] They are gregarious, often traveling in schools[3,8,9,14] by day, stratified by size and age; these schools disperse at evening twilight and reform at morning twilight. They are active diurnally all seasons, but their level of activity increases with the increase in water temperature. Regular movement from a nocturnal resting area to a diurnal active area is reported.[3] In MI and IA, they are reported to be more active in the daytime and more were caught in the afternoon than in the morning. Other reports found little evidence of change in activity at different times of the day, except for a moderate tendency to be nearer the water surface at night.[29]

During a 4-year mark-recapture study on the Fox River, WI, yellow perch averaged moving 7 km/day. The minimum rate of movement for angler-caught fish averaged 3.7 km/day (range, 1.3 to 11.3 km/day). The greatest movement was reported for a 180 mm male that traveled 33.8 km in 3 days.[28] Other than diurnal movements, in-lake movement is often restricted and may lead to discrete local populations, but a yellow perch is reported moving 57 miles in a lake.[3]

In some northern waters, yellow perch populations have been affected by exploitation, eutrophication, and the presence and proliferation of colonizing fish species. In 1977, yellow perch was the most abundant fish species in Lake Erie and was reported experiencing irregularity in recruitment, lack of strong year-classes, and increased exploitation.[30]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

There are records of yellow perch in the upper two-thirds of the Ohio River (ORM 0-654) dating from 1800 to 1969, and after 1970, they were reported from the lower third of the river (ORM 655-981).[37] They probably found their way from the Great Lakes to the upper Ohio River through the many connecting canals constructed before 1825.[10,36] They are considered sporadic and rare in the main channel from the mouth of the Big Sandy River downstream to the Cumberland River.[7] Reports from the upper Ohio River in the late 1970s indicated a reproducing population.[36] During the period 1973 to 1985, they were collected near five electric generating plants located on the upper and middle Ohio River. They were statistically more abundant in the upper third of the river.[38]

In NY, they are present in the Allegheny River.[14] In VA, they have been introduced into the New River.[8] They were accidentally introduced into the Tennessee River system in NC. They appeared in upstream reservoirs of the Hiwassee River as early as the 1950s, probably introduced along with walleye,[39] and first appeared downstream in the Tennessee River, TN, in 1968.[2] In 1974, they were reported as rare in the Hiwassee and Pigeon rivers in NC,[40] but are now considered common in the lower Hiwassee River.[2] They rapidly dispersed into impoundments along the Tennessee River downstream as far as the Pickwick Reservoir in 1987 and Big Sandy River in 1988, and upstream through Fort Loudon, Melton Hill, and presumably Tellico reservoirs. Except for the invasion of major tributaries, further dispersal upstream in the Tennessee River system, should be prevented by impassible dams (barring unauthorized introductions). They are not highly abundant in TN, but may become so.[2] In AL, they are present in reservoirs and tributaries of the Tennessee River.[41]

SPAWNING

Location

Yellow perch are classified as nonguarding, open-substrate spawners in the phytolithophil guild, but they may be part of a separate guild because of the special structure of their egg mass. Their eggs are not deposited individually, but in long gelatinous ribbons with a system of interior passages and a special water-pumping arrangement enhanced by the vibratory consistency of the whole egg mass. Clearly these gelatinous ribbons have a protective significance with a special solution to oxygen supply.[42] They are annual spawners that lay all their eggs at one time in the spring.[26]

Yellow perch make spawning migrations into the near shore shallows of lakes[1,8,12,26,28,34,35] and often into lake tributary waters.[1,12,28] Coastal Plain populations move into tidal and nontidal water to spawn[1,8,27,32,33] or the upper reaches of major tributaries.[12] These brackish water fish may spawn in salinities up to 2.5 ppt.[31] Spawning is usually associated with or near rooted aquatic vegetation[1,2,8,12,14,28,35] or submerged brush, roots, fallen trees, pilings, logs, or debris[1,2,8,12,14,28,35] over substrates of sand, gravel, rubble, rock, detritus or mixtures thereof.[1,2,8,12,14,28,35] Spawning is also reported in rocky trenches with hard clay shoals.[35] Reports of spawning depth vary from 0.6 to 12.0 m,[35] but most spawn in water between 0.5 and 3.0 m deep.[12,14,24,32,33,35] Spawning occurs typically at night[3,8,43] or in daytime.[3] It has been suggested that either photoperiod or temperature is the proximate determinant of the onset of spawning.[3] A recent study suggests that conflicting pressures of ultraviolet radiation and temperature create an optimal spawning-depth range for yellow perch that differs among lakes as a function of dissolved organic carbon.[73] Their relatively unspecialized requirements for spawning substrate allow yellow perch to use almost all slow-moving or static waters within their geographical range.[24]

Season

Generally, yellow perch start spawning at a lower temperature and later date as latitude increases.[3] Over their entire range, spawning is usually reported from February through June,[3] but may extend into July in some northern waters.[1,12,24,44] In northern waters they are often ready to spawn by the time the ice goes out or shortly after.[9,17,43] Coastal populations spawn from late February into April,[12,27,31–33] with peaks in mid-March in the Chesapeake Bay area.[31,32] Their spawning season is early April to late June in the Great Lakes.[9,35,44,45] Other reports put the spawning season from late March through May.[1,2,9,11,12,14,28,43,46] Peak spawning in the Missouri River, ND and SD, is reported as late April or early May.[11,46] They spawn in April and May in NY; mid-April in NH; April in IL; May in MN;[12] early February through March in NC.[39] The spawning season may be short, lasting only 0.7–3.0 weeks.[17,27,33,45]

Temperature

Temperatures at which yellow perch start spawning are generally lower as latitude increases.[3] A wide range of spawning temperatures is reported. Reports over entire range include 4–19°C[26] and 5.6–14°C[3] with many given between 8.9 and 12.2° C.[1,14,15,17,28,43] In laboratory studies, 80 percent of all viable spawnings were produced at temperatures from 6.2 to 16°C; gamete viability was highest at 8–11°C.[26] Populations in the Chesapeake Bay area spawned in water temperatures between 5 and 13°C, with peak spawning between 8.5 and 11°C.[12,31]

In the Severn River, Chesapeake tributary, yellow perch first appeared on the spawning grounds at water temperatures of 3.9–6.7°C; first spawning was observed in water at 6.7°C; the peak came in water 5.6–7.2°C.[32] In the Delaware estuary water temperatures at spawning ranged from 6.8 to 12.5°C.[27] The overall range of water temperatures for spawning reported for the Great Lakes basin was 5.6–18.5°C.[35] In a 6-year study on the Fox River, WI, the overall water temperature range for spawning was 0.6–15.6°C. The mean spawning range was 5.0–8.6°C and spawning peaked between 7.1 and 12.9°C over the 6 years. Spawning occurred under general rising water temperatures, although temperature fluctuations were numerous. Protracted spawning seasons occurred (19 and 20 days) and coincided with marked drops in temperature after spawning had started, when daily water temperatures steadily declined for 11 days reaching a low of 1.7°C.[28] In the Missouri River, ND and SD, a report indicated that water temperatures during spawning ranged from 8 to 13°C with a peak at 10°C,[11] while another 6-year study reported peak spawning between 8.7 and 9.6°C, each year after a sudden temperature rise.[46]

Fecundity

Fecundity of yellow perch varies between localities with an overall reported range of 950–210,000 eggs.[1,3,9,12,24,28,35] The total number of eggs increases with the size of the female.[1,9] Reports include: in MD, 36,600–109,00 eggs for fish 147–254 mm;[1] in Lake Ontario, 3,035 eggs for an age 2 female 135 mm FL (27 g) and 61,465 eggs for an age 8 female 257 mm FL (308 g);[1,28] in Lake Michigan, 10,654 eggs for an age 2 female 190 mm (82 g) and 157,594 eggs for an age 6 female 354 mm (678 g);[28] in WI, 4,200 eggs for an age 2 female 132 mm (28 g) and 121,000 eggs for an age 7 female 305 mm (542 g).[9,28] In WI, the average number of eggs per ovarian unit was 35,400. They averaged 14,400 eggs per 100 g female weight and 15,436 eggs per 100 mm of female TL. The average gonad weight/body weight ratio (fecundity index) for 150 WI females was 25% prior to spawning in April. In Lake Michigan, fecundity indices ranged between 20 and 25% for all age classes immediately before spawning.[28]

For additional reports of yellow perch fecundity, see Carlander.[47]

Sexual Maturity

Most reports indicate that yellow perch males reach sexual maturity by age 2 and females by age 3 or 4.[3,8,9,28] In northern populations, sexual maturity is reported at age 2 or 3 for males and age 3 or 4 for females,[1,9] though yearling males are often fertile in Lake Erie.[1] In MD, age 1 males, 115 mm, were reported mature, but females were not mature until age 3, 170 mm (Muncy, 1962, cited in reference 8). In SC, all age 2 males, >130 mm TL and all age 3 females >145 mm were mature.[8] Females are also reported mature at age 2 in MI at 190 mm TL and in Ontario at 135 mm FL.[28] In WI, full recruitment to the spawning population takes 2–3 years for males and 2–5 years for females. Almost all males, age 2 and older, were mature; minimum size of mature males was 115 mm. More than 80% of females were mature at an average TL of 189 mm; all females 270 mm and longer were mature and 99% of females 230 mm and longer were mature. If the average age of maturity for females is considered to be the age at which 50% of the fish reached maturity, female perch from Lake Winnebago, WI, matured at the end of their third year of life. All females were mature by the end of their fifth year.[28] In another report from WI, males were reported mature at age 2, 152 mm and females at age 3 or 4, 190 to 229 mm.[9] Males from stunted populations were reported mature at 102 mm.[9]

Spawning Act

Yellow perch are random spawners, the act usually associated with structure or vegetation over the substrate of the chosen area. Males arrive on spawning grounds first and remain longer than the females; females are only there long enough to spawn.[1,12] Eggs mature simultaneously in yellow perch populations and there is mass spawning, often of short duration. The season lasts for 1.5 to 3 weeks in some areas,[27,33,45] but there are reports of spawning completed in less than a week.[3,17] Yellow perch are usually reported to spawn at night, but spawning was observed during daylight hours, both in the field and in the laboratory.[1,12] The spawning act involves a single large female and 15–25 smaller males, who swim about in a long, compact queue, the first males with their snout pressed against the female. A double row of males follows the female so close together that the retinue moves as one body, led by the female. Several such groupings may form over the area at the same time and they create considerable disturbance as they traverse the spawning habitat. These yard-long queues travel a curved course through limbs and other debris from the bottom to near the surface. The males shed a cloud of milt near the female's vent as she releases the egg mass.[1,2,8,9,24,27] The fertilized egg mass is semibuoyant and is deposited or drifts into and becomes draped over, or rooted in aquatic vegetation or limbs, logs, or whatever debris or structure is present over the substrate.[1,2,8,12,14,28,32,35]

EGGS

Description

Yellow perch eggs are deposited in a single layer in a long, tough, gelatinous, hollow ribbon, arranged in transverse folds like bellows. There are numerous breaks in the walls of the egg strand. Aeration is accomplished by means of water circulation through these holes and a central canal.[1,12,32] Circulation is enhanced by the vibratory consistency of the whole egg mass.[42] When water hardened, these strands attain lengths as long as 2.1 m, as wide as 51–102 mm, weigh up to 2 lbs and may contain 2000 to 90,000 eggs.[1] Egg masses are a brilliant mass of clear, amber-colored eggs when extruded,[32] but are also described as light gray, translucent, or transparent.[12,32] The masses are nonadhesive and are semibuoyant or slightly heavier than water and float in current until they become entangled in brush, vegetation or debris.[1,32]

Within the egg mass, individual eggs are attached to others with three or four attachment discs.[33] Each egg is spherical[27] or irregularly shaped,[33] demersal, has a thick jelly-like, elastic capsule, and contains a single oil globule.[27,32,33] They are clear, amber, and brilliant or light and semitransparent; the oil globule is yellow.[12,32] The chorion is nonadhesive and thick, with three layers, the middle of which is striated and noticeably thick.[12,32] Diameter measurements of water-hardened eggs are variable due to the conglomerate nature of the egg mass[32] and have an overall range of 1.72–4.5 mm, depending on the extent of water hardening.[12,32] Diameter tends to decrease during the first 2 weeks of development and increases during 2 weeks prior to hatching.[12,32] There is little perivitelline space, the yolk and embryo occupy slightly more than 80% of the egg diameter. The oil globule is large, its diameter is about 25% of the egg's diameter.[33]

Yellow perch egg masses may be protected by an antipredator mechanism that renders them inedible. In a series of feeding trials, no egg masses were consumed when offered to a number of species considered potential predators, although alternate food items were frequently consumed when offered. Also, examination of the stomach contents of potential predators collected from yellow perch spawning sites, at the peak of the reproductive period, contained no egg masses. Egg masses were not lethal when ingested by a nonselective test fish (hatchery-reared brook trout), suggesting that an unpalatable rather than toxic substance protects the egg masses from predation.[48]

Incubation

Reports on the incubation time of yellow perch eggs are extremely variable.[9,32] In the laboratory, incubation took 25–27 days at water temperatures of 8.5–12°C.[9,27,32,33] Other reports include 8–10 days at "normal" water temperatures in spring;[1,9,35] 27 days at 8.3°C; [1,35] 51 days at 5.4°C; and 6 days at 19.7°C.[35] At 16°C, embryos developed eye pigment in 6–9 days and began hatching by 13 days.[49] In a 5-year WI study on the Fox River, incubation days ranged from 12 to 20 at mean daily water temperatures of 11.4–14°C (range: 2.7–21.6°C); the eggs were "eyed" in 9–10 days. In another WI study, over a 3-year period, incubation took 11–18 days at mean water temperatures of 11.6–12.2°C (range: 3.3–18.8°C); eggs were "eyed" in 9–12 days.[28] In SD, incubation of eggs laid earliest generally lasts about 3 weeks, but after water temperatures rise, the incubation period is reduced to 10–14 days.[11]

Mean temperature tolerance limits (TL50) of yellow perch eggs were 3.7–21°C in early embryonic stages and 7–22°C in later embryonic stages. Rising temperature regimes during incubation yielded optimal swim-up larval production and favored shorter hatching periods and lower incidence of abnormalities than did constant temperatures. Yellow perch tend to hatch prematurely at low incubation temperatures with poor survival.[26]

Development

Yellow perch egg development is illustrated and described in detail by Mansueti (1964).

YOLK-SAC LARVAE

See Figure 197

Size Range

Hatching of yellow perch larvae is reported between 4.7 and 7.2 mm.[1,9,12,28,32,33,35,45,50,51] Yolk absorption is usually reported complete between 7.0 and 8.0 mm[9,12,28,32,35,51] or by 8.25 mm.[44]

Myomeres

Total 34–42 (36); preanal 17–21 (18); postanal 17–20 (18).[12,32,51]

5.5–5.6 mm TL (at hatching or soon after). About 18 preanal and about 18 postanal (incomplete);[44,50] also, 16–21 postanal.[1]

5.0–8.0 mm TL. Total 34–42;[35] preanal 14,[45] 17–24,[35] or 17–21 (usually 18);[51] postanal 21,[45] 13–20,[35] or 17–20 (usually 18);[51] Reports higher from Lake Michigan: total 39–45 (usually 41–44); preanal 19–24 (usually 21–23);[52] postanal 18–3 (usually 19–22).[52]

Morphology

5.5–6.1 mm TL (at hatching). The yolk sac is relatively small and ovate, with a large, anterior oil globule.[12,32,33,44,50] The head is rounded and separate from the yolk sac.[32,33,44] The mouth opening is visible,[32,33] but the mouth is nonfunctional;[45] the lower jaw is not well-developed.[12] The heart is clearly visible in the pericardial sac anterior to the oil globule and

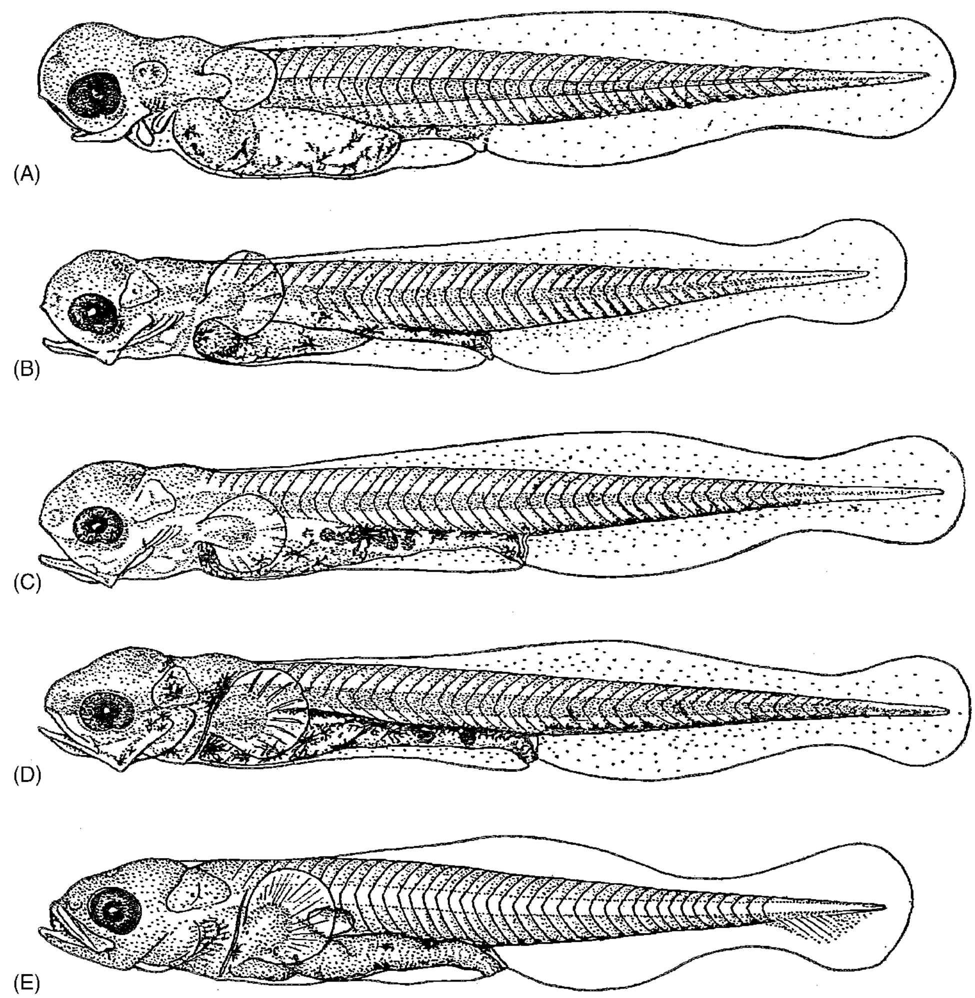

Figure 197 Development of *Perca flavescens*: (A) yolk-sac larva, 5.75 mm TL; (B) yolk-sac larva, 6.8 mm TL; (C) yolk-sac larva, 7.0 mm TL; (D) post yolk-sac larva, 7.2 mm TL; and (E) post yolk-sac larva, 8.7 mm TL. (A–D: reprinted from figure 10; E: from figure 12, reference 32, with publisher's permission.)

can be seen pulsating in the living animal. There are indications of gill formation.[32] The body is elongate and the back straight.[33] The vent is prominent.[45]

5.5–7.0 mm TL. The yolk sac remains an elongate, oval structure located posterior to the head.[27,51] It becomes smaller as development proceeds and is no longer feasible to measure by 6.8 mm.[51] Oil globule remains visible anteriorly in the yolk.[27,51] As yolk absorption begins, the mouth becomes more fully developed and appears functional by 6.8 mm.[32] The body is elongate and the notochord straight.[27,51] The intestine, from the posterior margin of the yolk sac to the anus, is straight.[51] The vent is positioned just slightly anterior to mid-body.[33] By 6.8 mm, three gill arches are visible, the auditory vesicle bulges prominently posterior to the eyes, and the urinary duct appears just posterior to the gut.[32] By 7.0 mm, the yolk and oil globule are nearly absorbed, the operculum is present behind the preopercle, and four gill arches are visible.[32] Teeth are evident in the well-developed mouth.[33]

7.2–7.3 mm TL. The head starts to elongate and flatten and takes the characteristic shape of post yolk-sac larvae;[32] the mouth is terminal, slightly below midline.[44] Vestiges of yolk remain and the oil globule is still visible.[32,44] The cleithrum and opercular flap are discernible and lines of ossification are visible along the notochord. The developing air bladder is visible.[32] The vent ends far from the body at the margin of the ventral finfold.[44]

Morphometry

5.5–5.6 mm TL. Oil globule 0.4 mm in diameter; length from tip of snout to end of yolk sac 2.2 mm, about 40% of TL; SnL 0.17, about 3% of TL; greatest depth behind vent 0.75 mm, about 13.4 % of TL.[44,50]

5.5–7.0 mm TL. Yolk sac is about 1.1–2.3 mm long and 0.4–0.8 mm wide. Intestine, from the posterior margin of the yolk sac to the anus, is 0.5–1.1 mm in length. Snout to anus length is 3–3.8 mm; anus to caudal length is 2.6–3.5 mm.[51]

Table 212

Measurements of young yellow perch from Lake Erie, expressed as percent TL.

		Measurements as percent TL				
TL (mm)	Number of Fish	SL	HL	ED	GD	Snout to Vent Length
5.5	1			6.5	15.1	49.1
5.6	1		13.4	5.7	16.6	49.1
7.3	1			6.2	13	49.3
9	1			5.6	11.6	55.6
12.5	1	96		4.8	16.8	49.6
14.4	1	89.6	24	5.6	17.4	52.1
20	1	85	23.5	7.8	19.8	52.5
20.5	1	84.1		7.3	17.6	51.2

Source: Content is based on data presented in references 44 and 50.

For additional morphometric data, see Tables 212 and 213.

Fin Development

5.5–6.1 mm TL (at hatching). Median finfold is continuous and almost straight from the nape posteriorly along the dorsum, around the urostyle, and proceeding anteriorly on the ventrum, past a break at the anus, to the ventral aspect of the yolk sac.[32,33,44,59,51] The finfold is granular in texture, moderate in height with no pronounced elevation,[44,50] and widest dorsally and ventrally just posterior to the vent.[51] Pectoral fins are present and well developed[12,32,33,44,50,51] with some ray elements visible.[32,33]

7.2–7.3 mm TL. Median finfold is prominent dorsally and ventrally, slightly elevated just posterior to the vent.[32,44] Caudal fin is lophocercal.[44] Pectoral fins are considerably larger with at least 8–9 developing rays present.[32]

Pigmentation

5.5–6.0 mm TL (at hatching). Eyes are very dark at hatching.[32,33,44,50] The oil globule is yellowish or amber.[32,44,50] Body pigmentation is present in the form of large, stellate chromatophores scattered ventrally on the yolk sac and on the dorsal and ventral aspects of the intestine, and as a series of 15–20 small, unequal chromatophores mid-ventrally on the caudal peduncle,[32,44,50] and as black ventrolateral pigment marking the margins of some or all of the postanal myomeres.[44,50]

6.0–7.0 mm TL. Pigmentation is sparse on yolk-sac larvae. A pair of large, stellate chromatophores appears over the oil globule and 6–10 become visible over the remainder of the yolk sac. One to three large chromatophores become visible near the anus and a few smaller ones appear along the dorsal margin of the intestine.[51] Otherwise, pigmentation is as described above.

