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Biological Services Program

DEVELOPMENT OF FISHES OF THE MID-ATLANTIC BIGHT

AN ATLAS OF EGG, LARVAL AND JUVENILE STAGES

VOLUME

I

ACIPENSERIDAE THROUGH ICTALURIDAE

Fish and Wildlife Service

U.S. Department of the Interior

Dr. Romeo J. Mansueti, 1923–1963. Dr. Mansueti initiated work on this project during his time of employment at Chesapeake Biological Laboratory. These six volumes represent our humble efforts to complete that work.

Biological Services Program

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DEVELOPMENT OF FISHES OF THE MID-ATLANTIC BIGHT

AN ATLAS OF EGG, LARVAL AND JUVENILE STAGES

VOLUME I

ACIPENSERIDAE THROUGH ICTALURIDAE

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Performed for
Power Plant Project
Office of Biological Services
Fish and Wildlife Service
U.S. Department of the Interior

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FOREWORD

The demand for electric energy often creates conflicts with the desire to preserve and protect the Nation's fish and wildlife resources. This is particularly true when the use of water for power plants is considered. Power plants require large volumes of water from rivers, lakes, reservoirs, and estuaries. Withdrawal of water for cooling purposes causes the loss of fish eggs, larvae, and juveniles through impingement or entrainment. The discharge of water causes thermal and chemical pollution, and can cause alteration of stream flow patterns and the disruption of the thermal and dissolved oxygen stratification in those water bodies.

The biological consequences of water use by power plants depend upon the species of organisms involved, the mechanical and physiological stresses on the organisms, and the ecological role of the organisms. To assess the impacts of power plants and other habitat modifications on fish populations, it is necessary to identify fish eggs, larvae, and juveniles of different species. However, up to now, descriptions of the developmental stages of fishes have been scattered throughout a large number of sources.

The *Development of Fishes of the Mid-Atlantic Bight* is a reference which compiles descriptions of the egg, larval, and juvenile stages of over 300 fish species, and includes dichotomous keys useful for identifying species. Descriptions of spawning migrations and life habits of adult fishes, their geographic range and distribution, and movements of fish at all life stages are also included.

With this kind of baseline taxonomic information, biologists will be able to assess the management implications of power plant siting and other habitat modifications on aquatic populations and provide information to decision makers. We believe these books are a major step in providing the type of information necessary to incorporate environmental considerations into resource development decisions.

Lynn A. Greenwalt

Director, U.S. Fish and Wildlife Service

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues which impact fish and wildlife resources and their supporting ecosystems. The mission of the Program is as follows:

1. To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.
2. To gather, analyze, and present information that will aid decision makers in the identification and resolution of problems associated with major land and water use changes.
3. To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

Information developed by the Biological Services Program is intended for use in the planning and decision making process to prevent or minimize the impact of development on fish and wildlife. Biological Services research activities and technical assistance services are based on an analysis of the issues, the decision makers involved and their information needs, and an evaluation of the state of the art to identify information gaps and determine priorities. This is a strategy to assure that the products produced and disseminated will be timely and useful.

Biological Services projects have been initiated in the following areas:

- Coal extraction and conversion
- Power plants
- Geothermal, mineral, and oil shale development
- Water resource analysis, including stream alterations and western water allocation
- Coastal ecosystems and Outer Continental Shelf development
- Systems and inventory, including National Wetlands Inventory, habitat classification and analysis, and information transfer.

The Program consists of the Office of Biological Services in Washington, D.C., which is responsible for overall planning and management; National Teams which provide the Program's central scientific and technical expertise and who arrange for contracting Biological Services studies with States, universities, consulting firms, and others; regional staff who provide a link to problems at the operating level; and staff at certain Fish and Wildlife Service research facilities who conduct in-house research studies.

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GENERAL INTRODUCTION

As noted by Mansueti and Hardy (1967) in the first edition of Volume I of this series, the early developmental stages of most fishes are either poorly known or completely unknown. Despite the fundamental importance of this knowledge to many aspects of fishery biology and ichthyology, this situation still persists.

OBJECTIVES

The primary purpose of this series is to synthesize the world literature on fishes occurring in the Mid-Atlantic Bight of the United States. The successful accomplishment of this goal serves a number of useful functions, among which are greater ease in identifying young fishes and fish eggs, the systematization of information gaps, and the stimulation of studies in areas where such gaps have been clearly demonstrated. Although some original data have been included in this series, time constraints have kept this to a minimum, primary efforts having been directed toward a comprehensive review of existing literature.

FORMAT

The geographical area considered extends from the northern boundary of New Jersey to the southern boundary of Virginia from tidal freshwater out to the 100 fathom contour (see fig. 1).

Data have been presented on 321 species. Mansueti and Hardy (1967) arranged the species in Volume I in the sequence used by the American Fisheries Society (1960). Although disagreements exist with this arrangement as a phylogenetic sequence it is used here to order the species and families in this series so that the revised Volume I will remain intact. In some cases recent systematic revisions have demanded realignment at familial levels or the updating of generic and specific names.

The series is presented in six volumes as follows: Volume I, Acipenseridae through Ictaluridae, 50 species; Volume II, Anguillidae through Syngnathidae, 48 species; Volume III, Aphredoderidae through Rachycentridae, 52 species; Volume IV, Carangidae through Ephippidae, 52 species; Volume V, Chaetodontidae through Ophidiidae, 52 species; and Volume VI, Stromateidae through Ogcocephalidae, 67 species.

Species accounts are arranged alphabetically within family groupings. Each species account is divided into the following major divisions:

ADULTS—meristics, morphometrics and general description.

DISTRIBUTION AND ECOLOGY—range, habitat and movements of adults, larvae, and juveniles.

SPAWNING—description of season, location, conditions of spawning, and fecundity.

EGGS—description of ripe ovarian, unfertilized or fertilized eggs.

EGG DEVELOPMENT—developmental sequences, physical limiting factors and incubation times.

YOLK-SAC LARVAE—size range, morphology, development and pigmentation.

LARVAE—size range, morphology, development and pigmentation.

PREJUVENILES (not recognized in all volumes)—size range, morphology, development and pigmentation.

JUVENILES—size range, morphology, development and pigmentation.

GROWTH (not given in all volumes)—average and/or representative growth rates, especially preadult growth.

AGE AND SIZE AT MATURITY—average age and size at maturity plus variation if these data are available.

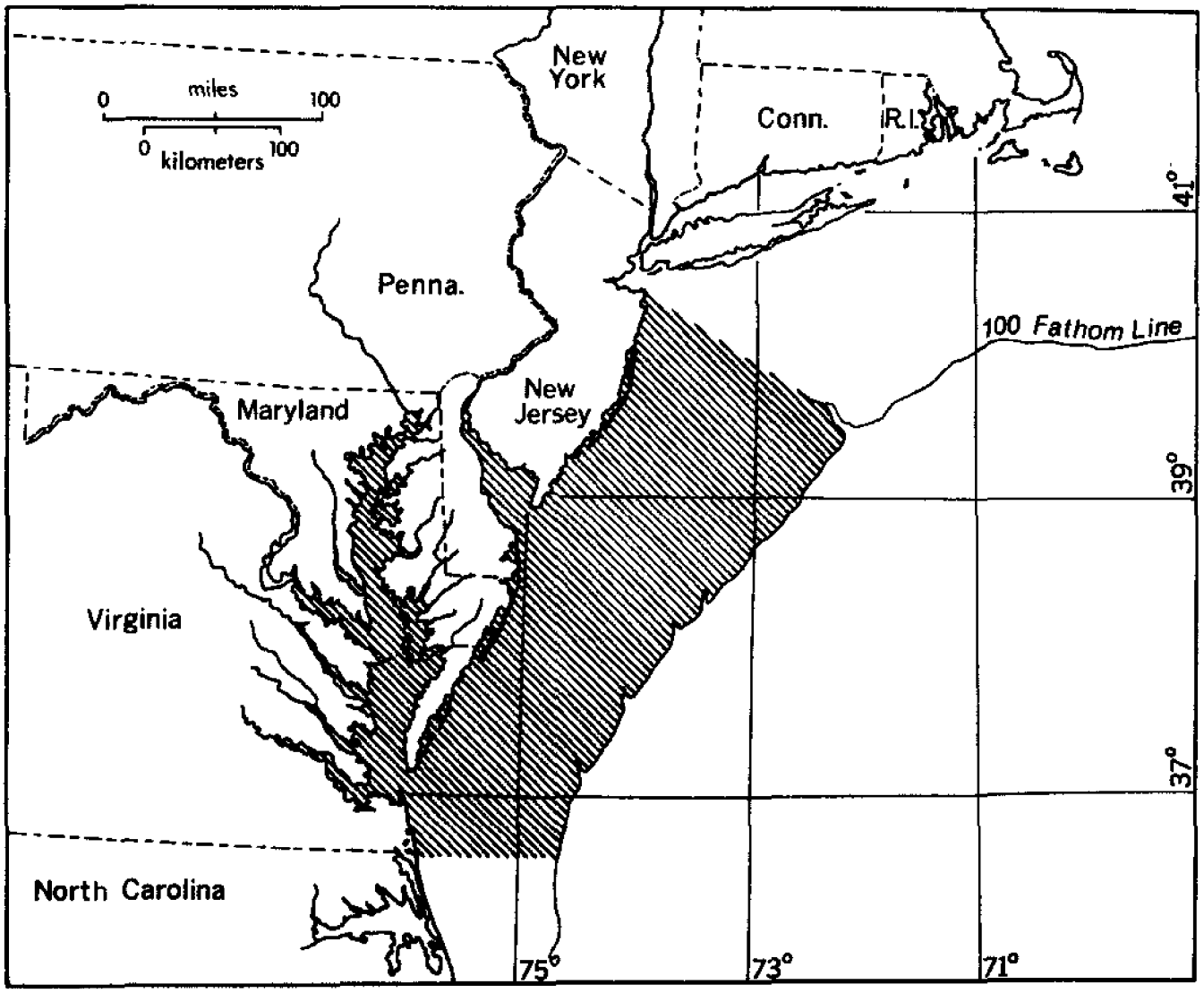

Fig. 1. Map of the Chesapeake Bay and adjacent Mid-Atlantic Bight. Hatching indicates the area considered in this series.

LITERATURE CITED—abbreviated citations to literature consulted for that account. Complete citations in Bibliography.

Superscript numbers in each species account refer to the abbreviated citations given at the end of each account. Complete citations may be found in the bibliography at the end of each volume. In prefaces, introductions, family accounts and figure legends, citations are given by author and date, rather than superscript. Throughout, parenthetical initials follow original unpublished information provided by the person whose initials are given (see preface for full name and address). Each volume has its own bibliography and index. No cumulative bibliography or index has been attempted.

Illustrations are of mixed quality and utility. For the most part they are simply reprinted from the literature. In some cases, however, previously published figures have been redrawn, and a number of original illustrations are in-

cluded. Figure legends cite the artist or delineator. Redrawings are usually of figures which are unique in that they provide the only illustrations of particular features or stages and will not reproduce well or are confusing or inaccurate in detail. Attempts have been made to exclude drawings of misidentified specimens; however, error in judgement is possible. Where available, multiple illustrations of the same stage are included if they show geographic variation or if the authors were unable to determine which illustration provided the most accurate representation. In addition, a number of drawings which have been published in rare or generally unavailable sources have been included primarily for their historic value.

TERMINOLOGY

For the most part, terminology and methods of measuring and counting are those of Hubbs and Lagler (1958); however, these terms are specifically for adult forms and must be modified or replaced by different ones for early developmental stages.

For illustrations of typical developmental stages and larval anatomy see fig. 2.

Definitions and terms for developmental stages vary considerably depending on the investigator and the species worked on. The following terminology has been standardized:

YOLK-SAC LARVA—stage between hatching and absorption of yolk;

LARVA—stage between absorption of yolk and acquisition of minimum adult fin ray complement;

PREJUVENILE—stage between acquisition of minimum adult fin ray complement and assumption of adult body form; used only where strikingly different from juvenile (cf. Hubbs, 1958; *Tholichthys* stage of butterflyfishes, querimana stage of mullets, etc.);

JUVENILE—stage between acquisition of minimum adult fin ray complement and sexual maturity or between prejuvenile stage and adult;

ADULT—sexually mature.

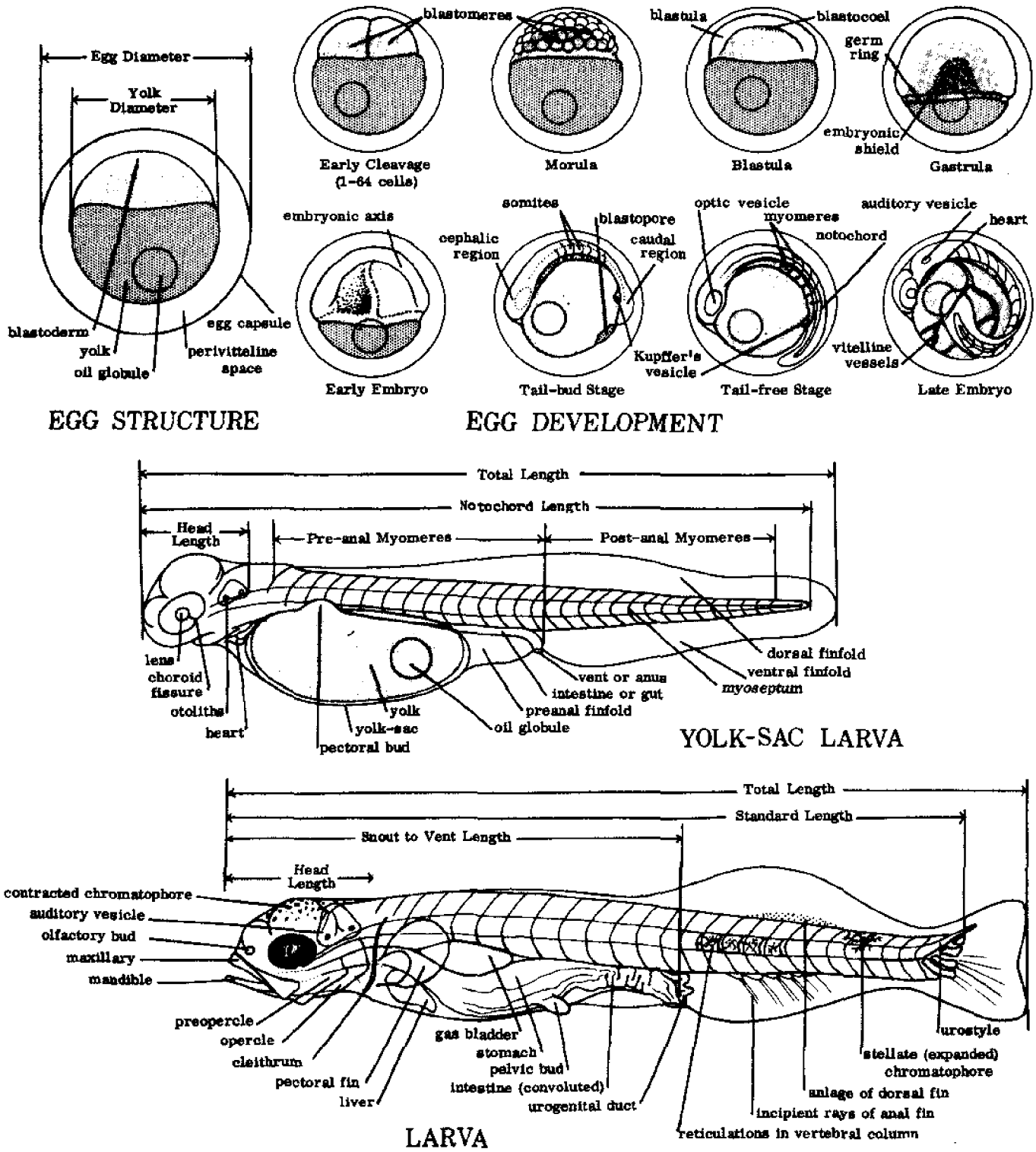

Fig. 2. Diagrammatic representation of morphology and development of egg and larval stages of a typical teleost.

GLOSSARY

A. Abbreviation for anal fin.

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

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 behind the true dorsal fin.

adnate. Congenitally united; conjoined.

adult. Sexually mature as indicated by production of gametes.

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.

anal fin origin. Anteriormost point at which the anal fin attaches to the body.

anlage. Rudimentary form of an anatomical structure; primordium.

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.

BL. Abbreviation for body length.

barbel. Tactile process arising from the head of various fishes.

blastocoel. Cavity of the blastula; segmentation cavity.

blastoderm. Sensu strictu, early embryonic tissue composed of blastomeres; more generally, embryonic tissue prior to formation of embryonic axis.

blastodisc. Embryo-forming area of egg prior to cleavage.

blastomeres. Individual cells formed during cleavage.

blastopore. Opening formed by and bordered by the germ ring as it extends over the yolk.

blastula. Stage in embryonic development which represents the final product of cleavage stages, characterized by formation of the blastocoel.

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

branched ray. Soft ray with two or more branches distally.

branchial arches. Bony or cartilaginous structures, supporting the gills, filaments and rakers.

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.

C. Abbreviation for caudal fin.

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

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.

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.

cirrus. Generally small, dermal, flap-like or tentacle-like process on the head or body.

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.

ctenoid scale. Scales with comb-like margin; bearing cteni.

cycloid scale. Scales with evenly curved free border, without cteni.

D. Abbreviation for dorsal fin.

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

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

dorsal fin origin. Point where first dorsal ray or spine attaches to body.

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.

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

embryonic axis. Primitive differentiation of the embryo; an elongate thickening of blastodermal tissue.

embryonic shield. Thickened shield-like area of the blastoderm at caudal edge of the germ ring.

erythrophores. Red or orange chromatophores.

esophagus. Alimentary tract between pharynx and stomach.

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

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

FL. Abbreviation for fork length.

fork length. Distance measured from the anteriormost point of the head to the end of the central caudal rays.

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.

germ ring. The thickened rim of the blastoderm evident during late blastula and gastrula stages.

germinal disc. The blastodisc.

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.

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

gular fold. Transverse membrane across throat.

gular plate. Ventral bony plate between anterior third of lower jaws, as in *Amia calva.*

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

HL. Abbreviation for head length.

head length. Distance from anteriormost tip of head to posteriormost part of opercular membrane, excluding spine; prior to development of operculum, measured to posterior end of auditory vesicle.

holoblastic. Type of cleavage in which the entire egg, including the yolk, undergoes division.

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.

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

hypurals. Expanded, fused, haemal spines of last few vertebrae which support caudal fin.

incubation period. Time from fertilization of egg to hatching.

interorbital. Space between eyes over top of head.

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.

juvenile. Young fish after attainment of minimum adult fin ray counts and before sexual maturation.

keeled. With a ridge or ridges.

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

larva. Young fish between time of hatching and attainment of minimum adult fin ray counts.

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.

mandible. Lower jaw, comprised of three bones: dentary, angular and articular.

maxillary. The dorsalmost of the two bones in the upper jaw.

Meckel's cartilage. Embryonic cartilaginous axis of the lower jaw in bony fishes.

melanophores. Black chromatophores.

mental. Pertaining to the chin.

meroblastic. Type of cleavage in which only the blastodisc undergoes division.

micropyle. Opening in egg capsule through which spermatozoa enter.

morula. Stage in development of egg in which blastomeres form a mulberry-like cluster.

myomeres. Serial muscle bundles of the body.

myoseptum. Connective tissue partitions separating myomeres.

nape. Area immediately posterior to occipital region.

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

NL. Abbreviation of notochord length.

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

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

occipital region. Area on dorsal surface of head, beginning above or immediately behind eyes and extending backwards to end of head.

oil globule(s). Discrete sphere(s) of fatty material within the yolk.

olfactory buds. Incipient olfactory organs.

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

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

P. Abbreviation for pectoral fin.

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

pectoral bud. Swelling at site of future pectoral fin; anlage of pectoral fin.

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

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

pelvic bud. Swelling at site of future pelvic (ventral) fins; anlage of pelvic fin.

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

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

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.

postanal myomeres. The number of myomeres between posterior margin of anus and the most posterior myoseptums.

preanal length. Method of measuring often not stated, assumed to be about equivalent to snout to vent length in larvae.

preanal myomeres. The number of myomeres between the anteriormost myoseptum and the posterior margin of anus.

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 (*cf.* Hubbs, 1958; *Tholichthys* stage of butterflyfishes, querimana stage of mullets, etc.).

premaxillary. The ventralmost of the two bones included in the upper jaw.

primordium. Rudimentary form of an anatomical structure; anlage.

principal caudal rays. 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.

pronephric ducts. Ducts of pronephric kidney of early developmental stages.

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

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

SL. Abbreviation for standard length.

snout to vent length. Distance from anteriormost part of head to posterior margin of anus; the precise method of measurement often not stated.

soft rays. Bilaterally paired, usually segmented, fin supports.

somites. Primitive, segmented, mesodermal tissue along each side of notochord.

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

standard length. In larvae, straight-line distance from anteriormost part of head to end of hypural ele-

ments; not applicable to larvae prior to notochord flexion. (In juveniles and adults measured from most anterior point of snout or upper lip.)

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

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

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

TL. Abbreviation for total length.

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

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.

V. Abbreviation for the central or pelvic fin.

vent. Anus.

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

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.

width of perivitelline space. Distance between yolk and egg capsule expressed either as direct measurement or a ratio of the egg diameter.

xanthophores. Yellow chromatophores.

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 plug. Yolk within the blastopore.

yolk sac. A bag-like ventral extension of the primitive gut containing the yolk.

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

VOLUME I DEDICATION

The senior author, Philip W. Jones, dedicates this volume to Marthe Anne Cole.

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INTRODUCTION TO VOLUME I

This first volume of the *Development of Fishes of the Mid-Atlantic Bight* is a revision of *Development of Fishes of the Chesapeake Bay Region, Part I* (1967) by Alice J. Mansueti and Jerry D. Hardy, Jr. Included are accounts of 48 species of teleostian fishes in 14 families (Acipenseridae through Ictaluridae).

Within the 14 families, two species from this region have not been included. They are *Anchoa duodecim*, reported by Hildebrand (1963) from a single specimen collected off the New Jersey coast, and *Esox masquinongy*, known from one specimen collected in the tidal portion of the Northeast River in the upper Chesapeake Bay.

This volume is primarily a summary of the existing literature relative to the species included. Since the availability of specimens representing the early life history stages of these species is severely limited and time constraints precluded original work, contributions from other biologists as well as critical review of manuscripts by experts were essential for providing accurate and complete species accounts. In this respect we are extremely grateful to Jules Loos of the Academy of Natural Sciences of Philadelphia for reviewing the Cyprinidae manuscripts and contributing illustrations and descriptions of several species in this family. We would also like to thank the following persons for reviewing manuscripts: William L. Dovel, Boyce Thompson Institute, for reviewing the Acipenseridae; Anthony A. Echelle, Baylor University, for reviewing the Lepisosteidae and the Amiidae; David G. Smith, University of Texas, for reviewing the Elopidae and Albulidae; James R. Chambers, U.S. Army Corps of Engineers, for an excellent review of *Alosa aestivalis, Alosa mediocris, Alosa pseudoharengus* and *Alosa sapidissima;* W. A. Richkus, Martin Marietta Laboratories, for reviewing *Alosa pseudoharengus;* William F. Hettler, Atlantic Estuarine Fisheries Center, for reviewing *Brevoortia tyrannus;* Thomas W. McKenny, Northeast Fisheries Center, for reviewing *Clupea harengus;* M. Kjelson, Atlantic Estuarine Fisheries Center, for reviewing *Dorosoma cepedianum* and *Dorosoma petenense;* Edward D. Houde, University of Miami for excellent reviews of *Etrumeus teres, Opisthonema oglinum, Sardinella aurita* and the Engraulidae; the late E. Clyde Prince, Towson University, for reviewing the Umbridae; E. J. Crossman, Royal Ontario Museum, for reviewing the Esocidae; William W. Anderson, St. Simons Island, Georgia, for reviewing the Synodontidae; Robert E. Jenkins, Virginia Commonwealth University, for reviewing the Catostomidae; W. L. Long, Western Maryland College, for reviewing *Catostomus commersoni;* George Drewry, Chesapeake Biological Laboratory, for reviewing the Ariidae; and William Ralph Taylor, United States National Museum, for reviewing the Ictaluridae.

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F. Douglas Martin took primary responsibility for writing *Dorosoma petenense* and *Sardinella aurita* as well as the revision of *Carassius auratus*. Jerry D. Hardy, Jr., revised *Cyprinus carpio*. Philip W. Jones took primary responsibility for reviewing the remaining species and writing the *Acipenser brevirostrum* account. Family accounts were collectively prepared.

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Acipenser brevirostrum
Acipenser oxyrhynchus

sturgeons
Acipenseridae

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FAMILY ACIPENSERIDAE

Sturgeons, of which there are four genera and 23 species, are anadromous and freshwater fishes restricted in distribution to the northern hemisphere. These fishes are moderate to large in size and have elongate fusiform bodies, extended snouts, inferior mouths, four barbels in front of the mouth, heterocercal tails, posteriorly placed dorsal fins, fewer than 50 gill rakers, and five lengthwise rows of bony plates or scutes.

This family is represented by two species in the Mid-Atlantic region, *Acipenser brevirostrum* and *Acipenser oxyrhynchus*. Their spawning begins in early spring and may continue into late summer, occurring in fresh and possibly slightly brackish water. Descriptive information on the early life history stages of these species is restricted to *A. oxyrhynchus*. During embryonic development, cleavage is intermediate between holoblastic and meroblastic. The eggs are about 2–3 mm in diameter, with a distinctly two-layered capsule and are strongly adhesive. Initially globular in shape, with a distinct cross- or star-shaped pigment patch at the animal pole, the eggs become oval as development proceeds.

At hatching, larvae are large in size (ca. 11 mm), the yolk is large, oval and vascular, the mouth is formed, barbels are lacking and the anus is somewhat posterior to the body midpoint. Descriptions of late stage yolk-sac larvae, larvae and early juveniles are lacking.

Acipenser brevirostrum Lesueur, Shortnose sturgeon

ADULTS

D. 33 [17]–42; [1] A. 18–24; [9] C. 60; P. 30–31; V. 17–21; [18] dorsal shields 7 [9]–13; [2] lateral shields 22 [11]–34; [9] ventral shields 6 [6]–11; gill rakers on first arch 22 [2]–32.[6]

Proportions expressed as percent FL: Head length 18–22.[10] Proportions expressed as percent HL: Postorbital distance 51 [2]–62; interorbital width 31–40; [10] snout length 37–50. Proportions expressed as percent snout length: Mouth width 44–77.[9] Proportions expressed as percent postorbital distance: Snout length 64–89.[10] Proportions expressed as percent interorbital width: Mouth width 63–90.[9] Proportions expressed as times in TL: Greatest depth 6.75; head 4.80. Proportions expressed as times in HL: Eye ca. 14.[6]

Body elongate [6] pentagonal in cross-section,[1] with 5 rows of enlarged shields.[2] Head large, convex, depressed between eyes; [18] snout, as compared to *A. oxyrhynchus* of similar size, shorter, more blunt, proportionately wider at base; [17] 4 barbels in ventral transverse row 1/3 to 1/2 distance from snout tip to upper lip.[6] Mouth width inside lips more than 3/5 width of bony orbit.[9] Eye small,[6] pupil rounded; [15] gill rakers rather long, triangular.[2] Shields regular, oblong, with sharp keel,[15] space separating dorsal shields as much as 1/2 length of shields themselves.[16] Postdorsal and preanal shields single or paired. No enlarged bony plates between base of anal fin and lateral row of shields.[9] Upper lobe of caudal much longer than lower; dorsal fin just before caudal peduncle; anal fin under posterior portion of dorsal fin; pectoral fins just behind gill openings; ventral fins at beginning posterior 1/3 of body.[6]

Pigmentation: Brown above, tinged with copper on the sides (WLD); below lateral shields reddish mixed with violet; abdomen white.[18] Dorsal shields with whitish centers, lateral shields paler than surrounding skin; viscera blackish.[2] Iris with greenish tint (WLD).