7.2–7.3 mm TL. The remaining oil globule is yellowish. Pigment is present ventrally on the yolk in a very irregular double row, fewer and smaller chromatophores than at smaller sizes. A single midventral row of small chromatophores is present posterior to the vent and a series of 1–3 small chromatophores is present on the ventrolateral margins of each postanal myomere. Two chromatophores are visible on the intestine at the vent.[44] Pigmentation increases over the head, auditory vesicles, and developing air bladder and a few melanophores are scattered over the body.[32]

POST YOLK-SAC LARVAE

See Figures 197 and 198

Size Range

Yolk absorption is usually reported complete between 7.0 and 8.0 mm TL[9,12,28,32,35,50,51] or by 8.25 mm TL.[44] Phase ends with completed fin development which is normally marked by transformation of the first soft element of the anal fin into the second anal spine. This transformation has been reported over a range from 20 to 27 mm TL.[32,44]

Myomeres

There is no linear relationship between total myomeres and TL,[52] but total myomere count is closely

Table 213

Measurements by size intervals for young yellow perch from Maryland, expressed as average percent TL.

Size Intervals TL (mm)	Number of Fish	Average TL (mm)	Average Percent TL				
			SL	HL	ED	GD	Snout to Vent length
5.5–6.0	46	5.78	96.5	18	5.7	15.2	51.9
6.0–6.5	7	6	96.7	18.2	5.5	13.5	52.7
6.5–7.0	17	6.86	96.5	17.3	5.1	16.2	52.2
7.0–7.5	67	7.17	96.2	17.9	5	15.2	52.6
7.5–8.0	1	7.5	96.7	16.7	4.7	15.3	53.3
8.0–9.0	1	8.7	96.6	19.5	5.9	12.6	47.7
9.0–10.0	2	9.45	95.8	19	6.3	13.8	51.6
10.0–11.0	1	10.4	97.1	20.2	5.8	15.4	54.8
11.0–12.0	1	11.6	94	23.3	6.4	12.1	55.2
12.0–13.0	1	12.6	88.1	22.2	6.6	15.9	54
13.0–14.0	1	13.41	75	24.8	8	18.2	54.2
14.0–15.0	7	14.73	80.5	24.6	7.7	18.1	53.8
15.0–16.0	6	15.39	78.1	25	7.6	18.1	53.1
16.0–17.0	8	16.54	80.8	25	8.3	18.1	52.2
17.0–18.0	7	17.29	79.7	25.9	8.2	18.5	51.8
18.0–19.0	5	18.29	79	25.5	8	19	51.6
19.0–20.0	4	19.67	79.1	25.6	7.5	19.8	52
20.0–21.0	1	20.63	82.1	27.7	7.3	20.1	57.2
21.0–22.0	4	21.43	79	26.6	7.6	21	53.4
22.0–23.0	9	22.59	79.4	27	7.5	20.6	55.1
23.0–24.0	3	23.74	79.1	26.8	7.2	20.8	54.5
24.0–25.0	13	24.55	79.6	27.5	7.2	20.9	55.2
25.0–26.0	8	25.61	79.6	27.2	7	20.7	55.4
26.0–27.0	10	26.52	79.3	27	6.9	21.2	55.5
27.0–28.0	6	27.29	80.1	27.3	6.8	21.2	56.3
28.0–29.0	5	28.47	79.8	27.2	6.5	20.9	55.6

Source: Content is based on data presented in Table 1, reference 32.

correlated with the number of vertebrae as tabulated by Bailey and Gosline (1955).[51,53]

Total 34–42[12,32,51] (usually 36–37);[32] preanal 17–22 (usually 19)[12,32,51] or 18–21;[54] postanal 16–21 (usually 18–19)[32,51] or 16–23.[54]

Other reports by length include:

8.0–15.0 mm TL. Total 39–45 (usually 41–44); preanal 19–24 (usually 21–23); postanal 18–23 (usually 19–22).[52]

8.0–10.0 mm TL. Total 35–43 (usually 38–39); preanal 18–22 (usually 20); postanal 17–21 (usually 19).[35]

11.0–15.0 mm TL. Total 35–37 (usually 36); preanal 21–23[35,44] (usually 21);[35] postanal 14–16 (usually 15)[35] or 18.[44]

15.0–20.0 mm TL. Total 35–38 (usually 36); preanal 20–24 (usually 22); postanal 13–14 (usually 14).[35]

20.0–20.5 mm TL. 18–24 to vent and 16–18 behind.[44,50]

Morphology

7.2–8.25 mm TL. Yolk is absorbed and the body appears more elongate. The intestine is simple and

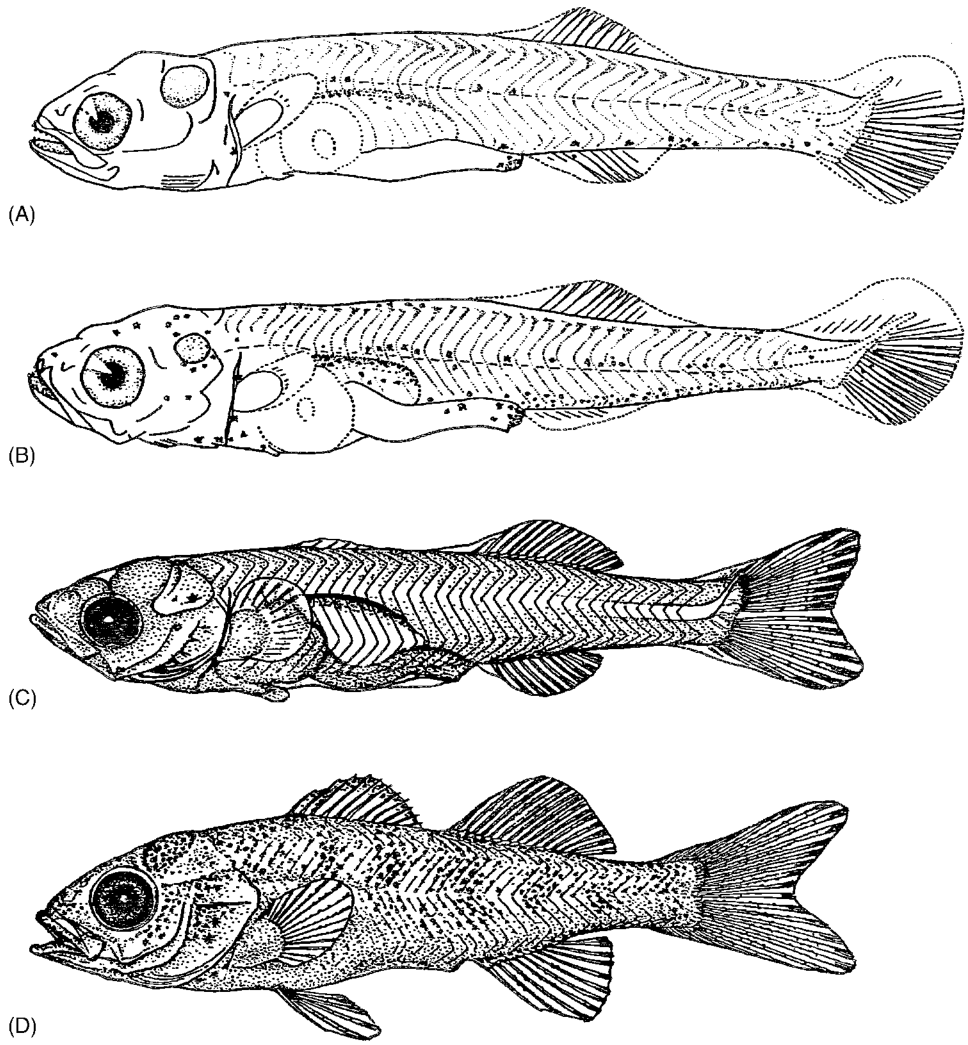

Figure 198 Development of *Perca flavescens*: (A–B) Post yolk-sac larvae 13.0 mm TL; (C) Post yolk-sac larva, 14.2 mm TL; (D) Late post yolk-sac larva; second anal spine not ossified. (A and B: reprinted from figures 2 and 3, reference 51, with publisher's permission; C and D: reprinted from figure 12, reference 32, with publisher's permission.)

straight. Jaws are well-developed, teeth are evident, and ossification of the notochord is apparent.[32,44] The cleithra, dentaries, premaxillae, and ceratobranchials show evidence of ossification.[51]

8.3–10.0 mm TL. Head continues to develop, but remains basically the same shape, with teeth visible.[32,44,51] At 8.7 mm, the operculum has not yet covered the gill arches.[32] The body appears heavier.[44] The urostyle begins to bend upward.[35] At 9–10 mm, ossification of vertebrae, quadrates, and branchiostegal rays is evident.[32,51]

10.0–11.0 mm TL. Deposition of bone occurrs in the opercle, preopercle, and frontal bones. Articulation of the partially ossified lower jaw is clearly visible below the orbit.[51]

12.5 mm TL. Stomach region is more prominent, the coiled intestine is visible. The head is pointed, jaws well-developed.[44]

13.0–14.0 mm TL. The air bladder is extremely large. The gut nearly completed its loop. Preopercle spines visible and teeth visible along both jaws. The urostyle is turned dorsally. Internal skeletal structure is evident through the body muscles. The head has assumed the adult contour. Twelve gill rakers are present.[32]

18.0–19.0 mm TL. Eight branchiostegal rays are present.[32]

20.0–22.0 mm TL. Body has characteristic percoid shape;[32,44] greatly compressed. The snout is pointed; mouth large with small, sharp teeth visible, but no canines; maxillary reaches posteriorly to the middle of the eye.[44,50] Body is scaleless at 20 mm[32] or with scales evident on the caudal peduncle[12,55] or scales first appear between 21 and 22 mm.[51] Preopercle spines have increased in number but are smaller. Thirteen gill rakers are visible.[32] By 22 mm, bony parts of all fins and the vertebral column are complete, but intermuscular and head bones remain unossified to a large degree.[32] A narrow band of scales is present mid-laterally from the posterior third of the spinous dorsal fin to near the base of the caudal fin.[12,55]

24.0–26.0 mm TL. The midlateral band of scales now extends from near the opercle to the base of the caudal fin, tapering on both ends from its widest point in midbody near the juncture of the spinous dorsal and soft dorsal fins.[12,55]

Morphometry

Snout to vent length increases and ranges from 53 to 54% of TL. Body depth proportions decrease with absorption of the yolk.[32]

14.4 mm TL. As percent TL: SnL 6.3; GD behind the vent 13.9.[44]

20.0 mm TL. As percent TL: HL 27;[32] length to first dorsal fin 30.5; length to second dorsal fin 51.5; length to anus 55; SnL 5; GD behind vent 16.[44]

20.5 mm TL. As percent TL: length to first dorsal fin 29; length of maxillary 10.[44,50]

For additional morphometric data, see Tables 212 and 213.

Fin Development

8.0–9.0 mm TL. The median finfold originates dorsally above the air bladder and is continuous around the urostyle, proceeding ventrally to the anus and beyond with remnants visible along the gut to about the base of the pectoral fins. It is elevated, dorsally and ventrally, just posterior to the vent, but undifferentiated except in the ventral half of the developing caudal fin, where ray development is evident.[32,44,51]

12.0–13.0 mm TL. Rays appear in dorsal and anal fins.[32,44,51] At 12.5 mm, the caudal fin is lophocercal, with developing rays visible in the ventral lobe. Pectoral fins are moderate in size.[44] Median finfold is almost gone by 13 mm.[51]

13.0–14.4 mm TL. Fins are incomplete, but the soft dorsal and anal fins are formed. Anal fin has one spine and about 8 rays. Spinous dorsal fin has 7–12 spines, and soft dorsal fin has one developing spine and about 12–13 rays. The caudal fin is well-developed and emarginate or forked with all, or most principal rays evident.[32,44] Pelvic fins are present,[32,44] but rays are not clearly differentiated.[32] Pectoral fin rays and dorsal and anal fin spines begin to ossify between 13 and 14 mm.[51] At 14 mm, a remnant of the ventral finfold persists anterior to the vent.[32]

15.0–20.0 mm TL. Ventral finfold is absorbed[35] or a remnant is present anterior to the vent at 20 mm.[44] Pelvic fin rays ossify between 15 and 16 mm.[51] By 17 mm, the spinous dorsal has 13–15 spines, soft dorsal has 1–2 spines and 12–15 rays; the two dorsal fins are distinctly separate.[27]

20.0–27.0 mm TL. All fins are formed, development is complete and the ventral finfold is absorbed. At 20 mm, a small remnant of the ventral finfold is present just anterior to the vent,[44] but it is not evident by 20.5 mm.[44,50] The first dorsal fin has 15 spines, the second has two spines and 13 rays. The anal fin develops two spines and 8 rays.[44] Transformation of the first soft ray of the anal fin into the second anal spine, marking the end of the post yolk-sac larval phase, is observed over a range of length from 20 to 27 mm.[32,44] This transformation is reported by 20 mm in Lake Erie[44] and at 25–26 mm in the Chesapeake Bay area.[32] An anal fin ray count that was I, 8 before transformation would become II, 7 after[33] or would change from I, 6–10 to II, 6–9.[27]

Pigmentation

Pigmentation on early post yolk-sac larvae (8–10 mm) is similar to that described for late yolk-sac larvae.[44] Postanal pigment consists of a single mid-ventral row which becomes double around the base of the anal fin, and ventrolateral pigment outlines the margins of some or all of the postanal myomeres.[27,32,35,44] Pigment over the dorsal surface of the air bladder becomes intense[32,35] and there are a few stellate chromatophores over the folding gut.[32]

Generally, the concentration of pigment in post yolk-sac larvae increases with age. However, fish of similar sizes from different locations may differ markedly in the degree of chromatophore development.[51] For example, post yolk-sac larval yellow perch captured from Lake Michigan are described as much darker than those collected from Lake Erie (see Figures 198, A and B).[51] Norden (1961) described the differences in pigment development for yellow perch 12–18 mm captured from the two lakes. His comparison is as follows.

12–18 mm TL. In specimens from Lake Erie, there is no dorsal pigment line, whereas Lake Michigan specimens have eight or more widely scattered chromatophores along the dorsum. A lateral pigment line is incompletely developed for larvae from both lakes, although chromatophores are more numerous on the caudal peduncle of Lake Michigan specimens. Visceral pigmentation, dorsal to the air bladder, is very concentrated on specimens from both lakes, but there are only 1–2 chromatophores along the length of the intestine on larvae from Lake Erie while those from Lake Michigan have 2–7. The ventral pigment line, from the anus to the caudal fin, is well-developed on larvae from both lakes, but a greater concentration appears on Lake Michigan specimens. Six to eight chromatophores are present in the region of the heart for larvae from Lake Michigan; those from Lake Erie have only 1 or 2. Chromatophores are more plentiful on the top of the head, on the cheeks, at the tip of the lower jaw, and along the pectoral girdle in larvae from Lake Michigan.[51]

Specimens of similar size from the same location (Lake Erie) are also reported as differing markedly in pigmentation density and patterns (see descriptions of 20 and 20.5 mm specimens that follow).[44]

Other reports of pigmentation by size follow:

12.5 mm TL. A few chromatophores are visible around both jaws, on top of the head, and on the preopercle. A subsurface layer of pigment is present over the air bladder and one very large chromatophore is located mid-ventrally about half way to the vent. Lateral and ventral postanal pigment is as described before.[44]

14.0–14.4 mm TL. Pigmentation is as described in preceding stages, but chromatophores are lighter and ventral pigment is less conspicuous or entirely lacking,[44] or soot-black pigmentation covers the air bladder and the body is sparsely pigmented.[32]

20.0–20.5 mm TL. At 20 mm, sparingly marked, with chromatophores limited to a few stellate ones on the jaws and dorsally on the head, a few at the dorsal and anal fin bases, and others distributed laterally on the caudal peduncle, extending on to the base of the caudal fin. The body from behind the head to the vent is almost colorless;[44] or at 20.5 mm, round and stellate chromatophores occur on the head, with a double row extending dorsally on the body. Chromatophores are scattered laterally on the head and evenly on the body. Internal pigmentation is visible over the air bladder. A distinct ventral row of large, stellate chromatophores extends to the vent, with an irregular double series continuing ventrally along the caudal peduncle, darkest at the base of the anal fin. Dorsal, anal, and caudal fins are speckled with pigment. The banded coloration of the adult is not evident.[44,50]

20.0–27.0 mm TL. At 20 mm, definite bandings are visible along the back,[32] or not,[44,50] connected to 6 or 7 vertical bands along the body.[32,33] Banding along the back is also reported visible at 21.7 mm,[12] and lateral bands at 22.5 mm.[12] By 27 mm; the lateral bandings darken. The dorsum is dark, olive color; the ventrum is light. Background is yellowish behind the 7 wide, dark bands that are present on the sides.[27]

JUVENILES

See Figure 199

Size Range
Phase begins between 20 and 27 mm.[32,44] Males mature in 1–3 years,[1,3,8,9,28] with most reports at 2 years and minimum TLs of 115–130 mm. Females mature as early as age 2,[28] but most reports indicate maturity at age 3[3,8,9,28] at TLs probably between 190 and 230 mm.[9,28]

Morphology
27.0–32.0 mm TL. Thirteen to fourteen gill rakers are present.[32] Scales cover the caudal peduncle area and are present anteriorly in a narrowing band to the posterior margin of the opercle, ventrally from about the vent and dorsally from near the insertion of the soft dorsal fin.[32,55]

35 mm TL. Squamation is nearly complete.[55]

39.0–96.0 mm TL. By 49 mm, squamation is complete, the eye is large, and the body configuration is like adult.[1] Precaudal vertebrae are 20–22 (usually 21); caudal vertebrae are 18–20 (usually 19–20); total vertebrae are 39–42 (usually 40–41)[52,53] or total vertebrae 38–41.[1] There are three pyloric caeca.[1]

Morphometry
Snout to vent length is 56% TL. Bodies become thicker and deeper thereby increasing body depth proportions.[32]

27.0–29.0 mm TL. See Table 213.

Fins
The two dorsal fins are separated. The spinous dorsal is high and rounded,[1] with 13–15 spines[1,2,27] or 11–15 spines (usually 12–14).[8] The soft dorsal is about the same height as the spinous dorsal[1] and has 1–2 spines and 12–15 rays[1,2,27] or 1–3 spines

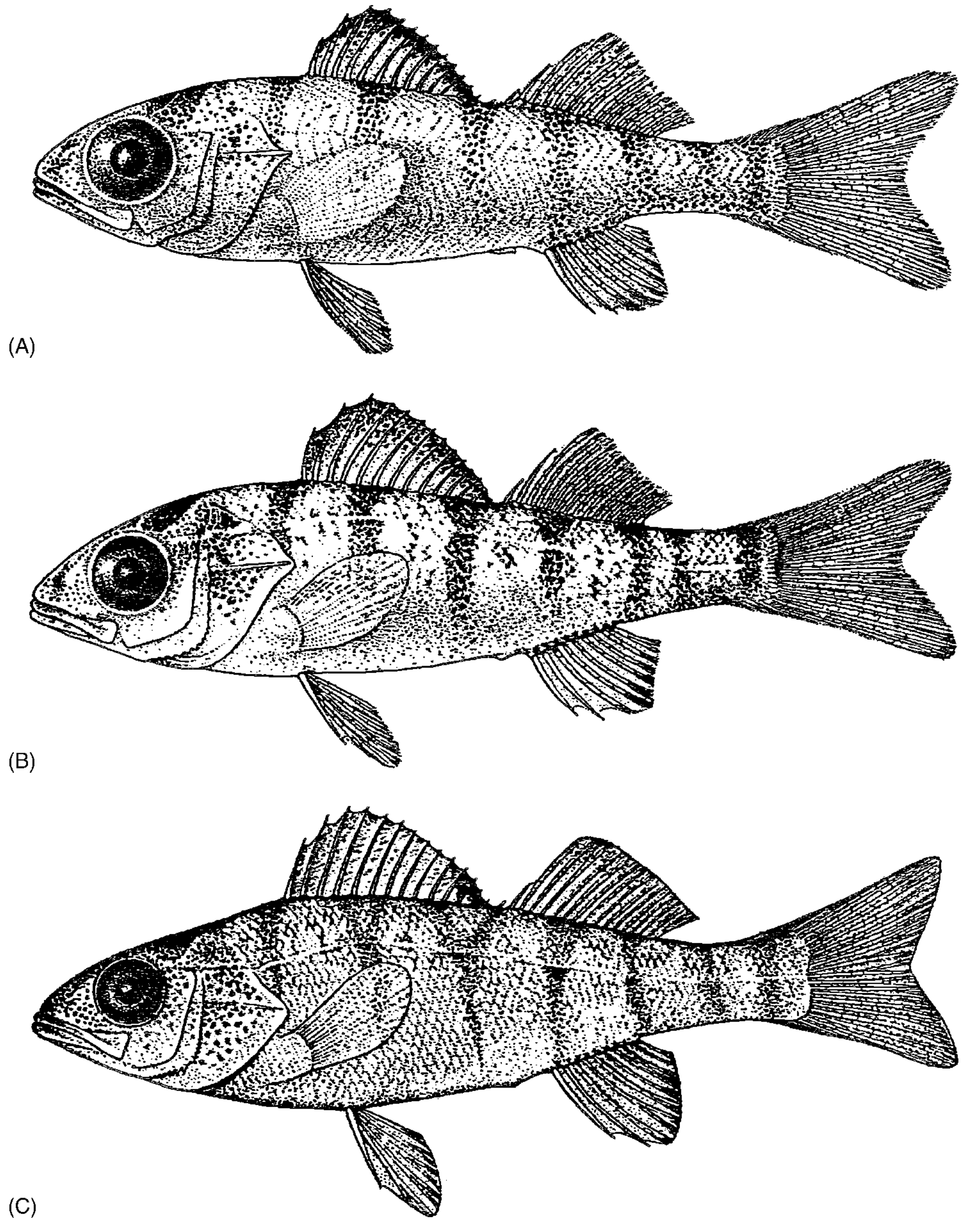

Figure 199 Development of *Perca flavescens*: (A) juvenile 22.5 mm TL; (B) juvenile 28.0 mm TL; (C) 44.0 mm TL. (A: reprinted from figure 191, reference 12, with artist's permission; B and C: reprinted from figure 13, reference 32, with publisher's permission.)

(usually 1–2) and 12–16 rays (usually 13–15).[8] The caudal fin is shallowly forked, the tips rounded[1] and has 17 principal rays.[2] Anal fin has two spines and 6–8 rays[1,2] or two spines and 6–9 rays (usually 7–8).[8] Pectoral fins have 13–16 rays[1,2,8] (usually 15).[2] Pelvic fins have one spine and five rays.[1,8]

At 28 mm, rays of the caudal fin, but not the soft dorsal or anal fins, bifurcate.[32]

Pigmentation

28.0–40.0 mm TL. The lateral bands are darkened and contrast sharply with a lighter, yellowish body.[12,27,32,44,50,56] A dark area of pigment over the brain and pigment concentrating along the edge of the spinous dorsal fin are distinct.[32]

Juveniles tend to be greenish, without conspicuous red, lower fins.[14] They are also described as transparent, silver or dull, pale green, with white ground color rather than golden yellow; bands more prominent than in adults; with indefinite dark spots on the sides in addition to the dark bands; with dark markings at the edge and rear of the spinous dorsal fin more sharply defined than in adults.[1,12]

Table 214

Comparison of selected characteristics during early life phases of yellow perch, sauger, and walleye.

	Yellow Perch	Sauger	Walleye
Eggs			
Deposition	Gelatinous strands[12,23]	Scattered singly[42,58,59]	Scattered singly[1,42]
Diameter (mm)	1.72–4.5[32]	1.44–1.86[57]	1.9–2.31[57]
Yolk-sac Larvae			
Hatching length (mm TL)	4.7–7.2[12,32]	4.5–6.2[1,57,60]	6–8[12,57,60]
Myomere ranges and (means)			
Total	34–45[12,32,51,52]	41–43 (41.8)[57]	43–51[57,72]
Preanal	14–24(18+)[12,32,45,51,52]	16–21 (19)[57]	18–22 (20)[57]
Postanal	17–23(18+)[12,32,51,52]	21–26 (23)[57]	20–30 (26+)[57,72]
Yolk-Sac length (mm)	1.2–2.3[51]	1.9–2.3[57]	2.1–2.7[51]
Length at yolk absorption (mm)	Usually 7–8[9,12,28,32,35,50,51]	7.7–9.6[15,44,57,60]	9.4–9.6[51,57,72]
Intestine	long, straight[51]	short, curves downward[57]	short, curves downward[51]
Post Yolk-sac Larvae			
First appearance of fin rays (mm TL)[51,57]			
Spinous dorsal	13 – 14	13 – 14	14–15
Soft dorsal	12 – 13	13 – 14	13–14
Caudal	8 – 9	10 – 11	10 – 11
Anal	12 – 13	13 – 14	13 – 14
Pectoral	13 – 14	13 – 14	14–15
Pelvic	15 – 16	15 – 16	16–17
Myomere Ranges and (Means)			
Total	33–45[12,32,51,52]	42–45 (43.5)[57]	45–46[51,57]
Preanal	17–24[12,32,51,52]	19–22 (21)[57,59]	16–25[51,57]
Postanal	13–23[12,32,35,51,52]	21–24 (23)[57,59]	22–29[51,57]
Canine teeth	Absent[51]	Present[57]	Present[57]
Juveniles			
Pyloric caeca	3[1]	4–7[57,60]	3[57,60]
Parietal bone pigment		Sparse[61]	Heavy[61]
Soft dorsal rays	12–16 (usually 13–15)[1,2,8]	16–22 (usually 17–19)[2,8]	18–23 (usually 18–21)[2,8]
Anal fin soft rays	$\leq$ 9[1,2,8]	$\geq$ 10[1,2,8]	$\geq$ 11[2]

TAXONOMIC DIAGNOSIS OF YOUNG YELLOW PERCH

Similar species: sauger, walleye, sauger and walleye hybrids, and darters. Young members of the Moronidae family superficially resemble yellow perch in general appearance and body proportion, but differences in total myomere count allow easy differentiation.[63] Yellow perch larvae have at least 33 or more total myomeres;[12,32,51] moronids have 26 or fewer.[12,33,35]

Yellow perch vs. sauger (see Table 214)
Reports of the diameters of fertilized, water-hardened eggs for sauger and yellow perch overlap,[12,32,33,57] however sauger eggs are scattered randomly over bottom substrates,[42,58,59] whereas yellow perch eggs are laid in long, gelatinous strands that attach to fallen limbs and other debris and cover.[12,33] Single yellow perch eggs are immediately recognizable by 3–4 attachment discs on the capsule.[33]

The number of postanal myomeres distinguish some sauger from yellow perch in both yolk-sac and post yolk-sac larval phases.[12,32,51] Yellow perch yolk-sac larvae reportedly have 17–23[12,32,51,52] (usually 18 or more)[12,32,51,52] postanal myomeres, compared to 21–26 (average 23) for sauger.[57] Sauger post yolk-sac larvae have 21–24 postanal myomeres;[57,59] reports for yellow perch range from 13 to 23.[12,32,35,51,52] (usually 19).[12,32,51] Other distinguishing characteristics include yolk absorption, usually complete at TLs between 7 and 8 mm for yellow perch[9,12,28,32,35,50,51] and at TLs ≥7.7 mm for sauger;[15,44,57,60] the intestine of yolk-sac larval sauger is short and bends downward to the anus, while the intestine of yellow perch is long and straight;[51] ossified rays first appear in the ventral half of the caudal fin at 8–9 mm TL for yellow perch[51] and at 10–11 mm TL for sauger;[57] posterior margin of jaw is below the middle of the eye for yellow perch[51] and extends to posterior margin of the eye for sauger;[57] small, noncanine teeth develop in jaws of yellow perch,[51] while canine teeth develop in the jaws of sauger;[2] 14 mm and larger post yolk-sac larval and juvenile yellow perch have 9 or fewer anal fin soft rays, while sauger have 10 or more;[1,2,8,32,51] juvenile yellow perch usually have 13–15 soft dorsal fin rays,[1,2,8] sauger usually have 17–19.[2,8]

Yellow perch vs. walleye (see Table 214)
Reports of the diameters of fertilized, water-hardened eggs of yellow perch and walleye overlap,[12,32,57] however walleye eggs, like those of sauger, are scattered randomly over bottom substrate,[1,42] whereas yellow perch eggs are laid in long, gelatinous strands that attach to fallen limbs and other debris and cover.[12,33] Single yellow perch eggs have 3–4 attachment discs on the capsule,[33] which are lacking on walleye eggs.[57]

Many of the characters that serve to distinguish yellow perch from sauger also distinguish them from walleye. For most yolk-sac and post yolk-sac larvae, total and postanal myomere counts are higher for walleye than for yellow perch (see Table 214).[12,32,51,57,72] Yolk sac length is 1.2–2.3 mm for yellow perch, while 2.1–2.7 mm for walleye.[51] Complete absorption of the yolk by yellow perch is usually reported between 7 and 8 mm,[9,12,28,32,35,50,51] walleye yolk absorption is reported complete between 9.4 and 9.6 mm.[51,57] The intestine is long and straight in yellow perch and is short and curves downward in walleye.[51] Fin rays are first evident in the ventral half of the caudal fin at 8–9 mm TL for yellow perch and at 10–11 mm for walleye.[51,57] The posterior margin of the jaw is below the middle of the eye for yellow perch[51] and extends to the posterior margin of the eye in walleye.[57] Soft ray counts in the dorsal and anal fins distinguish post yolk-sac larvae (≥14 mm) and juveniles (see Table 214). Canine teeth are well-developed in juvenile walleye and lacking in yellow perch.[2,51]

Yellow perch vs. sauger/walleye hybrids
The larvae of reciprocal hybrids from sauger and walleye closely resemble their female parent, making identification impossible.[57] Therefore, the diagnostic comparisons presented above should serve to distinguish yellow perch from whichever hybrid is encountered.

Yellow perch vs. darters
Yellow perch eggs are laid in long, gelatinous strands that attach to fallen limbs and other debris and cover.[12,33] Darter eggs may be randomly broadcast or scattered on the substrate, hidden, or laid in nests.[42] Single yellow perch eggs have 3–4 attachment discs on the capsule,[33] which are not present on darter eggs.

Yellow perch yolk-sac larvae have larger, more terminal mouths, with well-developed jaws, than most darters, which is evident by 5.75 mm (Figure 197A).[45,51] A developing air bladder is visible in yellow perch larvae by 7–8 mm;[32,62] air bladders are absent or reduced in darters.[2,8] Ventrolateral pigment is present along the margins of some or all postanal myomeres on yellow perch larvae;[32,44,62] postanal pigment varies with the darters. Fin development occurs at greater sizes for yellow perch than for darters.[33] By 14 mm, preopercle spines are evident on yellow perch;[32] darters lack preopercle spines.[10] By late larval or early juvenile sizes (20–30 mm), the adult pigment pattern of yellow perch becomes evident.[27,32,33] Juvenile yellow perch have slab-sided, fusiform (taper at both ends) bodies, pointed snouts, forked tails, and paired fins of moderate size.[8,41] While, most juvenile darters have a more flattened venter, teardrop-shaped bodies (thicker near the head), blunt snouts, rounded or slightly emarginate tails, and large pectoral fins.[8,41]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 200)
Eggs. Yellow perch egg strands or masses are semi-buoyant[1,27] or slightly heavier than water and float on the current[27,32] or undulate with water movement[1] until they become entangled on underwater objects, usually in shallow water.[27,28] They have been found entangled on debris, detritus, and fallen tree branches.[12,27,28,32] They also adhere to rooted aquatic vegetation[1,27,28] such as cattail, bulrushes, sedges,[28] reeds, cane, bushes, and weeds.[12] They have been observed in lateral ditches and small backwater areas adjacent to the Fox River in WI.[28] Occasionally found directly on the bottom[1] on stones, gravel, or mud.[12] However, in a

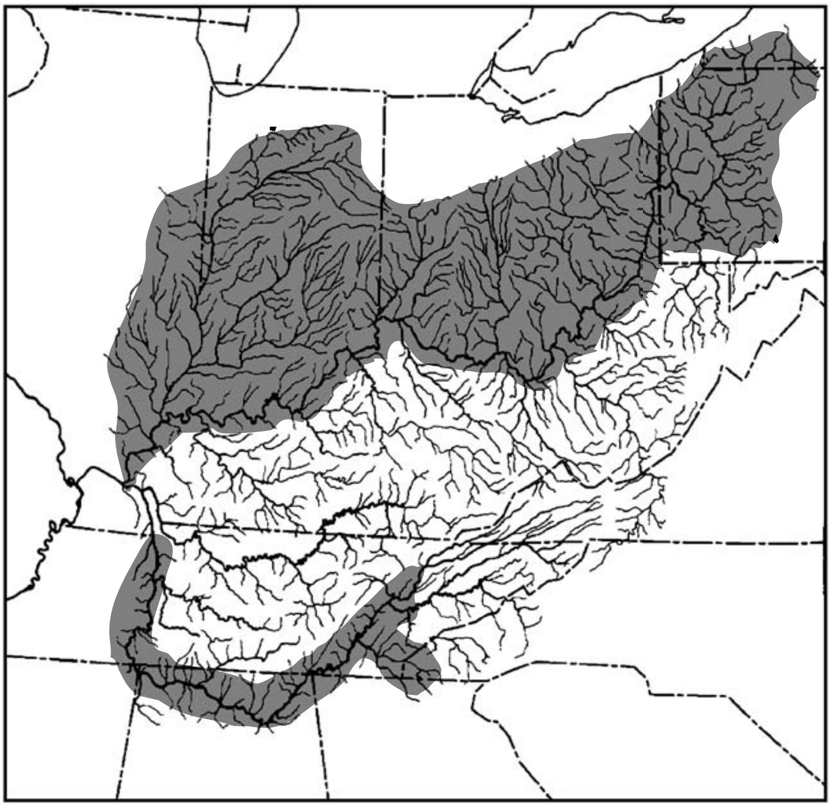

Figure 200 Distribution of yellow perch in the Ohio River system (shaded areas). Their presence in the Tennessee River is the result of human introduction.

6-year study on the Fox River, WI, yellow perch egg masses were never observed directly on the bottom.[28] Also reported from rip-rap on the Lake Michigan shoreline.[45]

No protection is given to the egg masses by the parents.[1,42] Eggs deposited on, or carried onto, muddy substrates probably die of suffocation.[27] Egg masses are sometimes stranded by receding tides[12] or cast ashore by wind, waves, or current, and lost.[1,28,60] Masses may be periodically exposed to air when carried into shallow areas of the littoral zone or when stranded out of the water in tree limbs.[12,27] Desiccation from exposure is possibly inhibited by the thick, gelatinous covering around the egg mass.[27] Within the mass, a thick, elastic egg capsule provides individual egg protection from abrasion and bumping and also from predators, since it is extremely difficult to pierce the membrane. In nature, the entanglement of egg masses in stream debris or tree branches also provides some measure of protection.[32] Egg masses may be protected by some antipredator mechanism that makes them unpalatable.[48]

Larvae. Yellow perch yolk-sac larvae receive no protection from their parents.[1] They have substantial swimming ability when they hatch[27,28] and are soon active[28,32] or inactive for about 5 days during absorption of the yolk.[1] Reports of immediate activity indicate that, soon after hatching, they are capable of swimming in swift, well-coordinated movements.[27,28,32] However, they are unable to sustain directed movement against a current.[28] They are reported typically limnetic, pelagic, and photopositive, in schools in shallow water, also in open water and subject to dispersal by wind-induced currents. Maximum, recorded depth of capture is 18 m. They are reported from water temperatures ranging from 10 to 19°C, surviving best between 16 and 19°C.[12]

Soon after yolk absorption, larvae move to deeper-water areas, where they are pelagic[1] and most abundant at or near the surface[9,12,36,56] at night.[36,56] They live and feed near the surface (upper 0.9–1.2 m)[9] for 3–4 weeks or until they are about 25 mm,[2,9] when they swim to the bottom,[9] usually in shallow water, and begin a more bottom-oriented behavior, typical of the adults.[2] In flowing water habitats, they are reported to utilize upper portions of tidal creeks for nursery grounds.[27] They are abundant in weedy, littoral backwaters of the upper Mississippi River and sometimes constitute a major component of the main channel ichthyoplankton drift in early spring, before most other species of fish have spawned.[15]Yolk-sac larvae 5.7–6.3 mm TL were captured in late May and mid-June with 0.5 m stationary nets, fished at the surface, in the forebay of a coal-fired generating station in the St. Clair River, Ontario.[64] In Lake Erie, larvae 5.5–13 mm TL were netted in June and July from depths of 3–6 m below the surface;[44,50] many were collected in meter-nets towed 0–4 m below the surface. From early June to early August, large numbers of yellow perch larvae were captured throughout the lake, usually inshore in shallow water, but sometimes even in the very center of the lake.[44]

In a Potomac Estuary study that spanned 5 years, yellow perch larvae were common to abundant in collections in 4 of the 5 years. The portion of the estuary sampled was tidal freshwater where salinities at downstream stations were greater than 0.5 ppt. Yellow perch larvae were most abundant upstream of the 1.9 ppt isohale. They were captured in towed plankton nets from early April through mid-May. First occurrence was from late March to early April at water temperatures of 7–13°C, but in all the years, larvae were assumed present prior to the start of sampling.[31] In the Patuxent Estuary, yellow perch larvae were collected in fresh to oligohaline water (4.4–5.0 ppt) from early April to mid-June.[31]

During a 2-year study in Lac Henry, Quebec, yellow perch larvae 5–14 mm were collected with light traps. The traps were fished for 60 min, between 2100 and 0030 h, in, or near, a shoreline bed of *Scirpus validus*, in water that varied from 60 to 100 cm deep. Surface temperature ranged from 15 to 21°C over the 2 years of the study. Yellow perch larvae were present in the traps in increasing numbers from early to mid-June and then in decreasing numbers until the end of June.[62] They appeared during May, 1 month earlier, at similar surface temperatures, in smaller lakes, which warm up faster in spring.[62]

It was assumed that yellow perch larvae, hatched in the Fox River, WI, were carried downstream by current until they reached quiet water. Meter-net captures of the larvae confirmed immigration into downstream lakes. No relationship was found between stream flow and rate of movement or distribution of yellow perch larvae into a downstream lake.[28]

Juveniles. Yellow perch juveniles are reported to aggregate and move about in large schools[3,12] in bright, diffuse light for about two months after hatching, at which time they seek darker areas, cease to be pelagic, and become demersal[3] or they are pelagic and abundant near the surface of deep water for about a month after yolk absorption or until they are about 25–30 mm,[1,2,9,28] when they swim to the bottom, usually in shallow water, and become demersal.[2,12,56] They are often reported from the inshore, open water areas of lakes.[1,11,17] Adults and young are gregarious, often moving about in loose aggregations of 50–200 individuals, segregated by size. The young, in shallower water and nearer to the shore than the adults, are often in mixed schools which may include many individuals of a cyprinid species, such as spottail shiner.[1] Seine catches of young yellow perch were generally highest in the shallow, more productive areas of Missouri River reservoirs.[11] Onshore movement occurs from mid-July to early August in Manitoba Lake.[56]

Depths of capture of juvenile yellow perch are variously reported from the surface to 31 m.[12,44,50] Juveniles 50 mm TL were common on shoals associated with aquatic vegetation.[12] There is also a report of a 50 mm specimen captured in August that came from the bottom of Lake Erie, in water 11 m deep.[44] A large number of juveniles, averaging 40 mm were collected with Peterson trawls from depths of eight and 20 m in the middle of Lake Erie.[50] YOY yellow perch in Lake Michigan live mostly in depths less than 5 m until fall; in October and November, they are most numerous at depths of 13–22 m, but have been found as deep as 31 m. After their first year, they are mainly at depths of 9–27 m in winter and early spring; found at depths of <18 m in late spring and early summer; less than 27 m in late summer; 18–23 m in the fall.[20]

Young yellow perch were present in trawl samples from Lake Winnebago, WI, from June through October, most years. Greatest abundance in collections was in June and July, with minimum catches August through October.[60] By late August, YOY and juvenile yellow perch were caught in gill nets from a lake in Manitoba.[56]

Juveniles <120 mm were found to be active only during the day. They were reported to remain motionless at night, either on the bottom or among submerged vegetation.[56] Diurnal movement patterns are reported for yellow perch 90–130 mm (7.8–26.5 g), at water temperatures of 18–22°C, in Lake Opinicon, Ontario. These movements were associated with late afternoon and morning feeding periods.[16]

Preferred laboratory temperatures established for YOY yellow perch are 10–13°C in winter, 18°C in spring, and 25–28°C in summer and fall.[25] Other reports of preferred temperatures vary from 13 to 29°C when ambient varied from 1 to 24°C; young yellow perch generally select higher temperature waters than adults in all seasons.[26] The ultimate upper incipient lethal temperature for juvenile yellow perch varies from 29.2 to more than 33°C for various test conditions.[26] Lethal dissolved oxygen concentration for YOY yellow perch in water averaging 23°C is 1 ppm, but this concentration is not lethal in water 15.1°C.[65] Signs of respiratory distress were observed at 7 ppm among Lake Erie yellow perch age 0+.[3,65] Salinity ranges reported for young yellow perch are 0.5–9.5 ppt.[12]

Early Growth

Growth of yellow perch is extremely variable depending on population size, habitat availability, and productivity.[1] Total lengths at ages 1–4 have been reported greater from a northern population than from one in the south, with comparable TLs at age 5. This contradicts the usual comparative growth relationship of northern and southern fish populations.[2] Virtually all populations of yellow perch from Lake Opinicon, Ontario, and other water bodies in North America had normal growth to the end of year class 0; thereafter growth rates varied greatly from lake to lake, probably related to the availability of food.[17] Stunting is often reported from crowded populations with adults not exceeding 152 mm.[1] A report of stunting in MN indicated that age 2 yellow perch only reached an average of 90–92 mm and then died. There was conclusive evidence of starvation in many individuals and very small organisms predominated in the stomachs. If large-bodied prey were in short supply, all age classes would be forced to compete for the smaller prey, which would be highly inefficient to the larger perch in terms of energy outlay.[17] Most reports indicate that females grow faster than males,[11,67,69] especially after the first 2 years.[20,70] Difference in growth is usually not great.[67,69]

In Manitoba, larvae were 5.6–5.9 mm in early June and 30 mm in August. They tripled in length and increased in weight by a factor of 9 from July 1 to August 31. Weekly specific growth rates increased when larvae were epilimnetic and declined when they moved into littoral habitat. Age 1 fish were 50–90 mm.[56]

In MN, average calculated SLs (mm) for ages 1–4 were: age 1, 84; age 2, 118; age 3, 154; age 4, 177.[67] Back calculated TL at age 1, for the period 1942–1956, ranged from 54 to 75 mm.[69] Females in MN grow more rapidly than males, but the difference is usually not great.[67,69] Mean TL and weight for yellow perch ages 1–4 were: age 1, 74 mm and 5.7 g; age 2, 132 mm and 34 g; age 3, males 173 mm and 73.7 g, females 178 mm and 85.1 g; age 4, males 201 mm and 121.9 g, females 218 mm and 153.1 g.[69] Other reports of first year growth in MN waters give TL range of 55–88 mm in October.[28] Additional data on standard lengths and weights of yellow perch from MN are presented in Table 215.

In WI, yellow perch average 11.5 mm by the end of May, 27 mm by mid-June,[28] and 102 mm by the end of the growing season in October.[9] First year growth generally follows a sigmoidal pattern, accelerating through May and June, increasing almost linearly through August, and then slowing through September and October. Fish from limnetic habitats average 78–90 mm in October; those from littoral habitat range from 64 to 81 mm in September. There was little variation in growth in the length of young yellow perch between littoral and limnetic habitats until mid-July, when fingerlings from limnetic areas showed a slight growth advantage over those from littoral habitats. First year weight gain was slow through mid-July then increased rapidly through September. Average weight in littoral habitats lagged behind weight in limnetic habitats most years, becoming evident between mid-July and mid-August and generally increasing with time. Yellow perch from limnetic areas averaged 4.9–7.5 g by late October, while those from littoral habitat averaged 2.9–5.3 g. Average daily growth increment was highest in September, most years.[28]

Additional reports from WI of age and growth in TL and weight are reported as follows:[9]

age 1, 66–142 mm, 13 g
age 2, 99–198 mm, 58–82 g

Table 215

Lengths and weights, in each age class at time of capture, for young yellow perch from Lake of the Woods, MN.

	SL (mm)			Weight (g)		
Age class	**Number**	**Mean**	**Range**	**Number**	**Mean**	**Range**
0	474	44	32–70	0	0	0
1	51	112	70–127	1	28	28
2	184	128	102–197	1	170	170
3	164	196	108–266	36	171	85–284
4	244	227	171–266	65	239	142–254

Note: Conversion to TL = 1.16×SL up to 150 mm; 1.154×SL from 151 to 200 mm; and 1.146×SL for fish over 201 mm.