Maximum size: 1353 mm TL; [9] 16.5 kg.[19]

DISTRIBUTION AND ECOLOGY

Range: St. John River, New Brunswick,[3] to St. Johns River, Florida; [2] rare and endangered.[3,19]

Area distribution: Possibly before Delaware [2] and Potomac Rivers; [5] also recorded from Virginia.[4]

Habitat and movements: Adults and juveniles—found most often in tidal rivers; [7] also recorded from open sea some distance from parent stream.[2] In St. John River, New Brunswick migrations to overwintering areas take place in September and October.[10] Overwintering occurs in estuarine lakes at depths exceeding 10 m,[9,19] and deeper regions of the lower estuary in salinities up to 20 ppt and temperatures of 4–8 C. During April move out of overwintering areas and concentrate in river channels. Around mid-June movement to summer feeding areas occurs.[19]

Larvae—on bottom for several days after hatching.[14]

SPAWNING

Location: Middle reaches of large tidal rivers.[1] In the St. John River, New Brunswick, spawning apparently occurs in the upper estuary adjacent to deep, turbulent sections of the river in extremely turbid water.[10]

Season: Females with mature eggs taken from the Hudson River in December (WLD), February [13] and April.[2] Spawning in the St. John River, New Brunswick, takes place between May 15 and June 15 [19] and may continue until late August or early September.[9]

Time: During peak flood tide.[10]

Temperature: Average 10 C.[19]

Salinity: Fresh during spawning; possibly becoming brackish with changes in tidal cycles.[19]

Fecundity: 48,000–99,000.[19]

EGGS

Mature ovarian eggs—average diameter 3.0 mm; [19] dark brown in color.[2]

Fertilized eggs—demersal, extremely adhesive just after fertilization, after ca. 2 hours essentially nonadhesive.[2]

Pigmentation: Brown 1/2 circumference, grayish white other 1/2; eye visible 6 days after fertilization, light in color; 8–9 days after fertilization darker, plainly visible.[2]

Incubation: 4–6 days at unspecified temperature; [12] at 7.8–12.2 C, 13 days.[2]

YOLK-SAC LARVAE

Very dark in color,[14] otherwise no information.

LARVAE

No information.

JUVENILES

Specimen described 197 mm FL.[2]

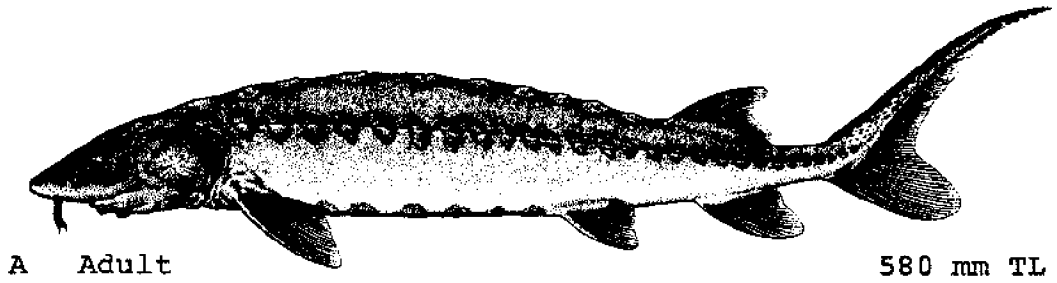

Fig. 3. *Acipenser brevirostrum*. Spawning female 580 mm TL. (*Vladykov, V. D., and J. R. Greeley, 1963: fig. 8.*)

Head 28% of FL, postorbital distance 33% of HL.[2]

Snout longer than postorbital distance. Scutes on 5 main rows sharp, set closely together.[2]

AGE AND SIZE AT MATURITY

In St. John River, New Brunswick, 8.8±1.7 years, but females apparently do not spawn until 15.5±1.4 years, even though mature.[19] (Reports of 4–8 years in both sexes in the Hudson River [7] are based on incorrect aging methods, WLD.) Males may mature at 490 mm,[7] most above 533 mm are mature.[2] Smallest mature female 460 mm, smallest ripe female 700 mm TL.[19]

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Acipenser oxyrhynchus Mitchill, Atlantic sturgeon

ADULTS

D. 30 [4]–46; [6] A. 22–32; P. 40–41; V. 28–29; [14] gill rakers on first arch 15 [9]–27; [18] dorsal shields 7 [2]–16; [4] lateral shields 24 [2]–36; [4] ventral shields 8–14.

Proportions as times in SL: Head 3.7–5.0, body depth 7.0–10.0. Proportions as times in head: Snout 2–3. Proportions as times in snout: Eye 5–7.[19]

Body elongate; [4] in cross-section more or less pentagonal; [2] with 5 rows of shields.[18] Head flattened above,[4] snout long, pointed; [22] eyes small, oval; mouth inferior, sucker-like, lacking teeth,[4] width inside lips less than 3/5 bony interorbit; [22] 2 pairs of short, slender barbels in transverse line midway between end of snout and anterior edge of mouth.[4] Dorsal fin origin between pelvics and anal, pelvics small, well to rear of abdomen; pectorals low, origin just behind head.[18] Two to six bony plates at least as large as pupil between anal base and lateral row of shields.[22] Successive shields in dorsal series touching or overlapping; [6] preanal and postdorsal shields in a double row.[2] On basis of head length, pectoral fin length, shape of scutes, and length of spleen,[20] *A. o. oxyrhynchus* Mitchill separable from *A. o. desotoi* Vladykov.

Pigmentation: Olive green, bluish gray, or brownish above, pale below; iris pale golden; peritoneum nearly white.

Maximum length: 4267 mm [2] to possibly 5486 mm.[6]

DISTRIBUTION AND ECOLOGY

Range: Nominate subspecies from Atlantic coast of Labrador and Gulf of St. Lawrence to eastern Florida; represented in Gulf of Mexico, Bermuda, and French Guiana by *Acipenser o. desotoi* Vladykov.[2]

Area distribution: Tributaries of Chesapeake Bay in Maryland and Virginia, also Delaware River.[2]

Habitat and movements: Adults—a bottom species closely associated with estuaries but sometimes wandering across continental shelf eastward at least to offshore fishing banks. Anadromous, moving toward fresh water in spring, returning to salt water in fall.[6] Postspawning migrations occur from October through November in Suwannee River, Florida,[21] June to November in Hudson River, New York (WLD) and in greatest numbers from September through November in St. Lawrence River.[17] Larger females apparently seek shallow water when migrating upstream and deeper waters when migrating downstream.[21] Maximum depth 46 m.[6]

Larvae—no information.

Juveniles—may remain in fresh or brackish water until 3–5 years of age (WLD) or 760–915 mm long; [2,6] possibly participate in prespawning runs as early as age one; [21] sometimes make oceanic excursions of at least 1450 km; [1] apparently move north along Atlantic coast during late winter and early spring and south from November through January.[23] Maximum depth at least to 18 m.[2]

SPAWNING

Location: Brackish or fresh water,[7] possibly preferring brackish,[5] over hard bottom of clay, rubble, gravel or shell [2,7,10] in shallow running water [10] or water up to 9 m deep; possibly in pools below waterfalls.[2,3] Earliest arrivals are said to spawn furthest upstream.[12]

Season: Migrations begin in early March in Suwannee River, Florida,[21] February in St. Marys River, Georgia, April in Chesapeake Bay,[2] late April in Delaware River,[15] April (males) and May (females) in Hudson River (WLD), May and June in Gulf of Maine,[2] May to July in the St. Lawrence River.[17] Peak activity occurs in April in Suwannee River, Florida,[21] mid- to late May in Delaware River [3,15] and May 15 to June 15 in Hudson River (WLD). Season ends in May in Suwannee River, Florida [21] and early June in Delaware River.[15]

Temperature: Ca. 13–18 C.[15]

Fecundity: 1,030,000 at 75 kg (WLD) to 3,755,745 at 160 kg.[2]

EGGS

Description: Demersal; adhesive, attached to weeds, stones, shells, sticks, etc.; [2,9] sometimes in stringy clusters or ribbons.[5]

Ripe ovarian eggs—2.5 [2]–2.6 mm in diameter.[15]

Freshly deposited, unfertilized eggs—globular; light to dark brown; [3] germinal disc evident; [12] 3–9 micropyles.[9]

Fertilized eggs—diameter 2.0 [14]–2.9 mm; [2,9] initially globular, becoming oval as development proceeds; [11] slate-gray [9] or light to dark brown [2,3,9] with distinct cross- or star-shaped pigment patch at animal pole; egg capsule distinctly 2-layered [9] with outer layer comprised of a viscous substance; strongly adhesive, and firmly attached to substrate within 20 minutes.[10]

EGG DEVELOPMENT

Cleavage, modified holoblastic.[16]

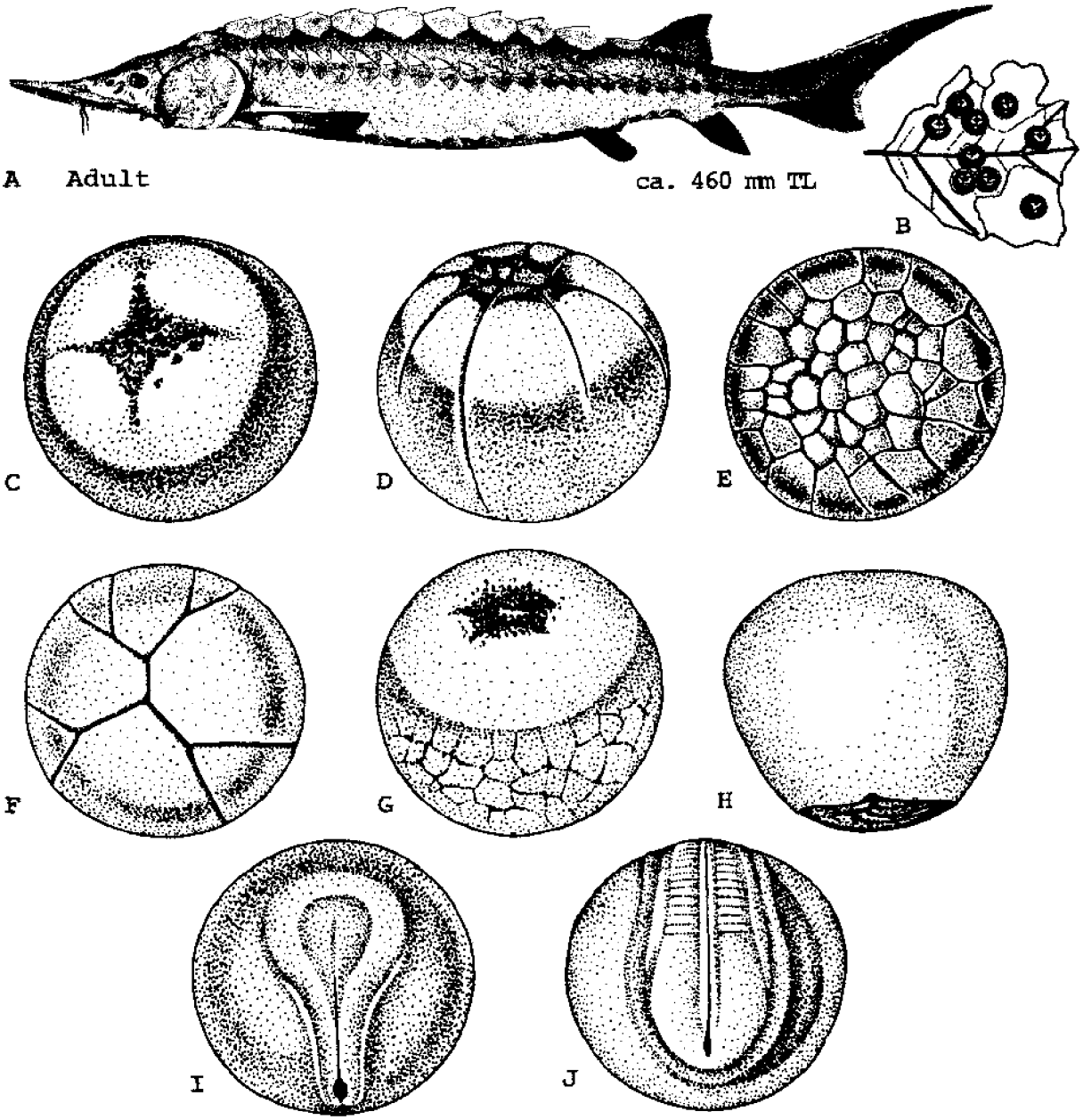

Fig. 4. *Acipenser oxyrhynchus*, Atlantic sturgeon. A. Adult, ca. 460 mm TL. B. Leaf with attached eggs. C. Egg, unfertilized. This and all following eggs incubated at 20 C, 2.5–2.9 mm diameter, yolk diameter ca. 2.2 mm; egg capsule removed for these drawings. D. Egg, third cleavage, lateral view, second furrow traverses yolk. E. Egg, sixth cleavage, 4 hours. F. Egg, sixth cleavage, lower pole. G. Egg, late blastula, 16 hours. H. Egg, gastrula, 28 1/2 hours. Dorsal lip of blastopore with indentations. I. Egg, early embryo, 43 hours. Blastopore still open; 8 somites present but not distinguishable in surface view. J. Egg, early embryo, 48 hours. View of tail region; 20 somites present. (*A, Goode, G. B.,* et al., *1884: pl. 243. B, Dean, B., 1895b: fig. 194. C-J, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 3 after Dean, B., 1895b.*)

At mean temperature 20 C:

1 hour	first cleavage.
1 hour, 15 minutes	second cleavage.
2 hours, 20 minutes	third cleavage.
19 hours	early gastrula.
33 hours	embryo around 90° of egg circumference.
42 hours	pronephric ducts formed.
43 hours	central nervous system formed.
46 hours	optic vesicles formed.
58 hours	blastopore closed.
76 hours	embryo around ca. 320° of circumference.
82 hours	first movement.[10]

Incubation: 92 hours at unspecified temperature;[10] 94 hours at ca. 20 C;[9] ca. 168 hours at 17.8 C.[2]

YOLK-SAC LARVAE

Hatching length ca. 11 mm TL. Duration of stage ca. 6 days.[2]

Yolk sac large, oval, vascular; head not deflected over yolk; mouth formed; eye relatively small; auditory vesicles round, equal to eye; branchial arches concealed by opercular folds; barbels lacking; pectoral buds present; origin of dorsal finfold in occipital region.[3]

Pigmentation: Head and tail darkly pigmented, yolk dirty yellow.[11]

LARVAE

Undescribed, except that this species is toothless "except in larval stages."[6]

JUVENILES

Minimum size tentatively included 60 mm TL.[2]

Head pointed up to ca. 915–2220 mm TL;[4] snout longer than postorbital distance in individuals up to 950 mm.[2]

Proportions as percent FL at 515–595 mm (*A. o. desotoi*): Head length 30.9–33.6; snout length 16.3–19.0; maximum body depth 15.6–15.7; postorbital distance 12.2–12.4. Proportions as percent HL at 515–595 mm FL: Mouth width 17.3–21.2; eye diameter 6.8–7.2.

Proportions as percent FL at 483–620 mm (*A. o. oxyrhynchus*): Head length 26.5–27.6; snout length 11.6–15.3; maximum body depth 12.6–16.1; postorbital distance 9.0–11.6. Proportions as percent head length at 483–620 mm FL: Mouth width 18.9–23.3; eye diameter 6.3–7.6.[20] Proportions as percent HL at 60–490 mm: 22.4–28.4.[2]

AGE AND SIZE AT MATURITY

Males age 7–9, females age 8–12 (Suwannee River, Florida);[21] males presumably mature at age 11–20 (1219–1829 mm), females age 20–30 (1829–2438 mm) (Hudson River, WLD); males age 22–34 (ca. 1650 mm TL), females age 27–28 (ca. 1900 mm TL) (St. Lawrence River).[17]

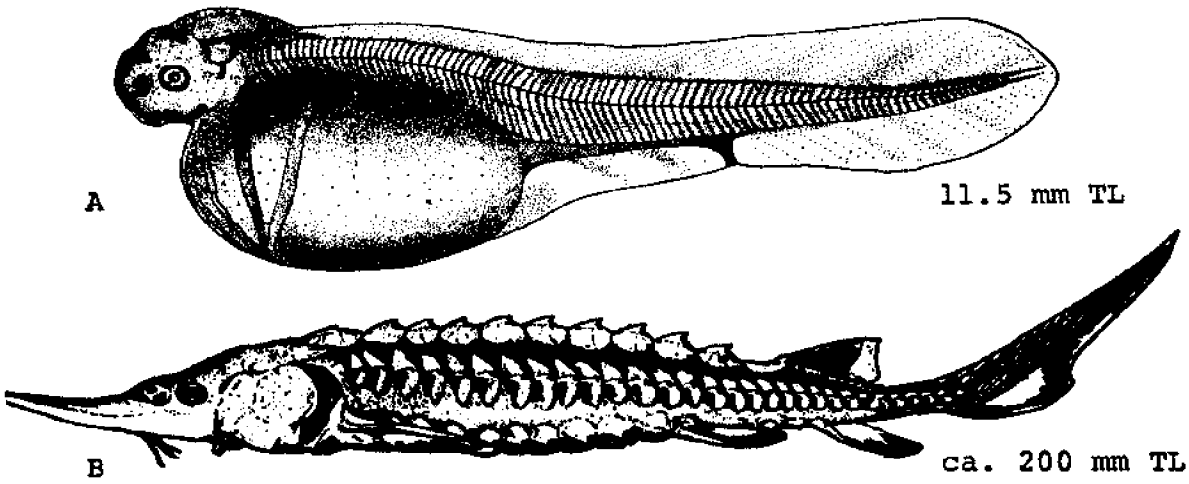

Fig. 5. *Acipenser oxyrhynchus*, Atlantic sturgeon. A. Yolk-sac larva, 11.5 mm TL, just hatched. B. Juvenile, ca. 200 mm TL, 12 months. (*A, Ryder, J. A., 1890: pl. 42, fig. 18. B, Dean, B., 1895b: fig. 302.*)

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Lepisosteus osseus

gars
Lepisosteidae

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FAMILY LEPISOSTEIDAE

Gars occur from Quebec, west to the Mississippi Valley and the Great Lakes region, and south to Costa Rica and Cuba. One species reportedly occurs in China. Typically inhabitants of freshwater, low gradient streams and lakes; several species enter brackish and marine waters.

These fishes have a long cylindrical body, produced snout, numerous teeth, asymmetrical caudal fin base, posteriorly placed vertical fins and two-layered ganoid scales. The swim bladder is capable of assimilating atmospheric oxygen.

The family Lepisosteidae is represented by one genus and seven species. One species, *Lepisosteus osseus*, is known from the Mid-Atlantic region.

L. osseus spawns in fresh and possibly slightly brackish water. Eggs are large (3.3 to about 5.0 mm in diameter), demersal and adhesive. The egg capsule is distinctly two-layered. Development is characterized by cleavage intermediate between holoblastic and meroblastic.

At hatching, yolk-sac larvae have a prominent suctorial disc, large spherical yolk, posteriorly placed anus and high myomere count. By about 15 mm TL a short snout with a terminal, suctorial disc is evident. Larvae at about 21–23 mm TL have incipient dorsal, anal, pectoral and caudal rays, an elongate fleshy caudal filament projecting from the notochord, posteriorly placed vertical fins and a heterocercal tail. At 25 to 40 mm TL the snout is elongate and the suctorial disc on the extreme end of the elongate upper jaw is disappearing.

Lepisosteus osseus (Linnaeus), Longnose gar

ADULTS

D. 6–9; A. 8–10; C. 11–14; P. 10–13; V. 6; lateral line scales 57[4]–65;[23] predorsal scales 47–55; transverse scale rows between pelvic and dorsal origins 31–35; gill rakers 14–31.[4] Distance from posterior edge of eye to posterior edge of opercular membrane 3.5 times in HL in fish more than ca. 100 mm long.[5]

Proportions as percent TL: Body depth 5.5–7.4; head length 27.0–30.3; least caudal peduncle depth 29.1–36.5.[23] Proportions as percent HL: Snout length 67.4[4]–75.4;[23] least snout width 3.1–4.5;[4] interorbital width 10.5–13.7.[23]

Body long, cylindrical, slender; head narrow, snout bluntly pointed, overhanging upper jaw. Teeth abundant, villiform, sharp,[23] present on jaws, vomer and palatines.[1] Scales ganoid; thin bony scutes on leading edges of unpaired fins, and on both edges of caudal fin. Dorsal fin nearly rectangular, its base 83.5–97.6% of anal base; caudal abbreviate heterocercal; pelvic fins midabdominal, blunt; pectoral fins low, tips pointed.[23]

Pigmentation: Generally olivaceous brown above,[4] lateral surface pale green or silver,[23] white below.[4] Median fins bright yellow to pale brown; with large dark green,

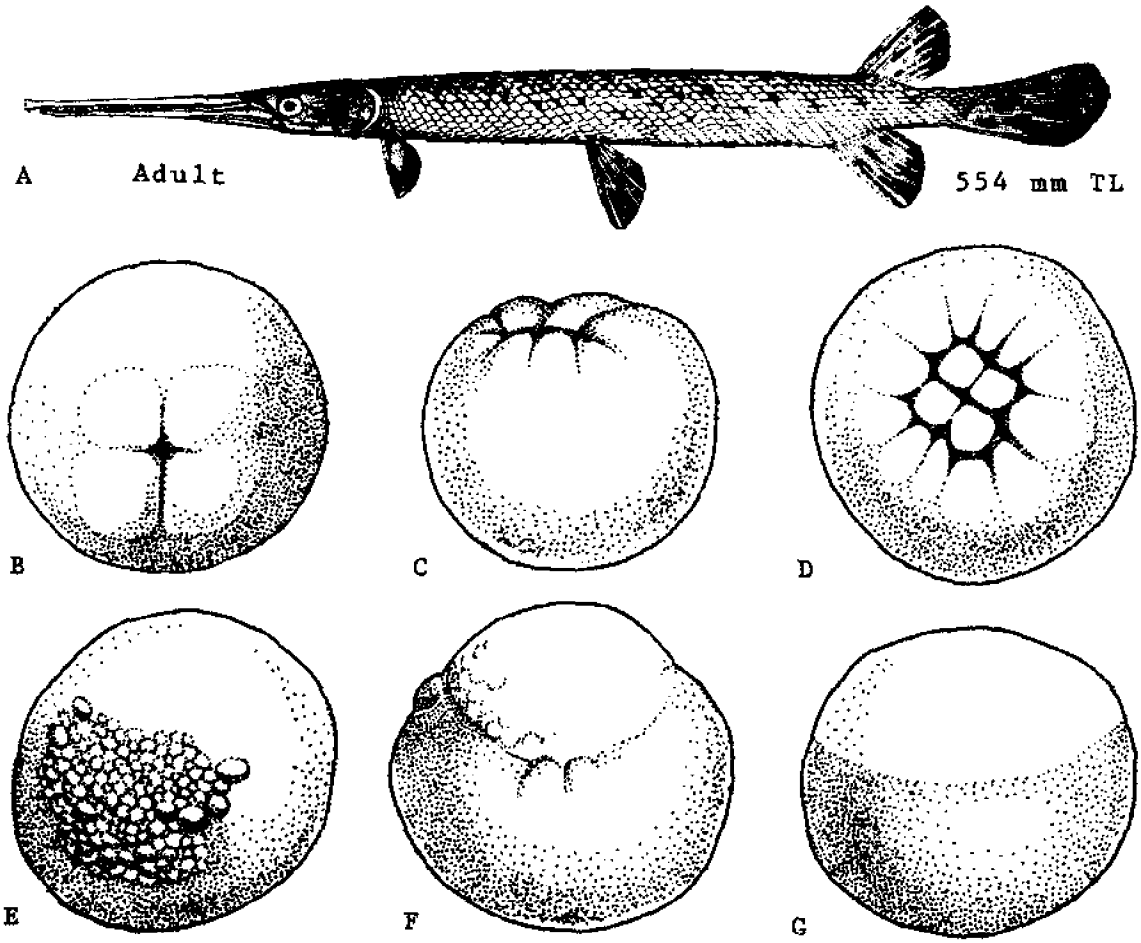

Fig. 6. *Lepisosteus osseus*, Longnose gar. A. Adult, 554 mm TL. B. Egg, four-cell stage, 2 hours. This and all following eggs incubated at ca. 17.8 C, diameter ca. 2.4 mm with egg capsule removed. C. Egg, eight-cell stage, 3 hours. D. Egg, 16-cell stage, 3.75 hours. E. Egg, early morula, 8 hours. F. Egg, late morula, 25 hours. G. Egg, early gastrula, 32 hours. (*A, Suttkus, R. D., 1963: fig. 13. B-G, Dean, B., 1895a: pl. 1; delineated by Joan Ellis.*)

brown, or black spots; paired fins dusky, usually lacking spots.[23] Body usually with dark spots,[4] primarily from pelvic fins back.[23]

Maximum length: Maximum recorded size 1524 mm,[4] possibly to ca. 1830 mm.[1]

DISTRIBUTION AND ECOLOGY

Range: Quebec to Florida, excluding eastern parts of the New England states;[4] Montana, Wyoming and South Dakota, south to northern Mexico and the Rio Grande River in New Mexico.[23]

Area distribution: Fresh and brackish tributaries of Chesapeake Bay in Maryland and Virginia;[1,2] Delaware;[20] New Jersey.[19]

Habitat and movements: Adults—clear, low or base gradient streams;[5] shallow mud flats[10] and grassy areas in rivers and lakes;[6] in more or less stagnant water[11] and midchannel areas of streams,[10] sometimes in moderately swift current.[5] Inshore movements occur at night.[29] In winter congregate at bottom of deep pools. Maximum salinity, taken in water which varies from 13–25 ppt.[9] Migrate up rivers during the spawning season and often run up smaller Lake Erie tributaries.[12]

Larvae—recently hatched larvae attached by adhesive organ to aquatic vegetation both near surface and at bottom; free swimming after yolk absorption,[15,16] capable of assimilating atmospheric oxygen.[29]

Juveniles—close inshore among weed beds in Lake Erie;[12] prefer shallow water, often along waveswept shorelines in Lake Texoma, Oklahoma.[29]

SPAWNING

Location: Fresh, shallow water,[27] usually in grassy or weedy areas, also around stone piles,[11] over algae[29] and over naked granite;[16] along windswept shorelines and rocky points.[29]

Season: March through August in Florida, with peak activity in April;[25] May or June in Maryland,[3] and until July in New York.[14]

Time: Usually during daylight hours,[13] possibly with peak activity between 1200 and 1500 hours.[14]

Temperature: Ca. 19–21 C in New York;[13] 20–30 C in Lake Texoma, Oklahoma.[29]

Fecundity: Ca. 1110–77,156.[10]

EGGS

Location: Demersal;[6] adhesive, attached singly or in irregularly arranged groups[16] to stones, sticks, and weeds, but becoming detached from slime-covered rocks in 2 or 3 days.