Source: Data are taken from Table 5, reference 67.

age 3, 160–231 mm, 84–132 g
age 4, 150–246 mm, 108–182 g

Yellow perch increase in length rapidly during the first two years of life. Thereafter, they show only small annual length increments, but significant weight gains.[9]

In Lake Michigan, average TL was similar for young male and female yellow perch after two growing seasons, but after that, females grew faster.[20] Range in average TL (mm) reported for males and females by growing season are as follows:

growing season 2, males 128–177, females 126–176
growing season 3, males 154–210, females 163–218
growing season 4, males 175–233, females 189–267[20]

In Sandusky Bay, Lake Erie, yellow perch averaged 10.2 mm TL on May 15, and 11.9 mm on May 23. In western Lake Erie, average TL increased from 7.3 to 10.7 during the period May 8 to June 5.[68] They were also reported 5–16 mm in June, 6–17.5 mm in July, and 40–50 mm in August.[44,50] Growth rate of yellow perch young taken in the bay was faster than the young taken from the lake.[68]

In Saginaw Bay, Lake Huron, growth of male and female yellow perch was similar for the first two years, later the females grew slightly faster.[70] Ranges of back-calculated TLs (mm) for males and females by age class were reported as follows:

age 1, males 66–91, females 69–89
age 2, males 107–147, females 109–155
age 3, males 142–196, females 150–206
age 4, males 163–236, females 191–244[70]

First year growth of yellow perch in Missouri River reservoirs ranged from 54 to 79 mm. In general, growth was most rapid during early years of impoundment, declined, and then improved slightly. Ranges of unweighted mean TLs (mm) for ages 1–4 in three Missouri River reservoirs were: age 1, 62–69; age 2, 132–149; age 3, 165–187; age 4, 184–211. Females grew faster than males.[11] Total lengths (mm) by date of capture for larval and juvenile yellow perch from a Missouri River reservoir are presented in Table 216.[66]

In OH, YOY were 4.6–10 cm in October; at about 1 year, they were 5.1–11 cm. The following length and weight relationships were reported:[10]

127 mm = 23–37 g
150 mm = 31–85 g
180 mm = 71–119 g
200 mm = 85–147 g
230 mm = 128–198 g
254 mm = 213–292 g

Table 216

Total lengths (mm) by date of capture for young yellow perch from Lewis and Clark Lake.[66]

Date	Number	TL range
6/14	69	12–19
6/20	150	12–24
6/29	570	17–35
7/7	585	23–40
7/12	653	25–45
7/19	658	33–54
7/26	220	36–60
8/2	148	45–63
8/9	355	46–71
8/16	235	50–77
8/23	94	55–81
8/31	229	56–87

Environment is important relative to TL attained at hatching. Laboratory larvae were significantly shorter than pond hatched larvae. Field-nurtured post yolk-sac larvae showed faster growth, but not necessarily more rapid development than those raised in the laboratory.[32]

For additional reports of age and growth information from other areas see Carlander (1964).[47]

Feeding habits
All but the largest YOY yellow perch feed primarily on zooplankton. Food items consumed were diverse and variable, changing with habitat (littoral vs. limnetic), year, and size of fish.[28] Age changes in the diet are gradual and involve shifts in the proportions of the major foods eaten.[17] Small zooplankton are important to the survival of young yellow perch when they first begin to feed; if zooplankton are too large for the young to eat, the fry starve soon after the yolk and oil is used up.[9] In Lake Opinicon, Ontario, when they hatch, yellow perch yolk-sac larvae are dependent on larval and small cyclopoid copepods, the only abundant prey of sufficiently small size.[16,17] The size at which yellow perch began feeding in WI ranged between 5.0 and 6.9 mm.[9,28] Food was found in the stomachs of yolk-sac larvae in 2 years out of a 4-year study and

occurred in 54% of the stomachs examined one year and in 12% of the stomachs examined in the other year. Immature copepods were the principal food item found, along with small numbers of cladocerans and ostracods.[28]

There is a general trend of young yellow perch feeding on zooplankton during their first summer of life,[1,9,17,28,56] up to lengths of about 50–60 mm.[17] During this period, most reports indicate that copepods and cladocerans are the most important food items,[17,28,56] with amphipods also of importance in some areas.[16,17,56] Among post yolk-sac larval perch, in WI, copepods were, by far, the most common food, occurring in all stomachs each year of a 5-year study, and making up 81–99% of total food items. They clearly dominated in the amount of food consumed by all size classes between 5 and 22 mm, although a small and gradual decline occurred for larvae longer than 9–10 mm. This decline occurred with an increase of cladoceran intake, which peaked at 20% for fish 17–18 mm. Immature copepods were consumed in larger amounts than mature forms among all size classes, although nauplii were absent from stomachs of yellow perch longer than 17–18 mm. The percent frequency of cladocerans increased steeply after larvae grew to 10 mm, reaching 100% for larvae 19–22 mm.[28] In another study, *Daphnia* longer than 1.3 mm could not be readily ingested until mid-July when larvae were 18 mm long.[56] In WI, copepods and cladocerans comprised 94% of total food items consumed by trawl-captured yellow perch larvae.[28] In a Manitoba Lake, yellow perch larvae utilized a narrow range of food items and relied largely on zooplankton. *Daphnia pulicaria* occurred in all but a few stomachs examined, contributing 77–96% of the total caloric content in each stomach. Copepods, *Cyclops*, and *Diaptomus* occurred less frequently.[56]

Dietary diversity expands when juvenile yellow perch exceed 30 mm. They eventually consume an assortment of prey including worms, crustaceans, mollusks, and fishes.[8] Equivalent size juveniles of several other fish species have a more or less common diet for the first few weeks, hence temporal separation is of basic importance.[17] In a Manitoba lake, amphipods, *Gammaris lacustris* and *Hyalella azteca*, are reported in stomachs only after the juveniles moved to the littoral areas at about 30 mm. Amphipods dominated juvenile yellow perch stomachs during July and were common in stomachs examined other times. Cladocerans were the major contributor, 69% by weight, to the juvenile diet in September and were also common in June. Fish, including yellow perch, were common in stomachs and at times made up 30% of total stomach weight. Crayfish, dipterans, and other insects occurred infrequently. Amphipods predominated in juvenile stomachs whether the fish were captured from deeper water habitats (*Gammaris*) or inshore (*Hyalella*).[56]

By the end of their first year, yellow perch utilize Odonata nymphs, Ephemeroptera, mollusks, ostracods, chironomid larvae, and apparently prey on the eggs and young of a wide variety of fishes.[1]

60–135 mm TL. In Manitoba, cladocerans were consumed more by yellow perch 60–99 mm; amphipods were consumed equally by all sizes; larger juveniles were more piscivorous, brook silverside and yellow perch constituting the bulk of the fish diet for juvenile yellow perch up to 120 mm.[56] In June, at water temperatures of 18–22°C, a period of accelerated early summer feeding in Lake Opinicon, Ontario, late afternoon and morning feeding periods for yellow perch 90–130 mm are reflected in diurnal movement patterns.[16] For fish 115–135 mm, cladocerans, isopods, *Diptera* (larvae and pupae), and Zygoptera occupied 81% (by vol.) of the stomachs examined.[17]

≥150 mm TL. Juveniles of this size feed on decapods, Odonata nymphs, and small fishes.[1,9] In Lake Opinicon, yellow perch are considered piscivores at about 150 mm, but a 70 mm fish, in a dense weed bed in August, was observed "literally gorged" with 20 to 30 mm long sunfish.[17] Yellow perch 200 mm are reported to consume chironomid larvae and pupae.[9] Copepods and cladocerans comprised 93% of the total food items observed in the stomachs of seine-captured yellow perch from WI.[28] Cannibalism begins as early as 210–250 mm[3] or at <120 mm.[56]

Timing relative to size of fish and size and availability of prey is important to the survival of yellow perch year classes. Yellow perch in West Blue Lake, Manitoba, inhabit a zone in which food is abundant and available at a critical time in their life. The offshore movement and epilimnetic phase of life coincides with the maximum abundance of *D. pulicaria*. This offshore dispersion seems to permit yellow perch larvae to take advantage of this food source and to minimize intraspecific competition for food, which would have been more intense had the larvae remained near spawning sites in the limited littoral area of the lake. Upon returning to the littoral area (at about 30 mm), the much less abundant age 0 yellow perch have a larger variety of larger organisms available, occupying more than one trophic level, to utilize as food.[56]

The importance of timing of larval development with the production of specific food organisms is evident. For yellow perch that received no food during the first 7 days after hatching and were then allowed to feed for 20 days; mortality was 94% in aquaria and 66% in a pond. All larvae that starved for 9 days died when placed in aquaria or pond.[26]

High water temperature can shorten the time for feeding opportunities of newly hatched yellow perch. The median period between swim-up and death of unfed larvae was 9 days at 19.8°C and 21 days at 10.5°C. It is suggested that feeding and survival of yellow perch larvae is possible at water temperatures >10°C and optimal at temperatures >20°C; temperature optima for survival would be lower if rations are restricted.[26]

The presence or absence of other species may affect the feeding habits. Before the removal of white sucker from a MN lake, microcructaceans were the prominent food for young yellow perch, making up 63.8% of the volume of food consumed. These organisms made up 43.1% of the diet of juveniles of 51–127 mm and 35.6% of the diet of those >127 mm. After removal of white sucker from the lake, juvenile yellow perch 51–127 mm increased consumption of crustaceans by about one third.[71]

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GENUS

Sander (Rafinesque)

Robert Wallus and Edwin M. Scott

The genus *Sander* contains five extant species, two that occur in North America: *S. vitreus* (Mitchill) walleye, *S. canadense* (Smith) sauger, and three in Europe: *S. lucioperca* (Linnaeus) European walleye or sander, *S. volgensis* (Gmelin) Volga pikeperch, and *S. marina* (Cuvier) sea pikeperch (Collette and Banarescu, 1977). Two subspecies of walleye are currently recognized. The "yellow walleye," *S. vitreus*, is the common form found throughout the United States and Canada. The blue pike or "blue walleye," once thought to be a distinct species, *S. v. glaucum* (Hubbs, 1926), now considered extinct (Ono et al., 1983; Campbell, 1987; McAllister et al., 1985) was found in Lake Erie and Ontario, although some authors believe it also existed in Lake Nipissing, Ontario (Jorgensen, 1974). The walleye hybridizes occasionally with sauger in TN (Stroud, 1948; Hubbs, 1955; Fletcher, 1977), rarely in OH. Artificially produced hybrids, *S. vitreus* × *S. canadense*, called "saugeye" are a recent addition to fisheries management. Both North American species and naturally occurring and artificially produced hybrids (saugeye) occur within the Ohio River system, and are important sport fishes.

Adult genus characteristics include: elongate, fusiform body, broad back, subconical, long head; cheeks, opercles, and top of head more or less scaly; mouth large, the jaws about equal; premaxillaries protractile, but less movable; teeth in villiform bands, the jaws and palatines with long, sharp canines; gill-rakers slender, but strong; gill membranes separate; preopercle serrate, the serrae below turned forward; opercle with one or more spines; dorsal fins well separated, the first with 12–15 spines, the second with 17–21 rays; last dorsal spine not erectile, but bound down by membrane; anal spines 2, slender, closely bound to the soft rays, which are 11–14; pelvic fins well separated; scales small, strongly ctenoid; the lateral line continuous (Jordan and Evermann, 1905). Vertebral counts are 46–47 for walleye and 44–45 for sauger (Bailey and Gosline, 1955). There is little sexual dimorphism in the genus; breeding tubercles absent; females reach a larger maximum size, and are longer and heavier than males of the same year class, at least after age 2 (Collette, 1965).

SAUGER

Sander canadense (Smith)

canadense: of Canada.

RANGE

Native range is entirely west of the Appalachian Mountains most of which is in central North America. Present in the Mississippi and Missouri River basins, the Great Lakes drainages, and the Hudson Bay drainage of southern Canada from Quebec west to Alberta; in the Mississippi River drainage south to AR and TN and northwest to MT. Successful introductions have been made in larger Gulf Coast and Atlantic Slope drainages.[1,2] In 1978, sauger was reported to occupy 10% of the total freshwater areas in North America.[3]

HABITAT AND MOVEMENT

Typical of large, often turbid, free-flowing streams, lakes, rivers, and impoundments.[1,2,4–10] Found in bays of large, deep lakes.[11] Largest population in Lake Erie in the shallower, more turbid waters of the western end.[8] Generally most abundant in the more river-like, turbid upper sections of the MO reservoirs.[12] Tolerant of silted bottoms,[8] but in big rivers, reported to occur in open waters or deep pools with abundant bottom cover over firm gravel or sand areas in moderate to rapid current.[9] Usually found in the top 6 m of water.[5] In bays of deep lakes, occupies the region above the thermocline.[11] Reported to have a wide depth distribution ranging from the surface to a depth of 15 m or more.[13] Taken as deep as 23 m in Norris Reservoir, TN, but more common above 15 m.[16] Usually found within 32 m of shore at a bottom depth ranging from 2.4 to 5.2 m in Old Hickory Lake, TN.[22,23]

A decreasing water transparency is favorable.[14] In sauger, the *tapetum lucidum* of the retina is more highly developed than in walleye, suggesting that the sauger's retina is better adapted than the walleye's for life in a dimmer, more turbid, environment.[15] However, the sauger is reported to be the least tolerant of several percid species, including walleye, to the detrimental effects of eutrophication. Tributary-spawning stocks of sauger are more vulnerable to loss of spawning habitat than lake-spawning stocks. Lake-spawning sauger broadcast their eggs on the bottom, where survival may be poor if enrichment has led to heavy sedimentation of organic matter.[14]

The preferred habitat of sauger is influenced by three main factors: temperature, dissolved oxygen, and turbidity.[21] Saugers are classified as temperature mesotherms.[17,18] Reported temperature preferendum is 22–28°C.[19] In northern waters, during summer, saugers are most often caught at water levels where water temperature is 18.6–19.2°C.[5] In the Wabash River, preferred summer temperature ranges were 22.3–27.7°C.[16] In TN, thermal preference was reported between 15 and 21°C from May to August.[20] Sauger have been found in heated effluents up to 33.6°C.[11] During summer stratification of a reservoir, they will be found at or near the thermocline, where the coolest waters with sufficient concentrations of dissolved oxygen are available. Also, suppressed light at thermocline depths is more suitable for this light-sensitive species. When a reservoir is not thermally stratified, behavior is influenced by the intensity of subsurface light penetration. Movement and feeding activity is restricted to periods of low light intensity, which may be caused by turbidities, water color, wave action, or ambient light conditions at the water surface.[21] In clearer water, they are most active for short periods in the evening and early morning; in more turbid water the period of activity is longer.[5] In turbid waters or on cloudy or windy days, sauger activity continues throughout the day.[33]

Sauger are more active at night than in the daytime.[25,31,32] In TN, they move more frequently and average greater movements at night.[22] Diel activity was reported greatest from dusk through midmorning; maximum linear distance moved was generally within 2.6 miles, except during spawning season.[23] Usually move little during summer.[5] Saugers tagged in June and July exhibit less movement than fish tagged in winter and spring and show strong preference for cove habitat.[24]

Sauger are the most migratory of the percids.[18] Tagged fish have been reported at distances up to 380 km (236 miles) from the point of release.[11] There are many reports of spawning migrations.[21,23,24,26–32] They do not "home-in" on natal spawning grounds, but instead migrate as far upstream as possible during the colder months of the year.[21]

Sauger were native to the Tennessee River system prior to the construction of dams. The creation of reservoirs increased the amount of habitat available and their populations expanded. However, by creating reservoirs, the impounded waters covered most of the original sauger spawning sites, limiting postimpoundment spawning to riverine stretches of reservoir headwaters.[21] Sauger disappeared from Cherokee Reservoir (Holston River), TN several years after impoundment, perhaps due to blockage of spawning runs by another dam, further upstream.[2,41] In late fall and winter, pre-spawning sauger, migrating upstream, congregate below dams on the mainstem Tennessee River.[31] When concentrated in tailwaters of dams, they are quite vulnerable to human activities.[28] Adult sauger can ascend through most of the navigation locks in the Tennessee River, and are able to move downstream through the same locks or survive passage downstream through the hydroelectric turbines.[21,31] After spawning, both sexes leave the spawning area, some fish moving upstream and others moving downstream, in the Tennessee River passing through dams in either direction.[31,32]

In Douglas Reservoir, TN, male sauger, radio-tagged in February, moved upstream showing a strong affinity for the old river channel.[24] In Old Hickory Lake, TN, sauger are most active between mid-October and May, with greatest movement in November and December, the peak of the spawning migration.[23] Movement of 37 saugers, radio-tagged and released downstream of Pickwick Dam on the lower Tennessee River, between December and mid-February, ranged from 1 to 276 km, with an average of 67 km. Four of these fish moved upstream through the dam, but most remained within 30 km of the dam through late March. By April, the tagged fish began dispersing downstream into the main body of Kentucky Lake; some of these fish moved downstream more than 200 km in less than 10 days.[28] In another study, 4 of 200 sauger, tagged and released upstream of Kentucky Dam in early December, were recaptured in 16 days below the next upstream dam (Pickwick), a distance of 296 km (movement of over 19 km per day). Another fish from this tagging area moved upstream through Pickwick Dam and was recaptured below the next upstream dam (Wilson); this fish traveled 380 km in 18 days.[31] Sauger traveled extensively in Norris Reservoir, TN, with reports of movement from 0 to 241 km from tagging areas.[35,36] The heated discharge from a steam plant posed no significant problem to winter migrations of sauger in Melton Hill Reservoir (Clinch River), TN, but it was unclear whether the heated effluent was a temporary hindrance and could have caused some delay in movement, and whether sauger move under, around, or through the thermal plume.[27] Upstream movements have been reported in the Clinch River, TN, not associated with spawning.[34]

In other studies, much variability is reported in the movement of tagged sauger, one of the reports showed a mean distance of 12.5 km with a standard deviation of 26.4 km.[22] Of the 290 saugers tagged and released in the Mississippi River immediately downstream of Lock and Dam 10 (IA), 63% were recaptured within 8 km; 84% were recaptured less than 80 km away, and only 4% were recaptured at distances greater than 161 km away. Sixty-five percent were recaptured in the pool in which they were tagged; 22% moved upstream, and 16% moved downstream.[38] In two other upper Mississippi River pools, 79 and 83% of saugers tagged were recaptured in the same pool. All but one from each group moved upstream, moving average distances of 71–95 km. Movement up the tributary rivers was reported.[39] A stocked sauger reportedly traveled 201 km from GA to FL.[40]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Sauger are common throughout the length of the Ohio River. A 1984 study indicated more reports of sauger after 1970 than earlier, particularly in the middle third of the river.[45] In OH, sauger are present in the Sciota and Muskingum drainages and generally distributed in the Ohio River.[8] In IL, they are present in the Wabash and Ohio Rivers; sporadic, but probably more common than indicated by the records.[44] In KY, they are generally distributed and common in the Ohio River and lower reaches of its major tributaries; also from reservoirs across the state.[9] In TN, the sauger is found throughout the Tennessee and Cumberland Rivers and their major tributaries.[2,21] It is reported to be a sensitive coolwater species which has been declining in abundance throughout the Tennessee River in recent years.[46,47] In NC, it is often caught during spawning season in the French Broad River near the NC/TN state line; less common in the Hiwassee River.[42] In VA, apparently native to the upper Tennessee River drainage and perhaps also to the Big Sandy River.[16] In AL, known only from the Tennessee River drainage.[43]

SPAWNING

Location
Usually seek riverine habitats to spawn,[48] but some may spawn in reservoirs.[37,50] In reservoir systems, they spawn in the tailwaters of dams,[12,20,28,29,37,48–52] riverine headwaters,[26,30,37,48,50] or major tributaries.[30] In lakes, they spawn along shorelines,[53] on

shallow, sandy, gravel, or rubble shoals or bars,[5,54] or up tributary rivers.[54] Increased turbidity in Lake Erie may have improved requirements for reproduction.[55]

Ripe males moved downstream from a congregation below a dam to the nearest spawning shoal.[21] Spawning in the Clinch River, TN, was widely dispersed through 9 miles of the Melton Hill Dam tailwaters.[51] In the French Broad River, TN, spawning occurred in a 10 by 300 m strip along the river bank.[26] Other reports of spawning areas include main channel border areas,[6] mouths of creeks, and midchannel islands.[52]

Sauger are simple, lithophilic spawners.[56] They scatter their eggs over firm substrates[2,11] of various mixtures of rock, gravel, pebbles, sand, rubble, and boulders.[5,12,26,44,48,51,53,54,56,57] Spawning is also reported over silt-free rock riprap[10] and mussel beds.[6] Water depths in spawning areas vary with reports of 61 to 366 cm deep.[5,57] Depths are reported up to 1.2 m on a lake shoreline in WI[53] and 6–7.5 m in a TN river.[51] Current velocities near spawning substrate have been reported at 18–20 cm/s.[26] Sauger spawn at the surface in Lake Winnebago (spawning depth up to 1.2 m),[53] but not in the Clinch River, TN, with water depths of 6–7.5 m.[51]

It is suspected that flooding may be responsible for strong year classes of sauger, since suitable spawning areas become increasingly available, as floodwaters rise.[11] Fluctuating water levels in rivers, during the period of incubation, appear to exert a great influence over spawning success. Abundance of larvae in the Missouri River increased when water level fluctuations below a dam decreased.[48] Low flows and unstable water temperatures during the sauger spawning season (April) in a Tennessee river tailwater were determined to be limiting factors for reproductive success.[58] Subsequent study revealed that an instantaneous minimum discharge of 8000 cfs from the upstream dam was sufficient to provide conditions for successful sauger reproduction. It was also suggested that 4000 cfs may be adequate to maintain a viable sauger population.[58,59]

Season

In Canada, late May through early June.[5] Late April to the end of June in ND[50] and MO[60] with peaks in May. Late April through early May in SD,[12,48] WI,[53] and the upper Mississippi River,[6] lasting for 2 weeks or less,[12,48,53] with the peak in May[53] lasting 5–7 days.[12,48] Mid-March through April in the Illinois River.[57] April in IL.[44] Spawning season lasts 3–4 weeks in TN, usually during late March through mid-April.[2,24,26,28,30] Spawning in the Clinch River, TN occurred between early April and mid-May with a peak in mid- to late April.[51]

In TN, sauger spawning begins later than walleye but overlaps; natural hybrids between the two are not uncommon.[2] It is speculated that the ultimate reason for the disappearance of sauger in Lake Erie was its absorption into the walleye gene pool, following a period of low sauger abundance. This was substantiated by interviews with commercial fishermen, who related that sauger began to merge morphometrically with walleye.[85]

Temperature

Spawning of northern populations is reported at water temperatures ranging from 3.9 to 6.1°C[5,6] and 3.9–11.7°C.[50,53] In SD, spawning begins at about 6°C.[12,48] Males were present in the spawning area at temperatures under 3.3°C; the number of females increased with rising water temperature and by the time the temperature reached 6.1°C, the females composed more than 50% of the catch, with many running ripe.[49] In the Illinois River, the optimal spawning temperature ranged from 7 to 10°C.[57] In TN, spawning begins at water temperatures of about 10–11°C.[2,21,28]

Fecundity

Scott and Crossman (1973) reported 15,000–40,000 eggs/lb of fish depending on size.[5] In MN, three female saugers 305–311 mm SL had 43,400–48,500 eggs.[64] The average number of eggs produced by saugers 257–371 mm from Lake Winnebago, WI, was 15,871 with a range from 4,208 to 43,396.[53] In ND, the number of eggs for saugers 328–625 mm ranged from 10,488 to 117,058; the average number/lb of fish was 27,498.[50] From the Illinois River, age 2 females (n = 3), averaging 396 mm and 877 g, averaged 78,643 eggs; an age 2 female 416 mm weighing 693 g had 55,592 eggs; age 3 females (n = 2), averaging 452 mm and 1189 g, averaged 63,021 eggs; and age 3 fish (n = 4), averaging 450 mm and 1201 g, averaged 123,876 eggs.[57] Reduction in sauger fecundity in northern states has been attributed to winter die-offs of shad.[20]

There is little information available on the fecundity of Ohio River drainage sauger. In TN, larger females may produce over 100,000 eggs, but most produce 20,000–60,000.[2,62] Females, from Norris Reservoir on the Clinch River, TN, averaged 58,250 eggs/fish and 31,600 eggs/lb of fish.[61] In another study from Norris Reservoir, fecundity ranged from 9,000 eggs from a 297 mm, 195 g fish to 96,000 eggs from a 483 mm fish weighing 1247 g.[62] The fecundity of sauger from the lower Clinch River ranged from 22,000 eggs from a 340 mm, 408 g fish to 117,000 eggs from a 459 mm female weighing 1390 g.[63]

See Carlander (1997) for additional fecundity reports.[65]

Sexual Maturity

Males mature earlier than females. In Canada and WI, males mature in 2–3 years and females in 4–6 years.[5,53] More than 50% of male and female sauger were mature in WI by 249 and 284 mm, respectively.[53] In ND, some male and female sauger were mature at age 3.[50] Illinois River sauger mature after 2 years at 330–380 mm.[57] Southern populations are usually reported to mature in 2–3 years.[2,16,21,32,62] Males in the Tennessee River drainage may mature by the end of their first year of life, as small as 254 mm and 165 g, and most are mature at the end of their second growing season. Females mature a year later at either 2 or 3 years of age.[21,32] In TN, the respective lengths at which more than 50% of male and female saugers attain maturity were 330 and 343 mm.[62]

Spawning Act

Sauger are simple lithophilic spawners, scattering their eggs randomly over the substrate and fertilizing them externally as they fall.[20,48] They do not build nests or give parental care to the young.[20,48,53,56] Instead of guarding their eggs, sauger develop aggregations of spawners on the spawning grounds to ensure spawning success.[56] Spawning occurs at night.[5,11,48] Mature males arrive before females[5,11,48,49,53] and remain on or near the spawning grounds for the duration of the spawning season. They move into the spawning areas during darkness and seek nearby deepwater or shaded refuges during the day.[21,48] The female will spawn all her eggs in one night through repeated spawning acts with one or more males.[5,21] Females leave the spawning area soon after spawning.[5,11,48]

EGGS

Description

The diameter of mature eggs from ripe female sauger range from 1.0 to 1.5 mm.[53] Fertilized eggs are pale yellow and have a single, anterior oil globule.[5,6,53] They are demersal[66] or semibuoyant[53] and strongly adhesive after water-hardening[48,49,66] or nonadhesive.[53] Fertilized eggs average 1.66 mm in diameter, with a range 1.44–1.86.[29] In another report, eggs measured just before hatching averaged 1.8 mm in diameter.[66]

Incubation

Reports of 22–29 days at water temperatures ranging from 4.5 to12.8°C;[5] 21 days at 8.3°C.[20,48] In a hatchery, 9–14 days at 12.8°C;[48,66] In TN, 1.5–2 weeks depending on water temperature.[21] Other reports include 37–58 days at 6.0°C; 22–35 days at 8.9°C; 12–21 days at 12.0°C; 8–13 days at 15.0°C; 7–10 days at 18.1°C; 5–8 days at 20.9°C.[67]

Development

Nelson (1968a) provides an illustration of a late embryo[29] and Priegel (1969) has a photograph of two fertilized eggs, one an eyed-egg.[53]

YOLK-SAC LARVAE

See Figure 201

Size Range

Reports of size at hatching for sauger are usually smaller than walleye and overlap those of yellow perch.[29,69,72] From hatcheries in SD and WI, they ranged from 4.6 to 5.1 mm;[29,48,53] also reported as newly hatched at 4.5–6.2 mm.[1,57,60,67] Yolk absorption was complete for WI sauger by 7.7 mm.[53] In SD, yolk absorption was completed between 9.4 and 9.6 mm.[29]

Myomeres

Total 41–43 (41.8); preanal 16–21 (19); postanal 21–26 (23).[29]

Morphology

Notochord is straight at hatching; yolk sac is large, oval, with a single anterior oil globule. Teeth begin developing late in yolk-sac phase.[29] Yolk is completely absorbed between 7.7 and 9.6 mm.[29,53]

Morphometry

See Table 217.

As the larvae increase in length, the yolk sac decreases in width and increases in length; yolk sacs ranged from 0.77 to 2.15 mm in depth and from 1.62 to 2.75 mm in length.[29]

Fin Development

Pectoral fin buds are present at hatching. The median finfold originates dorsally between the second and fifth myomeres and is continuous around the notochord to the posterior margin of the yolk sac. It is widest dorsally and ventrally just posterior to the anus. No fin ray ossification is evident during the yolk-sac phase.[29]

Pigmentation

During the initial phase, pigment is limited to a few faint, small chromatophores on the yolk sac. Later on, chromatophores increase in number and size

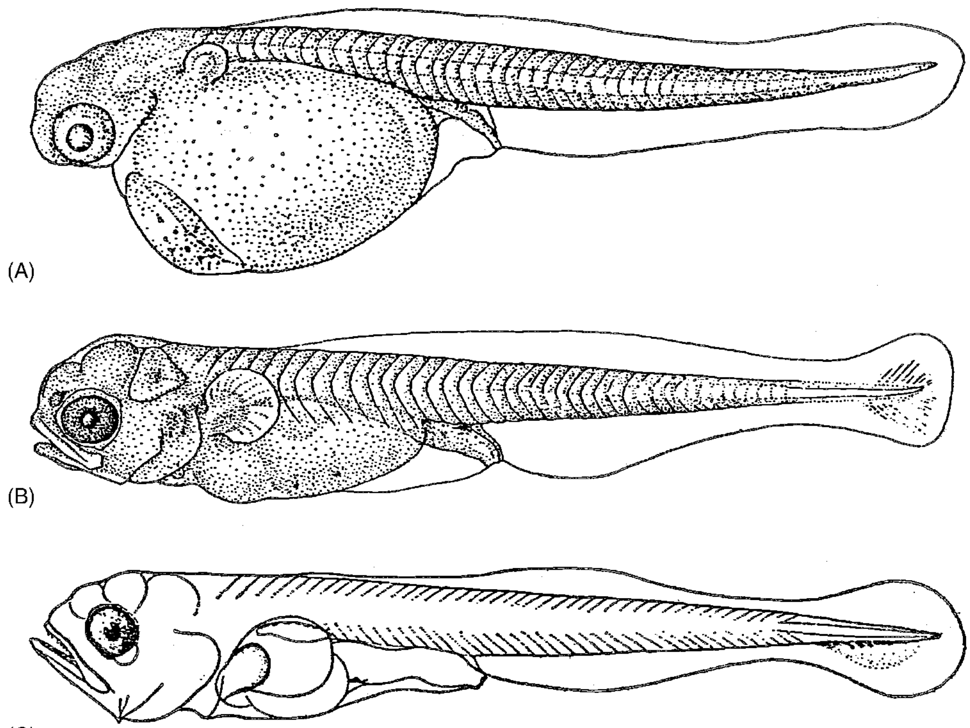

Figure 201 Development of young sauger: (A–C) yolk-sac larvae, (A) 5.5 mm TL, (B) 8.5 mm TL, (C) 9.0 mm TL. (A and B: reprinted from figures 2 and 4, reference 29, with publisher's permission; C: reprinted from Figure 91, reference 54.)

Table 217

Morphometric data (expressed as mean percent TL) and average myomere counts by length intervals for sauger yolk-sac larvae from South Dakota.

	TL Groupings					
TL Range (mm)	**4.6–5.0**	**5.1–6.0**	**6.0–6.6**	**7.1–7.7**	**8.4–9.0**	**9.1–9.6**
Mean TL	**4.9**	**5.6**	**6.3**	**7.5**	**8.7**	**9.3**
N	**10**	**10**	**10**	**10**	**10**	**10**
As Mean Percent TL						
Snout to anus	50.9	50.6	49.4	49.2	49.5	49.5
Head length	11.5	14.0	14.1	16.4	18.2	17.4
Eye length	6.2	6.1	5.6	5.9	5.7	5.6
Intestine length	2.3	6.3	7.5	6.2	7.8	7.7
Body depth	26.6	27.2	23.8	20.0	16.3	16.7
Yolk-sac length	40.0	34.5	31.6	29.1	24.4	24.4
Yolk-sac depth	25.8	24.2	21.2	13.9	11.0	10.1
Myomere Counts						
Preanal	—	—	18.9	18.9	18.5	18.6
Postanal	—	—	23.4	23.7	22.4	22.9

Source: Content is based on data presented in Table 1, reference 29.

and are concentrated along the ventral margin of the yolk sac, with 1–3 along the ventrum between the anus and the caudal fin.[29]

POST YOLK-SAC LARVAE

See Figure 202

Note. Auer (1982) believed that descriptions and an illustration of a 14.6 mm sauger, reported by Fish (1932), were based on a misidentified logperch *Percina caprodes*. We concur with Auer, and will not cite information or data reported by Fish for that specimen.

Size Range
Phase begins between 7.7 and 9.6 mm.[29,53] Completion of the phase is reported at about 20 mm.[29]

Myomeres
Total 42–45 (43.5); preanal 20–22 (20.9); postanal 22–23 (22.6).[29]

9.0 mm TL. 16 myomeres to the vent plus 26 behind (incomplete).[54]

13.0 mm TL. 17 myomeres to the vent plus 27 behind (incomplete).[54]

10–15 mm TL. Preanal 19–22 and postanal 21–24.[48]

Morphology
9.0–10.3 mm TL. Body robust. Mouth large, jaws well formed with maxilla extending, posteriorly, to the posterior margin of the pupil. Both jaws armed with teeth.[29,54] Urostyle begins to turn up.[67]

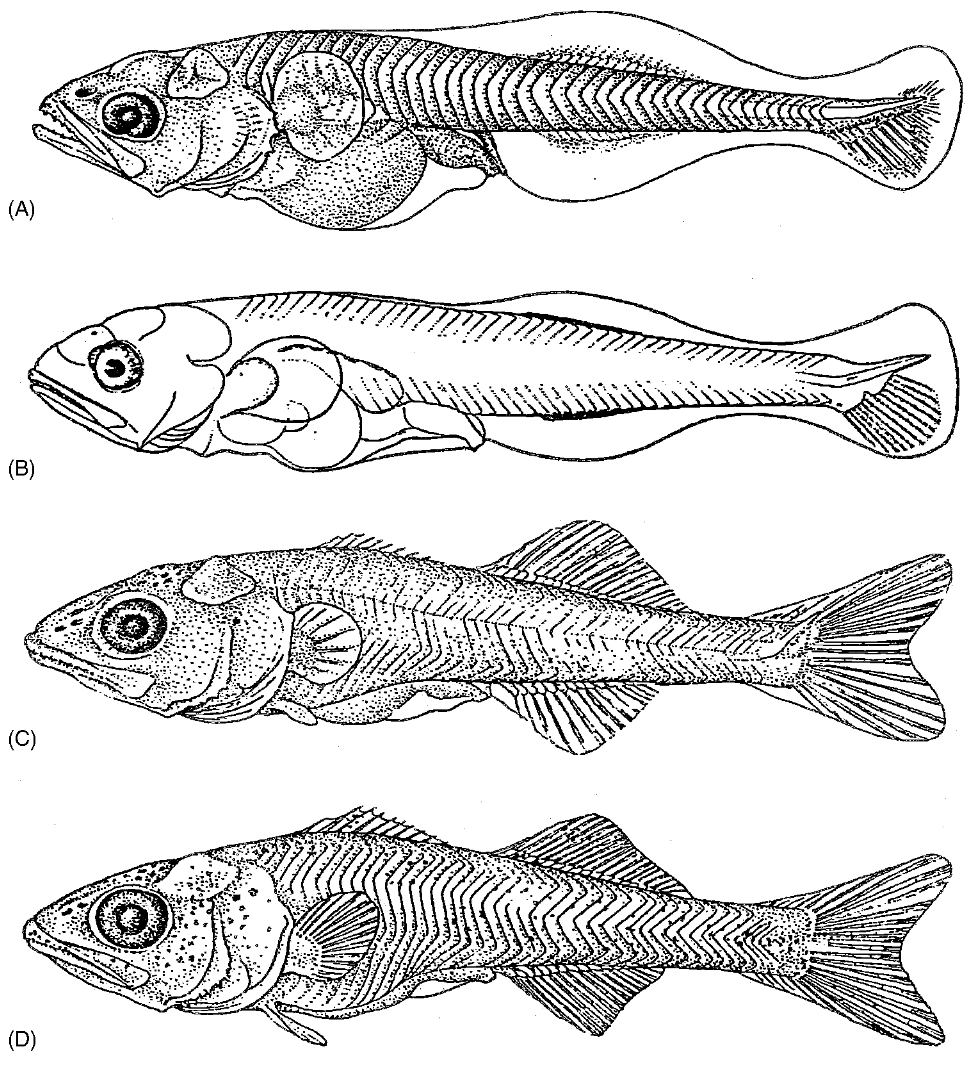

Figure 202 Development of young sauger: (A–D) post yolk-sac larvae, (A) 10.3 mm TL, (B) 13.0 mm TL, (C) 14.5 mm TL, (D) 17.5 mm TL. (A, C, and D: reprinted from Figures 6,7, and 8, reference 29, with publisher's permission; B: reprinted from Figure 92, reference

13 mm TL. Snout becomes pointed with well-developed teeth evident; mouth terminal; large, simple air bladder; intestine coiled; vent open, intestine ending away from the body at the margin of the finfold.[54]

19.0 mm TL. 4–7 pyloric caeca are present, which are much shorter than the stomach.[29]

Morphometry
See Table 218.

9.0 mm TL. As percent TL: SL 97.8; length to vent 47.2; HL 20.0; ED 5.2; GD before vent 16.1; GD behind vent 7.2.[54]

13.0 mm TL. As percent TL: SL 96.2; length to vent 50.0; HL 21.5; ED 5.2; GD before vent 19.2; GD behind vent 10.8.[54]

Fin Development
9.0 mm TL. Median finfold originates near the head and rises to its highest point posterior to the vent, continues around the urostyle and is present ventrally to the stomach. Primordial caudal fin development is evident.[54]

10.0–11.0 mm TL. Caudal fin rays visible below urostyle and pterygiophores evident in areas of future dorsal and anal fins.[29]

13 mm TL. Dorsal and anal fins forming, spines and rays visible;[29,54] rays visible in the pectoral fins;[29] caudal fin appears heterocercal, rays in the lower lobe well developed.[54]

14.5–15 mm TL. Pelvic fin rays forming; median fins well formed, dorsal fins separated, caudal fin development nearing completion. All that remains of the median finfold is a small remnant just anterior to the anus.[29]

17.5 mm TL. Remnant of ventral finfold still present just anterior to the vent.[29]

Pigmentation
Pigmentation patterns of sauger and walleye post yolk-sac larvae, at any given length, are similar.

Table 218

Morphometric data (expressed as mean percent TL) and meristic data (expressed as average counts) by length interval for sauger post yolk-sac larvae from South Dakota.

	TL Groupings								
TL range (mm)	**10.3–10.9**	**11.1–11.9**	**13.1–13.6**	**14.2–14.9**	**15.2–15.8**	**16.0–16.8**	**17.0–17.8**	**18.0–18.7**	**19.5–20.0**
Mean TL (mm)	**10.6**	**11.4**	**13.3**	**14.6**	**15.4**	**16.4**	**17.4**	**18.4**	**19.8**
N	**10**	**10**	**5**	**10**	**10**	**10**	**8**	**5**	**5**
As Mean Percent TL									
Snout to anus	49.7	50.7	50.9	52.0	51.6	52.4	52.6	53.1	53.5
Head length	21.1	22.5	25.6	25.9	25.6	26.9	27.6	29.2	28.6
Myomere Counts									
Preanal	19.7	19.6	20.1	21.9	21.4	21.0	21.6	22.0	20.4
Postanal	23.0	23.1	22.7	22.9	22.9	22.3	21.9	22.4	22.0
Fin Ray Counts									
Spinous dorsal	—	—	1.0	3.1	9.8	10.3	10.3	10.6	10.8
Soft dorsal	—	—	9.8	14.0	18.6	20.3	20.1	21.0	20.2
Caudal	5.0	8.8	18.8	19.8	23.2	27.3	28.5	30.6	32.4
Anal	—	—	8.6	11.0	14.1	15.3	16.0	16.0	15.8
Pectoral	—	—	4.2	4.1	6.4	6.9	12.0	12.5	12.5
Pelvic	—	—	—	—	0.7	3.2	3.9	4.0	5.6
Pyloric Caeca	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**2.0**	**5.0**

Source: Content is based on data presented in Table 2, reference 29.

Early in the phase, a few faint chromatophores are scattered along the ventral margin of the myomeres, but by the end of the phase, chromatophores were concentrated along the dorsal margin of the myomeres and 1–4 chromatophores per myomere were present laterally along the median myosepta. Head pigment is concentrated in the mandibular, maxillary, and occipital regions.[29,72] Visceral pigmentation is very conspicuous, with numerous chromatophores located dorsal to and around the air bladder and along the dorsal aspect of the intestine, decreasing in number near the anus, with 2–6 present near the vent. The ventral pigment line is present from the anus onto the caudal fin, with 1–3 chromatophores per myomere. Large stellate chromatophores are abundant on top of the head, from the tip of the snout to the nape, on the cheeks, at the base of the pectoral fin, and in the region of the heart. The sides and tips of both jaws are fairly well pigmented.[72] Pigment first appeared on the caudal and anal fins when the fish were 13 mm TL. Beyond 15 mm TL, walleyes were more heavily pigmented than saugers, but saugers exhibited heavier pigmentation on the head.[29]

9.0 mm TL. Pigment is confined to one large chromatophore ventrolaterally about halfway from the pectoral fin base to the vent and barely visible pigment on the dorsal aspect of the air bladder.[54]

13.0 mm TL. Pigment first appears on the caudal and anal fins.[29]

JUVENILES

See Figure 203

Size Range
From about 20[29] to 250–350 mm.[21,32,53,57,62]

Morphology
27 mm TL. Snout greatly produced and pointed, jaws equal; maxilla extends behind the posterior margin of the pupil; teeth large. Body elongate and terete.[54]

39.0 mm TL. Body rather slender, not much compressed, subterete. Head pointed with maxilla reaching behind posterior margin of pupil.[54]

Vertebrae. 44 to 45.[74]

Morphometry
27.0 mm TL. As percent TL: SL 81.5; length to vent 51.1; HL 28.5; SnL 7.4; ED 7.4; GD before vent 15.2; GD behind vent 11.7; length to dorsal fin 29.6.[54]

39.0 mm TL. As percent TL: SL 84.6; length to vent 51.4; HL 26.9; SnL 11.5; ED 7.4; GD before vent 15.6; GD behind vent 12.8; length to dorsal fin 30.8.[54]

Fins
Spines in the first dorsal fin 10–14 (usually 12–13), 13–15 in the northwest; second dorsal fin with 1–2 short, anterior, spine-like rays and 16–21 (usually 17–19) soft rays. Anal fin has two slender spines and 10–14 (usually 11–13) soft rays. Pectoral fin rays 13–16 (usually 14–16), 12–14 in the northwest.[2,5,54] Pelvic fin with one spine and five rays.[5] Caudal fin with 17 principal rays.[67]

Pigmentation
27.0 mm TL. There is heavy pigmentation on the tip of both jaws, on the top of the head, especially behind the eye, and on the operculum. A double row of pigment is present along the dorsum of the body, heaviest around the bases of fins; a double row of pigment is present at the base of the anal fin and a single row is present ventrally from the anus to the caudal fin. There are a few small chromatophores laterally on the caudal peduncle. All fins are unmarked except for pigment outlining the caudal fin base.[54]

35.0 mm TL. Adult coloration patterns are attained at about this size.[29]

39.0 mm TL. Body is white and covered with numerous melanophores, more numerous on jaws and top of the head. A slightly larger, single series of melanophores is present at the base of each median fin and along the lateral line posterior to the dorsal

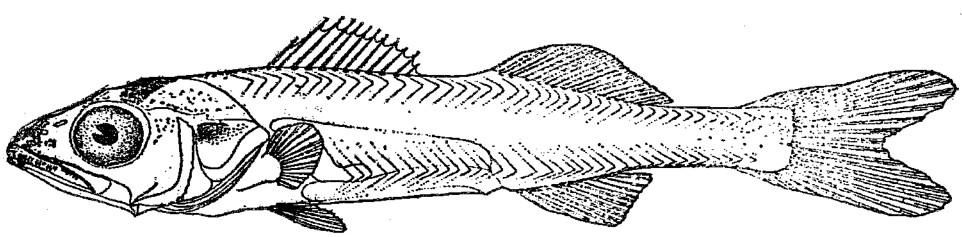

Figure 203 Young sauger, juvenile; 27.0 mm TL. (Reprinted from figure 94, reference 54.)

fins. The belly is white. The caudal fin is the only fin with pigmentation.[54]

Young sauger are marked with a sandy-colored background and a conspicuous, dark brown, almost continuous saddle under the dorsal fin.[5]

TAXONOMIC DIAGNOSIS OF YOUNG SAUGER

Similar species: walleye, sauger and walleye hybrids, yellow perch, and darters. Young members of the Moronidae family superficially resemble sauger in general appearance and body proportion, but differences in myomere counts allow easy differentiation.[88] Sauger larvae have at least 41 or more total myomeres;[29] moronids have 26 or fewer.[67,70,71]

Sauger vs. Walleye (see Table 214)
Sauger eggs average 1.66 mm in diameter (range: 1.44–1.86 mm) and walleye eggs average 2.07 mm in diameter (range: 1.90–2.31 mm). Just before hatching, walleye embryos have numerous chromatophores on the yolk sac and ventrally from the anus to the caudal peduncle; sauger embryos have fewer chromatophores on the yolk and ventrum.[29]

Newly hatched sauger are generally smaller (4.5–6.2 mm)[5,29,53] than walleye (usually 6–8 mm TL).[29,53,71] Pigmentation on sauger yolk-sac larvae is confined to the yolk sac where only a few faint chromatophores are visible; walleye pigmentation includes distinct chromatophores on the yolk sac and a ventral line of pigment between the anus and the caudal fin.[53] The yolk sac of walleye is more elongated than the oval-shaped yolk sac of sauger; yolk-sac depth ranged from 0.77 to 2.15 mm for sauger and 0.63 to 1.25 mm for walleye.[29] Sauger yolk-sac larvae have a lower average preanal myomere count of about 19 (range: 16–21) compared to about 20 for walleye (range: 18–22), based on Missouri River data, only.[29] Postanal myomere counts for yolk-sac larval sauger were also lower, ranging from 21 to 26 with an average of about 23 compared to 20–28 for walleye with an average of about 26.[29]

Total myomere counts average about 43 for sauger post yolk-sac larvae and 45–46 for walleye.[29] At any given length, post yolk-sac larval sauger are more robust and have more development in their fins than walleye.[29] Pigmentation, although generally more profuse in walleye, becomes highly variable among individuals during the post yolk-sac phase, making it less reliable for identification than during the yolk-sac phase.[53] The most useful characteristic to distinguish the two species at total lengths of 13–18 mm is the number of ossified dorsal spines, which develop earlier (i.e., at smaller sizes) in sauger than walleye.[29] Sauger measuring 15 mm have an average of nearly ten dorsal spines, while similar-sized walleye have not yet formed one dorsal spine.[53] Walleye reach 19 mm before having ten dorsal spines.[53]

By 19 mm TL, sauger and walleye can be identified by pyloric caeca counts, three in walleye and 4–7 in sauger.[29,53] An external pigmentation characteristic has been used to distinguish between young sauger and walleye 25–75 mm. This "color-spot" technique is based on the abundance or lack of melanophores on the dorsal surface of the head, especially in the area of the parietal bone. In sauger this area is pale, with little pigmentation; in walleye, the area is heavily pigmented and appears dark to black.[53,68] Young sauger and walleye 15 mm and larger[29] can be identified using soft dorsal fin ray counts; sauger usually have 17–19, walleye 18–21 or more.[2,16]

Sauger vs. Sauger/Walleye Hybrids
The larvae of reciprocal hybrids from sauger and walleye closely resemble their female parent, making identification impossible. Hybrids longer than 100 mm can be distinguished by their coloration pattern.[29]

Sauger vs. Yellow Perch
See Taxonomic Diagnosis Section in Yellow Perch species account (page "562").

Sauger vs. Darters
Distinguishing sauger eggs from darter eggs may be possible on a specific basis, depending upon the availability of information describing the darter eggs in question.