Mature ova (preserved): Diameter 2.1–3.2 mm, green in color.[8]

Fertilized eggs: Diameter 3.3[13] to ca. 5.0 mm.[16] Egg capsule distinctly two-layered;[15] micropyle single. Color variable; slate gray at time of extrusion, 3 hours later cream yellow, 2 days later dull greenish brown;[13] also described as having yellowish green outer envelope and whitish blue yolk.[16]

EGG DEVELOPMENT

At mean temperature of 17.8 C:

1 hour	first cleavage.
2 hours	second cleavage.
3 hours	third cleavage.
37 hours	early gastrula; pigment noticeable in yolk region.
46 hours	closure of blastopore.
70 hours	central nervous system outlined; pronephric ducts apparent.
80 hours	optic vesicles distinct; notochord, blood vessels, 4 somites developed.
90 hours	7 somites.
ca. 140 hours	embryo around ca. 200° of egg circumference.
149 hours	first movement.
160 hours	embryo around 320° of egg circumference.[22]

Incubation: Ca. 72 hours at unspecified temperature,[22] 120–144 hours at 18.9–21.1 C;[29] 200–220 hours at 16.7–22.2 C.[13]

YOLK-SAC LARVAE

Hatching length 8.0[16]–10 mm TL.[21] Duration of stage up to 9 days at 18.9–21.1 C;[29] also reported as lasting 3 weeks.[4]

Mouth open, more or less rhomboidal, and preceded by papillate suctorial disc at 11 mm, becoming narrow slit accompanied by elongation of preoral region into short snout with terminal, suctorial disc at 15 mm. At 21 mm, snout increased greatly in length, and lower jaw elongated.[21] Eye poorly developed at hatching,[16] choroid fissure retained to at least 11 mm.[21] Dorsal, anal, and caudal fins indicated by dense pigment in finfold at 11 mm, becoming even more dense at 15 mm; pectorals forming as prominent, vertically projecting, longitudinal ridges on surface of yolk sac at 11 mm; pectoral insertions oriented more or less horizontally with body and covered by large opercular flap at 15 mm; ventrals visible as small longitudinal projections near posterior end of yolk sac at

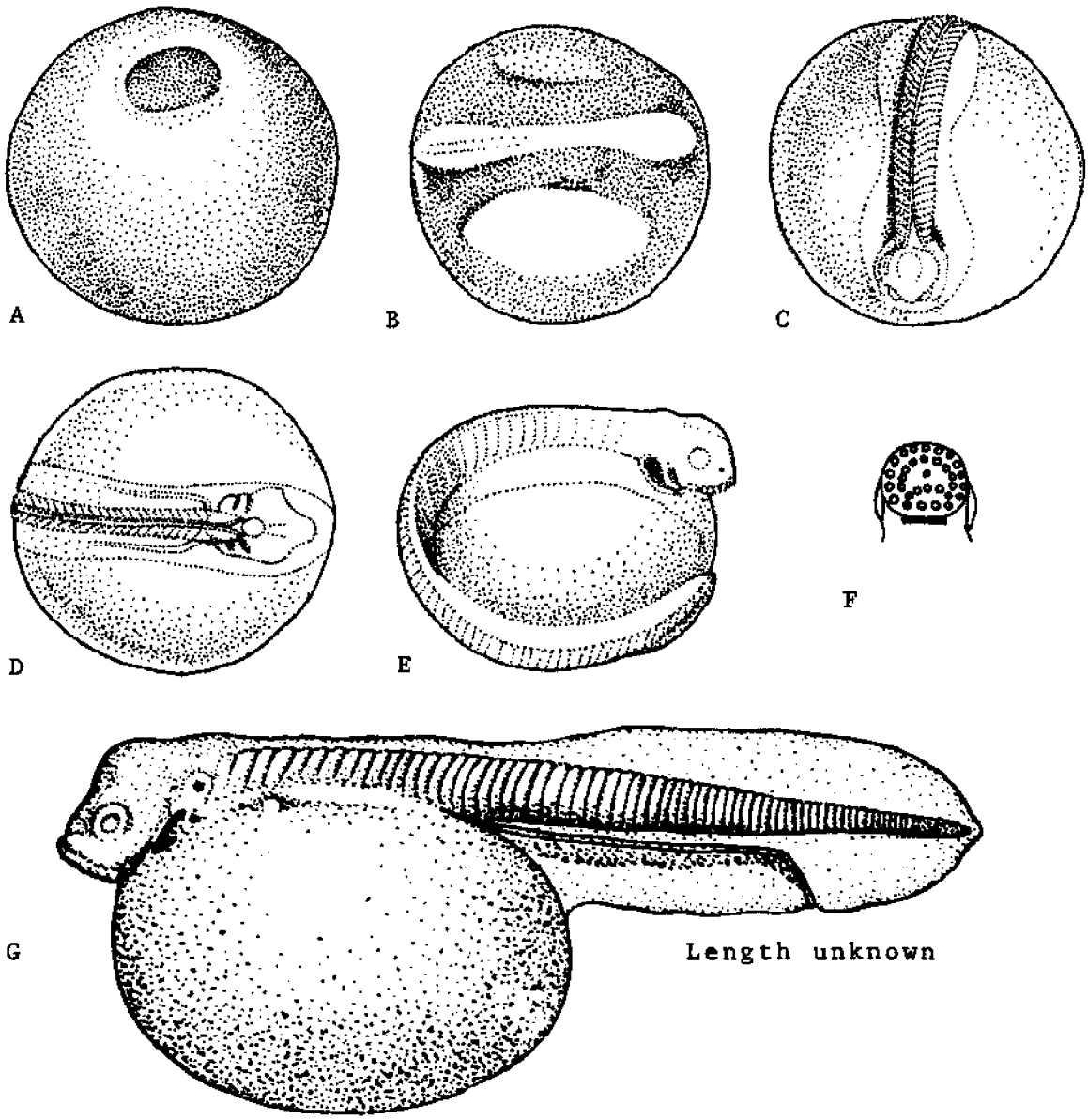

Fig. 7. *Lepisosteus osseus*, Longnose gar. A. Egg, late gastrula with blastophore, 44 hours. This and all following eggs incubated at ca. 17.8 C, diameter ca. 2.4 mm with egg capsule removed. B. Egg, early embryo with notochord, 90 hours. C. Egg, embryo 6 days. Myomeres and gill region well-developed. D. Egg, embryo 7 days. Rudimentary opercular flaps present. E. Egg, embryo just before hatching, ca. 10 mm TL, 11 days. Mouth, gill region and suctorial disc well-developed; complete myomere count. F. Ventral view of head of 11 day embryo with details of mouth and adhesive organ. G. Yolk-sac larva. Newly hatched, with prominent adhesive organ. (*A, B, Dean, B., 1895a: pl. 1; delineated by Joan Ellis. C-F, Balfour, F. M., and W. K. Parker, 1882: pl. 21; delineated by Joan Ellis. G, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 6A, after Kerr, J. G., 1919.*)

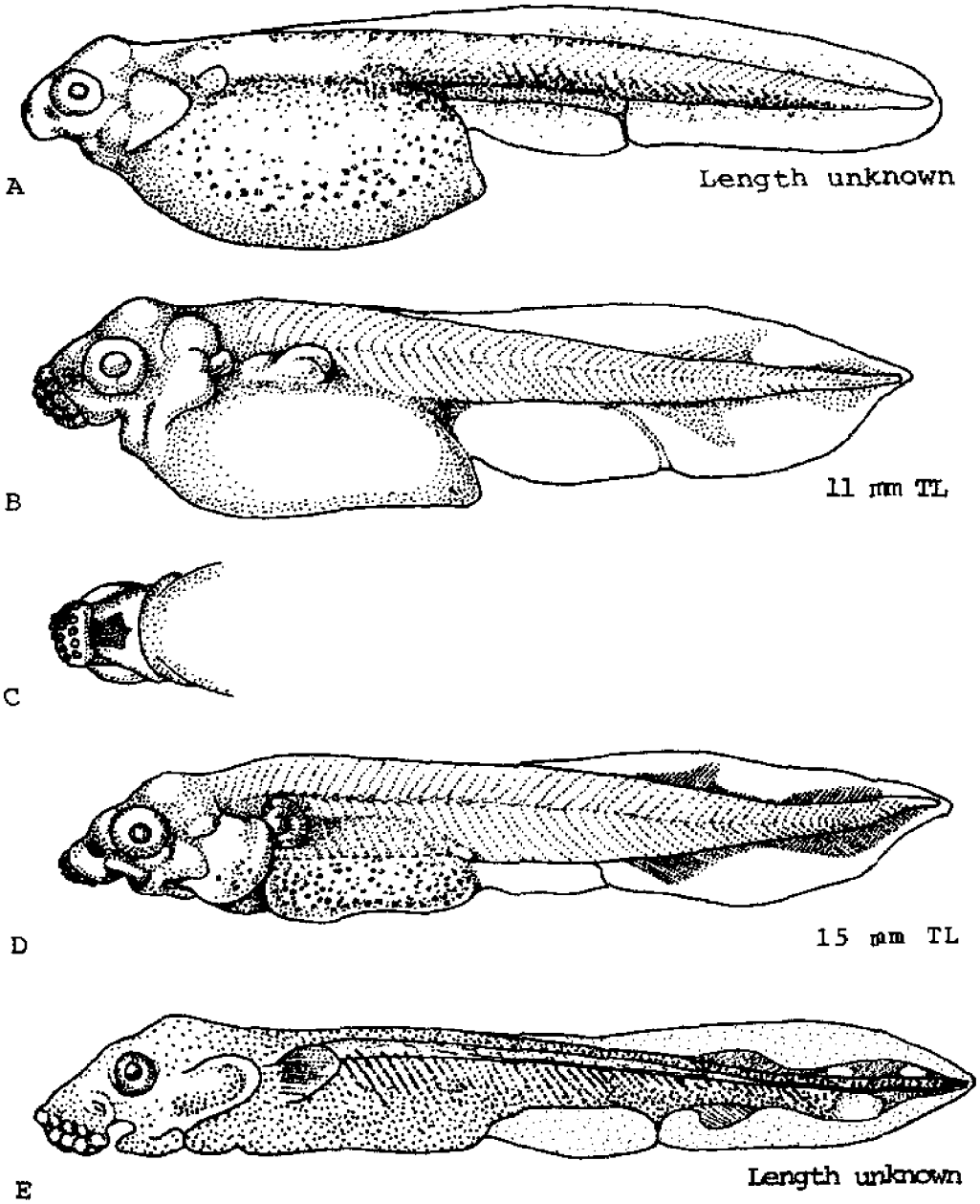

Fig. 8. *Lepisosteus osseus*, Longnose gar. A. Yolk-sac larva. Yolk partially absorbed; opercular flaps prominent. B. Yolk-sac larva, 11 mm TL. Olfactory pit formed; darkening in areas of dorsal, anal, and caudal fins. C. Ventral view of head of "B" with details of mouth and adhesive organ. D. Yolk-sac larva, 15 mm TL, 5–6 days. E. Yolk-sac larva, 11 days. (*A, Kerr, J. G., 1919: fig. 198, © 1919 by Macmillan & Co. Ltd. Used with permission of the publisher; delineated by Joan Ellis. B-D, Balfour, F. M., and W. K. Parker, 1882: pl. 21; delineated by Joan Ellis. E, Agassiz, A., 1879: pl. III, fig. 19; delineated by Marthe Anne Cole.*)

15 mm;[21] urostyle oblique by 2nd day.[16]

Pigmentation: Body colorless, transparent; yolk sac opaque bluish gray at hatching. "Somewhat later" upper edge of yolk sac and surface of alimentary canal with small melanophores; at 3 days, body with numerous, small melanophores toward head region and on sides; by 5th day, entire body with melanophores except yellowish gray venter. By 11th day, melanophores most numerous above eye, in dorsal region, in dark band from upper margin of yolk to tail, and in region of future vertical fins. White areas completely enclosed in black, developed dorsally and ventrally in caudal region; fleshy lobes of pectorals and outer edge of gill cover bluish.[16]

LARVAE

Specimens described 20[16]–41 mm TL.[12]

D. 7; A. 7.[12]

At ca. 20 mm, teeth evident; suctorial disc reduced to a swelling on extremity of elongate upper jaw,[16,21] disappearing by ca. 25–40 mm.[27] Incipient rays of dorsal, anal, pectoral, and caudal fins evident by ca. 20 mm; pelvic rays evident at ca. 23–24 mm,[16,21] although pelvics may develop before pectorals in some cases.[4] Notochord produced posteriorly into an elongate fleshy filament above caudal at ca. 23 mm.[21] Preanal finfold still evident at 41 mm.[12]

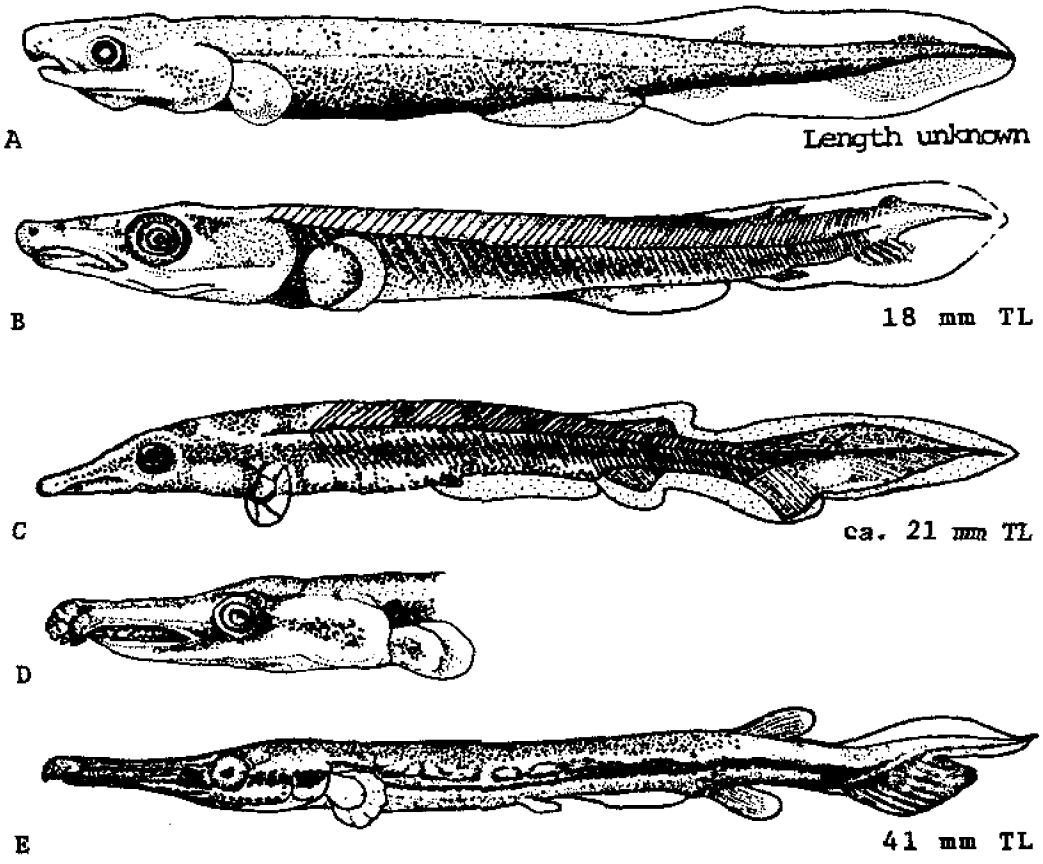

Fig. 9. *Lepisosteus osseus*, Longnose gar. A. Larva, lower jaw and ventral buds developed. B. Putative larva, 18 mm TL. Snout more elongate. C. Larva, ca. 21 mm TL. Marked heterocercal tail. D. Head of larva, 23 mm TL. End of snout markedly bulbous; adhesive organ still evident, teeth present. E. Larva, 41 mm TL. Adhesive organ apparent; tail heterocercal. (*A, Kerr, J. G., 1919: fig. 198, © 1919 by Macmillan & Co. Ltd. Used with permission of the publisher; delineated by Marthe Anne Cole. B, Wilder, B. G., 1877: fig. 9; delineated by Marthe Anne Cole. C, Agassiz, A., 1879: pl. IV, fig. 38; delineated by Marthe Anne Cole. D, Balfour, F. M., and W. K. Parker, 1882: pl. 21; delineated by Marthe Anne Cole. E, Fish, M. P., 1932: fig. 2.*)

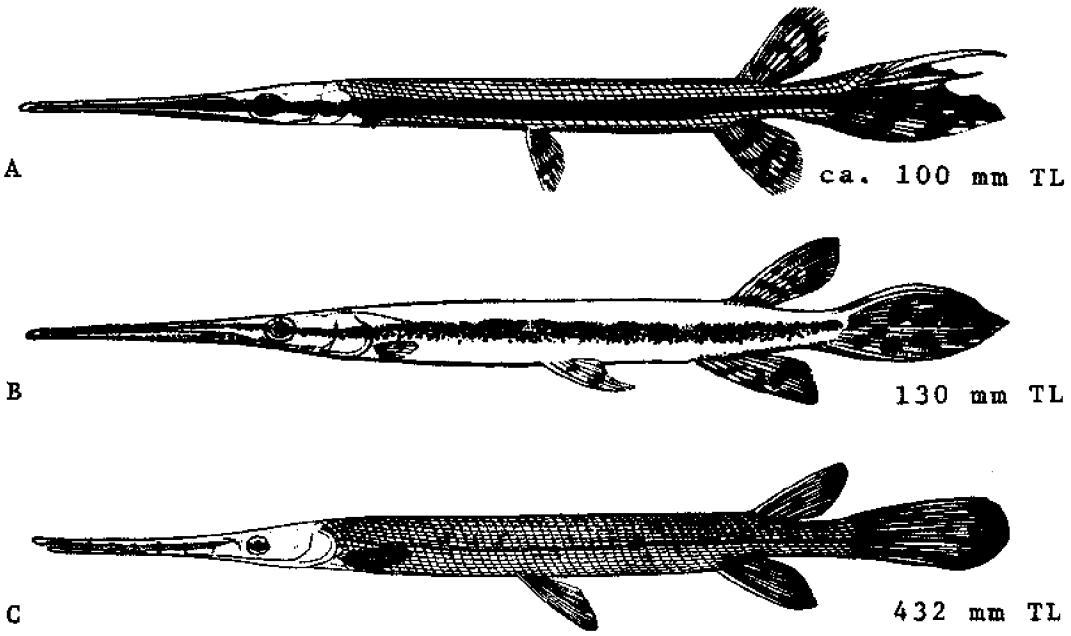

Fig. 10. *Lepisosteus osseus,* Longnose gar. A. Juvenile, ca. 100 mm TL. Ventral lobe of caudal enlarged; dorsal lobe reduced; lateral band pronounced. B. Juvenile, 130 mm TL. Lateral band persists; snout attaining adult proportions; tail abbreviate heterocercal with pointed tip. C. Juvenile, 432 mm TL, 365 mm SL. Tail adult-like. (*A, Fowler, H. W., 1945: fig. 6. B, Fowler, H. W., 1935: fig. 1. C, Trautman, M. B., 1957: fig. 14,* © *Ohio State University Press. Used with permission of publisher and author.*)

Pigmentation: At ca. 20 mm, dorsal region mottled with broad, irregular patches of brown and a heavy black line extends from back of eye to tip of tail.[16] At 41 mm, various shades of brown banded irregularly on sides with white.[12]

JUVENILES

Smallest specimen tentatively included 55.0 mm.[17]

Distance from posterior edge of eye to posterior edge of opercular membrane contained 3.0–3.5 times in HL in specimens 50–100 mm long.[5] Scale outlines visible on posterior part of body at 108 mm.[18] Caudal filament adnate to lower portion of caudal fin at 247–301 mm.[7] Vertebral constrictions visible in notochord at 55 mm.[17]

Pigmentation: Young less than ca. 75 mm long with black or chocolate brown bellies, a light yellow ventrolateral band, and a dusky lateral band; young ca. 75–375 mm long with dusky lateral band, midline of belly white, bordered on each side with band of chocolate.[5] May and Gasaway state that juveniles display a "heavy pigment line on sides extending through eye."[24] This is evident in Fowler's[28] juvenile 130 mm TL, but not in the 432 mm TL juvenile presented by Trautman.[5]

AGE AND SIZE AT MATURITY

Males and females by ca. 500 mm;[26] males average 660–686 mm; females average 838 mm; males ca. 3–4 years, females ca. 6 years.[8]

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Amia calva

bowfins
Amiidae

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FAMILY AMIIDAE

Amia calva, the only living species in this family, is limited in distribution to freshwater regions of the eastern United States.

The bowfin has an oval shape, scaleless head, large mouth, numerous teeth, gular plate between the mandibles, slightly asymmetrical caudal fin base and long dorsal fin. Like the gars, it is capable of breathing atmospheric oxygen. The spiral valve in its large intestine is a feature almost unique among bony fishes.

Eggs attach to various objects by thread-like extensions of the chorion. Initially oval (major axis 2.16–3.0 mm, minor axis 2.14–2.5 mm) eggs become spherical after blastodisc formation and gradually distend with a jelly-like fluid until they are about twice the original size. Cleavage during development is modified holoblastic.

At hatching yolk-sac larvae have about 60 myomeres, an adhesive organ, a posteriorly placed anus and a large spherical yolk. By about 10 mm TL the adhesive organ is much reduced, the snout is rounded, the maxillary is established, the gular plate is visible, the yolk is greatly reduced and incipient rays are evident in the dorsal, anal, caudal and pectoral fins. Larvae are tadpole-like in appearance and by about 20 mm have lost the adhesive disc. Late stage larvae and small juveniles are predominantly black in color with a greenish hue.

Amia calva Linnaeus, Bowfin

ADULTS

D. 42–53;[24] A. 9[8]–12;[24] P. 16–18;[35] scales in lateral line 62–70, in transverse series 18–20;[24] vertebrae 80[35]–90;[13] branchiostegals 10–12.[35]

Proportions as percent TL: Body depth 14.2–19.7; HL 21.9–24.1; snout length 5.9–7.3; caudal peduncle depth 11.0–13.2; dorsal fin base 42.7–47.5. Proportions as percent snout length: Eye diameter 30.5-38.5. Proportions as percent HL: Interorbital width 25.9–29.8.[35]

Body long, robust; head conic;[24] mouth large, maxillary extending well past eye;[35] jaws with strong, conical teeth;[24] anterior nostrils at base of short barbels.[25] Large gular plate between anterior halves of lower jaw. Scales cycloid.[7,8] *Dorsal fin origin at 1/3 of total length; anal* fin origin at midpoint of dorsal base; pelvics inserted at midpoint of body.[35]

Pigmentation: Dark olive above combines with lighter color on sides to form reticulated pattern; venter cream or greenish; head yellow to brown with darker horizontal bars; lower fins vivid green; caudal light olive with irregular darker vertical bars. Adult males with prominent yellow to orange bordered black spot at upper caudal base, less intense or absent in females.[7,8,35]

Maximum length: 914 mm.[24]

DISTRIBUTION AND ECOLOGY

Range: Quebec; Minnesota, Vermont,[12] and Great Lakes region;[11] south to Florida and Texas; north on Atlantic coastal plain to Susquehanna River;[12] probably introduced in Hudson River (ECR) and in Connecticut.[11]

Area distribution: Tidal tributaries of Chesapeake Bay in Virginia;[9,10] introduced into Gunpowder and Sassafras rivers in Maryland.[37]

Habitat and movements: Adults—clear water in lakes, low or basic gradient portions of streams, oxbows, marshes, and harbors among aquatic vegetation;[7] occasionally in slightly brackish water (RJM); apparently somewhat migratory during spawning season.[15,21]

Larvae—in nest, remaining attached to roots or lying on bottom until adhesive organ is absorbed, thereafter in tight "swarm" guarded by male parent outside nest.[14]

Juveniles—with male until ca. 100 mm long, but with schools becoming smaller, loosely aggregated, and not well guarded after 35 mm;[2] specimens 25–60 mm long among weeds in water as shallow as 15.0 cm.[5]

SPAWNING

Location: Shallow, sluggish, or stagnant water[1,24] up to 1.2 m deep or deeper[3] among thick vegetation in hollowed-out, more or less circular[1] or elliptical[6] depressions, 455–760 mm in greatest diameter,[4] and with bottoms of fibrous roots, water-soaked leaves or gravel; also under stumps, logs, and bushes.[15] Number of eggs per nest 2000–5000.[5]

Season: Last week of March to June.[17,33]

Time: Usually at night, occasionally by day,[8,17] with spawning lasting 1–3 hours.[26]

Temperature: 16–19 C.[26]

Fecundity: 2765[36]–64,000.[26]

EGGS

Adhesive, attached to decaying vegetation and upright reeds[6] by thread-like extensions of egg surface;[28] cleavage intermediate between holoblastic and meroblastic;[27] micropyle apparently single.[21]

Fertilized eggs: Oval,[17] becoming nearly spherical following blastodisc formation; greatest diameter 2.16[28]–3.0 mm;[17] least diameter 2.14[28]–2.5 mm,[17] but with egg capsule becoming progressively distended with jelly-like fluid until dimensions are about twice original size. Color variable, with white[28] to yellowish brown animal pole[17] and charcoal gray[28] to dark, grayish brown[17] yolk; egg possibly becoming darker with age[15] or varying in color with locality.[2]

EGG DEVELOPMENT

At 16–17 C:[28]

9 hours	30–40 cleavage furrows present.[30]
26 hours	late cleavage.
36 hours	blastoderm distinctly 2-layered.
40 hours	3 primary germ layers established: blastoderm over 230° of egg.
58 hours	neural cord established.
73 hours	*tail bud, 4–5 pairs of somites formed.*
124 hours	choroid fissure and ca. 25 somites (10–12 in trunk) formed; heart sigmoid in shape and beating.
129 hours	adhesive organs developed as pair of crescent-shaped protuberances; lens and anlagen of pectoral fins formed; liver developing; hypochord greatly

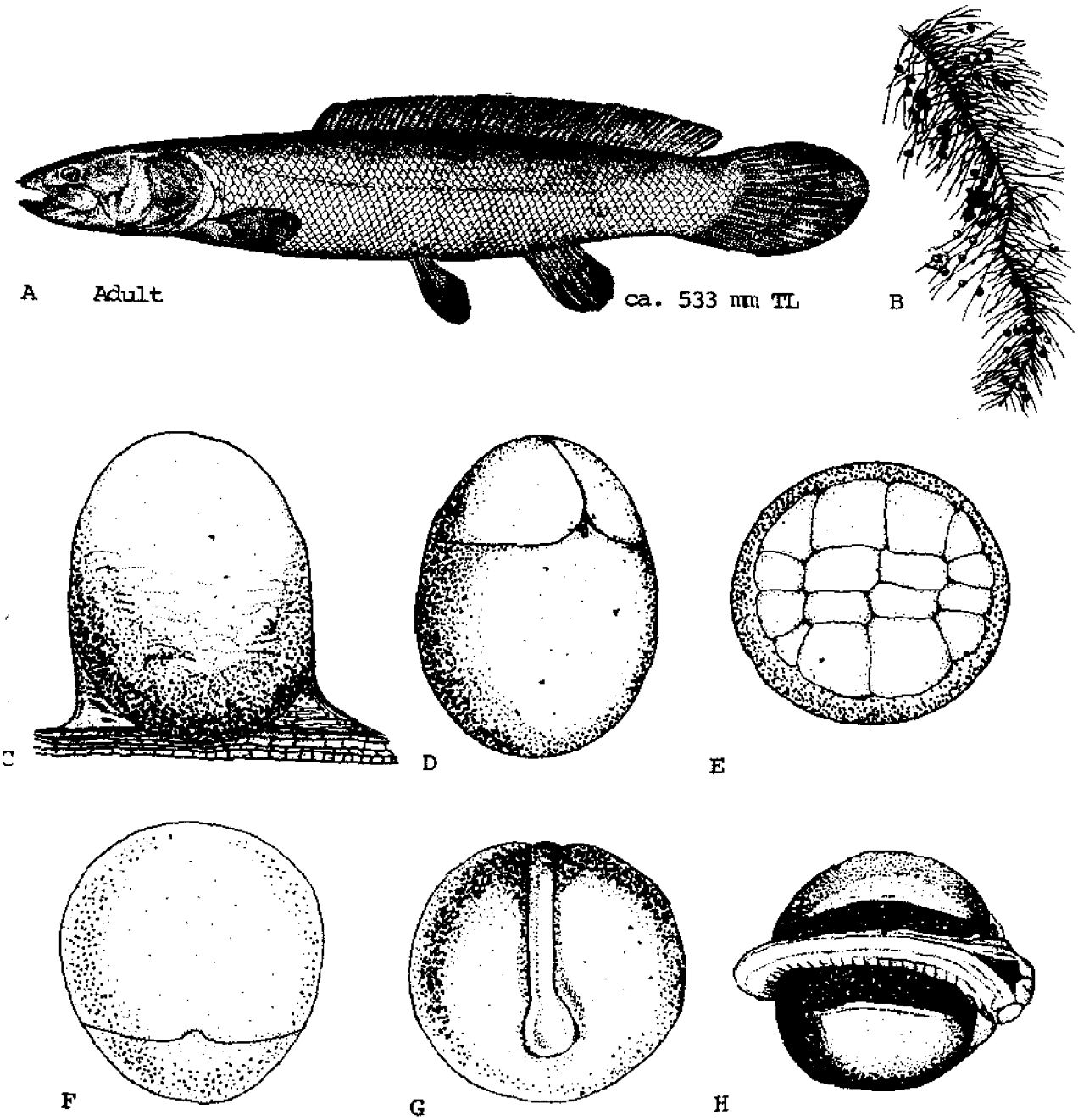

Fig. 11. *Amia calva*, Bowfin. A. Adult, ca. 533 mm TL. B. Eggs attached to bulrush. C. Egg, blastodisc forming 1/2 hour; major axis 2.2–3.0 mm; minor axis 2.0–2.5 mm. D. Egg, two-cell stage. This and all following eggs major axis 2.2–3.0 mm; minor axis 2.0–2.5 mm; membrane removed. E. Egg, 16-cell stage, 3 hours. F. Egg, gastrula, 54 hours. G. Egg, early embryo 4 days. Head undeveloped; 2 somites; embryo encircles 195° of egg circumference. H. Embryo, 5 days. Eyes, adhesive organ, and auditory vesicles formed. (*A, Goode, G. B., et al., 1884: pl. 241. B-G, Dean, B., 1895c: fig. 1, pl. 30; C-G, delineated by Marthe Anne Cole. H, Dean, B., 1896: pl. 9, fig. 1; delineated by Marthe Anne Cole.*)