Sauger resemble darters only as early yolk-sac larvae, but hatching size is larger than many of the darters.[67,70,71,73] The yolk sac of sauger is large and round (see Figure 201A) and, relative to TL, much longer, wider, and deeper than the yolk sacs of most darters. By 8–8.5 mm TL, sauger yolk-sac larvae have large heads, robust bodies, and a large, well-developed mouth, with jaws extending posteriorly to the posterior margins of the eyes (see Figure 201B). Most illustrations of darter larvae, show much smaller mouths with jaws that do not extend posteriorly beyond the middle of the eye.[61,70–73] The number of total myomeres reported for sauger larvae (41–45)[29] is greater than counts for many of the darters.[67,70–73] Myomere count is closely correlated with the number of vertebrae,[72] as tabulated by Bailey and Gosline.[74] The number of vertebrae reported for sauger is also greater than counts reported for many of the darters, for most in the genus *Etheostoma*.[74] By 10 mm TL, its characteristic, large, beak-like mouth (with many teeth visible), serrated preopercle, deep robust body, and short, thick, muscular gut (see

Figure 202A), will distinguish sauger from darters. Darters have small mouths, blunt snouts, and no spines on the preopercle.[8,16,43] Also, fin development occurs at larger sizes for sauger (see Table 214) than for darters,[70] and young sauger develop large prominent canine teeth on their jaws and the roofs of the mouth.[29] Darters have teeth that are small and inconspicuous.[4]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 204)

Eggs: Sauger eggs are scattered randomly over the substrate, fertilized externally as they fall, and abandoned by the parents.[20] Conflicting reports of the characteristics of sauger eggs indicate that they are demersal and adhesive, even after water-hardening,[48,49] or semibuoyant and nonadhesive.[53] Higher turbidities may prevent stickiness in sauger eggs.[7] The eggs are scattered over rock, rubble, gravel, sand or mixtures thereof, in turbulent areas of streams, rivers, lakes, and impoundments.[51,56] They fall to the bottom and incubate between the substrate.[5] Viable eggs are reported abundant from flat rubble areas, especially where filamentous algae covered the rocks.[48] Survival of the eggs of lake-spawning sauger, broadcast on the bottom, may be poor if enrichment has led to heavy sedimentation of organic matter.[14]

In TN, sauger eggs have been collected at water depths of 1–1.5 m[26] and 3–7.5 m.[51] In the Missouri River, viable eggs were collected 0.6–3.7 m below the maximum reservoir water level; the maximum number of viable eggs came from water 1.2 m below minimum reservoir water level.[48,49] If eggs are released much above the substrate in high water current (such as dam discharges), they could be dispersed and carried considerable distances downstream before they settle and attach to the bottom substrate.[51]

The difference in amounts of water released from an upstream dam, during day and night, caused fluctuations in the water level over downstream spawning grounds, that exposed incubating eggs to the air, affecting year class strength.[12] It is suggested that eggs exposed to the air were destroyed.[48] Incubation, coupled with high water levels, possibly promoted fry and fingerling survival; fluctuating water levels and water temperatures greater than 15°C during April may have negatively affected embryo and fry survival in the Illinois River.[57]

Sauger eggs were collected in drift samples in the Missouri River after April; first eyed-eggs were collected on May 14.[48]

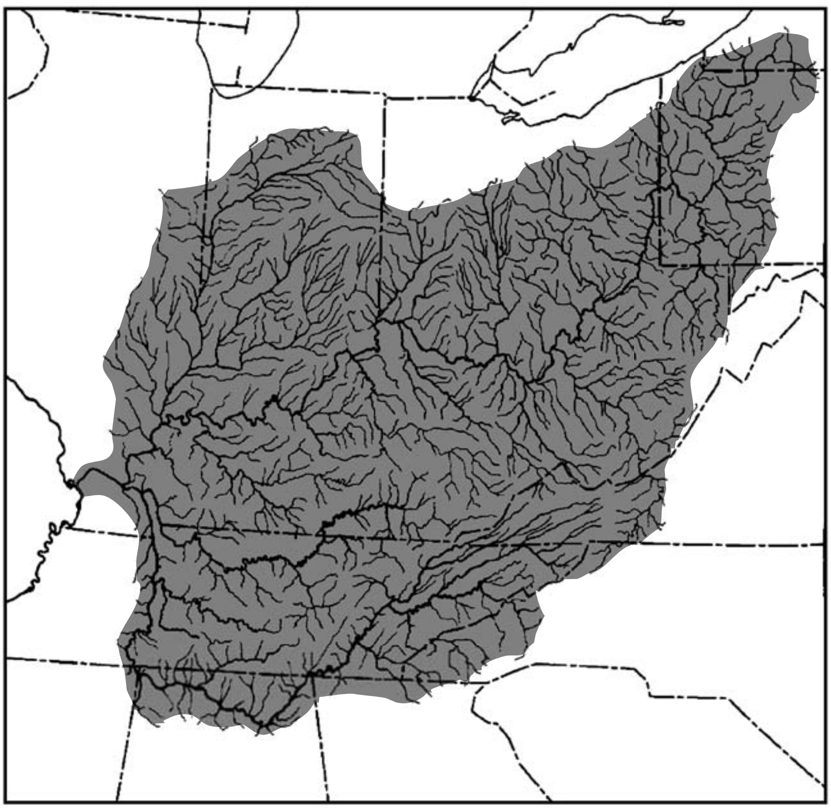

Figure 204 Distribution of sauger in the Ohio River system (shaded area).

Yolk-sac larvae. Embryos hatch very early and require well-oxygenated water, as embryonic respiratory organs are only weakly developed.[56] Newly hatched larvae are active swimmers. The large oil globule, located anteriorly in the yolk sac, causes larvae to orient in a head-up position. As the larvae swim up from the substrate into the water column, water currents will carry them downstream.[21,30] Upon hatching, larvae are carried by the current downstream in the Missouri River into Lewis and Clark Lake; plankton nets set downstream of the spawning grounds captured yolk-sac larvae.[48,49] Catches of larval sauger in drift nets, in the upper Mississippi River, were significantly higher in night samples than day samples, but were similar at the surface and at the bottom.[86] Transport of larvae into downstream reservoirs via dam passage has been observed in the Tennessee River.[21,30] It is also reported that sauger larvae spend 7–9 days at the bottom absorbing their yolk,[5] and that they hide at the bottom several days after hatching before schools are formed in shallow water.[56]

Yolk-sac larvae <8 mm were concentrated in the main channel of Tennessee River reservoirs. Migration onto overbank habitats began between 8 and 10 mm.[30]

Post yolk-sac larvae. Young sauger may receive protection from sight-feeding predators in clouded or turbid waters.[7] At 9–10 mm, the paired fins of sauger are well developed, such that the larvae can swim horizontally and capture prey — at this point, they begin to move out of the flowing water onto overbank areas. The majority of sauger larvae 15 mm or longer collected from the Tennessee River came from overbank areas and embayments; they were also captured at night near the surface in the river channel.[30] Post yolk-sac larvae were captured throughout a Missouri River reservoir until they reached about 15 mm; highest catches occurred at a depth of about 3 m, none were caught below 6.1 m.[48] The first post yolk-sac larvae taken from Lake Winnebago, WI, were captured with a bait trawl in early June and ranged from 12 to 20 mm; they were usually captured after June 10 and exceeded 20 mm.[53]

Juveniles. The fall abundance of age 0 sauger, in the upper Mississippi River, was highly correlated with the rate of water warming between mid-April and early May.[86] YOY sauger are pelagic during the early part of their first summer.[2,48] In mid-July, juveniles 20–50 mm were collected with a trawl in deep open areas of a WI reservoir; from mid-July through mid-August, juveniles 51–150 mm TL were collected from the same areas.[53] In SD, young sauger were generally most abundant in the more river-like, turbid, upper reaches of reservoirs.[12] YOY primarily inhabited areas with water depths less than 3.7 m during June and July and then dispersed throughout the reservoir. Diel movements of young sauger are reported from a small cove onto a sand and gravel beach; onshore movement occurred just before sunset and the catch was high until sunrise, when it decreased rapidly.[48] Juvenile sauger 28–30 mm were taken in late June with surface tows at the western end of Lake Erie and others this size were captured with seines at the mouths of creeks.[54] Juveniles 26–150 mm inhabited coves sampled by summer rotenone surveys along the main channel and larger embayments of Tennessee River reservoirs.[30] YOY sauger have been captured with seine hauls from shallow water, over sandy substrate that had a mix of organic debris and submerged vegetation.[76]

Studies for the first two seasons after completion of Watts Bar Dam on the Tennessee River indicated that YOY sauger migrated from Watts Bar Reservoir up the Clinch River to Norris Dam at the conclusion of their first growing season.[75]

Early Growth

Sauger in concrete raceways, fed zooplankton, average 22 mm TL after 37–41 days posthatching and 63 mm (range: 29–81 mm) after 49–53 days.[66] In OH, young sauger are 76–150 mm in October.[8] In WI, sauger are 12–50 mm by mid-July, 51–75 mm from mid-July to mid-August, and 98–154 mm by October.[53] In SD, they average 134–171 mm by October.[48]

Young sauger in the South grow at faster rates than reported for northern populations (Table 219).[20] More rapid growth in length is reported during the first year.[34,53,63,64] In TN, females grew more rapidly than males.[80] In ND, growth of males and females was reported about equal for the first 2 years, but females were larger than males after that. Average TL (mm) at capture for ages 1–6 (male/female) were: age 1 (148/152); age 2 (251/250); age 3 (335/346); age 4 (363/427); age 5 (441/484); age 6 (-/571).[50] In TN, age 2 sauger captured between April and October ranged from 333 to 376 mm.[81] Sauger in TN reservoirs are 84–106 mm at age 1; 126–156 mm at age 2, 150–174 mm at age 3, and 170–180 mm at age 4.[2]

The range of averaged calculated TLs (mm), by age, for young sauger in Missouri River reservoirs is reported as follows: age 1,122–221; age 2, 224–335; age 3, 297–432; age 4, 363–516; age 5, 371–544; age 6, 485–638.[79] See Table 219 for additional reports of mean calculated TLs for young sauger.

In WI, average calculated weights in grams for sauger ages 1– 6 were 9, 91, 195, 259, 313, and 372.[53] In MN, mean weight in grams for young sauger by age was reported as follows: age 1, 28; age 2, 170; age 3, 171; age 4, 239; age 5, 342; age 6, 411.[64]

Table 219

Reports of mean calculated TL (mm) by age classes for young sauger.

Area	Number of Fish	Mean Calculated TL (mm) at Each Annulus					
		1	2	3	4	5	6
Mississippi River, Iowa							
Pool 11[77]	218	145	269	356	414	450	480
Mississippi River, Iowa							
Pools 7–10[77]	259	249	300	351	391	412	427
Mississippi River, Iowa							
Pools 13–15, 19[77]	267	216	333	384	455		
Mississippi River, Iowa							
Lock and Dam 10[39]	146	147	269	358	422	461	513
Lock and Dam 12[39]	317	168	297	376	424	462	490
Lake of the Woods, Minnesota[64]	1,498	167	196	265	318	348	360
Lake Winnebago, Wisconsin[53]							
Males	784	124	241	302	338	361	389
Females	957	135	241	297	325	358	394
Garrison Reservoir, South Dakota[50]							
Males	96	122	216	292	358	447	
Females	222	127	216	318	399	467	587
Lewis and Clark Lake, South Dakota[78]	479	160	310	414	483	521	538
Cherokee Reservoir, Tennessee[80]	121	236	373	442			
Douglas Reservoir, Tennessee[80]	78	251	396				
Watts Bar Reservoir, Tennessee[20]	178	270	366	424			
Watts Bar Reservoir, Tennessee[63]	24	209	300	367	417		
Chickamauga Reservoir, Tennessee[81]	71	218	333				
Clinch River, Tennessee[63]	47	238	338	382	418	445	
Norris Reservoir, Tennessee[82]	3,393	212	336	396	438	472	498

Calculated weights reported for sauger in TN, were 52–65 g at 200 mm, 111–127 g at 250 mm, 208–234 g at 300 mm, and 347–400 g at 350 mm.[63] In OH, young sauger weigh 14–28 g at 130 mm, 142–255 g at 254 mm, and 0.5–0.7 kg at 406 mm.[8]

For additional reports of age and growth information from other areas see Carlander (1997).

Feeding Habits

In SD, sauger begin feeding before their yolk sacs are completely absorbed. Larvae 8–17 mm consumed *Cyclops* predominately, but with increasing size began utilizing *Diaptomus* and *Daphnia*. Fish, generally emerald shiners and gizzard shad, became the major food item between 70 and 110 mm.[48,49] Sauger <50 mm were considered plankton feeders in WI, but at 50 mm, they ceased consuming plankton if forage fishes were extremely abundant. In the 12–50 mm size range, *Daphnia* was the most important item consumed, with copepods and chironomid larvae and pupae utilized to a lesser extent. This size sauger also consumed troutperch, white bass, and freshwater drum fry. Fish were present in 46.9 and 54.7% of the stomachs examined during 2 years of this 4-year study. Sauger 51–75 mm, captured during the period mid-July to mid-August, utilized invertebrates, including *Cyclops*, *Daphnia*, and chironomids when fish fry were not available in sufficient numbers. For sauger 76–150 mm, chironomids, fish, and *Leptadora* were the important food items.[53] In the Ohio River, fishes were the number one food item by weight (99.7%) and by frequency (100%) for sauger 151–400 mm. Emerald shiners were the number one forage species, with gizzard shad second.[83] In another report, YOY and yearling sauger, in July and August, consumed mostly *Notropis spp*. despite the fact that gizzard shad were the most abundant forage fish available.[78] Sauger <30 cm may be restricted by mouth size to feeding on shad <30 % of their body length; they were not found to prey on shad >8 cm in length.[84]

When zooplankton food supply became inadequate, sauger cannibalism became a serious problem in concrete raceways.[66]

Greater concentrations of microcrustacea are found near the water surface under turbid conditions than when the water is clear, so turbidity may enhance feeding opportunities for sauger fry that feed near the surface.[7]

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OTHER IMPORTANT LITERATURE

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WALLEYE

Sander vitreus (Mitchill)

vitreus: "glassy", referring to eyes.

RANGE

The native range of walleye is from the Mackenzie River, Great Slave Lake, the Peace River system, British Columbia, the Saskatchewan River system and the Hudson Bay region to Labrador; southward on the Atlantic slope to NC (apparently native in the coastal streams of NC, but generally thought to be introduced further north along the slope), and west of the mountains, to the Alabama River system, GA, to the Tennessee River drainage, AL, and to northern AR and NE. Considered common throughout the Great Lakes and many of the inland lakes and rivers of that basin; in Lake Erie chiefly to the westward.[61] Also reported as genetically unique[127] south of the Tennessee River at seven localities in the Alabama River system and two localities in the Tombigbee River system,[8] where it is widely distributed, but not abundant in MS.[111] Widely introduced outside its native range, and its present range has been expanded to virtually all of the contiguous states.[16,40,41,99]

HABITAT AND MOVEMENT

Walleye is a schooling, negatively phototrophic, crepuscular species usually found in cool, clear water in lakes, or moderate to rapid flowing streams and rivers.[5,129] It is a species typical of middle-aged lakes that are fairly rich in fish species and slightly turbid, but that have high oxygen concentration and sufficiently large areas of clean bottom, where they spend much of their time resting and where they may successfully reproduce.[106] Except in the northernmost part of its range, walleye occur more abundantly in lakes than in streams.[40] They are temperate mesotherms,[22,57] and most successful in mesotrophic waters;[106] they do less well in oligotrophic or eutrophic environments.[129] Physiological differences exist among populations related to latitude.[137] Found over substrates of sand, gravel, bedrock, rocky reefs, and hard clay,[5,129] in relatively quiet waters (except during the spawning season).[5] Sometimes associated with pondweed or in close proximity to weed beds. Frequently hide under sunken logs, rocks, banks, or weeds.[129] Also inhabit pools of streams, especially those deeper than 3 m with boulders or submerged logs.[98] Its optimum habitat, like that of other percids, is the littoral and sublittoral areas of lakes analogous to those of large, temperate rivers, which include sand–gravel substrates, low current velocity, reduced light penetration, optimal temperature for reproduction and growth, and well-oxygenated spawning substrates.[12,72] Physical features may be used to discriminate lakes where walleyes presently occur from lakes where they do not presently occur, and fish community differences exist between stocked and self-containing walleye populations in WI.[132]

Movements involve a spring spawning run to shallow shoals or tributary rivers, daily movements up and down in response to light intensity, and daily and seasonal movements in response to temperature and food availability.[113] They migrate upstream from lakes or rivers to spawn, some populations ascending tributary streams as far as 56 to 156 km,[102,129] while others spawn along reservoir or lake shorelines or on reefs.[129] Homing instinct to spawn has been observed,[5,25,37,92,93,102,113] but is not always the case.[92,129] Homing behavior is thought to be learned as adults, rather than inherited or coming from natal conditioning, as in some salmonids.[93] Movement onto spawning grounds occurs as early as late January to mid-February, males preceding the females, when water temperature approaches 5°C.[74,112] They return to the lake soon after spawning.[86,105] In northern WI, walleye moved among lakes in all chains as they left spawning areas and apparently moved to feeding areas. In some lakes, estimates indicated that at least half of all walleyes present at a spawning area might leave the lake within 1 week.[140] Also reported to remain in the headwaters of spawning rivers 3–6 weeks after spawning before moving downstream.[129]

Light is the principal abiotic factor controlling the spatial and temporal dimensions of adult walleye, due to the sensitivity of the subretinal *tapetum lucidum* layer of the eye.[22,108] Increase in water clarity recently observed in the Great Lakes basin (as a result of phosphorus control and dreissenid mussel invasion) has reduced the supply of thermal-optical walleye habitat, and consequently has had negative effects on walleye production.[138] During the day walleye have been observed in clear-water regions of a lake, resting on the substrates with their eyes shielded from the ambient light by physical shelter, such as boulders, vegetation, or logs.[108] In turbid waters, walleye have been reported active during the day.[108]

The walleye niche has been described as that of an opportunistic piscivore that partitions the food resource in time with other predators by feeding during twilight periods, or nocturnally.[45,55,98,109] Some apparently move into shallow water at night to feed,[15] or may utilize turbid waters to feed during daylight hours.[2] In spring and early summer, walleye are widely distributed vertically, to a depth of 16 m.[13] Summer reservoir habitat is either in or near the thermocline.[2,43] They avoid temperatures above 24°C, even in dissolved oxygen concentrations of 1–2 mg/L.[43] They become widely vertically distributed in October following the fall overturn and continue feeding throughout the winter, providing popular ice fisheries.[5,37,113] Most commonly found within 1 m of the bottom.[53] Some populations appear to establish home feeding areas.[93] Schooling is common;[5,129] schools range in size from 3 to 4 individuals to perhaps 150.[108]

DISTRIBUTION AND OCCURRENCE IN THE OHIO RIVER SYSTEM

Walleye have been reported from throughout the Ohio River since 1800.[65,143] Their numbers are greatest in the upper river,[17,142] although they are not important in the sport catch.[17] In recent studies, they were occasionally captured in the Ohio River proper from Markland Pool and tailwater and from the Meldahl tailwater.[66] They are apparently declining and becoming less common than sauger in recent years.[11,83,97]

Early records from the Kentucky, Licking, Wabash, and Miami Rivers,[29,103,123] as well as the Clinch,[73] Wolf,[74] Tellico, and French Broad Rivers,[38] indicate that walleye was widespread throughout the larger tributaries of the Ohio River prior to impoundments. It is recorded from the Allegheny, in NY.[66] Formerly very abundant in the Scioto River, OH, but declined drastically following the construction of a dam at Chillicothe, according to a 1874 report.[120] Reported from the lower Wabash River, IL.[3] Occur in all large waters in TN,[37] but not captured in the Tennessee River, AL in recent collections.[144] Important walleye fishery waters in TN are Center Hill, Dale Hollow, Norris, and Watauga Reservoirs.[37] They are also present in six headwater tributary reservoirs to the Tennessee River in western NC,[82] and two in northeastern GA. They are absent from the Pigeon River, TN, and NC below the town of Canton, NC, where no fish were found due to severe pollution.[83] They were also absent from, and considered extirpated from, the French Broad River, which receives the flow of the Pigeon River.[52] Present KY distribution includes the Green, Salt, Kentucky, Big Sandy, and Cumberland Rivers and their impondments.[11,18] In OH, Hoover Reservoir supports a markedly successful, naturally reproducing walleye population, which may contribute to the walleye fishery of the Scioto River downstream.[120]

Although the construction of dams had serious impacts on native walleye populations, by blocking spawning migrations and creating coldwater discharges that prevented successful reproduction,[26,124] the habitat made available to walleye in the new reservoirs was greatly expanded and improved.[19,124] For several years following impoundment, many reservoirs had excellent walleye fisheries,[19,35–37,40,51,73,119] but eventually populations declined,[40,51] until new populations of self-sustaining stocks became established.

One report stated, "The importance of walleye as a glamorous trophy fish and its psychological impact on the angler cannot be overestimated in this state (TN)."[41] Walleye stocking in southeastern reservoirs during the 1950s was never known to have had undesirable results,[95] although it appears that the native river race of walleye in TN was either swamped or eliminated by the introduction of northern fry.[37] In contrast, native river-spawning populations have continued to survive in some AR reservoirs.[107] Present day walleye populations in reservoirs of the Ohio River system are virtually the result of fry stocking programs,[23,28,33,41,51,70,71,74,82,112,121] although stocking is not always successful in creating self-reproducing populations.[2,28,33,122] Recent studies indicate that fingerling walleye must be stocked annually to sustain the walleye populations in several tributary impoundments of the Cumberland and Tennessee Rivers.[135] They are not abundant in the Allegheny River in spite of massive fry introductions.[6] Introduction of fingerlings, 15–125 mm long, succeeded in creating a spawning population in Nolin River Lake, KY.[70]

SPAWNING

Location

Walleye are open-substrate, broadcast spawners in the lithophilic guild.[79,145] They spawn in tributary streams of reservoirs and lakes,[43,46,47,74,77,86,98,102,105,112,115,129] usually over clean gravel, rubble, or boulder substrates (where survival is best),[129] but in some locations over sand, muck, detritus, submerged sticks, mats of grass and sedges, and other marsh vegetation.[5,102,129] Spawning in marshes is limited to those marshes having both inlets and outlets and, consequently, good water flow.[129] Some populations spawn along wind-swept shorelines or shoals of reservoirs[74] or lakes,[34,89,102] rip-rapped areas on lake shorelines, or small streams.[24] Wind-generated wave action is said to be a key factor in stimulating reservoir shoreline spawning.[74] There is a possibility that southern populations are genetically obligate riverine spawners.[21] Walleye in the upper Mississippi River spawn along the riprap wing dams downstream of navigation locks.[48] Gravel substrates, when available,[34,67] are chosen over sand or muck substrates, which has a positive impact on survival.[67]

Season
Across their range, walleye spawning is usually reported from March through May,[30,34,102,129] but spawning occurs in June in PA,[129] and to the end of June or later in the far north.[113] Begins earlier in southern portions of range.[112,123,127] Spawning runs, up the Pearl River, MS were observed in January and February.[124] In TN, males arrive on spawning grounds in late January;[112] with spawning documented as early as late February;[112] also reported March to early April in TN.[37] There are reports of spawning activity in March and April[43,74,86] in NC,[82] in OK,[50,129] NY, and Ontario;[129] reported in April and May in MI, MN,[129] and WI.[5,129] In northern populations, males appear on spawning grounds 1–20 days after ice breakup;[5,34,47] they will not spawn some years if the temperature stays too cold.[113] A season duration of 5–16 days was reported, with peak activity occurring over 1–2 days.[102]

Temperature
Overall spawning activity (spawning run, prespawning activity, and spawning) is reported from 1.1 to 17.2°C.[34,50,74,86,102,105,113,129,134,146] Temperatures at peak activity vary geographically.[129] Spawning begins at warmer temperatures in south, ranging from 5.5 to 14.4°C,[74] peaking at 10–12.8°C.[74,86] In the north, spawning is reported between 2.2 and 15.5°C,[102] peaking between 5.5 and 10°C.[34,102,105,128] Optimum temperature range for the fertilization of eggs is 6–12°C.[129]

Fecundity (see Table 220)
Walleye is a highly fecund species, but fecundity is extremely variable among populations and year classes, ranging from 22,000 to 615,000 eggs/fish.[113,126,128,129] Fecundity is almost linearly related to body weight,[126] and is also related to feeding conditions during the previous summer, with the number of eggs set by late summer or early fall.[114] Population density may also influence egg production, as fecundity increased after harvest was allowed in a previously unexploited population.[3] Southern populations have greater fecundity at a given age or size than northern populations.[3]

For additional reports of fecundity information, see Carlander (1997).[48]

Sexual Maturity
In faster growing populations, as in the southern portion of their native range and Lake Erie, most males mature at the end of their second growing season, age 2;[32,74,86,112,126] and females mature a year later,[74,86,112] sometimes older.[126] The majority of spawning runs are composed of 2- and 3-year-old fish.[32,86] In WI, males mature at ages 2–5; females at ages 5–7.[5] Farther north, some Saskatchewan walleye mature at age 5, but spawning runs were reported dominated by age 8 fish.[105] In the Midwest, males mature at age 4,[14,114] while females mature at ages 5 and 6.[14] Corresponding mean total lengths at maturity for Center Hill Reservoir, TN, walleye are 403 mm and 503 for males and females, respectively.[112] Most IA males are mature at 305 mm, and females mature at 338–356 mm.[20] In OK, males are

Table 220

Fecundity data (× 1000) for walleye from several water bodies.