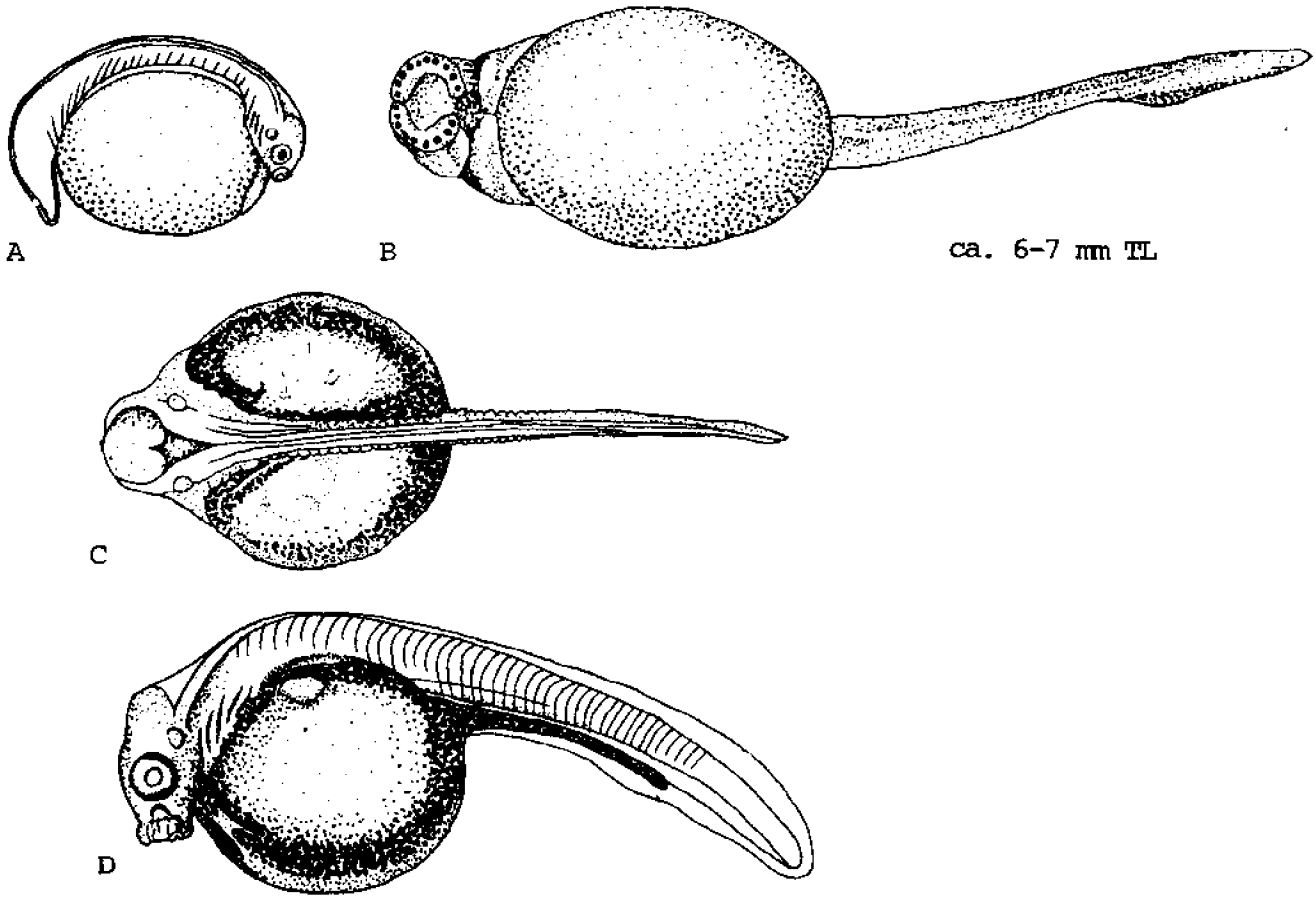

Fig. 12. *Amia calva*, Bowfin. A. Late embryo, 6 days, membrane removed. Head free from yolk. B. Ventral view of straightened embryo just before hatching, ca. 6–7 mm TL. C. Yolk-sac larva, recently hatched, dorsal view. D. Yolk-sac larva, recently hatched. Pectoral buds on dorsal surface of yolk. (*A, C, D, Dean, B., 1896: pl. 9, figs. 4, 6, 7; delineated by Marthe Anne Cole. B, Reighard, J., and J. Phelps, 1908: pl. 1, fig. 4; delineated by Marthe Anne Cole.*)

	reduced; cilia developed over entire body; ca. 43 somites; melanophores beginning to develop.
141 hours	sensory canal system established; gas bladder developing; ca. 53 somites; melanophores concentrated in cephalic region, but found over entire area dorsal to yolk sac.[28]

Incubation period: At 16–17 C, ca. 6 days (141–150 hours); [28] at unspecified temperatures, 4 [21]–14 days.[17]

YOLK-SAC LARVAE

Length at hatching ca. 3.0 [32]–7.0 mm TL; [2] length at end of stage ca. 9 [17]–13 mm.[28]

Total myomeres ca. 60.[29] By ca. 10 mm, incipient rays as follows: D. 47; A. 9; C. 16; P. 14.[19]

Body "tadpole-like," [17] flexed at hatching, straightened by 2nd day. Yolk initially spherical and with prominent vitelline vessels; [19] egg-shaped at 1 day; [18] posterior end distinctly pointed, ventral surface concave, and anterior part covered by opercular flap by ca. 7.0 mm; greatly reduced by 10.5 mm.[19] Mandible distinct by ca. 9.0 mm. At ca. 10.0 mm, adhesive organ reduced to small, nonfunctional tubercle; gular plate visible; maxillary and premaxillary established.[18] Mouth functional by 11.0 mm.[2] Eye oval at hatching.[29] Choroid fissure still evident at ca. 7.2 mm.[19] Pectorals oblique in specimens 6–8 mm long, vertical at 9–10 mm,[17] and with ossified support elements at 11.0 mm.[21] Origin of dorsal finfold over pectorals at 10 mm,[18] further back at earlier stages.[19] Lateral line evident anteriorly at 1 day.[18]

Pigmentation: At hatching, body pale, flesh-colored; yolk sac deep sepia [17] or pale slate; eye with traces of pigment.[19] At 6–8 mm, pigment developed on head.[17] At

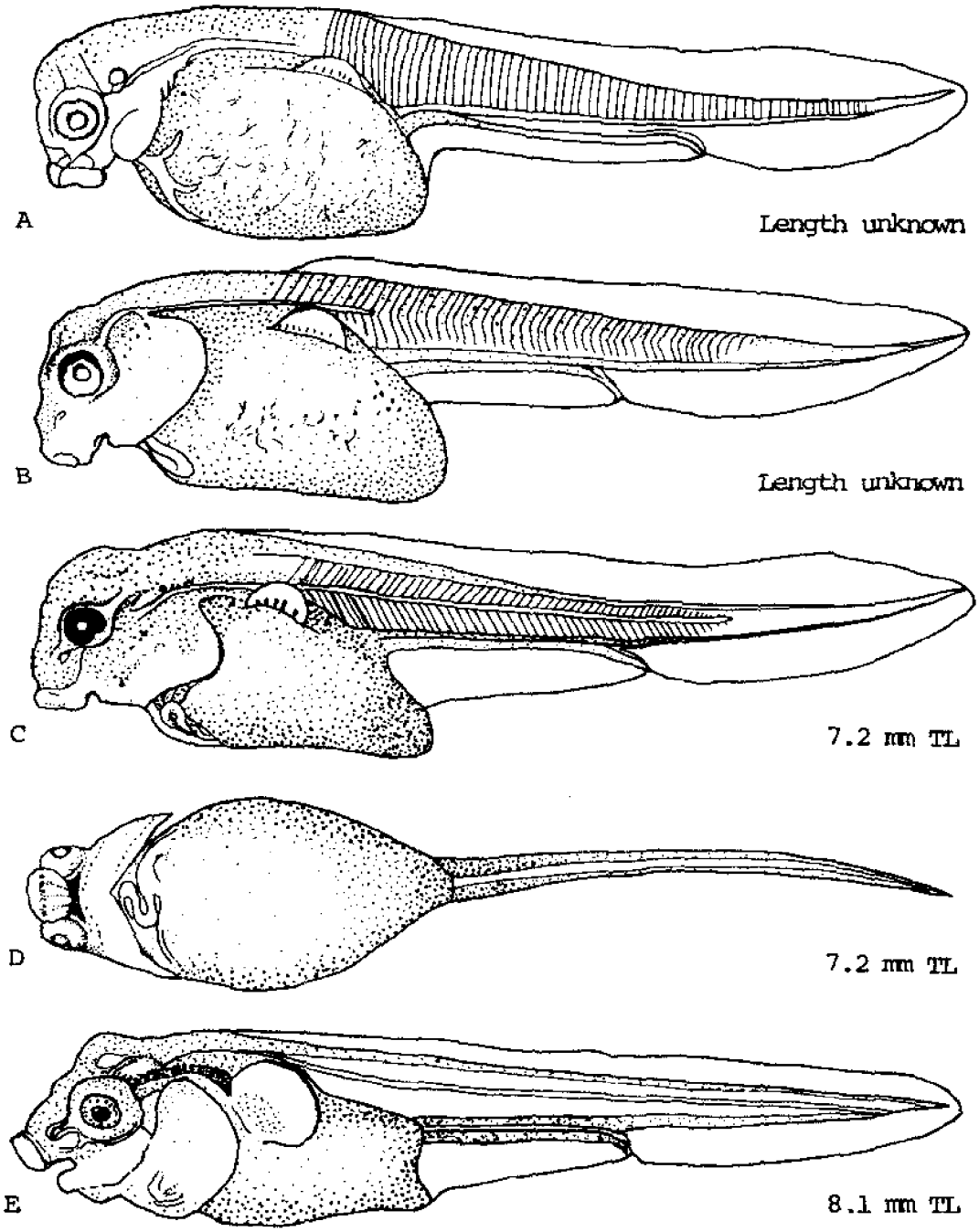

Fig. 13. *Amia calva*, Bowfin. A. Yolk-sac larva, ca. 1 day. B. Yolk-sac larva, 3 days. C. Yolk-sac larva, 7.2 mm TL, 4 days. D. Yolk-sac larva, ventral view of "C." Opercular flaps continuous; gular plate not yet developed. E. Yolk-sac larva, 8.1 mm TL, 5 days. (*A-E, Dean, B., 1896: pl. 9, figs. 8–10, 12, 13; delineated by Marthe Anne Cole.*)

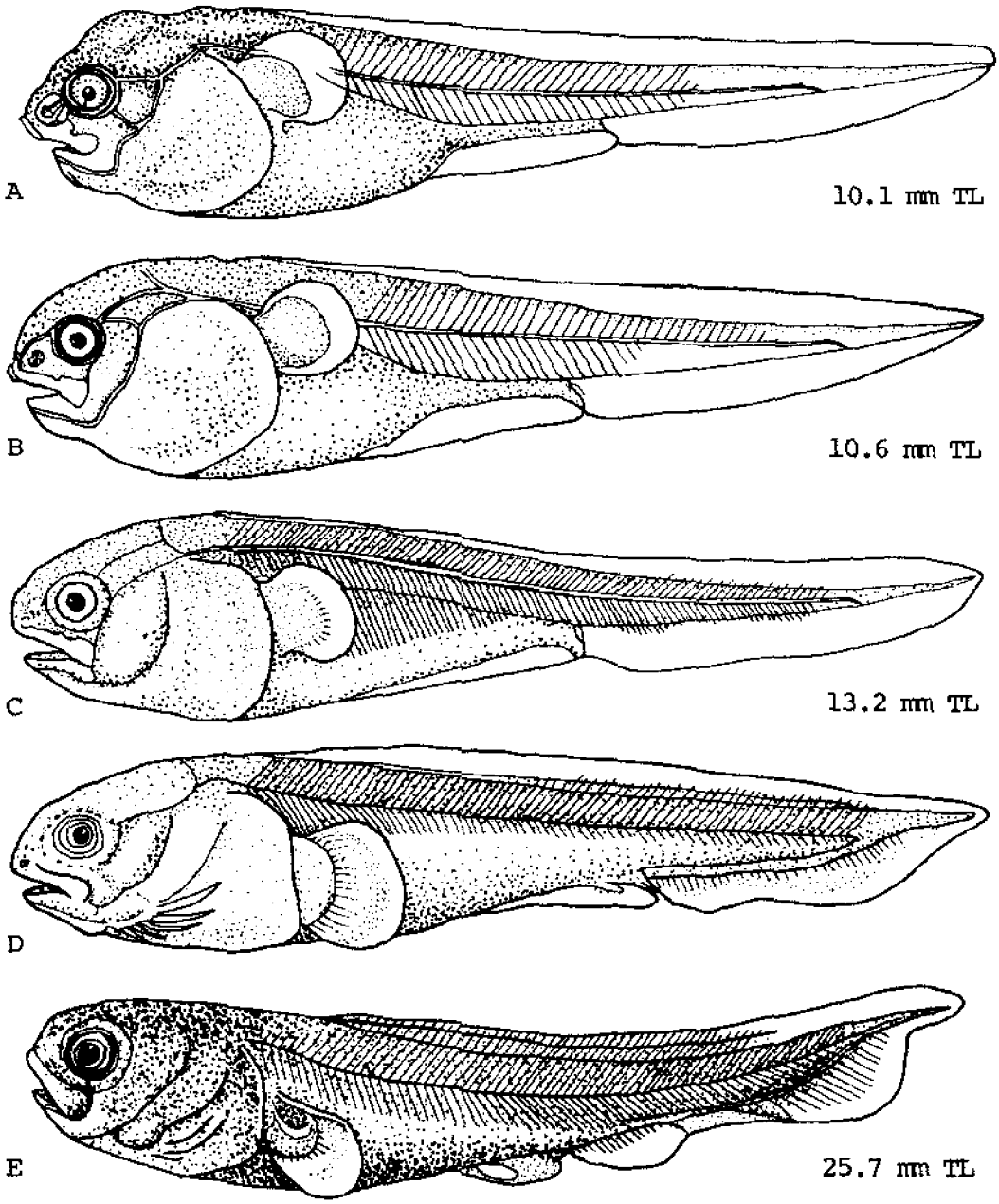

Fig. 14. *Amia calva*, Bowfin. A. Yolk-sac larva, 10.1 mm TL, 6 days. B. Yolk-sac larva, 10.6 mm TL, 8 days. *Adhesive organ reduced and nonfunctional; gular plate forming.* C. Larva, *13.2 mm TL, 10 days.* D. Larva, 15 days. E. Larva, 25.7 mm TL, 22 days. (*A-E, Dean, B., 1896: pls. 10, 11, figs. 15, 17, 19, 20, 22; delineated by Marthe Anne Cole.*)

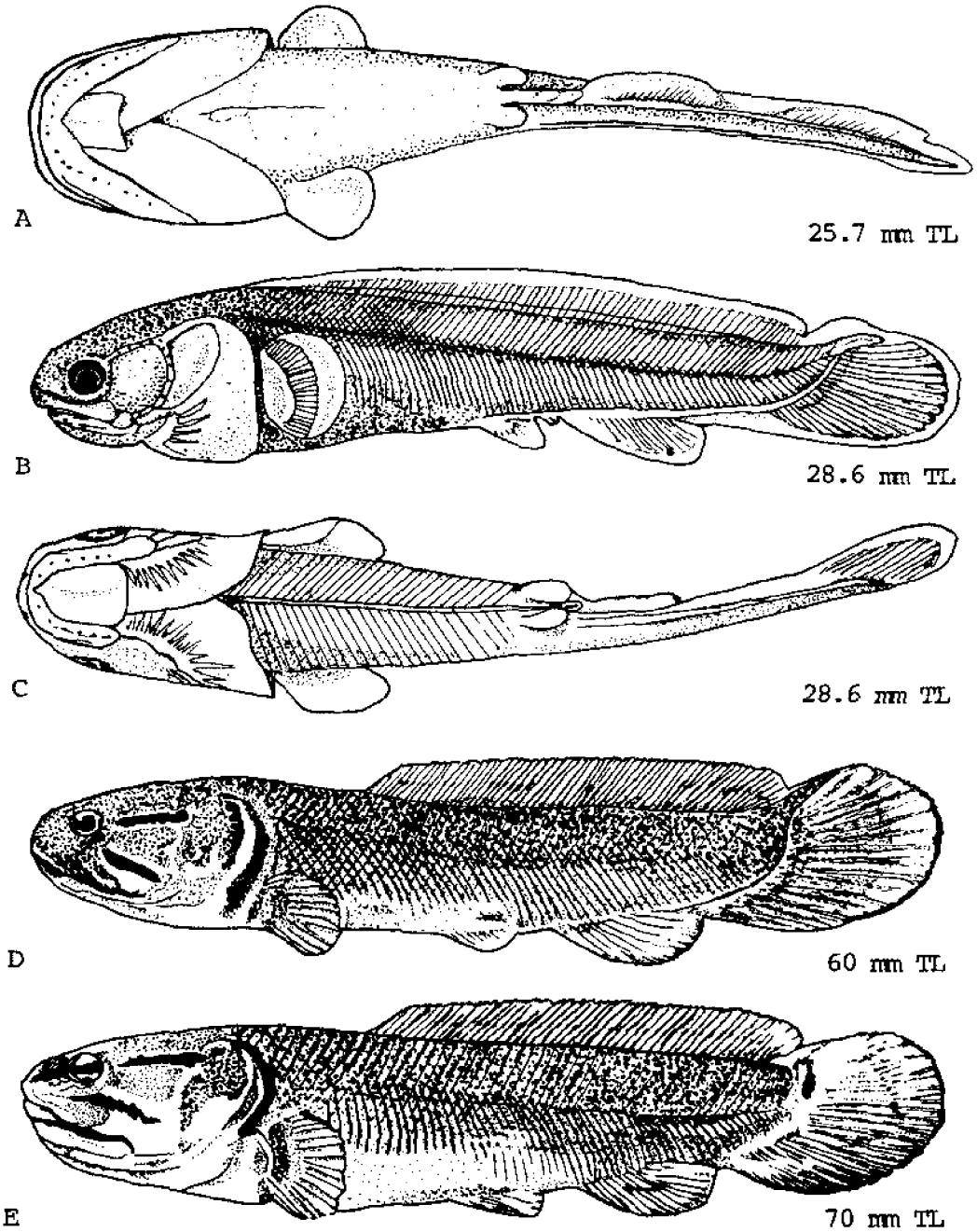

Fig. 15. *Amia calva*, Bowfin. A. Larva, 25.7 mm TL. Ventral view. B. Larva, 28.6 mm TL, 35 days. C. Larva, ventral view of "B." D. Juvenile, 60 mm TL. E. Juvenile, 70 mm TL. (*A-C, Dean, B., 1896: pl. 11, figs. 24-26; delineated by Marthe Anne Cole. D, E, Reighard, J., 1903: pl. 7, figs. 1, 2; delineated by Marthe Anne Cole.*)

12 mm, body dark greenish black, greenish brown, or black above, dirty white below; iris metallic golden.[2]

LARVAE

Sizes described ca. 9 [17]–29 mm.

D. 47 (a count of 70 rays by 35th day is questioned, JDH); A. 10–13; C. 20–21; P. 17–22.[19]

Body tadpole-like;[17] lower jaw shorter than upper.[18] Adhesive disc evident as small, median opening at apex of upper jaw at 17–18 mm;[22] no longer visible, except histologically,[16] at 20 mm.[22] Skull cartilagenous at 15–16 mm.[23] Gular plate 4-lobed at ca. 13 mm.[19] Nasal openings fully established by 10th day (ca. 13 mm), developing as tube-like outgrowths by ca. 15th day.[28] Pelvics first evident at 10–11 mm;[28] preanal finfold lost by ca. 29 mm. Scales first evident by ca. 26 mm, entire trunk region scaled at ca. 29 mm;[19] lateral line complete at ca. 11 mm.[18,20] Urostyle tipped slightly upward at 21 mm,[18] conspicuously upturned and extended into dorsal lobe of caudal at ca. 25 mm.[20]

Pigmentation: At 9–11 mm, body deeply pigmented with brown;[17] at 12–30 mm, back and sides black and acquiring a greenish hue.[2]

JUVENILES

Estimated minimum size ca. 30 mm.[18]

Gular plate complete by 78 mm; teeth present on both jaws at 136 mm;[18] scales fully formed at 30–32 mm.[2]

Pigmentation: Predominantly black to at least 30–40 mm. At 40 mm, top of head, back, and sides dark green; sides of head olive green with 3 black stripes, the 2 uppermost bordered with orange. At 50 mm, a small black spot at caudal base.[2] At 60 mm, upper parts olive green or nearly black; lower parts silvery; ventrolateral aspects of head greenish white; ocular and subocular stripes bordered with yellow; caudal spot bordered with orange; fins and opercle bordered with black; sometimes a black stripe lengthwise through middle of dorsal. At 70 mm, a vertical black band on caudal; yellow stripes on opercle. At 170 mm, fins green rather than yellow; black pigment increased in dorsal and caudal; males with reticulated pattern.[3]

AGE AND SIZE AT MATURITY

Males at age 4, females at age 4 or 5;[36] minimum ca. 380 mm.[7]

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Elops saurus
Megalops atlantica

tarpons
Elopidae

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FAMILY ELOPIDAE

This family is widely distributed in warm, shallow coastal waters, estuaries, rivers, canals, freshwater lakes and streams. These silvery fishes are moderate to large in size with slender, rounded bellies, large terminal or superior mouths, moderately long gill rakers, numerous branchiostegals (23–35) and bony gular plates.

The family Elopidae includes two or three genera and about eight species. Two species are known from the Mid-Atlantic region, *Elops saurus* and *Megalops atlantica*.

The spawning location of these two species is not known, but is generally considered to be in offshore waters, or in areas where the eggs can be carried offshore by currents. The eggs of both species are undescribed. As determined by Eldred (1972), Breder's (1944) description of eggs and larvae do not apply to this species.

Larval growth of *E. saurus* and *M. atlantica* is characterized by two periods of length increase separated by a period of length decrease. Terminology used to distinguish these developmental stages is modified from Wade (1962). Larvae in the initial period of length increase are termed Stage I leptocephali. The ribbon-like, transparent body and large fang-like teeth are outstanding features in the earlier portions of this stage. The following stage, characterized by decreasing length, the gradual loss of the ribbon-like leptocephalous form and anterior fin migration is termed Stage II. Late in this stage and throughout most of Stage III (which is the second and final period of length increase that terminates with the onset of the juvenile stage), larvae undergo pronounced changes in body form. Among these are an increase in depth at the pectoral fins, as well as increases in snout length, head length, dorsal and anal fin height and pectoral fin size. The body may become more opaque and late in Stage III the dorsal and lateral portions of some larvae become silvery in color.

Myomere counts separate *E. saurus* and *M. atlantica* larvae of all sizes. Late Stage I leptocephali and all older specimens of these two species are also distinguishable on the basis of fin ray counts and relative position of the dorsal and anal fin. To separate these species from *Albula vulpes*, see the family account of Albulidae.

Elops saurus Linnaeus, Ladyfish

ADULTS

D. 25–29; A. 16–19 (dorsal and anal counts include rudimentary rays);[7] C. 9–11 + 10 + 9 + 7–8;[22] P. 17–18; V. 14–15;[7] lateral line scales 100[21]–120; total vertebrae 73[1]–85,[7] precaudal 55–56, caudal 24;[22] gill rakers on first arch 5[8]–8 + 10–15 (excluding rudiments); branchiostegals 26[1]–33.[7]

Proportions expressed as percent SL (based in part on immature specimens): Body depth 14.5–19.3; head length 25.0–31.0; eye diameter 5.0–6.3.[1]

Body very slender, moderately compressed; snout rather long, usually somewhat longer than eye; mouth large, nearly horizontal; maxillary extending beyond rear edge of eye. Gular plate present. Scales small, thin. Lateral line nearly straight, extending onto caudal base; axillary scale of pectoral reaching to about midlength of fin.[1]

Pigmentation: Bluish above, sides silvery, venter yellowish; dorsal and caudal dusky and yellowish; pelvics and pectorals yellowish with dusky punctations;[2] eye greenish gold and silver with black pupil.[7]

Maximum length: Ca. 915 mm TL.[3]

DISTRIBUTION AND ECOLOGY

Range: Cape Cod[1] and possibly Gulf of Maine[5] to Brazil; Indian and western Pacific oceans;[18,21] and Red Sea.[12,13]

Area distribution: "Large rivers" in Chesapeake Bay region;[6] also Cape Charles and Lynnhaven Roads, Virginia.[2]

Habitat and movements: Adults—often in schools; usually in shallow, salt or brackish water; sometimes encountered several miles offshore[11] or up rivers to nearly fresh water;[8] inshore from June to October in South Carolina;[10] occurring sporadically north of Chesapeake Bay in autumn.[1] Minimum salinity 0.17–0.18 ppt.[9]

Stage I Larvae (leptocephali)—offshore in water 36–182 m or deeper.[7] Salinity 26.1–38.5 ppt, temperature 11.8–29.0 C.[15]

Stage II Larvae (shrinking)—primarily along beaches; also tidal marshes.[7,8] Salinity 1.4[14]–38.5 ppt; temperature 16.1[15]–28.9 C.[14] Collected as far north as James River, lower Chesapeake Bay.[23]

Stage III Larvae—in brackish to nearly freshwater pools and ponds in marshes.[7,8]

Juveniles—in Texas reported from 17 to 97.3 ppt;[24] mortality may result at temperatures of ca. 13 C and lower.[16]

SPAWNING

Area: Unknown, probably at sea;[7] nearly ripe females have been taken in Gatun Locks, Panama.[4]

Season: Extending throughout most of year,[15] possibly concentrated in the fall.[8]

Fecundity: No information.

EGGS

Undescribed, probably pelagic.[2]

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

Development is represented by profound changes in body form accompanied by 2 periods of length increase (Stages I and III), interspaced by a period of length decrease (Stage II).