Location	Fecundity Range	Fecundity/kg
Lake of the Woods, Minnesota[14]	35–137	49.9
Lake Gogebic, Michigan[34]	37–155	61.8
Lake Winnebago, Wisconsin[102]	43–227	—
Escanaba Lake, Iowa[114]	22–207	61.6–72.6
Lake Erie, Ohio[110]	48–61	—
Norris Reservoir, Tennessee[115]	78–171	28.6–33.0
Dale Hollow Lake, Tennessee[74]	35–194	41.8–48.4
Center Hill Lake, Tennessee[112]	72–231	70.2

mature by 246 mm, females by 320 mm.[50] In WI, males are mature at about 323 mm, females by about 439 mm.[129] Slower growth delays maturity and is related to increased length at maturity and sometimes even age at maturity.[54]

A minimum winter temperature of 10°C is required for gonad maturation[57] and introductions into reservoirs with very mild winters, such as El Capitan, CF, and Casa Blanca, TX, produce walleye that grow well, but do not mature.[21]

Spawning Act

Males arrive on spawning grounds before the females, and stay longer.[30,74,102] Schooling by sexes occurs until the onset of spawning.[37] Females enter the spawning grounds only when imminently ready to spawn, release their eggs in repeated acts (every 5 min) over a short time, maybe only one night, and then leave the spawning area.[37,102,113] Males spawn repeatedly throughout the 2-week reproductive period.[37] Spawning usually occurs at night;[24,30,34,74,86,98,102] in the daytime the shallow spawning grounds are vacated[30,86] or fish simply hold positions during the day.[24,30,102] Limited daytime spawning activity may occur during the peak of the spawning season.[9,102]

Courtship behavior has been noted among fish grouped over shallow spawning grounds at night[5] and involved preliminary butting and pushing.[37] Accounts vary of the actual spawning act. It has been described as "a series of violent synchronized acts by promiscuous groups of fish, preceded by short courtship behavior (approaches and bodily contact) leading to an upward rush of grouped spawners."[30] Two to six males per female are reported.[86,102,112] No nest is built, eggs and milt are broadcast, and there is no parental care of eggs.[102,113] In one account, four males and one female, in 1 m of water, swam in interweaving patterns in the current until "the female rose to the surface, thrust her head out of the water and with violent contortions thrashed from side to side, swimming 3–4 ft before submerging," with males following. This act was repeated. At the conclusion of such acts, the water became cloudy with what was thought to be sex products.[102] In another account, a female, closely flanked by two smaller males, made a sudden rush toward the surface. Shortly thereafter, the female turned, or was pushed, to her side, and eggs and sperm were released.[37]

EGGS

Description

Prior to hydration, eggs are flaccid and delicate, containing a large, central oil globule and numerous smaller oil globules; pale yellow in mass;[80] diameter ranging from 1.63 to 1.85 mm.[80,114,126] They are demersal and strongly adhesive when first laid.[98,128,129] Eggs water-harden in about 1 h,[89] and lose adhesiveness. After water-hardening, eggs are imperfect spheroids with a mean diameter of about 2.1 mm,[80,87] range 1.9–2.31 mm.[87] They are hyaline and turgid early in development, but may become flaccid during eyed stage.[102] In dead eggs the embryo becomes a white speck before the entire egg becomes opaque.[102]

Incubation

Incubation times are inversely related to incubation temperatures (Table 221). Hatching times, expressed in thermal units (TU, the number of degree-days above 0°C), are reported as 398–478.[63] Optimum incubation temperature is 17.8–19.4°C.[1]

Development

Described with illustrations.[80,129]

YOLK-SAC LARVAE

See Figure 205

Size Range

Mean hatching lengths are variously reported between 6 and 8 mm TL,[47,87,90,129] but reported range is 4.8 to 8.7 mm TL.[102,129] Hatching size is influenced by incubation temperature:[116] 6.0 mm at 6°C; 7.3 mm at 8.9°C; 7.8 mm at 12.0°C; 7.2 mm at 15 and 18°C. Yolk absorption is completed by 9.4–9.6 mm.[80,87,90]

Myomeres

Total 43–51;[80,87,90] preanal 16–20 (18), postanal 25–28 (26),[90] or preanal 18–22 (mean = 19.7), postanal 20–28 (mean = 25.8), with the number of postanal

Table 221

Reported hatching times (days) related to incubation temperatures.[1,89]

Incubation Temperature	Days to Hatch
4.4	26
12.8–14.4	10
16.1	8
17.8	8.5
19.4	6
21.7	5
23.9	4

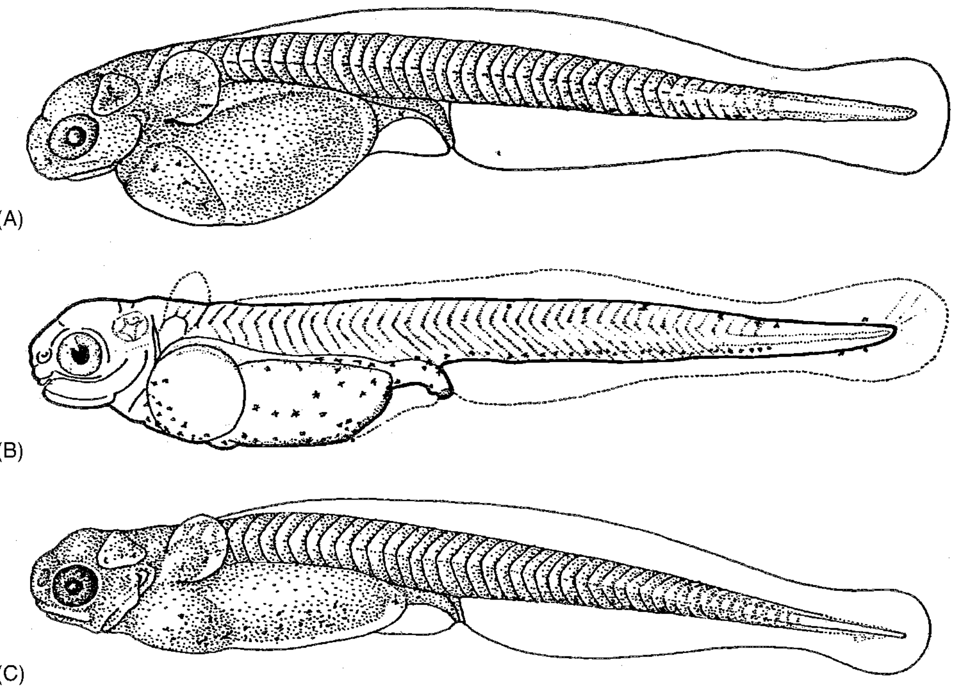

Figure 205 Development of young walleye. (A–C) Yolk-sac larvae, (A) 6.8 mm TL, (B) 8.0 mm TL, (C) 8.5 mm TL. (A and C reprinted from figure 2 and figure 4, reference 87, with publisher's permission; B reprinted from figure 4, reference 90, with publisher's permission.)

myomeres increasing by four during the yolk-sac phase.[87] Also reports of 49–51 total and 28–30 postanal myomeres,[80] and 15 to vent, 26 behind.[42]

Morphology

6.0–8.5 mm TL. Newly hatched.[42,80,87,90,102] The body is elongate;[129] notochord is straight;[87,90] head extends forward beyond the yolk sac;[129] mouth is inferior[42] and open, but only partly developed;[129] choroid fissure is closed.[129] Yolk sac very large and elongate with a single, clear, round oil globule positioned anteriorly.[87,90] Intestine bends abruptly down to the vent,[90,129] which is open.[42] Distinguishable cartilaginous elements include dentaries, branchial arches, semicircular canals, and cleithra.[90]

8.5–9.5 mm TL. At 8.5 mm, mouth has 6–10 teeth on each side of lower and upper jaw[78] or teeth are not visible until 10.5 mm.[90] The gut is a simple, straight tube with a small, bag-like extension on the intestine (precursory stomach).[78] At 8 mm SL, the olfactory organ appears as an exposed circular pit, ventral to the median frontal-plane, anterior and adjacent to the eye, and dorsal and anterior to the mouth.[31] Air bladder is evident by 9.25 mm.[129] At 9.5 mm, the cleithrum, dentaries, premaxillary, and ceratobranchial bones begin to ossify.[90]

Morphometry

At hatching, yolk sac measures 0.63–1.25 mm deep,[87] 0.8–1.3 mm wide,[90] and 2.13–2.88 mm long.[87,90] Intestine is 0.3–0.7 mm long.[90] As percent TL at 7.75 mm (at hatching): PreAL 47.7; GD 19.4; ED 6.5.[42] At 8.5 mm, the mouth is 0.6–0.8 mm wide; gape 1.4–1.8 mm.[78] As yolk-sac larvae increase in length, the yolk sac decreases in width and increases in length, becoming smaller as the development proceeds, such that it becomes impractical to measure after the larvae reach a length of about 9.4 mm.[90] Head length increases slightly in relation to total length late in yolk-sac phase.[87] Anus-to-caudal measurement (preanal length) is greater than the snout-to-anus measurement (postanal length).[90]

See Table 222 for additional morphometric data.

Fin Development

6.1–6.9 mm TL. At hatching, median finfold is complete and pectoral fins are present.[87,90] The ventral finfold commences along the posterior margin of the yolk sac, breaks at the anus, and continues around the urostyle to its dorsal origin at about the second to sixth preanal myomere.[87,90] It is widest, dorsally and ventrally, just posterior to the anus. No fin ray ossification is reported during the yolk-sac phase.[87,90]

Pigmentation

6.1–9.6 mm TL. At hatching, the yolk is bright yellow in color, covered completely by light-colored, stellate chromatophores,[42,87] which extend over the heart and the clear yellow oil globule.[42] There is a ventral line of chromatophores between the anus and

Table 222

Morphometric data (expressed as mean percent TL) and average myomere counts by length intervals for walleye yolk-sac larvae from South Dakota.

	TL Groupings			
TL Range (mm)	**6.1–6.9**	**7.1–7.8**	**8.1–8.9**	**9.1–9.6**
Mean TL	**6.6**	**7.4**	**8.6**	**9.3**
N	**5**	**10**	**10**	**10**
As Mean Percent TL				
Snout to anus	48.7	49.3	48.1	48.8
Head length	12.8	13.0	14.0	16.8
Eye length	5.0	5.1	5.2	4.8
Intestine length	5.3	5.5	6.1	6.6
Body depth	20.4	17.5	14.8	14.0
Yolk-sac length	33.6	35.8	30.2	28.8
Yolk-sac depth	16.6	14.3	9.4	8.0
Myomere Counts				
Preanal	19.8	19.6	19.7	19.9
Postanal	23.4	24.3	27.7	26.7

Source: Content is based on data presented in Table 1, reference 87.

caudal fin[87] and the eye is darkly pigmented.[42,129] As development proceeds, pigmentation becomes more profuse. The yolk sac has many small chromatophores scattered over its lateral and ventral surfaces. Two to four chromatophores are usually present on the intestine between the anus and the yolk sac and, occasionally one or two are visible on the lateral margin of the lower jaw. The postanal, ventral pigment line is well-developed, with one or two chromatophores per body segment,[90] which by the end of the phase, form a continuous chain of interlocking, stellate chromatophores between the anus and the caudal fin.[87] A few small chromatophores are visible along the dorsal margin of the yolk sac and one or two are present mid-dorsally on the caudal peduncle.[90] One to five small chromatophores are scattered over the notochord.[87] By the end of the phase, the body is transparent.[129]

POST YOLK-SAC LARVAE

See Figure 206

Size Range

9.4–9.6 to about 20 mm.[87]

Myomeres

Total myomeres 45–46,[87,90] but conflicting reports for preanal and postanal counts: preanal 16–24 (19), postanal 22–29 (26),[90] or preanal 21.2–25 (23.2) and postanal 20.9–25.0 (22.5).[87] Also reported 21 to vent plus 25 + behind.[42] For larvae 13.75 mm and larger, the number of preanal myomeres becomes greater than the number of postanal myomeres.[87]

Number of myomeres is closely related to number of vertebrae.[4,90]

Morphology

10–11 mm TL. Teeth are evident on the premaxillary at 10.5 mm.[90] Maxillae, premaxillae, branchial arches, quadrate bones, and branchiostegal rays are ossifying.[90] Sphincter develops, dividing gut into intestine and rectum.[78]

12–15 mm TL. Body is rather slender; small canine teeth in both jaws; large, simple air bladder; vent situated away from the body at the margin of the finfold.[42] Urostyle is oblique, conspicuously projected at 14.8 mm. Intestine "somewhat coiled" near the stomach, essentially straight posterior to the stomach.[129] At 12–13 mm, the opercle, preopercle, frontal bones, and vertebrae have begun to ossify.[90]

13–18 mm TL. Bone deposition is continuous and rapid.[90] First intestinal loop develops.[78]

19 mm TL. Complete number of pyloric caeca (3) are developed.[87] Teeth have become large and

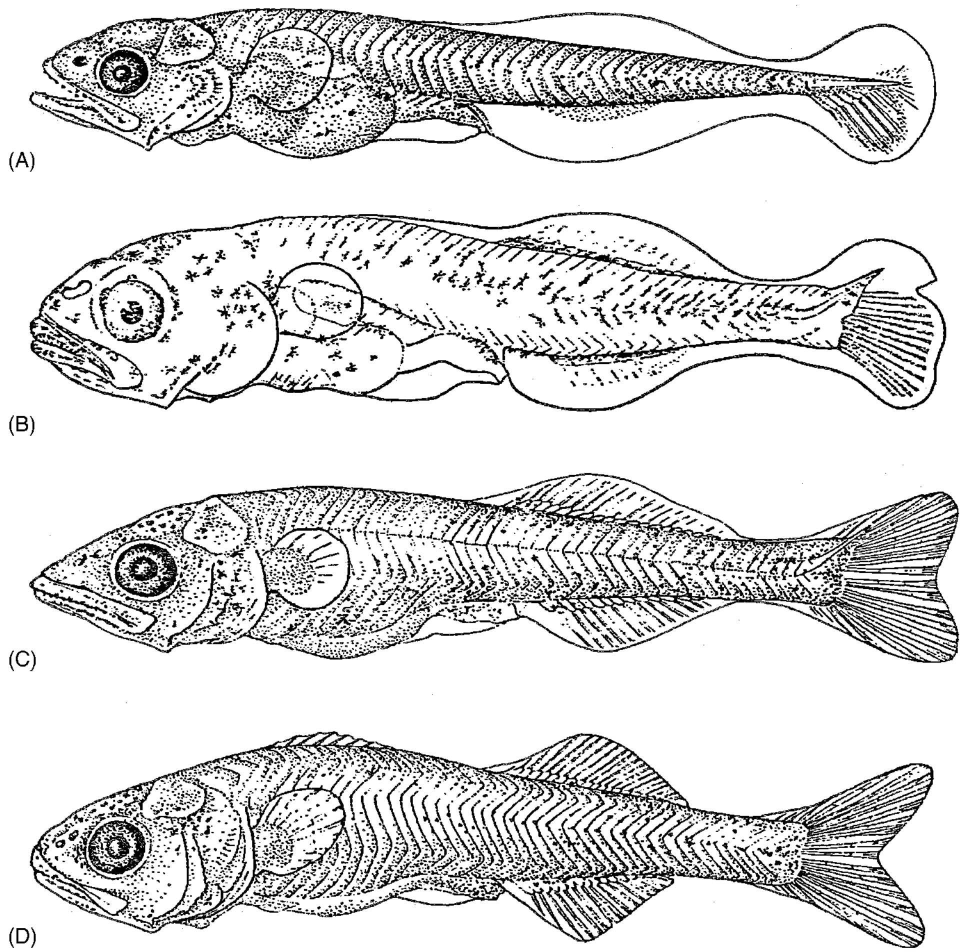

Figure 206 Development of young walleye. (A to D) Post yolk-sac larvae, (A) 11.1 mm TL, (B) 12.5 mm TL, (C) 14.5 mm TL, (D) 17.6 mm TL. (A, C, and D reprinted from figure 6 to 8, reference 87, with publisher's permission; B reprinted from figure 96, reference 42.)

well-developed; anterior-most teeth larger than others, conical and curved.[129] As the bones of the mouth region (premaxillary, maxillary, and mandible) grow forward, the olfactory pit moves dorsally to the median frontal plane, becoming enlongated anteriorly–posteriorly. Ridges surrounding the pit gradually grow together, forming the anterior and posterior nares.[31] Otolith growth is directly proportional to body growth, and daily increments can be used to back-calculate fish lengths and growth rates.[85]

Morphometry

12.5 mm TL. As percent TL: SL 94; PreAL 52; HL 26.8; SnL 7.2; ED 6.4; GD anterior to vent 20; GD posterior to vent 22.[42] Intestine length measures about 15% of TL, approximately equal to length of lower jaw. [90]

For additional morphometric data see Table 223.

Fin Development

10–11 mm TL. Ossified rays appear in the ventral half of caudal fin.[87,90]

13–14 mm TL. Finfold is reported "practically gone" by 13 mm TL,[90] but an illustration of a 17.6 mm specimen (Figure 206D) shows a remnant of ventral finfold still present just anterior to the vent.[87] Ossified rays appear in the soft dorsal, anal, and pectoral fins.[87,90]

14–16 mm TL. At 14 mm, ossification of dorsal spines begins [87] or at 15–16 mm.[90] Also at 15–16 mm, pectoral fin rays and anal spines begin to ossify.[87,90] The anal fin is fully formed at about 15 mm. The pelvic fins are first evident at about 15 mm in some specimens, although they are not developed in others at 17 mm.[129] In 10–12 days from hatching the paired fins develop sufficiently for horizontal swimming.[102]

16–17 mm TL. Pelvic fins begin to ossify.[87,90]

18 mm TL. Adult complement of dorsal spines attained.[87]

19–20 mm TL. Pelvic fins development complete.[87]

Table 223

Morphometric data (expressed as mean percent TL) and meristic data (expressed as average counts) by length interval for walleye post yolk-sac larvae from South Dakota.

	TL Groupings									
TL range (mm)		**11.2–12.0**	**12.3–12.8**	**13.2–14.0**	**14.3–15.0**	**15.2–15.5**		**17.0–17.8**	**18.0–18.8**	**19.0–19.8**
Mean TL (mm)	**11.0**	**11.9**	**12.6**	**13.6**	**14.6**	**15.3**	**16.5**	**17.6**	**18.4**	**19.4**
N	**2**	**10**	**10**	**10**	**10**	**6**	**1**	**10**	**10**	**10**
As Mean Percent TL										
Snout to anus	51.2	52.2	51.8	51.6	52.6	53.3	51.5	53.2	53.4	52.7
Head length	21.3	21.8	23.1	23.8	24.5	24.8	24.2	24.9	26.2	27.3
Myomere Counts										
Preanal	21.5	21.2	21.2	22.2	23.2	23.3	23.0	25.0	24.7	24.9
Postanal	25.0	24.5	24.4	23.1	22.0	22.5	23.0	21.1	20.9	21.2
Fin Ray Counts										
Spinous dorsal	—	—	—	—	0.2	0.3	2.0	6.9	9.2	10.5
Soft dorsal	—	—	—	10.9	15.8	16.5	19.0	18.7	20.0	20.3
Caudal	6.5	10.3	13.8	16.6	19.1	19.7	21.0	25.1	26.3	30.2
Anal	—	—	—	—	—	—	14.0	14.4	15.2	15.4
Pectoral	—	—	—	—	—	—	7.0	6.8	8.0	10.1
Pelvic	—	—	—	—	—	—	2.0	0.7	2.6	5.7
Pyloric Caeca	—	—	—	—	—	—	—	1.5	3.0	3.0

Source: Content is based on data presented in Table 2, reference 87.

Pigmentation

Pigmentation patterns of sauger and walleye post yolk-sac larvae, at any given length, are similar. Early in the phase, a few faint chromatophores are scattered along the ventral margin of the myomeres, but by the end of the phase, chromatophores were concentrated along the dorsal margin of the myomeres and 1–4 chromatophores per myomere were present laterally along the median myosepta. Head pigment was concentrated in the mandibular, maxillary, and occipital regions.[87,90] Visceral pigmentation is very conspicuous, with numerous chromatophores located dorsal to and around the air bladder and along the dorsal aspect of the intestine, decreasing in number near the anus, with 2–6 present near the vent. The ventral pigment line is present from the anus onto the caudal fin, with 1–3 chromatophores per myomere. Large stellate chromatophores are abundant on top of the head, from the tip of the snout to the nape, on the cheeks, at the base of the pectoral fin, and in the region of the heart. The sides and tips of both jaws are fairly well pigmented.[90] Pigment first appears on the caudal and anal fins when the fish are 13 mm. Beyond 15 mm, walleye are more heavily pigmented than saugers, but sauger exhibit heavier pigmentation on the head.[87]

JUVENILES

See Figure 207

Size Range

From about 20 mm[87] until sexual maturity is attained, which occurs in TN at 403 and 503 mm TL for males and females, respectively;[112] in IA, at 305 mm and 338 to 356 mm;[20] in OK, at 246 and 320 mm; in MI, at 323 and 439 mm.[50,129]

Morphology

32.0 mm TL. Body long, of moderate depth; mouth large, maxilla to beyond pupil; preopercle serrate; canines strong.[42] Scales first appear at 24 mm on caudal peduncle, then progress, anteriorly, along the lateral line. Young are completely scaled at 45 mm TL (Figure 208).[100]

Vertebrae 43–48[113] or 45–48 (usually 46–47).[4]

Morphometry

32.0 mm TL. As percent TL: SL 81.3; PreAL 53.1; HL 28.4; SnL 6.3; ED 5.6; maxilla 12.5; GD anterior to

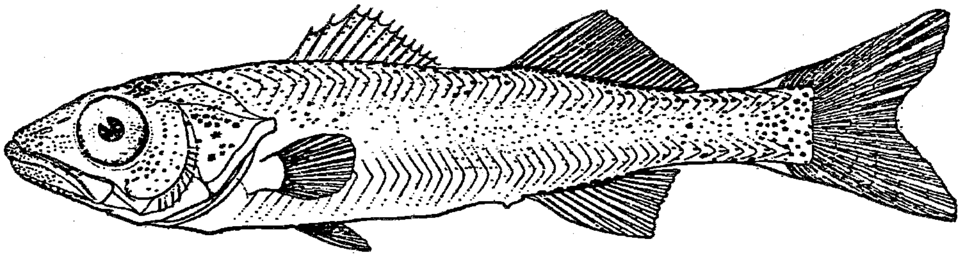

Figure 207 Walleye juvenile; 32.0 mm TL. (Reprinted from figure 97, reference 42.)