STAGE I, LEPTOCEPHALUS

Specimens described 5.3[7]–38.3 mm[15] SL; size at end of stage ca. 40–45 mm.[7]

D. 21–24; A. 13–15; C. 1 + 19 + 1 to 1 + 19 + 2; total myomeres 74–83; preanal myomeres 66–77; predorsal myomeres 59–66 at 14.3–38.3 mm SL; myomeres at air bladder 28 to 39 at 5.3–38.3 mm SL; myomeres at kidney 47–55 at 11.2–38.3 mm SL.[7,15] Hypurals 4 at 10 mm, 8–9 at 15 mm. Four teeth in a single row on each side of jaw at 5.3 mm, the anterior two in upper jaw the longest fang-like, uniform throughout their length, and beveled at tips; at 10.0 mm SL, 6 teeth on each side of each jaw;[7] at 14.0 mm SL upper jaw 2 + 4, lower 4 + 4; at 24.5 to 38.3 mm SL upper jaw usually 2 + 5 to 2 + 8, lower jaw usually 4 + 8 to 4 + 11;[15] at ca. 40–45 mm, ca. 10–11 teeth in upper jaw, 12–14 in lower, all of approximately equal size.[7]

Proportions as percent SL: Predorsal length 80.2–85.8 (one specimen 69.6 may be in error, PWJ); preanal length 89.8–95.2; HL 7.7–10.5; eye diameter 1.3–2.1.[15]

Body ribbon-like, long, thin, deep. Head at 5.3 mm broader and slightly deeper than body; at ca. 10 mm

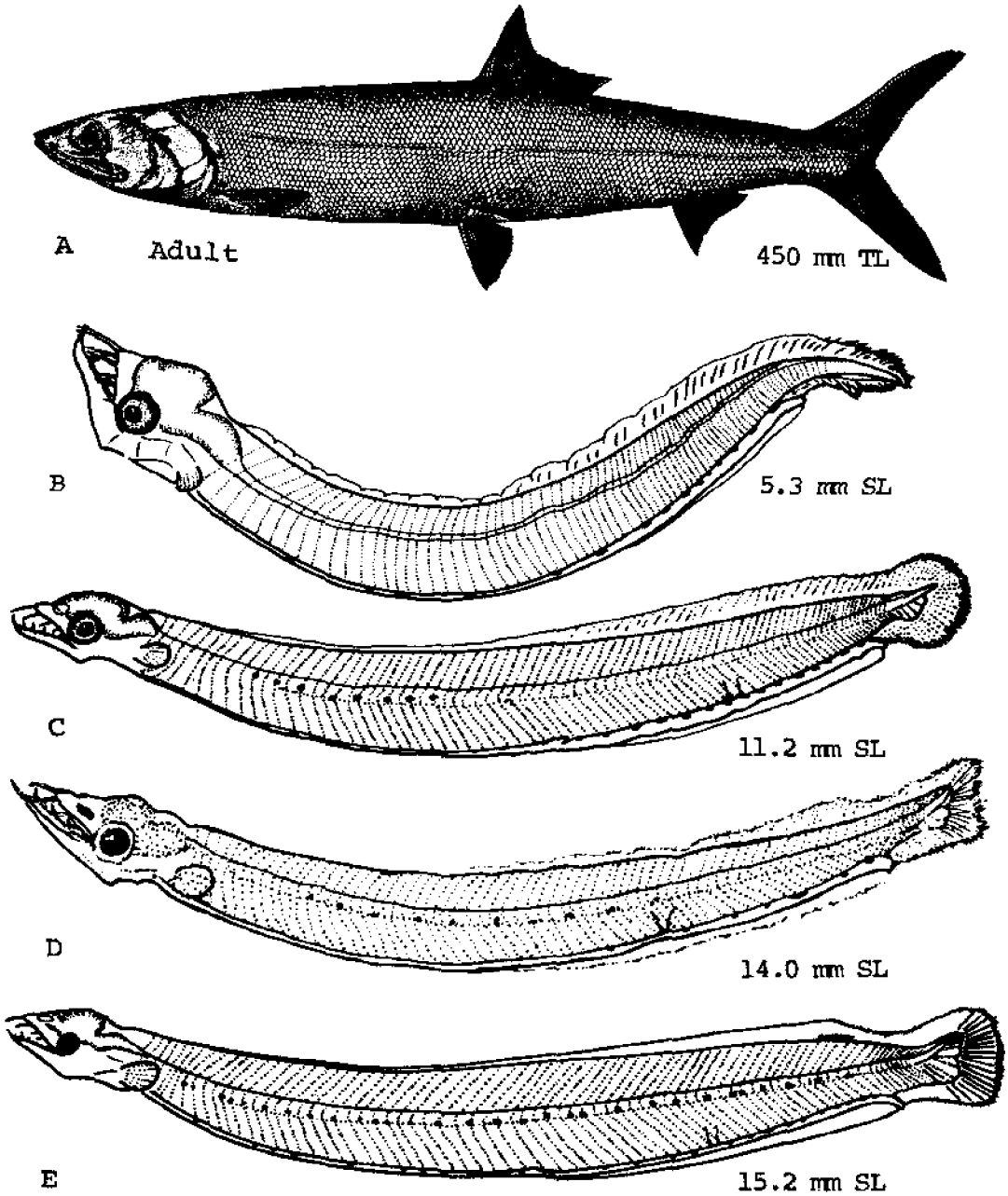

Fig. 16. *Elops saurus*, Ladyfish. A. Adult, 450 mm TL. B. Stage I larva, leptocephalus, 5.3 mm SL, 5.8 mm TL. Four teeth on each side of upper and lower jaws. C. Stage I larva, leptocephalus, 11.2 mm SL, 11.5 mm TL. Caudal fin forming; number of upper teeth increased to 6 on each side; blood vessels of kidney visible as dark parallel lines at myomeres 51 and 52; gas bladder discernible at myomeres 35–36. D. Stage I larva, leptocephalus, 14.0 mm SL. Upper teeth 2+4, lower teeth 4+4, kidney at myomeres 48–49. E. Stage I larva, leptocephalus, 15.2 mm SL, 15.9 mm TL. Dorsal ray bases, hypurals and caudal rays present. (*A, Goode, G. B., et al., 1884: pl. 218. B, C, E, Gehringer, J. W., 1959a: figs. 2–4. D, Eldred, B., and W. G. Lyons, 1966: fig. 1a.*)

triangular in dorsal aspect, less deep than body;[7] at 34.5–36.5 mm strongly depressed;[1] at end of stage relatively smaller than at any other stage of development. At 5.3 mm, dorsal finfold originating immediately behind head; preanal finfold from anus to point 1/3 distance to head; by ca. 11.0 mm, dorsal finfold reduced anteriorly; at 31.3 mm, dorsal and ventral finfolds diminished except in region of developing vertical fins. Dorsal ray bases discernible at ca. 15 mm,[7] incipient rays at ca. 28.1[15]–31.3[7] mm, although sometimes not developed at 37 mm.[1] Anal ray bases at ca. 17 mm, incipient rays first evident at 33.0[15]–34.5. Posterior margin of caudal somewhat truncate at 15 mm, forked and with 1 secondary ray at ca. 20 mm. Pectoral a rounded bud throughout stage. Urostyle tipped slightly upward at ca. 10.0 mm. Rudimentary gas bladder visible as slight bulge in dorsal wall of digestive tract at ca. 35–36th myomere in an 11.2 mm specimen. Two large renal blood vessels at myomeres 51 and 52 at 11.2 mm; at ca. 20 mm, a mass of renal tissue along dorsal wall of digestive tract.[7]

Pigmentation: At 5.3 mm, body translucent; few melanophores along dorsum of digestive tract; eye silvery, pupil black; by end of stage, melanophores increased along digestive tract, developed on myosepta, along mid-lateral line of body, on caudal fin, between anal ray bases, and on dorsal surface of eye[7] as a crescentic patch and below iris as a small patch.[15]

LATE STAGE I, LEPTOCEPHALUS, OR EARLY STAGE II

Specimen described 43.3 mm SL. D. 22; A. 14; C. 1+19+2 with 6 principal rays branched in each lobe.[7]

Gas bladder long, cylindrical, blind sac directed dorsally from digestive tract at 34th myomere.[7]

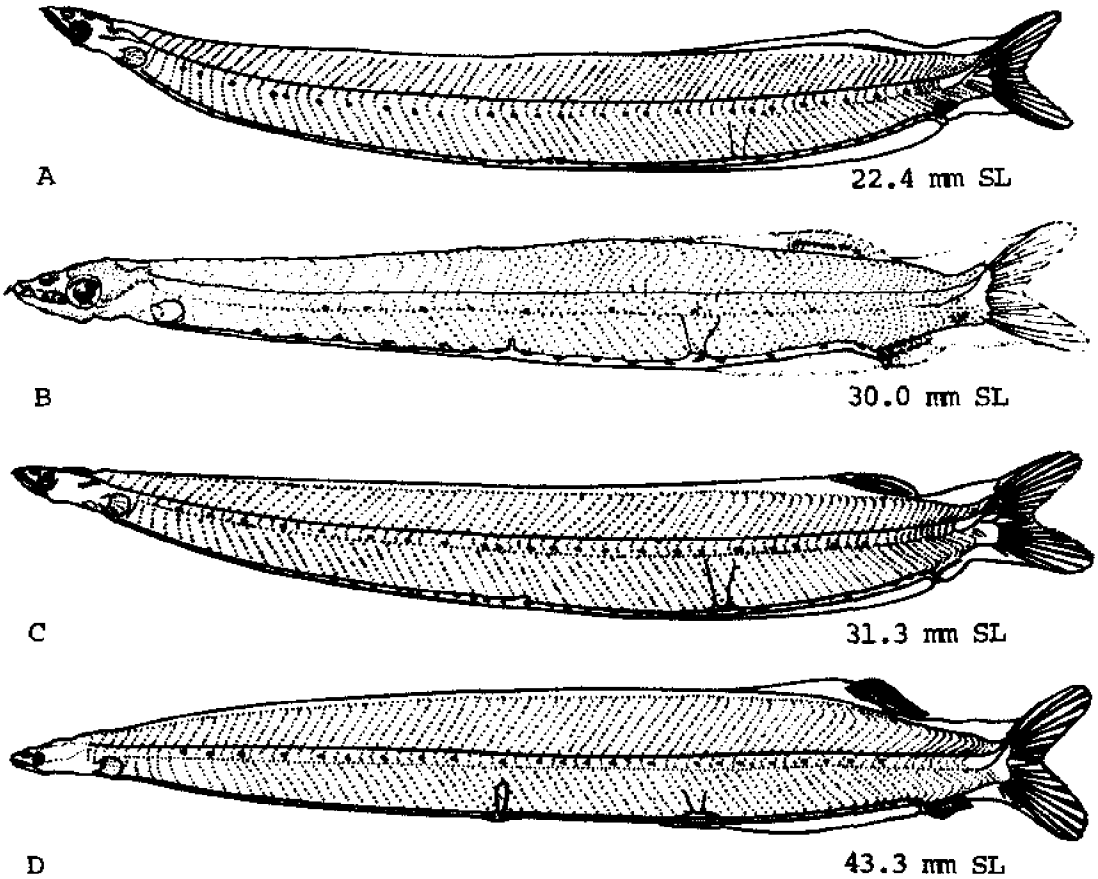

Fig. 17. *Elops saurus*, Ladyfish. A. Stage I larva, leptocephalus, 22.4 mm SL, 24.0 mm TL. Anal ray bases present. B. Stage I larva, leptocephalus, 30.0 mm SL. Air bladder at myomeres 34–35, kidney at myomeres 50–51. Dorsal rays present. C. Stage I larva, leptocephalus, 31.3 mm SL, 34.2 mm TL. D. Stage I larva, leptocephalus, 43.3 mm SL, 46.7 mm TL. Anal rays present; caudal rays branching; upper teeth increased to 11 on each side; gas bladder cylindrical, directed dorsally; pigment on dorsal surface of eye. (*A, C-D, Gehringer, J. W., 1959a: figs. 5–7. B, Eldred, B., and W. G. Lyons, 1966: fig. 1b.*)

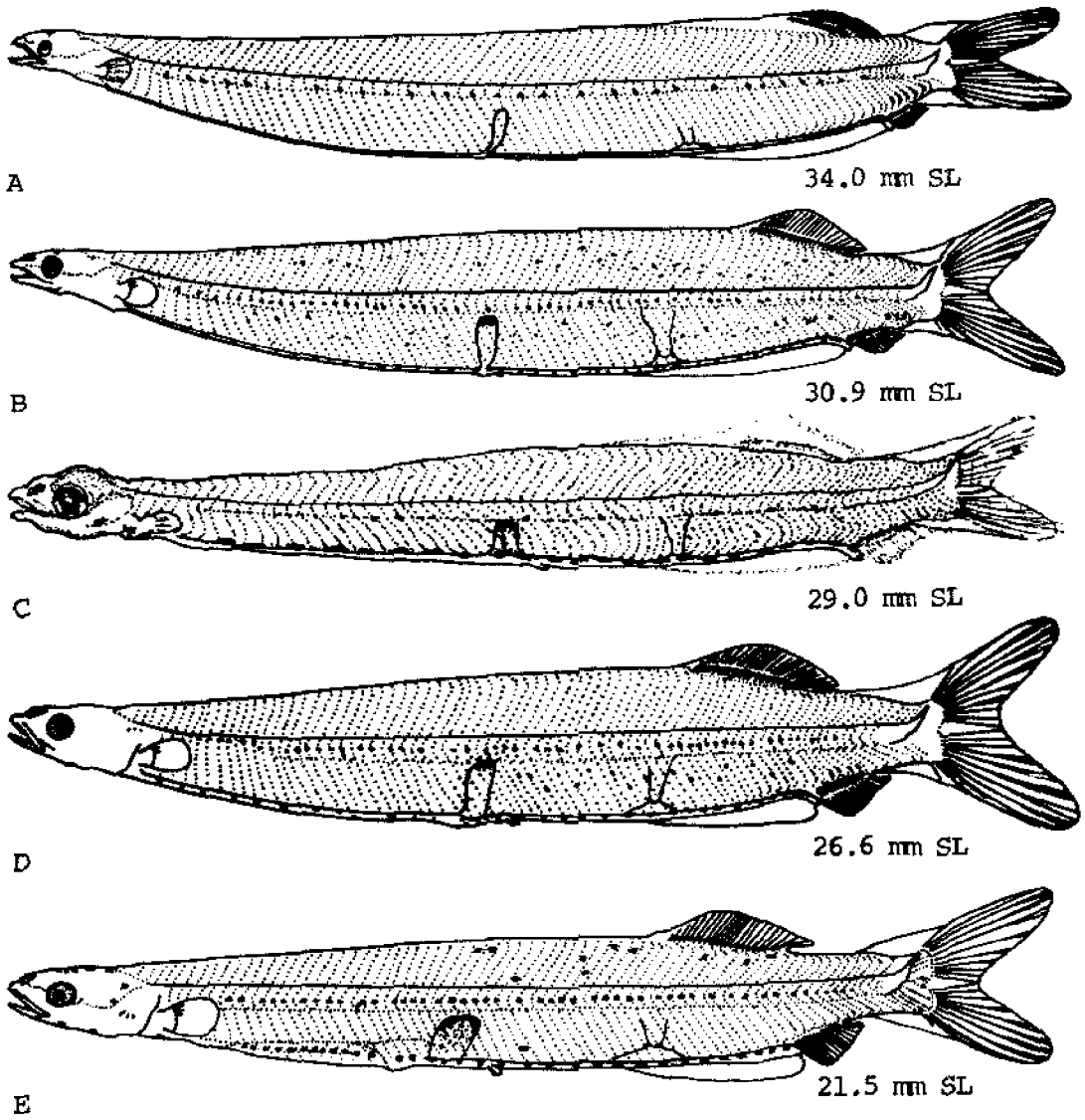

Fig. 18. *Elops saurus*, Ladyfish. A. Stage II larva, 34.0 mm SL, 38.4 mm TL. Ventral fin buds evident. B. Stage II larva, 30.9 mm SL, 34.5 mm TL. Pectoral rays forming; dorsal surface of air bladder pigmented. C. Stage II larva, 29.0 mm SL. Predorsal myomeres 56–58, preanal myomeres 67. D. Stage II larva, 26.6 mm SL, 30.3 mm TL. Branching of caudal rays complete. E. Putative Stage II larva, 21.5 mm SL, 24.4 mm TL. Pelvics with 5 rays, gas bladder more pigmented and thickening. (*A, B, D, E, Gehringer, J. W., 1959a: figs. 8–11. C, Eldred, B., and W. G. Lyons, 1966: fig. 1C.*)

STAGE II, LEPTOCEPHALUS

Specimens described 44.0 [15]–21.5 mm SL; size range from ca. 40–45 mm SL down to ca. 18–20 mm.[7]

D. 22–25; A. 13–16; C. 1+19+1 to 2+19+2; V. 4;[15] P. 2–3;[7] total myomeres 83 [15]–72;[7] preanal myomeres 77 [15]–60;[7] predorsal myomeres 66–48;[15] prepelvic myomeres 39 [15]–32;[7] myomeres at air bladder 39–28; myomeres at kidney 55 [15]–44.[7]

Proportions as percent SL: Predorsal length 84.1–68.8; prepelvic length 55.0–50.4; preanal length 93.4–81.7; HL 7.1–15.1; eye diameter 1.2–3.9.[15]

Body thicker, shorter; ribbon-like appearance lost. Head no longer triangular in dorsal aspect by end of stage.[7]

Upper jaw teeth, range 0+3 to 24; lower jaw teeth, range 0+8 to 34. Branchiostegals forming in some specimens as large as 30 mm SL.[15] Incipient rays of pectorals

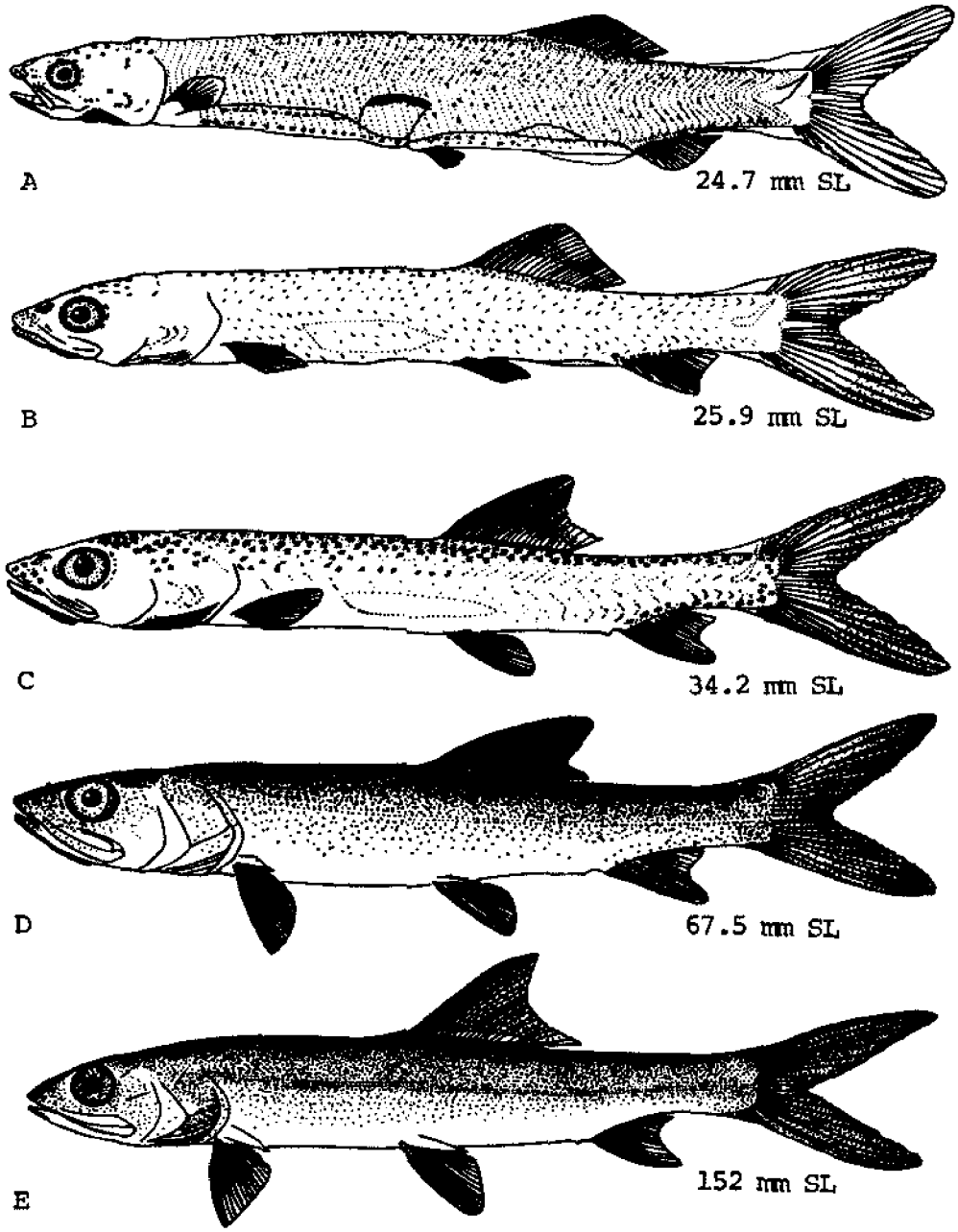

Fig. 19. *Elops saurus*, Ladyfish. A. Stage III larva, 24.7 mm SL, 29.0 mm TL. Dorsal and anal shifted anteriorly; dorsal with distinct pigment pattern. B. Stage III larva, 25.9 mm SL, 31.1 mm TL. Remnants of preanal finfold present; elongate gas bladder visible through body wall. C. Juvenile, 34.2 mm SL, 41.4 mm TL. Gas bladder visible, pigmentation dense over back. D. Juvenile, 67.5 mm SL, 82.5 mm TL. Lateral line formed; scalation complete although not illustrated; axillary scales with scalloped margins; adipose eyelid formed; fins punctate. E. Juvenile, 152 mm SL, 190 mm TL. Axillary scales smooth. (*A-E, Gehringer, J. W., 1959a: figs. 12–16.*)

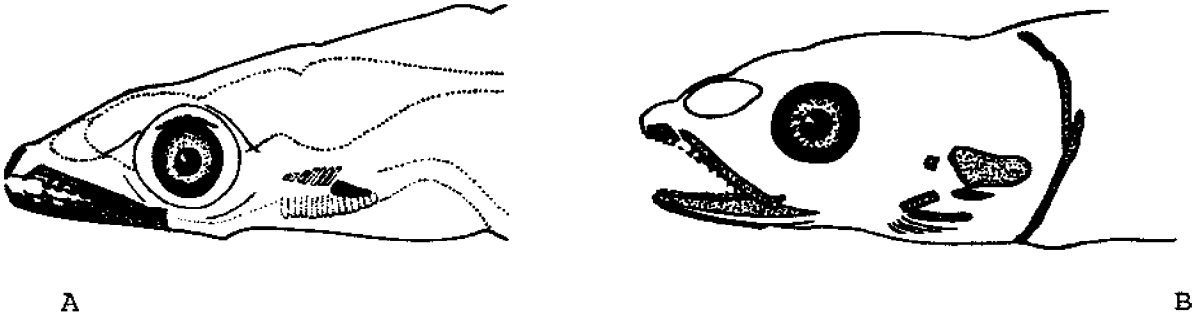

Fig. 20. *Elops saurus*, Ladyfish. A. Head of Stage I larva, leptocephalus, 43.3 mm SL. Pigmentation evident over eye; ossification appears as stippled areas. B. Head of Stage II larva, 26.6 mm SL, showing ossification as stippled areas. (*A-B, Gehringer, J. W., 1959a: figs. 18–19.*)

first evident in dorsal portion of fin at ca. 30 mm in some specimens,[7] possibly at 21.8 mm SL in others;[15] pelvic buds opposite 36th myomere at 34.0 mm SL.[7] Incipient rays first evident at 21.8 mm SL.[15] Gut loosely attached to abdomen;[1] gas bladder extended to and flattened against vertebral column at ca. 30 mm.[7]

Pigmentation: Melanophores increased in number and size; gas bladder densely pigmented.[7]

STAGE III, LEPTOCEPHALUS

Specimens described 24.7 and 25.9 mm SL, size range of stage from ca. 18–30 mm SL.[7]

Gill rakers first evident at 20–25 mm; at 25 mm, 3 palatine teeth in a row on each side of mouth; teeth on vomer, and in bands on ventral surfaces of maxillae. Finfold partially retained to ca. 25–30 mm. Gas bladder elongate and occupying a considerable portion of body cavity at ca. 26 mm. Kidney between myomeres 48 and 54 at ca. 25 mm.[7]

Pigmentation: Silvery color may develop on body at ca. 20 mm[8] while leptocephalid pigmentation may be retained in specimens up to ca. 32 mm.[7]

JUVENILES

Minimum size ca. 35 mm SL.

Branchiostegals ca. 30 at ca. 35 mm, usually with more on left side than right; gill rakers on first arch 5–7 + 12–15 in specimens exceeding 30 mm; teeth present on tongue at ca. 35 mm; pterygoid teeth developed in juveniles of unspecified size. At ca. 50 mm, adipose eyelid evident at anterior and posterior margin of eye; lateral line[7] scales on body,[8] and axillary scales developed.[7] Scalation, including sheaths of scales at dorsal and anal bases, complete at ca. 60–65 mm.[1,7] Gas bladder long and thin at ca. 35 mm.[7]

Pigmentation: By ca. 35 mm, pattern on dorsal surface of head and body more dense; pigment extended on dorsal and caudal fins and developed on anal. At 50–60 mm, dorsum dense greenish black, grading to silvery below; dorsal and caudal fins with uniform pepper spots; pectorals, pelvics, and anal with few scattered spots.[7]

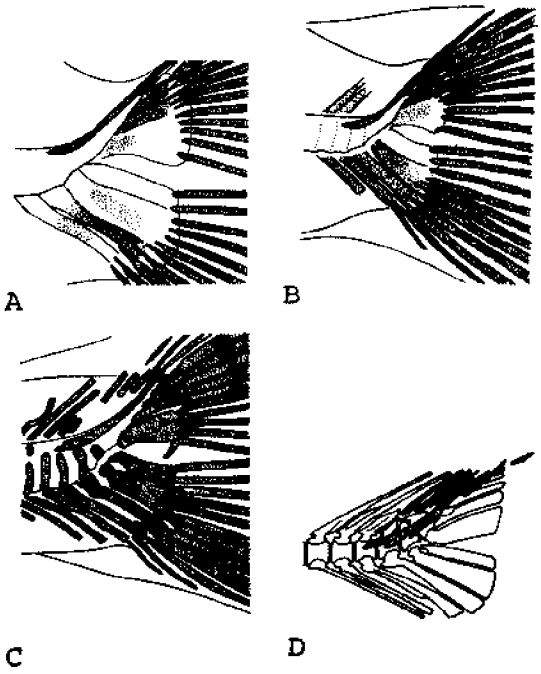

Fig. 21. *Elops saurus*, Ladyfish. A. Caudal osteology of Stage I larva, leptocephalus, 31.3 mm SL. B. Caudal osteology of Stage II larva, 30.9 mm SL. C. Caudal osteology of Stage III larva, 25.9 mm SL. D. Caudal osteology of 258 mm specimen. (*A-D, Gehringer, J. W., 1959a: figs. 21–24.*)

AGE AND SIZE AT MATURITY

No information.