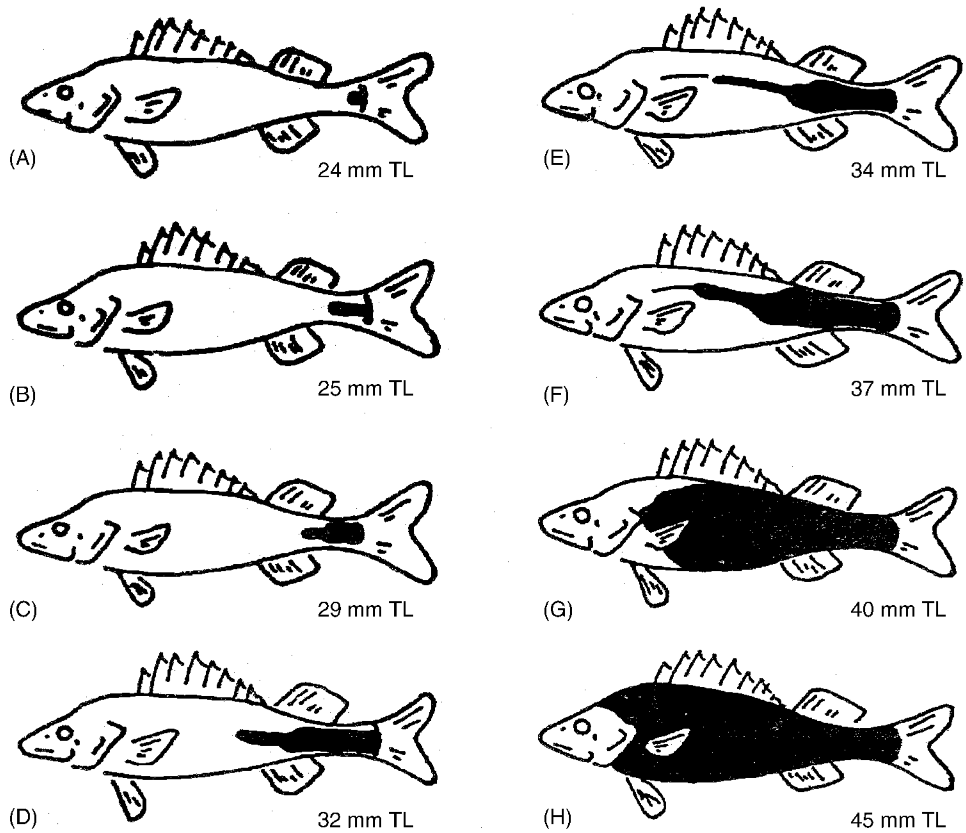

Figure 208 Scale development of young walleye. (A to H reprinted from figure 1, reference 100, with publisher's permission.)

vent 17.5; GD posterior to vent 12.5; length to spinous dorsal fin 31.3; length to soft dorsal fin 53.1; length to anal fin 56.3.[42]

Fins

Two dorsal fins, obviously separated, the first dorsal spiny, high, long, and rounded with 12–16 strong spines[37,42,113] (usually 14).[113] The second dorsal is as high, or higher, with one spine and 18–23 rays[37,42,113] (usually 18–21).[37,113] Caudal fin is long, not overly pointed, and forked. Anal fin has two spines and 11–14 rays[37,42,113] (usually 12–13).[113] Pectoral fins have 13–16 rays[37,113] (usually 14).[113] Pelvic fin count of one spine and five rays is a family character.[37,76,113,128]

Pigmentation

32.0 mm TL. Chromatophores are heavy on head and usually in seven patches or bars crossing dorsal ridge extending a short distance down each side of the body, then broken, and other oblique bands starting in the interspaces, cross the lateral line and extend midway to the ventral ridge. Ventral surface of the body is colorless except for a double series of chromatophores extending from anal fin origin posteriorly to the caudal fin. Both dorsal fins and the caudal fin are pigmented; other fins are not pigmented, except for a few chromatophores at the base of the pectoral fin.[42]

Walleye 25–75 mm long have a heavily pigmented black area on the dorsal surface of the head, visible through the parietal bone. Pigmentation of this area is utilized to distinguish between young walleye and sauger. The area is pale with little pigmentation in sauger.[101,147] Specimens from 25 to 350 mm TL are reported to have vague to obvious, dark, vertical bands across the back and down the sides.[87,113,129] In young the eyes are brilliant emerald.[129]

TAXONOMIC DIAGNOSIS OF YOUNG WALLEYE

Similar species: sauger, sauger and walleye hybrids, yellow perch, and darters. Young members of the Moronidae family superficially resemble walleye in general appearance and body proportion, but differences in total myomere count allow easy differentiation.[130] Walleye larvae have at least 43 or more total myomeres;[87] moronids have 26 or fewer.[128–130]

Walleye vs. Sauger
See Taxonomic Diagnosis Section in Sauger species account (page 579).

Walleye vs. Sauger/Walleye Hybrids
The larvae of reciprocal hybrids from sauger and walleye closely resemble their female parent, making identification impossible. Hybrids longer than 100 mm can be distinguished by their coloration pattern.[87]

Walleye vs. Yellow Perch
See Taxonomic Diagnosis Section in Yellow Perch species account (page 562).

Walleye vs. Darters
Walleye resemble darters only as yolk-sac larvae, but their reported hatching sizes (usually 6–8 mm TL),[47,87,90,129] and maximum TLs as yolk-sac larvae (up to 9.6 mm)[87,101] are much greater than reports for many of the darters. The mouths of walleye are well developed early and visibly large by 6.8 mm TL (see Figure 205A), extending posteriorly behind the posterior margin of the eye.[87] Most illustrations of darter larvae show smaller mouths with jaws that do not extend posteriorly past the eye.[128–131] The number of total myomeres reported for walleye larvae (43–51)[80,87] is greater than counts for many darters.[128–131] Myomere count is closely correlated with the number of vertebrae,[90] as tabulated by Bailey and Gosline (1955).[4] The number of vertebrae reported for walleye is also greater than counts reported for many of the darters, for most in the genus *Etheostoma*.[4] Between 8.5 and 11 mm, the moderate-sized head of walleye develops into a large head with the characteristic pointed snout and well-developed beak-like mouth (see Figures 205C and 206A).[87] Darter larvae have small mouths and blunt snouts.[128-131] Fin development occurs at larger sizes for walleye than for darters,[130] and young walleye develop large prominent canine teeth on their jaws and the roofs of their mouths.[87] Darters have teeth that are small and inconspicuous.[98]

ECOLOGY OF EARLY LIFE PHASES

Occurrence and Distribution (Figure 209)
Eggs. Eggs are broadcast at random,[102,145] and reported from waters 5–122 cm deep.[102,129] The demersal eggs are adhesive prior to water-hardening and adhere to the spawning substrate.[102] After water-hardening, the eggs lose adhesiveness and may settle into interstitial spaces between gravel or rubble substrates, or be washed downstream. Wind-driven wave action may cause eggs spawned in lakes to be a washed onto the shore,[67,75,102,129] or into areas unsuitable for survival or eggs may be stranded by receding water.[67,129] Eggs spawned in river currents may be transported great distances from the spawning site, during the embryonic period.[93,129]

Hatching rates vary from 50 to 65% under hatchery conditions at temperatures of 12.8–19.4°C, but fall to 10% at 21.7°C and above.[1] Incidence of abnormalities increases with incubation temperature: 1–3.8% at 6–15°C; 15% at 18°C; 18% at 21°C.[116] Hatching times are extended and size of larvae at hatching are smaller when eggs are incubated in dissolved oxygen concentrations less than 5 mg/L.[94] Concentrations below 4 mg/L are thought to prevent normal embryonic development.[102] Optimum oxygen concentrations are at least 5–6 mg/L.[94] Embryos and larvae are not harmed at oxygen tensions of 50% saturation, but survival dropped sharply at 35%.[150] Hydrogen sulfide concentrations exceeding 0.025 mg/L caused extended incubation period, decreased survival, and resulted in smaller hatching sizes with increased incidence of deformities.[83,117] Low pH due to acidic precipitation is especially detrimental to walleye eggs prior to the eyed stage.[62]

Yolk-sac larvae. Phototrophic.[59,102,129] At hatching, they swim to the surface, but sink back to the bottom immediately; free swimming by the second day.[60,129] A primitive, temporary embryonic respiration system and an early tendency to swim to the surface and remain there aided by a large oil globule and surface tension, indicates the importance of a lotic environment, rich in dissolved oxygen, to the early phases of walleye development.[79] Upon hatching,

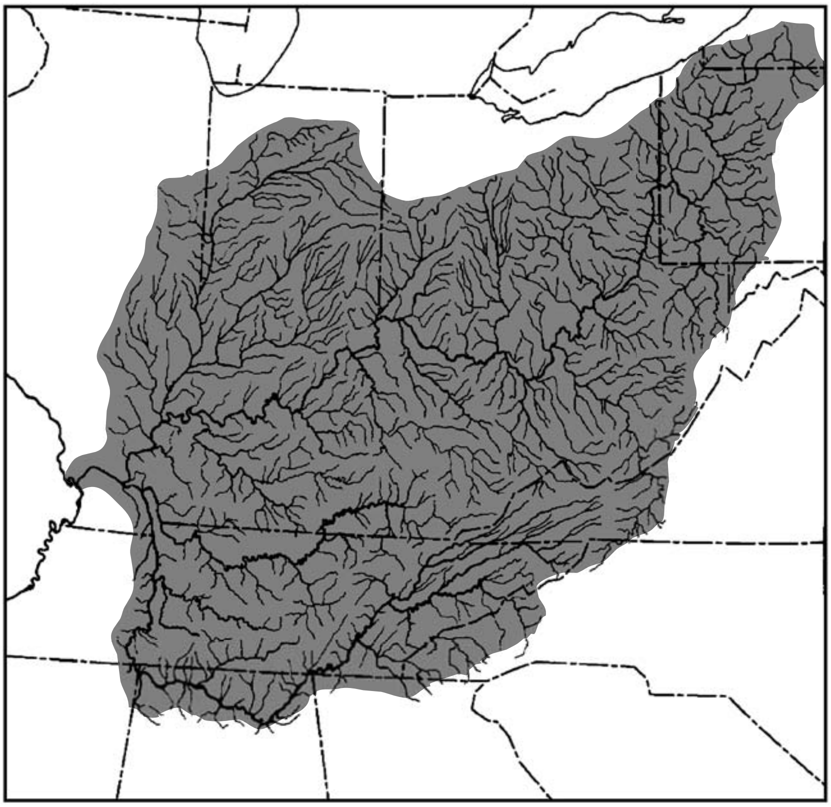

Figure 209 Distribution of walleye in the Ohio River system (shaded area).

larvae leave the spawning grounds,[24,50,68,88,102] and become pelagic and widely distributed in lakes and reservoirs.[39,50,68,102] In small streams, newly hatched larvae passively drift downstream during periods of decreasing light (2100 to 0100 h).[24] Early yolk-sac larvae are reported to drift passively for about 4 days in bottom currents,[60] and in another report until yolk is absorbed.[129] In a river situation, larvae became concentrated near the surface in mid-channel areas where the current was greatest.[102] In a lake-spawning population, masses of newly hatched larvae were observed over the spawning grounds during the morning hours, but became pelagic within 12 h.[68] In Oneida Lake, NY, they move offshore soon after hatching.[60] Late yolk-sac larvae become concentrated in the upper 2 m stratum where they are transported by surface currents,[59,68] unless high winds (>5 m/s) cause strong surface currents. During such conditions, the larvae move deeper in the water column, to a depth of 2–3 m, to avoid the strong surface currents.[59,129] They exhibit diel migration toward the surface at night.[118]

Post yolk-sac larvae. After their yolk is absorbed, walleye larvae disperse into the upper levels of open water, where they continue a pelagic existence.[59,68,69,102,118,129] In lakes they are generally limnetic, typically in open water at or near the surface,[60,129] but have also been reported at the bottom.[39,129] As development proceeds, they become concentrated inshore in coves and bays,[50,59,129] perhaps by subsurface currents,[59,68] where they are sometimes stranded by receding water.[102] They are initially dispersed by currents, but can regulate their distribution within 1–2 weeks after hatching.[60] No evidence of pelagic schooling of larvae was found.[102] Overall, walleye larvae are pelagic during their first 3–5 weeks of life,[68,129] until reaching lengths of 25–30 mm,[44] although rarely, young walleye are reported pelagic throughout their first year of life.[102] Pelagic larvae remain 0.3–3.6 m below the surface,[106] typically concentrated in the upper 3 m.[60,129] In an OK reservoir, walleye larvae moved from a spawning site soon after hatching and assumed nonstratified distribution throughout the lake.[50] In WI, they moved off spawning marshes over a 10–15-day period and moved downstream in rapid current, in the upper meter of water; transport was measured, with 75 km in 43 h reported.[102] In laboratory experiments, 1–3 week-old larvae are positively phototrophic, but start being negatively phototrophic at 4 weeks of age.[10]

Catches of walleye larvae in conical and rectangular drift nets was significantly higher in night samples than in day samples. In an 8-year study, fall abundance of age 0 walleye in the tailwaters of an upper Mississippi River lock and dam was not correlated with the spring abundance of their larvae. The fall abundance of age 0 walleye was highly correlated with the rate of water warming between April 15 and May 5.[141] Walleye larvae were probably taken in plankton tows from western Lake Erie from mid-May to mid-June.[42]

Juveniles. Walleye are reported to remain pelagic until they are about 25–30 mm TL.[102] During the summer, fingerlings may either return to shore or remain in open water.[50,129] When inshore, they concentrate in bays, coves, or other sheltered areas along the shore.[50,102,129] They appear along the shallow shorelines of lakes and reservoirs in June and July[34,42,44,50,68,104,112] at lengths of 30 to 40 mm in northern waters,[34,60,68,118] but much larger in southern waters. The average length from inshore-captured walleye juveniles during July in TN was 131 mm,[112] although they may have become shoreline-oriented earlier in the summer.

They are usually found in water less than 1.2 m deep in mid-summer,[68,112] but they are reported from depths of a few inches to 12 m,[102] over substrates of gravel, sand, silt, rubble, boulders, or mixtures thereof.[104,112,129] In late August or early fall, young walleye are found in deeper water,[34,104] approximately 1.2 to 4.8 m in depth, usually near weed beds and drop-offs or offshore shoals.[68] At this point, they are reported demersal.[50,102]

Walleye juveniles exhibit schooling behavior,[34,102] either in groups of walleye only or mixed with young yellow perch.[34] Schools of young walleye are often associated with stands of rooted aquatic vegetation.[104,106] Schooling is definite in September at depths of 3.3–3.7 m.[104]

Although known to occur in littoral areas, small walleye (79–84 mm) were also incidentally captured in water 7–10 m deep approximately 100 m from shore, when their canine teeth became entangled in large-mesh gill nets.[34] In contrast to most reports of juvenile distribution in shoreline habitats, intensive day and night seining in Lake Winnebago, WI, failed to collect any small walleye. Instead, they were found by trawling in pelagic areas of the lake.[102] The distribution of young in reservoirs becomes essentially that of older walleye year classes by December.[50,112] In OK, they were concentrated near the bottom of a reservoir in deep water from November through February.[50] Extensive movement and activity of young walleyes are reported under the ice in winter.[106] Downstream-migrating YOY were collected in turbine gatewells of John Day Dam on the Columbia River, WA-OR, from July to December at lengths of 40–226 mm.[7]

Walleye are reported strongly phototrophic to about 37.5 mm.[106] This behavior was evident in Center Hill Reservoir, TN, as walleye juveniles were only captured in shoreline seining at night.[112] In a laboratory study, most 35–40 mm young were negatively phototrophic.[10]

Early Growth

Growth is highly dependent upon water temperature, food availability, and food type.[58,115] Mesocosm and pond experiments demonstrate that zooplankton abundance and size composition are important for survival and growth of larval walleye. Growth rate (0.7–1.5 mm/day) increases with crustacean zooplankton density in both mesocosm and ponds. Survival increases with zooplankton density in the mesocosm experiments (11 to 37%), but not in the ponds.[139] In KS reservoirs, the growth increments of ages 0 and 1 walleye were positively related to the catch rates of gizzard shad smaller than 80 mm.[133] Although walleye typically grow faster in systems with gizzard shad as prey than in those with bluegill as the predominant prey, juvenile walleye can still grow well in bluegill-dominated systems.[136]

Growth is more rapid in the southern portion of the range where ambient water temperatures are higher, spawning occurs earlier, and the growing season extends further into the fall (Table 224). In Lake Erie, walleye may reach 89–203 mm by the end of the first growing season, but only 76–102 mm from more northern populations.[113] Late summer growth (July and August) is the most rapid, especially when fish is the primary forage instead of invertebrates.[44,102] Less growth after September is reported from northern waters.[104] The growth of ages 2 and 3 walleye in KS reservoirs was inversely related to mean summer air temperature.[133] Optimum water temperature range for growth of juveniles is 19–26°C.[58,115]

In Tennessee and Cumberland River reservoirs, walleye total lengths averaged 265 mm at age 1, 420 mm at age 2, 475 mm at age 3, and 505 mm at age 4.[37] Females averaged larger in age classes. Ranges of average total lengths for walleye ages 2 and 4 from nine VA lakes were 323–437 mm for age 2 and 455–554 mm for age 4.[149] In OH, YOY in October were 5.1–13 cm; at about 1 year, 8.9–17 cm.[120] In WI, walleye males mature at ages 2–5, females at ages 5–7. Females are longer and heavier than males in a given year class, especially after the first 2 years of life.[5] A summary of age and growth information for WI waters is presented in Table 225.

For additional reports of age and growth information from other areas, see Carlander (1997).

Feeding Habits

Larvae begin to feed at 8.5–9 mm,[78,118] even though some yolk material is still present.[9] They are "strike"

Table 224

Comparison of first year growth in mm of walleye from northern and southern populations (monthly averages).

	Northern		Southern	
Month	Lake Winnebago[102]	Oneida Lake[64]	Center Hill Reservoir[112]	Cherokee Reservoir*
May	20–26	—	—	—
June	38–59	36–64	—	—
July	66–104	73–108	131	140
August	83–148	103–143	176	141
September	114–176	118–163	227	157
October	127–185	—	251	—
November	—	—	287	—
December	—	—	314	—

* Unpublished TVA data.

Table 225

Ranges of total length averages by age class of young walleye from several locations in Wisconsin and average weight by year class from Wisconsin lakes and Pool 7 of the Mississippi River.

	TL (mm) Ranges			Weight (g)	
Age Class	Mixed	Males	Females	Lakes	Mississippi River
1	135–226	142–226	152–216	22	86
2	208–345	259–333	257–345	73	241
3	267–439	323–399	340–439	161	431
4	307–500	361–470	396–500	268	844
5	333–559	384–493	439–559	347	1158
6	358–617	396–480	472–617	431	1249
7	381–691	411–498	495–691	530	1512

Source: All content is from reference 5; length information is summarized from a portion of an unnumbered Table on page 875.

feeders with well-developed jaws and teeth, and rely on vision to capture food.[78] Early in the post yolk-sac phase, larval feeding behavior is to curl the trunk of the body into an "S" shape and then lunge at the intended food organism. As swimming strength increases, feeding attacks are accomplished by rapid motions of the trunk and tail.[78] In their ichthyoplankton phases, walleye consume, zooplankton, *Daphnia, Cyclops*, and *Diaptomus* as primary food organisms.[9,56,64,81,91,96,118] *Cyclops* is the primary food of small larvae (8–12 mm), while larvae larger than 12 mm select *Daphnia*.[81] *Bosmina* and *Keratella* are also important food items.[68] At low zooplankton densities, larval walleye feed more heavily on chironomid larvae.[139] Other studies found phytoplankton (diatoms) to be the first food of larval walleye. Larvae up to 9 mm in length had ingested diatoms, while those 9–17 mm in length switched to zooplankton. Another study found that larvae <11 mm ingested diatoms, mainly *Melosira*, in addition to *Cyclotella, Nitzchia*, and *Fragilaria*, while larger fry consumed zooplankton and *Chaoboris*.[112] *Leptodora*, ephemeropterans, and chironomids were occasionally consumed,[34,102] as the growing walleye fed on progressively larger zooplankton.[84] Median zooplankton prey size increased from 0.46 mm in late May to over 2 mm in July.[84]

Fish become increasingly important in the diet of walleye juveniles.[27,104] If and when fish larvae are abundant, they are consumed by young walleye according to their density,[102] however the timing of larval gizzard shad presence in a pond system did not affect walleye growth or survival.[136] Fish, mainly yellow perch larvae, were important food of walleye larvae larger than 9.5 mm during 1 year of a 3-year study.[81] In northern waters, yellow perch are the primary prey species consumed by young walleyes,[27,34,75,104] although white sucker *Catostomus commersoni*, carpsuckers *Carpiodes* spp., troutperch *Percopsis omiscomaycus*, white bass *Morone chrysops*, sauger *Sander canadensis*, and freshwater drum *Aplodinotus grunniens* have also been found in the stomachs of small walleye.[102] In TN, walleye fingerlings ate 10–14 mm *Lepomis* spp. fry during July, then switched to age 0 threadfin shad *Dorosoma petenense* in late August.[112] In western Lake Erie, age 0 walleye consume age 0 gizzard shad *Dorosoma cepedianum* and alewives *Alosa pseudoharengus* during summer, and emerald shiners *Notropis atherinoides* in the fall.[125] Where fish are not available, young walleye continue feeding on invertebrates into the fall, such as *Leptodora*, *Daphnia*, mayfly nymphs, and midge larvae.[34] Walleye are aggressive feeders; a 28 mm walleye was captured in the process of swallowing a 22 mm white sucker.[34]

The feeding intensity of juveniles held in ponds peaked at dusk, and was lowest at dawn.[78] July and August cohorts of young walleye averaging 74 and 102 mm TL, respectively, had three feeding peaks: before dusk, after dusk, and at midmorning. Smaller cohorts in the same pond, averaging 40 and 75 mm in July and August, respectively, also showed three peaks, however, these occurred during the feeding “lows” of the larger group of fish.[78] Zooplankton (*Chaoboris* sp. and *Daphnia pulex*) were most commonly eaten during the day in test ponds, while scuds (*Gammarus lacustris*) and brook stickleback *Culaea inconstans* were eaten at night.[78] One study indicates that walleye had a larger mouth gape at given body lengths than three other sympatric species, which allowed them to select larger zooplankton.[84]

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