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Megalops atlantica Valenciennes, Tarpon

ADULTS

D. 13–16;[26] A. 22–25;[1] C. 7+10+9+6–7;[27] P. 13–14; vertebrae 53–57,[1] precaudal 33–34, caudal 22;[27] gill rakers 19[1]–22[2]+36–40; lateral line scales 41–48 (counts based in part on juvenile specimens).[1]

Proportions expressed as percent SL (based in part on juveniles): Body depth 23.5–29.0; head length 25.0–31.0; snout length 4.5–6.2; eye diameter 5.3–9.5.[1]

Body moderately deep, rather strongly compressed; mouth large, oblique; maxillary extended far beyond eye in large individuals; elongate gular plate between rami of lower jaw; mandible projecting prominently. Scales very large, firm, with crenulate membranous border. Lateral line complete, decurved anteriorly.[1] Last dorsal ray elongate.[26]

Pigmentation: Silvery, darker above.[3]

Maximum length: 2489 mm.[3]

DISTRIBUTION AND ECOLOGY

Range: Nova Scotia to Brazil;[2] also to Pacific terminus of Panama Canal;[13,14] Bermuda; in the eastern Atlantic from French West Africa to the Belgian Congo.[2]

Area distribution: Chesapeake Bay,[4] north to Anne Arundel County, Maryland (FJS); New Jersey;[5] Virginia.[6]

Habitat and movements: Adults—primarily coastal waters, seldom more than few miles from land; also estuaries and freshwater lakes and streams; some individuals northward along coast of United States during summer.[1]

Stage I larvae (leptocephali)—warm, offshore epipelagic waters of North Atlantic,[2] as far out as 240 km;[7] also recorded from inshore waters.[23,25]

Stage II larvae (shrinking)—inshore waters[16,23] collected as far north as Cape Fear River, North Carolina.[20]

Stage III larvae—euryhaline; along beaches in lagoons, rivers, canals,[2] potholes, and ponds;[8] rarely as far north as North Carolina.[12]

Juveniles—at smaller sizes, in shallow pools,[19] ponds and mosquito drainage ditches partially or completely cut off from access to ocean for most of year; also in ditches at headwaters of small creeks;[21] typically in dark-colored brackish waters,[2] still or flowing,[10] over bottom which is usually soft dark mud and peat, sometimes containing H_2S.[21] Specimens 305–487 mm common in headwaters of brackish and freshwater streams.[1] As size increases, movement to ocean occurs. Salinity, 0–47 ppt. Temperature, maximum encountered 40 C;[21] minimum ca. 12–16 C, possibly lower.[19]

SPAWNING

Location: Unknown, apparently restricted to offshore waters—possibly Florida Straits,[23] Gulf Stream and Caribbean Sea;[18] or areas where currents can carry eggs offshore;[21] possibly in shallow water between coastal islands[9] or close to shore in salty or brackish water.[1] Some populations may complete life cycle in freshwater; e.g., Lake Nicaragua in Central America,[1] and Deep Lake, Florida.[10]

Season: Estimated from May[9] to August in Florida;[23] possibly throughout year with peak from September to November in Colombia.[24]

Fecundity: Ca. 12,202,000 in a specimen 2032 mm long.[15]

EGGS

No information. Eggs attributed to this species by Breder[9] were erroneously identified.[17]

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information. Yolk-sac larvae attributed to this species by Breder[9] were erroneously identified.[17]

LARVAE

Early stages attributed to this species by Breder[9] were erroneously identified.[17]

Larval development is divided into 3 stages modified from Wade:[2] Stage I, a period of initial length increase ending with a fully formed leptocephalus; Stage II, a period of marked shrinkage during which the larva loses its leptocephalous form; Stage III, a second period of length increase which terminates with the onset of the juvenile stage.

STAGE I, LEPTOCEPHALUS

Sizes described 9.4[17]–27.9 mm SL.[24]

D. 12–13; A. 20–22;[17,23,25] C. 17 at 11.7 mm, 19 at 17.5 mm and older.[2] Total myomeres 54[23]–57;[17] predorsal myomeres ca. 37[2]–42;[23] preanal myomeres 40[18]–43;[25] myomeres at air bladder 21–25; prepelvic myomeres 22–

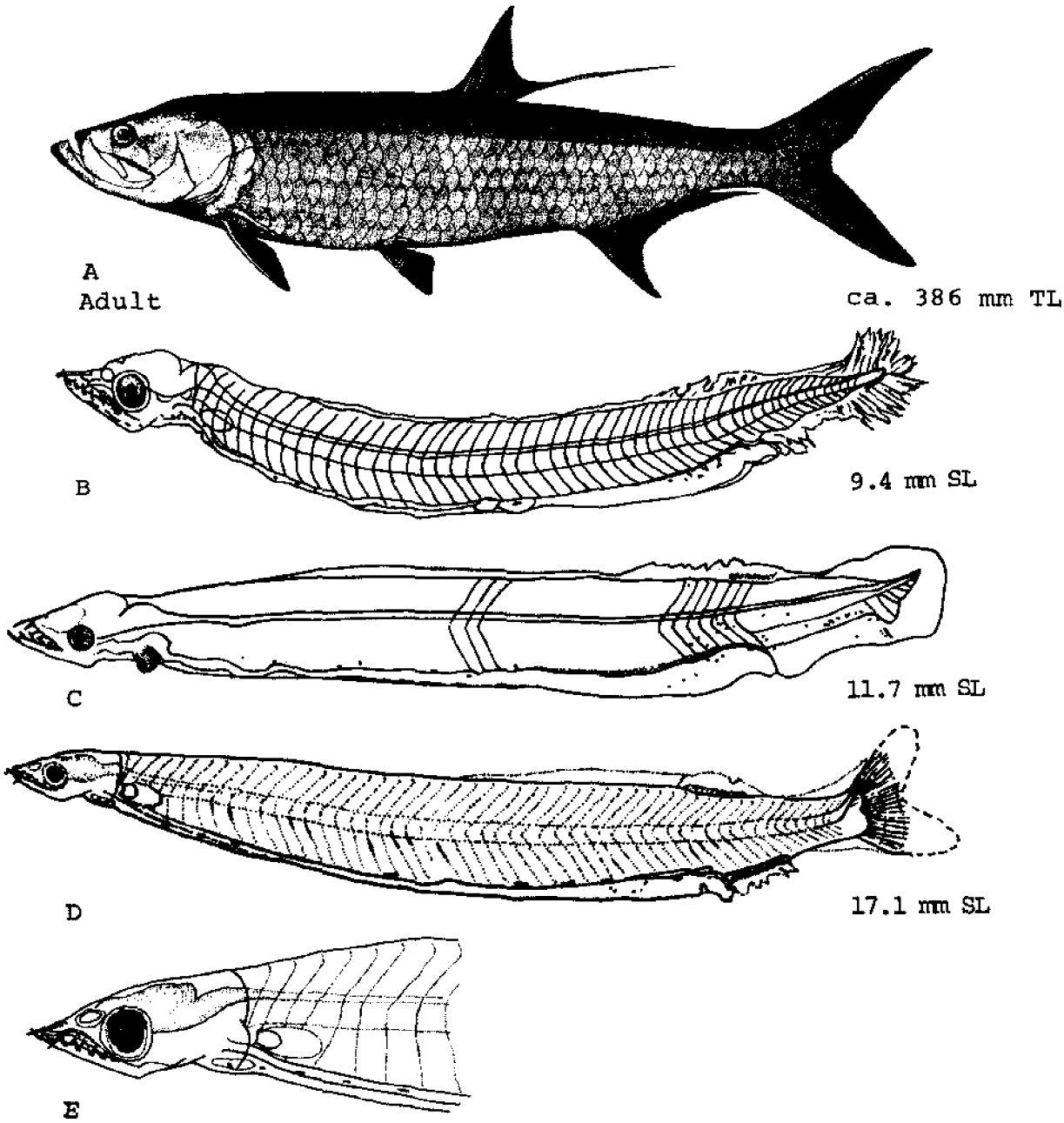

Fig. 22. *Megalops atlantica*, Tarpon. A. Adult, ca. 386 mm TL. B. Stage I larva, leptocephalus, 9.4 mm SL, 40+14=54 myomeres. C. Stage I larva, leptocephalus, 11.7 mm SL. Kidney shown as shaded area above posterior gut; incipient rays in dorsal. D. Stage I larva, leptocephalus, 17.1 mm SL. Slight loop or indentation in ventral surface of intestine just in advance of anus. E. Lateral view of head, Stage I larva, 17.1 mm SL. Pigmentation pattern evident above eye. (*A, Goode, G. B., et al., 1884: pl. 217B. B, Eldred, B., 1972: fig. 1 redrawn by Marthe Anne Cole. C, Wade, R. A., 1962: fig. 2a. D, E, Eldred, B., 1967: figs. 1A, B.*)

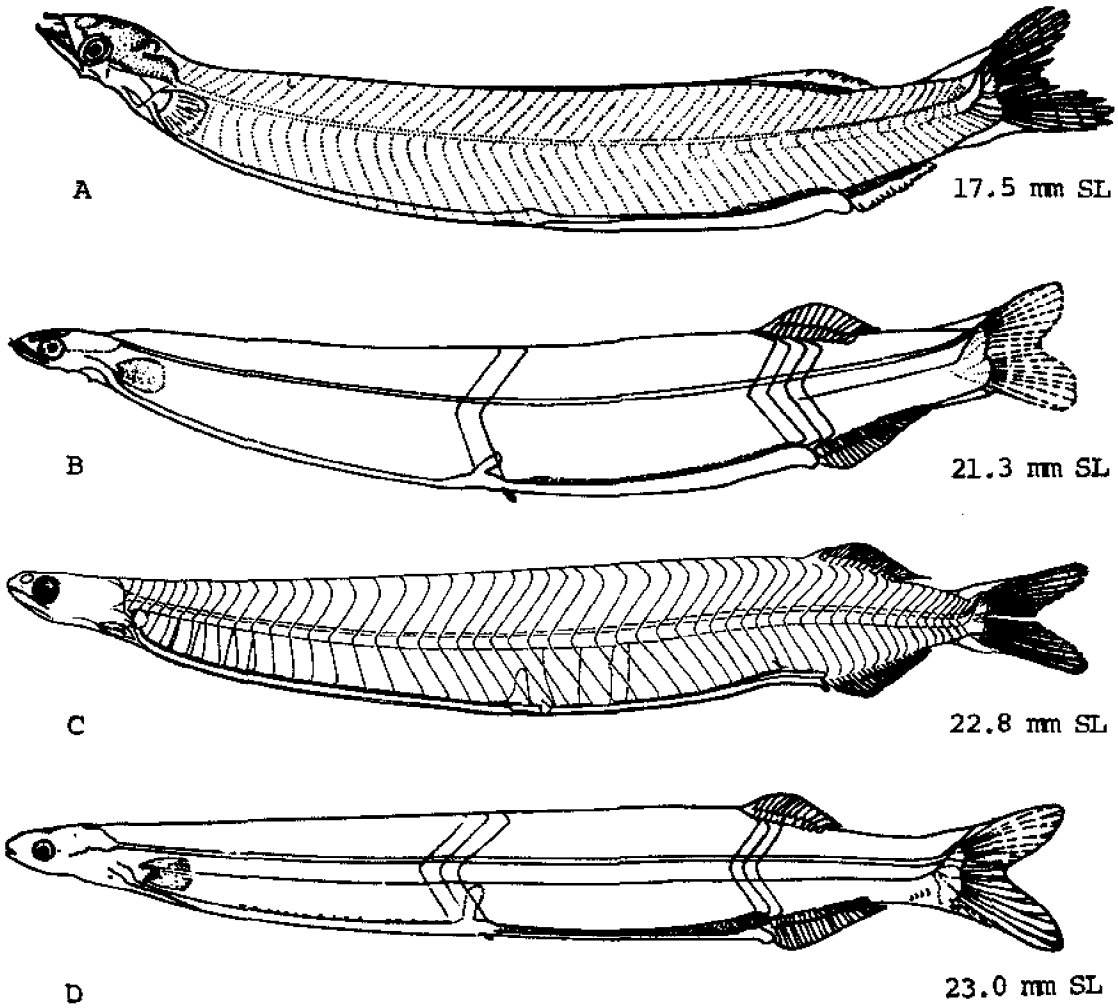

Fig. 23. *Megalops atlantica*, Tarpon. A. Stage I larva, leptocephalus, 17.5 mm SL, total myomeres 57, 12 dorsal and 21 anal ray bases. Gas bladder at 23rd myomere. B. Stage I larva, leptocephalus, 21.3 mm SL. Dorsal rays 12; anal rays 20; pelvic buds at 23rd myomere; kidney extends anteriorly to 24th myomere; gas bladder a cylindrical sac extending dorsally. C. Stage I larva, leptocephalus, 22.8 mm SL. First collection from coastal West Africa. Dorsal rays 12, anal rays 20, pelvic fin at 25th myomere, dorsal origin at 40th myomere, anal origin at 42nd myomere. D. Stage I larva, leptocephalus, 23.0 mm SL. Head shape changing, body thick. Pelvic fin at 24th myomere, kidney extends from myomeres 35 to 45. (*A, Gehringer, J. W., 1959b: fig. 1. B, D, Wade, R. A., 1962: figs. 2c, d. C, Richards, W. J., 1969: fig. 2.*)

24 (at 22.0–27.9 mm).[2,23,24,25] Teeth, upper 1+7 to 0+3, lower 1+6 to 1+3 (at 9.4–22.0 mm).[17,23] Hypural plates 7 at 17.5 mm.[2]

Proportions expressed as percent SL: At 9.4–22.0 mm body depth at pectorals 5.1[23]–8.5;[17] snout length 2.9–4.9;[23] eye diameter (horizontal) 2.0–3.2.[17] At 9.4–27.9 mm head length 8.2[25]–14.5;[2] preanal length 77.6–88.0.[23] At 13.4–27.9 mm predorsal length 73.0[2]–82.1.[23] At 21.3–27.9 mm preventral length 49.2[25]–55.9.[2] Proportions as percent HL: At 11.0–21.3 mm snout length 24.4–31.3; eye diameter 17.7–23.5.[2]

Body initially ribbon-like, elongate, thin and deep; by 17.5 mm depth reduced in pectoral region; at 23.0 mm body laterally compressed, but thicker along its entire length and no longer ribbon-like;[2] at 24.0–27.9 mm greatest depth at pelvic fins, depth at caudal peduncle and area of pectoral fins decreased.[25] Head triangular in dorsal aspect and wider than body, at least to 17.5 mm; at 23.0 mm "bullet shaped" rather than "eel-like," slightly broader than body in dorsal aspect but not triangular, width nearly uniform except for slight bulge at eyes; snout rounded.[2] At 27.9 mm snout more pointed, cartilaginous structures evident in posterior operculum.[25]

Nostrils first visible as shallow depressions at 17.5 mm, apparently not bifurcate. Mouth initially large, oblique, lower jaw protruding at 11.7 mm, jaws equal at 17.5 mm; at 23.0 mm mouth smaller, gape much shorter. First tooth in upper jaw fang-like followed by needle-like teeth of uniform diameter in single row extending to angle of gape; teeth in lower jaw thicker with anterior pair apparently not set in jaw; teeth absent at 23.0 mm, cartilage developing in maxillary and mandible. Eye nearly round at 11.7 mm, oval at 17.7 mm. Gill filaments fairly well formed at 23.0 mm; gill rakers lacking. Origin of dorsal finfold ca. 2/3 body length behind head; caudal finfold truncate, its margin invaginated dorsally and ventrally anterior to urostyle at 11.7 mm. Finfold reduced to small remnants anterior to caudal fin at 21.3 mm. At 11.7 mm, 8 probable ray bases in dorsal finfold opposite myomeres 41–45,[2] at 13.4–14.0 mm 8 incipient dorsal ray buds,[17,18] rays first evident at 20.3 mm;[23] at 23.0 mm 12th dorsal ray split, its posterior half slightly elongate;[2] at 24.0 mm dorsal origin at myomere 42.[24] At 11.7 mm opaque area evident in postanal region of median finfold, which may indicate developing anal fin;[2] at 13.4–14.0 mm, 14–15 incipient anal ray buds,[17,18] rays first evident at 20.3 mm;[23] at 27.9 mm anal origin under myomere 44.[25] Caudal fin forked and with unbranched rays at 17.5 mm; rays beginning to branch at 23.0 mm. Pectoral a rounded bud at 11.7 mm, slightly larger at 21.3 mm, fleshy base enlarged and fins more rigid at 23.0 mm. Pelvic fin buds present at 20.0 mm, at 24th myomere at 23.0 mm. Vertebrae developing and visible at 11.7 mm. Urostyle prominent, tipped up slightly at 11.7 mm, more sharply at 17.5 mm. Gut tubular,[2] extending more than 3/4 length of body at 11.7 mm; terminating at anus opposite myomere 44–47;[2,25] at 17.1 mm slight loop or indentation in ventral surface just in advance of vent.[23] At 24.0 mm heart located posteroventrally to pectoral fin, "figure 8" in shape, not functional.[25] Gas bladder evident at 11.7 mm at myomeres 22–23, gradually expanding and

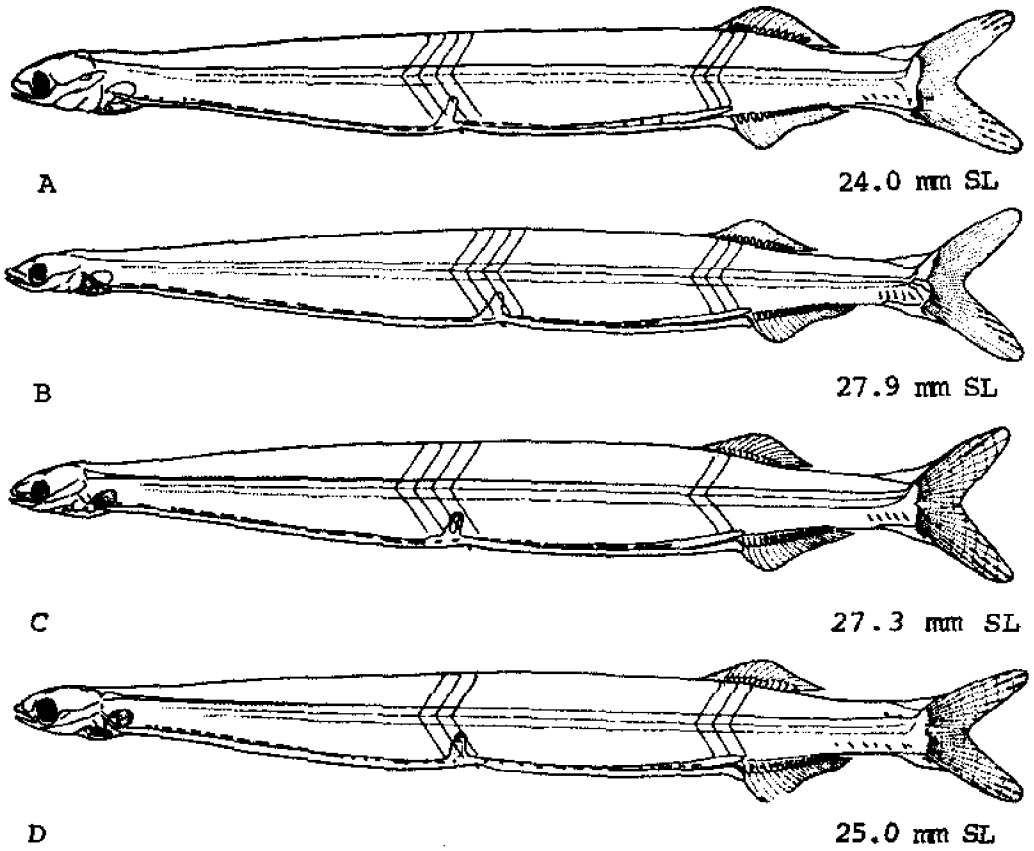

Fig. 24. *Megalops atlantica*, Tarpon. A. Stage I larva, leptocephalus, 24.0 mm SL. Dorsal origin over 42nd myomere, anal origin under 44th myomere, pelvic origin under 23rd myomere. B. Stage I larva, leptocephalus, 27.9 mm SL. Dorsal origin over 42nd myomere, anal origin under 44th myomere. C. Stage II larva, 27.3 mm SL. Dorsal origin over 41st myomere, anal origin under 42nd myomere, air bladder from myomere 23 to 24. D. Stage II larva 25.0 mm SL. Dorsal origin over 40th myomere, anal origin under 41st myomere. (A-D, Mercado S., J. E., and A. Ciardelli, 1972: figs. 4, 5.)

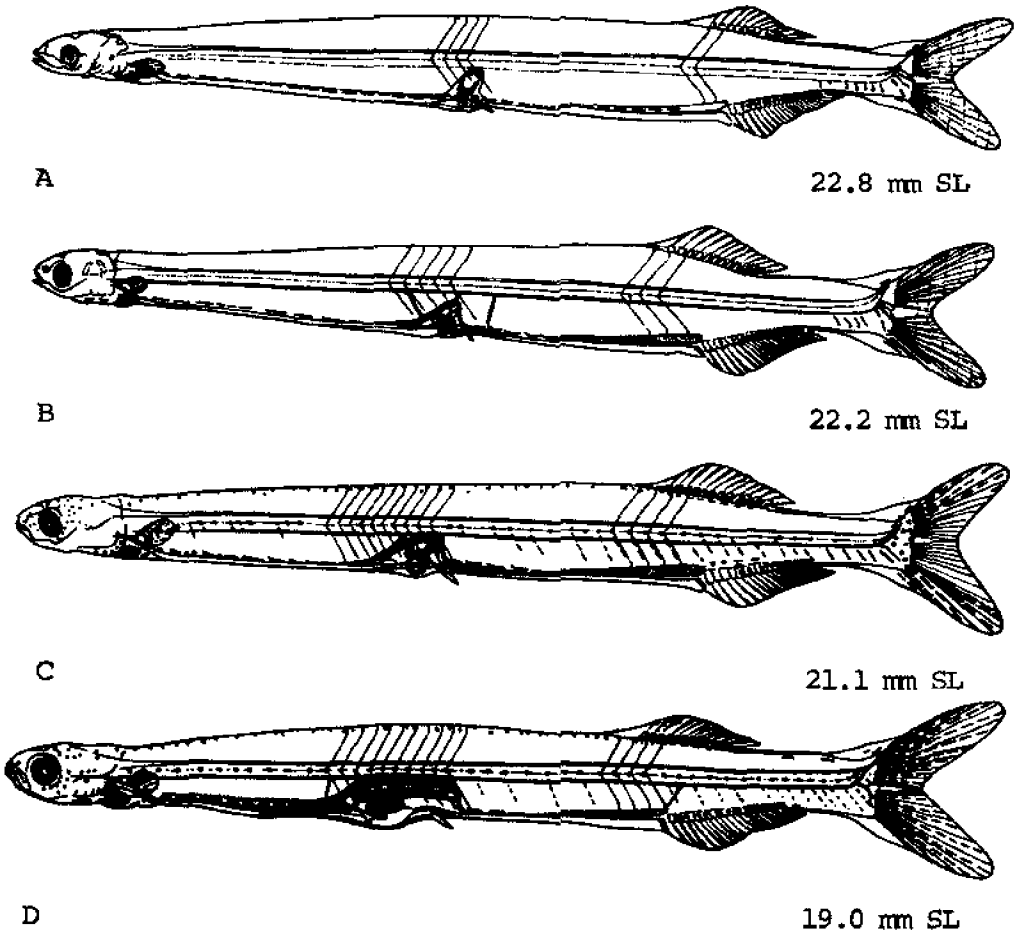

Fig. 25. *Megalops atlantica*, Tarpon. A. Stage II larva, 22.8 mm SL. Dorsal origin over 39th myomere, anal origin under 41st myomere. B. Stage II larva, 22.2 mm SL. Dorsal origin over 39th myomere, anal origin under 41st myomere. C. Stage II larva, 21.1 mm SL. Dorsal origin over 39th myomere, anal origin under 42nd myomere. D. Stage II larva, 19.0 mm SL. Dorsal origin over 38th myomere, anal origin under 41st myomere. (*A-D, Mercado S., J. E., and A. Ciardelli, 1972: figs. 6–8A.*)

by 21.3 mm appears as short cylindrical sac arising from digestive tract at myomeres 23–24, extends dorsocaudally about 1/3 distance to central nerve cord; by 23.0 mm extending about 2/3 distance to central nerve cord, base extending from myomeres 23 to 25. Kidney dorsad to gut between myomeres 35 and 41 at 17.5 mm;[2] at 23.0–27.9 enlarged, extending from myomeres 35 to 45, separated from posterior end of digestive tract.[2,25]

Pigmentation: At 11.7 mm, a few scattered melanophores on posterior part of gut dorsally to central nerve cord; also 3 chromatophores on ventral surface of opercle, 6 on dorsal border of gut anterior to gas bladder, and 1 on air bladder.[2] From ca. 13.4 mm to end of stage densely packed dark brown chromatophores appear as fringed patch curving over eyeball (when examined dorsally), small patches of chromatophores sometimes evident on fleshy margin below eye. At 17.1 mm series of elongate chromatophores along dorsal edge of intestine, a few small chromatophores scattered over posterior intestine with series concentrated above anus, scattered series of elongate chromatophores on myosepta below midline, a few chromatophores on caudal fin, one below pectoral fin.[23] At 22.8 mm ca. 5 lines of pigment below lateral line on caudal peduncle.[16] At 24.0 mm, one stellate chromatophore on lower head anterior to heart, one on heart and 3–4 behind heart, behind this a row of elongate chromatophores extends along dorsal surface of gut to separation of kidney and intestine, followed by ca. four chromatophores over kidney. Series of melanophores at base of anal fin rays; below lateral line on caudal peduncle four lines of melanin in dorsoventral alignment. At 27.9 mm dorsoventral lines on at least 5 myomeres of caudal peduncle J-shaped.[25]

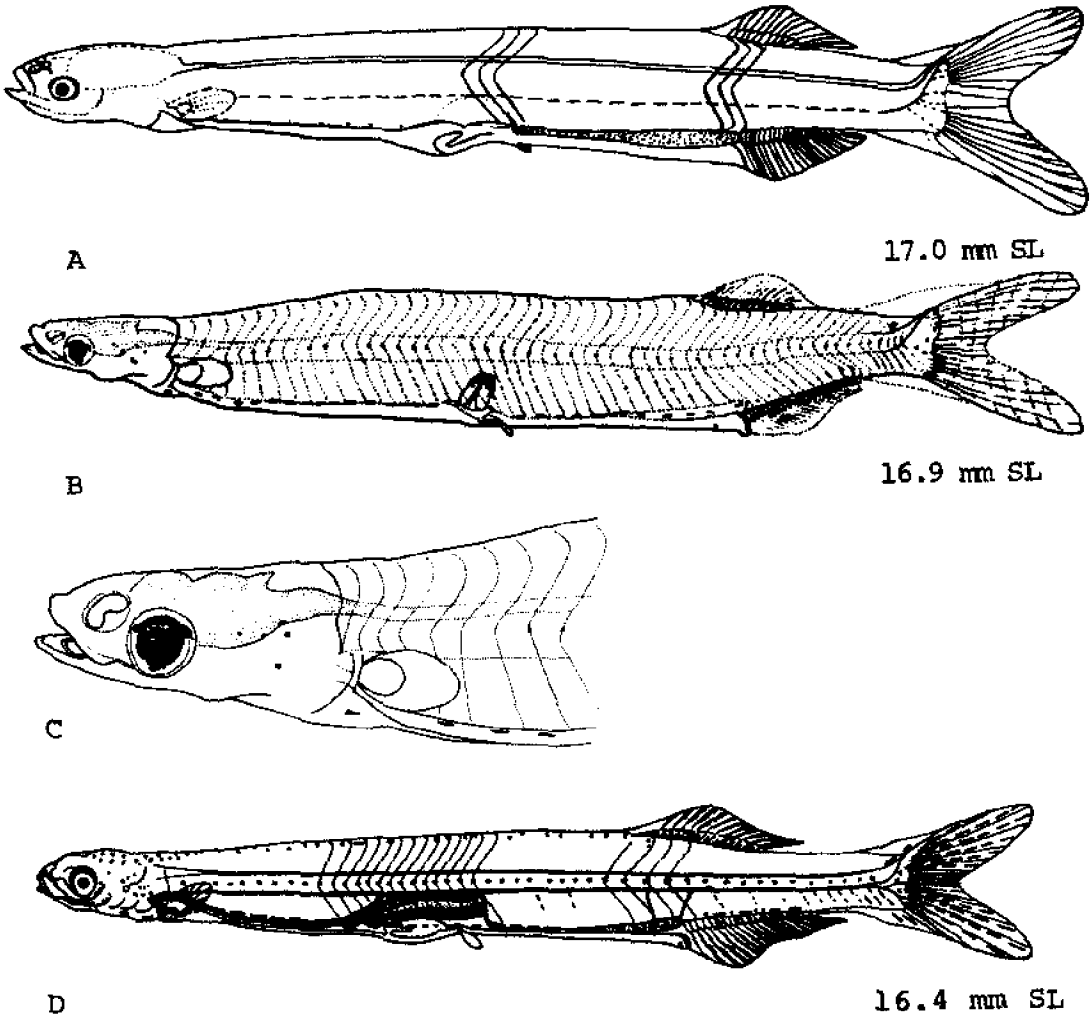

Fig. 26. *Megalops atlantica*, Tarpon. A. Stage II larva, 17.0 mm SL. Dorsal and anal have moved anteriorly; area of gular plate swelling. B. Stage II larva, 16.9 mm SL. C. Lateral view of head, stage II larva, 16.9 mm SL showing eye pigmentation. D. Stage II larva, 16.4 mm SL. Dorsal origin over 37th myomere. (*A, Wade, R. A., 1962: fig. 3a. B, C, Eldred, B., 1967b: figs. 1c, d. D, Mercado S., J. E., and A. Ciardelli, 1972: fig. 8B.*)

STAGE II, LEPTOCEPHALUS

Sizes described 27.3–13.0 mm SL.[25]

D. 12[23]–13;[22] A. 20–22. Total myomeres 55–57;[23] predorsal myomeres 42[23]–36;[25] preanal myomeres 43[23]–38;[25] prepelvic myomeres 24–21; myomeres at coelom 14–24.[25] Hypurals ca. 6 at 17.0 mm.[2]

Proportions expressed as percent SL: At 23.7–16.9 mm body depth at pectoral 6.8–9.5; snout length 3.8–4.7; eye diameter (horizontal) 1.7–2.5.[23] At 27.3–13.0 mm head length 9.2–26.9; prepelvic length 53.0[23]–48.4;[25] preanal length 83.7[23]–71.5;[25] predorsal length 79.3[23]–69.2.[25]

From 27.3 mm to 25.0 mm body depth decreases;[25] at 17.0 mm depth at pectorals increased considerably eliminating bottleneck-like appearance.[2] At 27.3 mm, dorsal concavity of snout almost completely lacking, cranial bones visible; at 20 mm mouth more dorsal in position, jaws longer,[35] by 17 mm lower jaw slightly longer than upper.[2] At 17 mm head increased greatly in relative size; a slight swelling visible between developing mandibles *in region of future gular plate.*[2] At 15 mm nostrils well formed, gular plate forming. Eyes more rounded at 25.0 mm, rounded by 15–13 mm.[25] At 15 mm teeth present; by 15–13 mm, upper and lower jaws well formed. At 17.0 mm, dorsal and anal fins increased in height and length; caudal fin with some branched rays; pectorals larger, more pointed, their fleshy bases reduced;[2] at 15

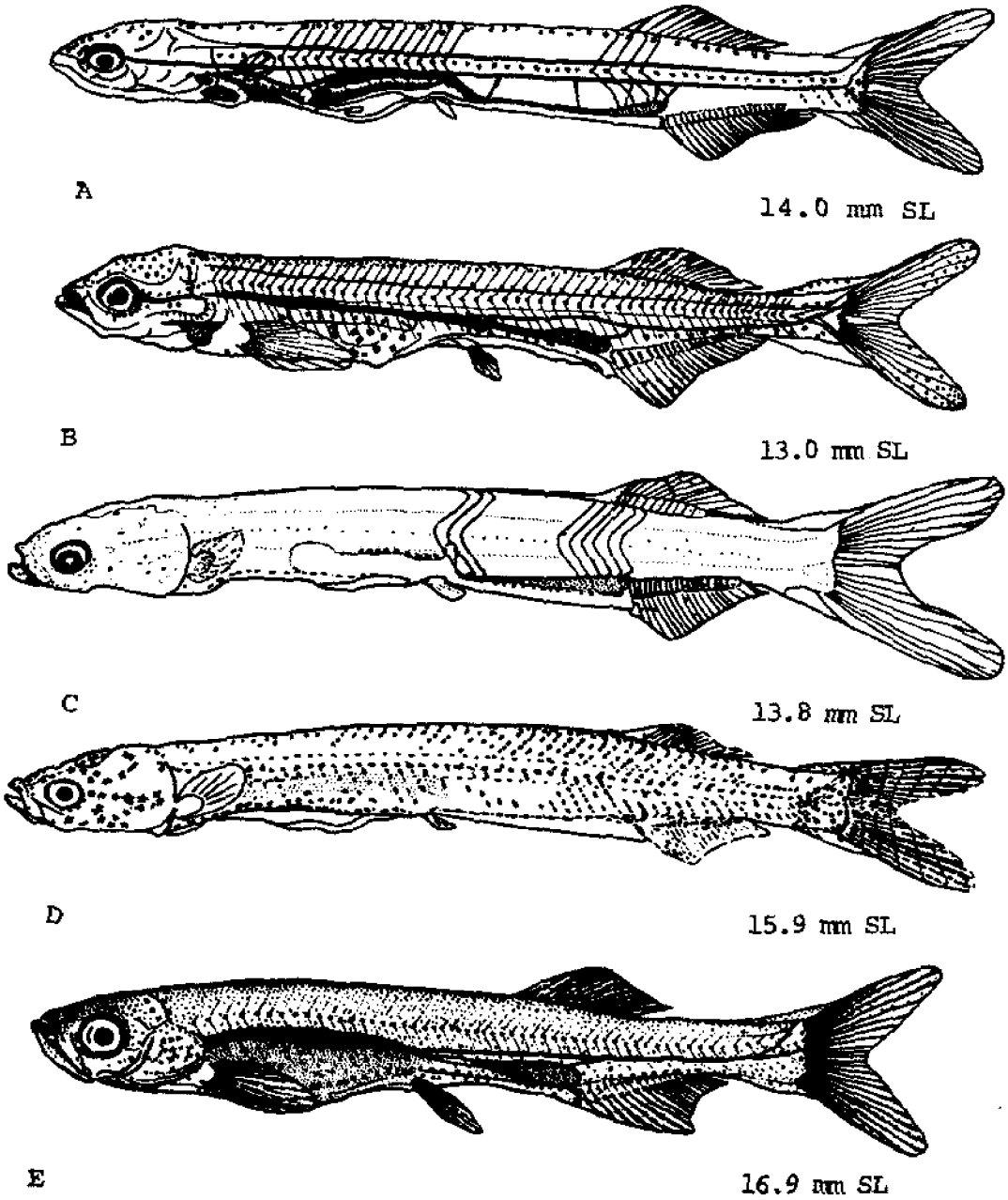

Fig. 27. *Megalops atlantica*, Tarpon. A. Stage II larva, 14.0 mm SL. Dorsal origin over 37th myomere, anal origin under 39th myomere. B. Stage II larva, 13.0 mm SL. Coelomic cavity extends from just behind head to anus. C. Stage III larva, 13.8 mm SL. Dorsal and anal continue to move anteriorly; gas bladder extends forward to 12th myomere. D. Stage III larva, 15.9 mm SL. Pigmentation increased over body, particularly between myomeres; dark band over gas bladder. E. Stage III larva, 16.9 mm SL. (*A, B, E, Mercado S., J. E., and A. Ciardelli, 1972: figs. 9, 10A. C, Wade, R. A., 1962: fig. 3b. D, Harrington, R. W., 1958: fig. 5.*)

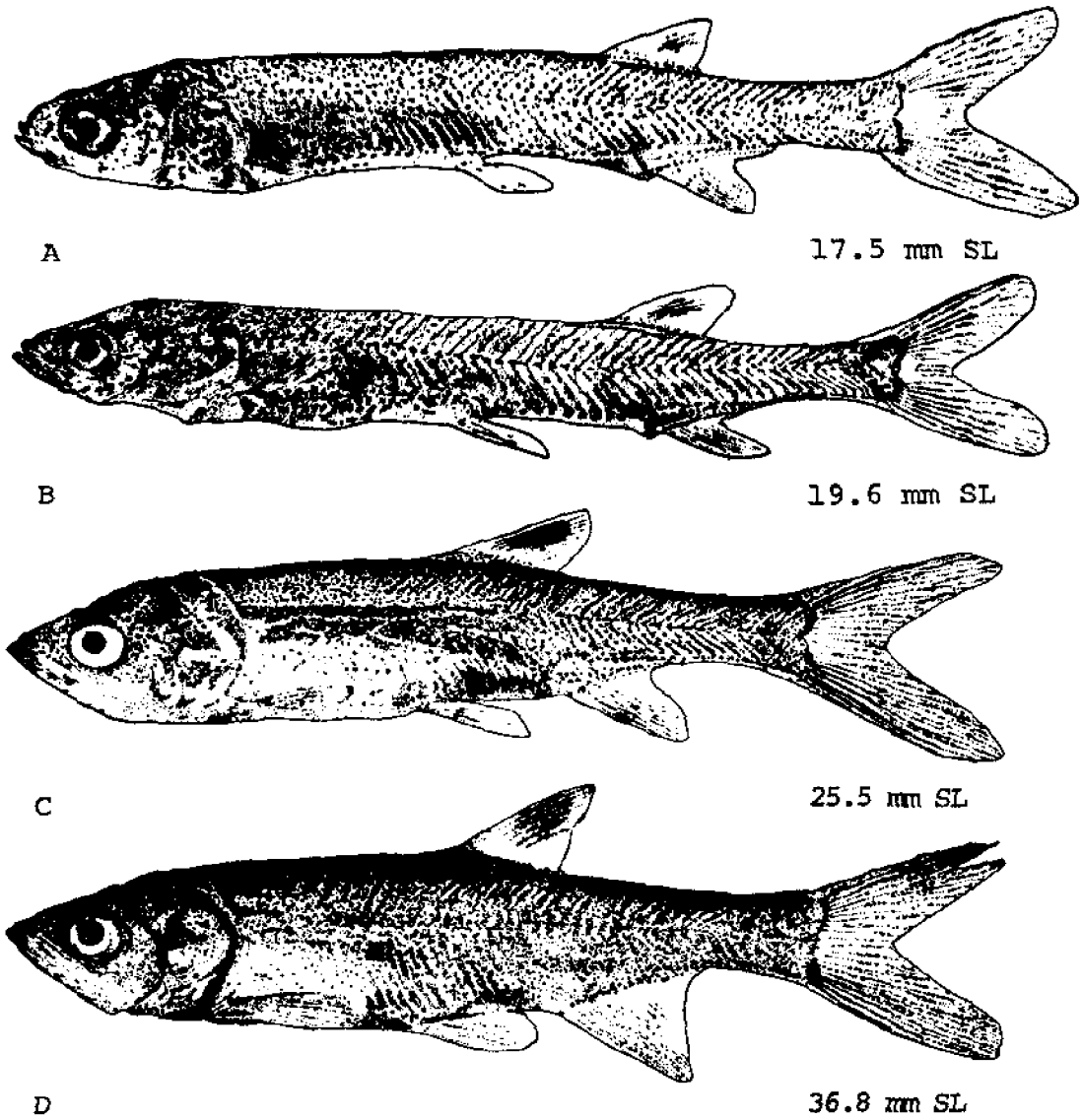

Fig. 28. *Megalops atlantica*, Tarpon. A. Stage III larva, 21.0 mm TL, 17.5 mm SL. Pigmentation concentrated between myomeres; pigmented dorsal surface of gas bladder visible through body wall. B. Stage III larva, 23.0 mm TL, 19.6 mm SL. Spots developing on dorsal and anal. C. Juvenile, 31.5 mm TL, 25.5 mm SL. Spot on dorsal fin distinct; body pigmentation more profuse. D. Juvenile, 41.0 mm TL, 36.8 mm SL. Scales forming along lateral line. *(A-D, Harrington, R. W., 1958: pls. I, II delineated by Marthe Anne Cole.)*

mm caudal lobes symmetrical. At 15.0 mm scales lacking, gut completely formed.[25] At 16.9 mm slight loop or indentation in ventral surface of gut just in advance of vent.[25] At 27.3 mm heart clearly visible, by 20 mm circulatory system functional. Ovoid gas bladder evident at 27.3 mm over myomeres 23–24, at 21.1 mm extending from myomeres 24–27; at 17.0 mm, more inflated and extending forward to myomeres 20 [25]–21.[2]

Pigmentation: At 27.3 mm, similar to 27.9 mm specimen (Stage I), with two melanophores evident over dorsal portion of swim bladder. At 25 mm dorsal portion of caudal peduncle with two stellate chromatophores, ventral portion with dorsoventral lines which in some specimens have lost "J" shape; increase of pigment on head and extremes of upper and lower caudal lobes; pigment evident over hypurals, on pectoral fins, central nerve cord and ca. 3/4 of kidney; pigment over air bladder unites forming one spot.[25] At 23.7–16.9 a series of elongate chromatophores along dorsal edge of intestine; series of small chromatophores on intestine above anus; series

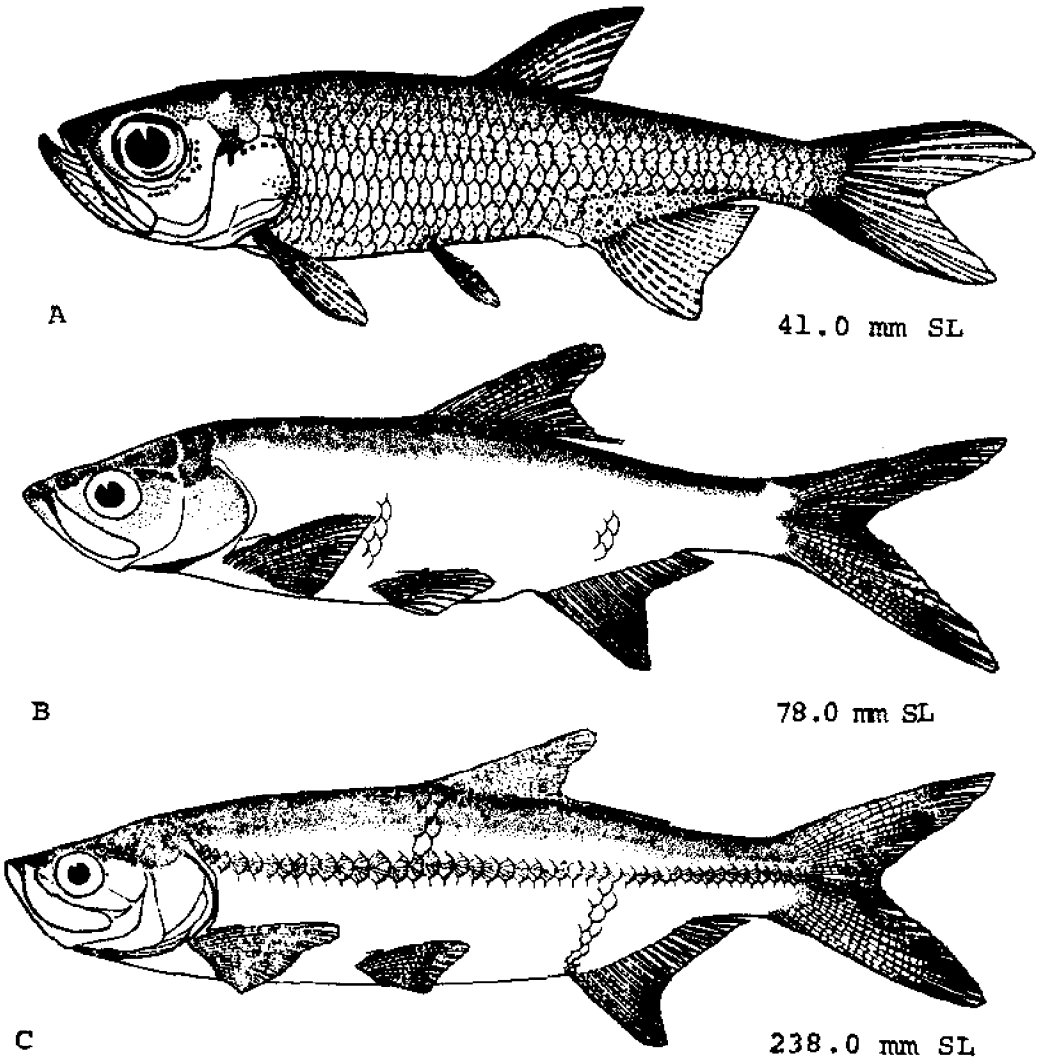

Fig. 29. *Megalops atlantica*, Tarpon. A. Juvenile, 41.0 mm SL. B. Juvenile, 78.0 mm SL. Last dorsal ray elongating; scalation including axillaries, complete. C. Juvenile, 238.0 mm SL. Last dorsal ray filamentous; pattern on individual scales formed. (*A, Mercado S., J. E., and A. Ciardelli, 1972: fig. 10b. B, C, Hollister, G., 1939: figs. 10, 11.*)

on myosepta at midline; a few small chromatophores on myosepta above kidney and anal fin, small chromatophores on dorsal surface of air bladder, a few chromatophores on anal, dorsal and caudal fins, one below pectoral fin. Pigment evident above and on eyeball, and on fleshy margin below. One specimen with four subsurface and one surface chromatophores on or below lower part of brain.[23] At 15 mm body more opaque, dorsal and lateral parts silvery; pigment concentrated along top of head extending along body dorsum, coelomic cavity densely pigmented. At 13 mm eye black.[25]

STAGE III, LEPTOCEPHALUS

Size described 12.6 to ca. 25 mm SL.

D. 12[2]–17;[8] A. 19[2]–25[9] (including rays which consolidate as growth continues[8,9]). Predorsal myomeres 37–39; preanal myomeres 38–41. Upper teeth 0–6, lower teeth 0–8. Gill rakers 1+7 at 13.1 mm, 2+13 at 13.8 mm, 5+14 at 15.9 mm, 8+21 at 20.2 mm. Branchiostegal rays 7–15 at 13.1–15.9 mm.[2]

Proportions as percent SL at sizes less than 17.1 mm:

Body depth at pectoral 9.9–17.0; head length 20.7–28.6; prepelvic length 48.2–54.0; predorsal length 61.8–76.0; preanal length 70.2–78.6.[2] Proportions as percent HL: Eye diameter 21.4–29.3; snout length 17.3–26.2.[2]

Body depth at pectorals increased in relation to SL at 13.8 mm, but decreased just behind this region. Head somewhat irregular in outline at 15.9 mm; mandible oblique, extending to point in vertical alignment with pupil; posterior end of mandible distinctly flared. Teeth on lower jaw throughout stage, developing on upper jaw from 13.9–14.1 mm. Eye compressed dorsoventrally at 12.6 mm; nares bifurcating. At 13.8 mm, gas bladder enlarged anteriorly extending to myomere 12 and having a dorsal finger-like projection from posterior region to midlateral line.[2] Dorsal fin origin at 37th myomere, anal origin at 39th myomere; depth of anal greater than dorsal; last anal ray split; fleshy base of pectoral reduced; pelvics with incipient rays.[2]

Pigmentation: At 13.8 mm, chromatophores on head and body concentrated on snout, opercle, over brain, and in area below midline. Pigment also on dorsal fin ray bases and anterior dorsal and posterior anal rays, on dorsal surface of gas bladder and gut, and in region separating gut and kidney. At 15.9 mm, chromatophores outline myomeres and are developed on body above midline.[2]

JUVENILES

Minimum size described 25.2 mm SL.[2]

D. 14–18; A. 24–28 in specimens up to 59.9 mm, with anal and dorsal counts lowered by consolidation of rudimentary rays as growth continues.[8] Gill rakers 9+24 at 25.2 mm, 16+34 at 35.0 mm, 17+34–22+40 at 51–271 mm. Branchiostegals 22–25 at 51–271 mm.[2]

At 25.2 mm, body torpedo-like; at 51.0 mm, body deepened. At 25.2 mm, mouth large; lower jaw projecting; maxillary broad, reaching posterior margin of eye. At 194.1 mm, maxillary extending beyond eye; snout obtusely conical; villiform teeth on jaws, tongue, vomer, palatines, pterygoids, and sphenoid.[2] Incipient scales first evident along lateral line at ca. 30–34 mm; 4 rows of scales, 1 above, 2 below the lateral line at 36.8 mm;[8] lateral line pores visible at 51.0 mm;[2] axial scales formed at least by 78 mm SL.[11] At 25.2 mm, 4th dorsal and 5th anal ray longest; anal falcate, its origin slightly posterior to dorsal insertion; pectorals broad, the central rays almost to origin of pelvics; pelvics about midway from snout to hypural plate.[2] By at least 140 mm two specialized ray scales cover uppermost and lowest caudal rays.[11] At 194.1 mm, filamentous ray of dorsal grooved on underside; anal with scaly sheath and last ray produced; caudal scaly.[2]

Pigmentation: At 25.2 mm, body opaque, internal organs no longer visible, pigment mostly above the lateral line; gular plate heavily pigmented; opercles silvery; pigment on tip of mandible, snout, and occiput.[2] Juveniles become darker dorsally with age.[8]

AGE AND SIZE AT MATURITY

End of 6th or 7th winter, ca. 1220 mm.[9]

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Albula vulpes

bonefishes
Albulidae

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FAMILY ALBULIDAE

This family is widely distributed in warm waters around the world. Adults are silver in color with slender bodies, rounded bellies, conical snouts and inferior mouths. These fishes differ from the Elopidae by lacking a gular plate and having a lower number of branchiostegal rays (12–14).

The family Albulidae includes two genera and three species (Böhlke and Chaplin, 1968). One species, *Albula vulpes*, occurs in the Mid-Atlantic Bight.

The spawning location of *A. vulpes* is unknown but is probably in offshore waters. Rass (1972) describes the eggs of what he considers to be this species as being about 1.3 × 1.4 mm in diameter with a single, large oil globule.

Larval development of *A. vulpes* is characterized by profound changes in body form associated with two periods of length increase separated by a period of length decrease. Terminology used to separate these stages, as well as general body form at each stage, is comparable to that of the Elopidae (see account for that family).

Total myomere counts will, at all sizes, separate Stage I leptocephali of *A. vulpes* from *E. saurus* and *M. atlantica*. Late Stage I leptocephali and all older larvae of these three species differ in dorsal and anal fin ray counts.

Albula vulpes (Linnaeus), Bonefish

ADULTS

D. 17 [20]–19; A. 8 [1]–10; [23] P. 15–17; [1] C. 8+10+9+6; [28] V. 9 [23]–10; [27] *lateral line scales 65* [1]–75,[20] *predorsal scales* 23, average scales above lateral line 9.5, below 7.5; [23] total vertebrae 69–74, preanal vertebrae 42–47,[3] precaudal vertebrae 42, caudal vertebrae 27; [28] gill rakers on first arch 7–8+9–10; [1] branchiostegal rays 12–14.[23]

Proportions expressed as percent SL: Body depth at origin of dorsal 14.0 [1]–24.5; [23] head length 27.5–32.0; eye diameter 4.5 [23]–8.0; snout length 8.5–13.6; length of maxillary 9.1–12.7.[1]

Body slender, dorsal profile more convex than ventral; [1] abdomen flattened.[23] Head flat above; snout conical; [1] mouth small, inferior; [23] gular plate much reduced, not visible externally; [15] maxillary not quite reaching eye.[1] Roundish teeth on tongue, roof and floor of mouth.[7] Scales large, silvery, adherent. Dorsal base nearer caudal than snout, pelvics beneath posterior portion of dorsal fin.[23]

Pigmentation: Silvery white [16] to bluish above with dark streaks between scale rows.[1]

Maximum length: Ca. 1054 mm.[17]

DISTRIBUTION AND ECOLOGY

Range: Virtually all warm seas; in the western Atlantic from Woods Hole, Massachusetts and possibly Bay of Fundy to Rio de Janeiro, Brazil; also the West Indies and Bermuda.[1]

Area distribution: Known from a single specimen off Seaford, Virginia in the Chesapeake Bay.[5]

Habitat and movements: Adults—in schools or singly over mud and sand flats,[10] usually in comparatively shallow water.[1]

"Leptocephali" (exact stage unknown)—sometimes in shallow tide pools [1] but mainly offshore where bottom depth may reach 4000 meters.[10]

Stage I larvae—usually in first 100 m of water with greatest concentration at 33 m.[10]

Stage II (shrinking)—in shallow bay areas and around piers,[10] dropping to sand bottom as metamorphosis begins.[6]

Juveniles—among islands in Panama; in shallow tide pools; [1] over bottoms of hard sand and shell at Great South Bay, New York.[14]

"Young" ca. 70 mm long and still transparent ca. 275 m offshore on bottom in water 7.3–10 m deep.[20]

SPAWNING

Location: Unknown, probably at sea.[10]

Season: In Florida, ripe and near ripe specimens of both sexes present throughout the year; [26] ripe individuals reported only from November through January in the West Indies.[14]

EGGS

Fertilized egg—diameter 1.3×1.4 mm; oil globule present [29] (identity questioned, PWJ).

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

Larval development is represented by profound changes in body form accompanied by two periods of length increase (Stages I and III) interspaced by a period of length decrease (Stage II), as with the tarpon and *ladyfish*.

STAGE I, LEPTOCEPHALUS

Size range described 7.8 mm SL [10] to ca. 87 mm.[2]

D. 3–12 at 38–40 mm, 10–16 at 47–49 mm, 16 at 50–52 mm and beyond; A. 4–7 at 44–52 mm, 7 at 53 mm and beyond; C. 10/9 at 29–31 mm, 11/11 at 32 mm and beyond. Total myomeres 65 [10]–73; [27] preanal myomeres 62–72; prepelvic myomeres 31 [10]–35; [27] predorsal myomeres 40 [10]–61.[27] At 58.0–59.0 mm SL myomeres from dorsal origin to pelvic origin 21.[24]

Proportions expressed as percent SL: Head length 6.0–10.1; [10] snout length 2.0–2.7; eye diameter 1.7–2.7; [24] predorsal length 79.9–85.0; prepectoral length 6.8–12.2; preanal length 96.7 [10]–98.2; dorsal origin to pelvic origin (at 58.0–59.0 mm) 27.6–29.0.[24]

Depth greatest at 30th myomere at 7.8 mm.[10] Head narrow, eel-like; snout small, conical.[10,12] At 7.8 mm, upper jaw with 2 protuberant incisors and 3 smaller teeth

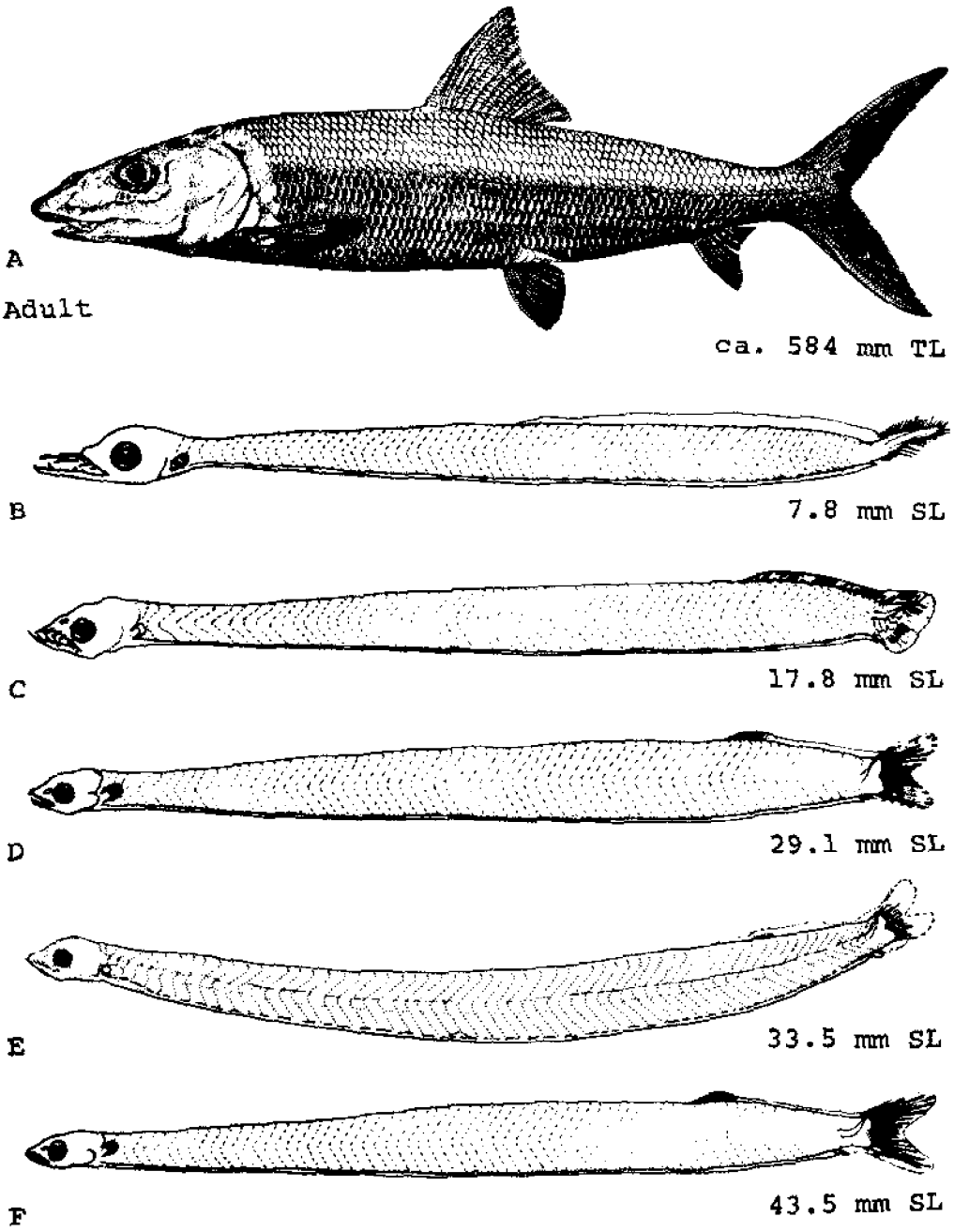

Fig. 30. *Albula vulpes*, Bonefish. A. Adult, ca. 584 mm TL. B. Stage I larva, leptocephalus, 7.8 mm SL. Anus at base of caudal. C. Stage I larva, leptocephalus, 17.8 mm SL. Myomeres 68; gas bladder forming at myomere 32 but not illustrated. D. Stage I larva, leptocephalus, 29.1 mm SL, dorsal 5, gas bladder forming at myomere 31. E. Stage I larva, leptocephalus, 33.5 mm SL. Predorsal myomeres 55, preanal myomeres 66. F. Stage I larva, leptocephalus, 43.5 mm SL. Gas bladder at myomere 30; pelvic buds at myomere 33; rays in all fins except pelvics. (*A, Goode, G. B., et al., 1884: pl. 218. B-D, F, Alexander, E. C., 1961: fig. 2. E, Eldred, B., 1967a: fig. 1.*)

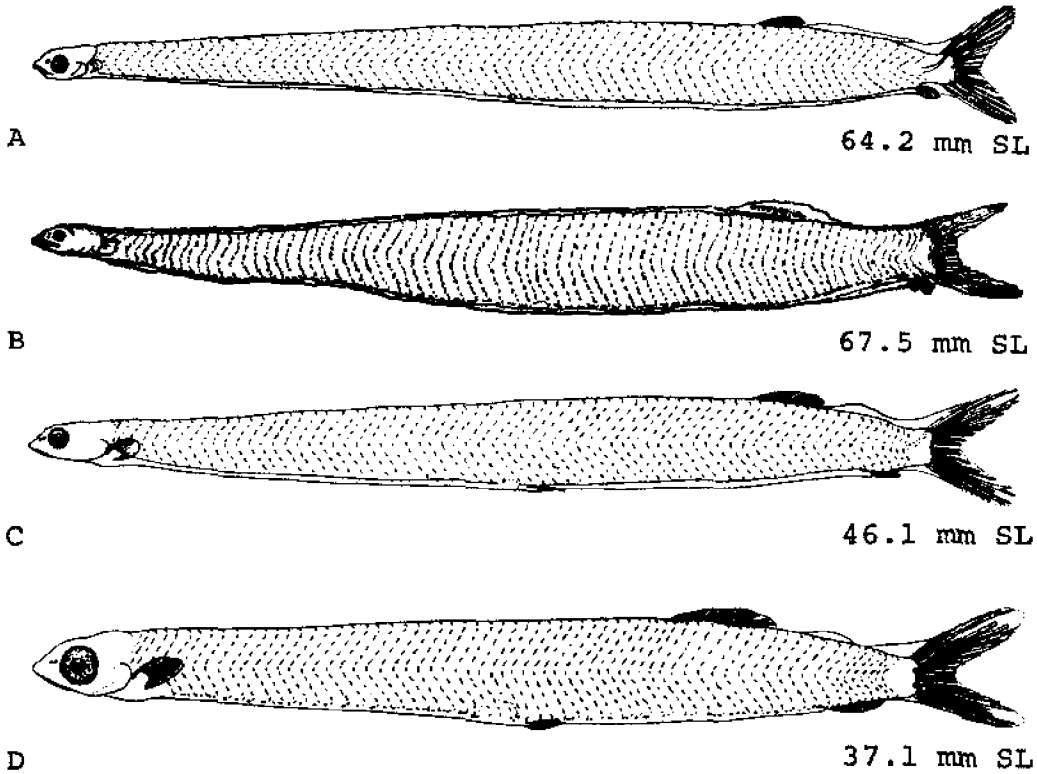

Fig. 31. *Albula vulpes*, Bonefish. A. Stage I larva, leptocephalus, 64.2 mm SL, anal 7, gas bladder a slight protuberance. B. Stage I larva, leptocephalus, 67.5 mm SL. Myomeres 70+3=73. C. Stage II larva, 46.1 mm SL. Total myomeres 67; dorsal and anal more anterior; gas bladder inflated; anus at myomere 63. D. Stage II larva, 37.1 mm SL. Anal at myomere 60; dorsal at myomere 47. (*A, C, D, Alexander, E. C., 1961: fig. 2. B, Shen, S.-C., 1964: fig. 1.*)

posteriorly; lower jaw remarkably longer than upper, with ca. 4 teeth. At 17.8 mm, teeth reduced in size; both jaws equal. At 29.1 mm, teeth smaller and more numerous.[10] At 33.5 mm upper jaw teeth 1+12, lower jaw 1+5.[24] At 43.5 mm snout slightly hooked.[10] At 58.0–59.0 mm upper jaw teeth 1+15, lower jaw 1+9 to 1+10.[24] At 64.2 mm, small numerous teeth on both jaws; snout sharply hooked; upper jaw distinctly overlapping lower.[10] Mouth reaching to below eye at 58 mm TL;[9] nostril divided and bony opercle scarcely visible at 64.2 mm. Origin of dorsal finfold at about 30th myomere at 7.8 mm SL. Incipient dorsal rays at 20–22 mm; dorsal ray count nearly complete but rays unsegmented at 43.5 mm;[10] origin of dorsal over 50th myomere at 48 mm TL.[9] Anal with incipient rays at ca. 26–28 mm. Incipient caudal rays visible at 7.8 mm; caudal rays segmented at 26–28 mm, beginning to branch at 64.2 mm; caudal forked at 29.1 mm. Pelvics first evident at 35–37 mm SL. Notochord with 72 visible divisions at 7.8 mm; urostyle turned upward and hypural plate developing at 17.8 mm, nearly complete at 64.2 mm.[10] Anus below 61st myomere at 58 mm,[9] below 70th at 67.5 mm SL.[27] Gas bladder present at 30th myomere at 7.8 mm (although not indicated in illustration of this stage).[10]

Pigmentation: At 7.8 mm, small dark brown spots along dorsal edge of gut changing to series of thin red-brown dashes at 43.5 mm;[10] at 33.5 mm a few chromatophores at base of some caudal rays and a few chromatophores may be present on anal fin;[24] pigment formed on posterior edge of caudal and cephalic region becoming opaque by end of stage.[10] At 33.5 mm and longer, dense curved and fringed patch of dark brown chromatophores over eyeball; fleshy margin below eye usually with small patches of chromatophores.[24]

STAGE II, LEPTOCEPHALUS

Size range of specimens described ca. 60–65 mm SL[10] to ca. 20 mm TL.[3,4]

D. 14[10]–19;[22] A. 7[18]–9;[22] C. 11/11. Total myomeres 65[18]–75;[27] preanal myomeres 70[27]–55; predorsal myomeres 55–29; prepelvic myomeres 35–28.[10] At 46.0–41.0 mm SL dorsal-pelvic myomeres 21–16.[24]

Proportions expressed as percent SL: Prepectoral length 6.38–21.05; predorsal length 80.99–55.44; preanal length 96.46–82.46; head length 5.49–19.30. Proportions as percent HL: Horizontal diameter of eye 35.01–24.54; snout 31.75–27.27.[10] Proportions as percent SL at 46.0 to 41.0 mm SL: Snout length 2.4–2.7; prepelvic length 50.0–54.0; dorsal origin to pelvic origin 26.0–21.0.[24]

Body deeper than in previous stage, much thicker and more "fish-like" by 31.6 mm SL. Head bullet-shaped, becoming proportionately larger as stage progresses; mouth inferior at 31.6 mm SL;[10] teeth minute, projecting somewhat forward at 57 mm SL;[1] at 46.0 mm SL upper jaw teeth 1+11 to 1+14, lower jaw 8; at 41.0 mm SL teeth very small and numerous;[24] crushing palate forming at 28.5 mm SL.[10] Auditory vesicles about equal to eye at 58 mm;[8] opercle prominent at 46.1 mm SL; bifurcate nostrils surrounded by prominent ridges of cartilage at 31.6 mm SL.[10] Remnant of dorsal finfold present at 37.1 mm SL, sometimes absent at 31.6 mm SL.[10] Dorsal fin migrating forward from myomere 50–56[27] to myomere 29,[10] anal fin from myomere 65–70[27] to myomere 57 during stage. Pectoral fins appear at 37.2–56.0 mm SL, rays becoming pointed at 37.1 mm SL, fleshy base absent at 28.5 mm SL.[10] Vertebrae present at 22 mm.[3] Anus located at myomeres 64–69 at 56.0–37.2 mm SL,[27] moving forward to myomere 56 at 28.5 mm SL; gas bladder inflated at 46.1 mm SL, extended to midline of body at 28.5 mm SL.[10]

Pigmentation: Initially with dusky blotches mixed with yellow, becoming dusky silver as stage progresses.[4] At 57 mm SL, 2 rows of chromatophores along intestinal tract from pectoral fins to vent; vertical series of dark dots on caudal base; eyes dark; body transparent.[1] At 46.0–41.0 mm SL two chromatophores just below and anterior to pectoral fin, a few chromatophores on anal, caudal and dorsal fins,[24] as well as on dorsal and ventral contours.[7] At 39 mm SL, as in earlier stages but with few chromatophores on head and a broken dark line of pigment on upper and lower lobe of caudal.[1] At 28.5 mm SL, no visible pigment.[10] Three days after capture, in specimens of unspecified size, 7 small spots along dorsal surface each surrounded by an opaque area; 2

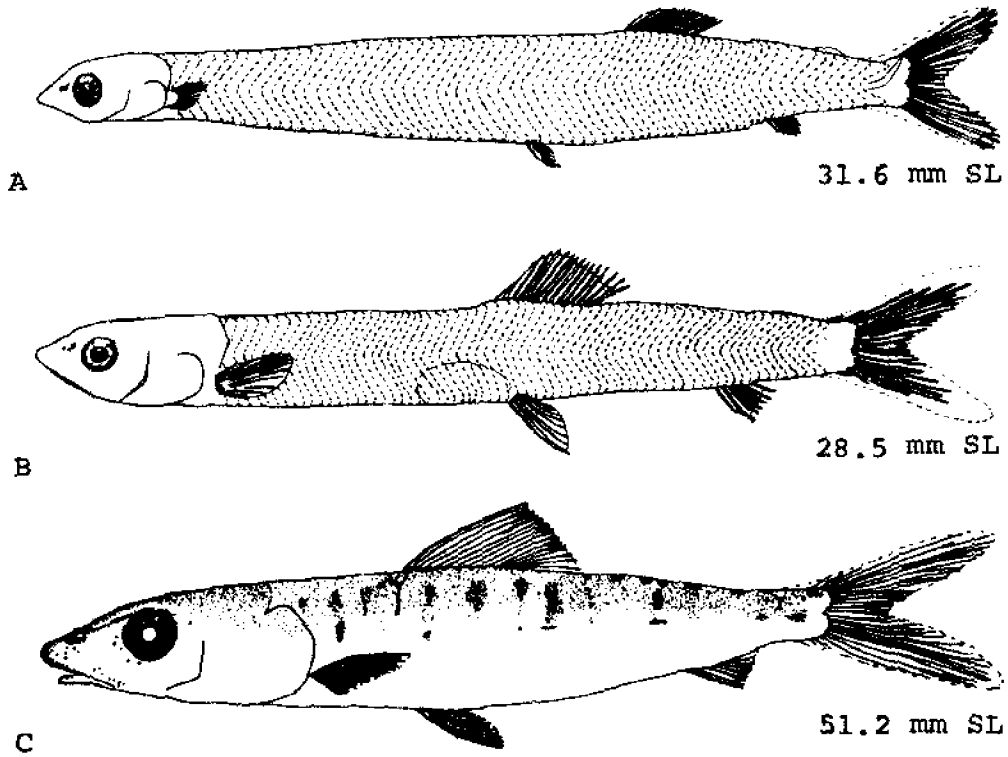

Fig. 32. *Albula vulpes*, Bonefish. A. Stage II larva, 31.6 mm SL. Total myomeres 69; anus at myomere 59; dorsal at myomere 42; anal at myomere 60. B. Stage II larva, 28.5 mm SL. Anus at myomere 56; anal at myomere 57. C. Juvenile, 51.2 mm SL. Scales present. (*A-C, Alexander, E. C., 1961: fig. 2.*)

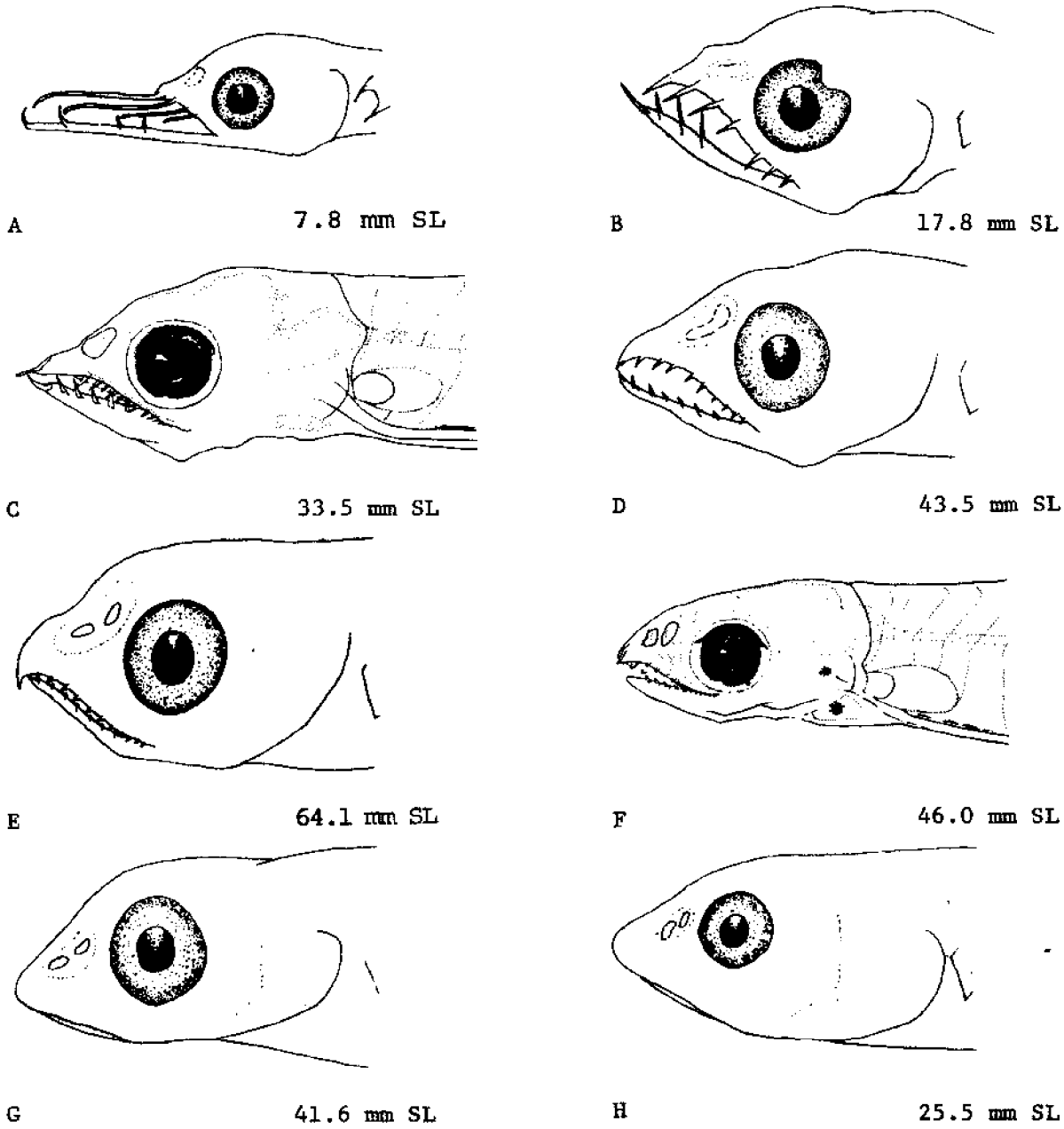

Fig. 33. *Albula vulpes*, Bonefish. A. Head of Stage I larva, leptocephalus, 7.8 mm SL. Exact number of teeth not illustrated. B. Head of Stage I larva, leptocephalus, 17.8 mm SL. Snout longer, teeth shorter. C. Head of Stage I larva, leptocephalus, 33.5 mm SL. Pigmentation pattern evident over eye. D. Head of Stage I larva, leptocephalus, 43.5 mm SL. Upper jaw slightly hooked. E. Head of Stage I larva, leptocephalus, 64.1 mm SL. Snout hooked; upper jaw overlaps lower; numerous teeth barely visible. F. Head of Stage II larva, 46.0 mm SL. Pigmentation pattern evident. G. Head of Stage II larva, 41.6 mm SL. Teeth barely perceptible. H. Head of Stage II larva, 25.5 mm SL. (*A, B, D, E, G, H, Alexander, E. C., 1961: fig. 3. C, F, Eldred, B., 1967a: fig. 1.*)

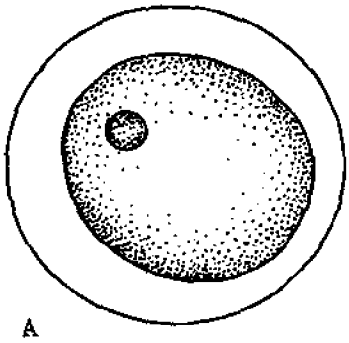

Fig. 34. *Albula vulpes*, Bonefish. A. Egg, 1.3×1.4 mm in diameter. Oil globule evident (identity questioned, PWJ). *A, Rass, T. S., 1972: fig. 3.)*

opaque spots on caudal peduncle; whitish areas along lateral surface. On 5th day after capture, xanthophores prominent over brain, around spinal cord, on dorsal and ventral surfaces, and around snout.[11]

STAGE III, LEPTOCEPHALUS

Size range described ca. 20–36 mm SL.

P. ca. 12; V. ca. 8 at 28.5 mm.[10] Depth at dorsal origin 6.5 times in SL, eye 5.05 times in head length at 28.0 mm TL.[1]

Gape extending to anterior margin of pupil; dorsal origin equidistant between base of caudal and tip of snout at 28.0 mm. Scales first evident at ca. 35 mm.[1]

Pigmentation: At 25 mm, body transparent; dark spots along, above, and below lateral line; 5 dark saddles over back.[13] At 28 mm, 2 dark lines along sides of intestine; 2 rows of dark spots on back; few elongate dark spots along sides; some pigment at base of anal and ventrally on caudal peduncle.[1] Living specimens of unknown size 8 days after capture, melanophores on caudal; 5 clusters of melanophores along line of junction of dorsal and ventral myomeres; iridocytes over brain; large clumps of iridocytes over dorsal surface interspaced by melanophores and xanthophores.[11]

JUVENILES

Minimum size described 23 mm (based on pigmentation and branching of one anal fin ray).[25]

Proportions as percent SL in "juvenile" 51.2 mm SL: Head length 31.3; predorsal length 57.60; prepectoral length 31.30; preanal length 82.68.[10] Proportions expressed as times in SL: Head 2.95–3.03; body depth 5.44–7.18; tip of snout to dorsal origin 1.85–2.51; tip of snout to anal origin 1.15–1.43; tip of snout to pelvic origin 1.56–2.00. Proportions expressed as times in head: Eye 4.23–4.72, snout 2.60–2.95; interorbital width 3.74–4.33.[27]

At 81.2–102.0 mm TL body elongate, subcylindrical, tapering at both ends.[27] At 51.2 mm SL, head bullet-shaped, snout conical, mouth inferior, teeth quite small, crushing palate formed.[10] At 40–45 mm, pectorals more than halfway to pelvics, not yet falcate; scalation complete except, perhaps, on belly; lateral line formed; anus in advance of anal fin by a distance nearly equal to length of snout.[1] Branching in all fins at 51.2 mm SL.[10]

Pigmentation: About 12 crossbands on back extending to lateral line [10] and persisting to ca. 75 mm.[1] At 51.2 mm, pigment developed on snout and above eye; chromatophores on dorsal and caudal fins.[10] At 81.2–102.0 mm TL brownish above lateral line, silvery white below; dorsal and caudal fins brownish on margins. Anal, pectoral and pelvics hyaline.[27]

AGE AND SIZE AT MATURITY

One year, at sizes as small as 210 mm; near ripe females as small as 251 mm SL.[26]

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Alosa aestivalis
Alosa mediocris
Alosa pseudoharengus
Alosa sapidissima
Brevoortia tyrannus
Clupea harengus
Dorosoma cepedianum
Dorosoma petenense
Etrumeus teres
Opisthonema oglinum
Sardinella aurita

herrings
Clupeidae

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FAMILY CLUPEIDAE

This family is comprised primarily of marine and estuarine species. A number of its representatives are able to complete their life cycle in freshwater and even more are anadromous. Members of this family are widely distributed, being present in all seas except in the polar region. There are about 190 species in 50 genera.

Adult and juvenile herrings are silvery, schooling fishes which are usually strongly, laterally compressed. They have one dorsal fin, a deeply forked caudal fin, numerous long slender gill rakers, and in most species a row of sharp-edged scutes along the midline of the belly. The head is scaleless and the body is covered with deciduous, cycloid scales.

Eggs are characteristically round with a moderate to wide perivitelline space, and a granular or segmented yolk; there is often one oil droplet, and frequently a number of smaller satellite droplets. The chorion is unornamented and the marine species usually have pelagic eggs. See Table 1 for a brief comparison of the eggs of regional clupeids.

TABLE 1. Spawning season and egg characteristics

Species	Spawning season	Spawning temperature (C)	Salinity	Egg diameter (mm)	Location in water column	Oil droplets
Dorosoma cepedianum	Late spring–early summer	10–28.9	Fresh	ca. 0.75	Demersal attached	1 large 1–5 smaller
Dorosoma petenense	April–July	14.4–27.2	Fresh or brackish	ca. 0.75	Demersal attached	1 or more
Alosa pseudoharengus	Late March–mid-May	10.5–ca. 26	Fresh	0.80–1.27	Essentially pelagic	Numerous, tiny
Alosa aestivalis	April–June	14–ca. 27	Fresh or brackish	0.87–1.11	Essentially pelagic	Scattered, unequal
Sardinella aurita	Summer	19–28	Marine	0.94–1.40	Pelagic	1 large 1–3 smaller
Alosa mediocris	April–June		Fresh	0.96–1.65	Demersal or pelagic	Few, small
Clupea harengus	Fall and spring	0–15	Marine	1.0–1.4	Demersal attached	None
Opisthonema oglinum	Summer	22.5–30.3	Marine	1.08–1.31	Pelagic	1
Etrumeus teres	Summer	18.4–28.9	Marine	1.17–1.53	Pelagic	None
Brevoortia tyrannus	Fall and spring	4.4–23.6	Usually Marine	1.3–1.95	Pelagic	1 small
Alosa sapidissima	April–July	8–26	Fresh and perhaps brackish	2.5–3.8	Demersal or pelagic	None

Yolk-sac larvae are characteristically long and slender with a long straight gut, poorly developed pigment and a preanal length of 70% SL or more. The yolk-sac larvae of anadromous clupeids (genus *Alosa*) from the Mid-Atlantic Bight lack oil globules but may have tiny oil droplets, whereas members of the fresh and brackish water genus, *Dorosoma*, have one large oil droplet and several smaller ones. Of the marine spawners reported from this region, yolk-sac larvae of *Brevoortia tyrannus*, *Opisthonema oglinum*, and *Sardinella aurita* have oil globules while those of *Clupea harengus* and *Etrumeus teres* do not.

With the exception of *Brevoortia tyrannus*, the regional clupeid larvae occur in fresh and brackish waters or they are strictly marine. Menhaden larvae enter estuaries at sizes of 10 mm and larger. This species is separable from larval

fresh and brackish water clupeids on the basis of its comparatively advanced state of development.

Table 2 shows characteristics useful in separating larval clupeids of the Mid-Atlantic Bight. In addition to this, ventral pigment patterns are useful in separating *Alosa sapidissima* from *Alosa aestivalis* and *Alosa pseudoharengus* (see accounts for those species) and may be helpful in identifying other fresh and brackish water larvae as well. In addition to myomere counts, spawning season is useful in separating marine clupeids. *Brevoortia tyrannus* and *Clupea harengus* spawn during the colder months while *Etrumeus teres, Opisthonema oglinum* and *Sardinella aurita* spawn during summer. *Etrumeus teres* differs from other regional clupeids by having an elongate pointed snout at about 7 mm.

TABLE 2. Characteristics of larvae in the family Clupeidae

Species	Location	Size range described (mm)	Preanal myomeres	Total myomeres	Myomeres between insertion of dorsal fin and posterior margin of vent	Predorsal myomeres
Alosa aestivalis	Fresh and brackish	4.0–15.9 SL	42–45	47–53*	11–13	
Alosa mediocris	Fresh and brackish	6.5–18.0 TL putative	ca. 38–42	42–52		
Alosa pseudoharengus	Fresh and brackish	4.3–19.9 SL	39–43	46–50*	7–9	
Alosa sapidissima	Fresh and brackish	9.7 SL ca. 27 TL	44–52	ca 55–57		
Dorosoma cepedianum	Fresh and brackish	7.0–ca. 21 TL	39–44	45–52		
Dorosoma petenense	Fresh and brackish	5.2–20 TL	ca. 36	43–44*		
Brevoortia tyrannus	Fresh to marine	5.0–28.7 TL	37–40	45–50		
Clupea harengus	Marine	6.5–34 TL	41–47	53–63		
Etrumeus teres	Marine	6.9–33 TL	42–44	48–50		25–35
Opisthonema oglinum	Marine	3.8 NL–19.3 SL		46–49		19–24
Sardinella aurita	Marine	5.9–16 TL		ca 48		24–28

* indicates vertebral account

In clupeid larvae, the vent is always posterior to the dorsal fin. This character separates larvae of this family from those of the Engraulidae.

Within the Mid-Atlantic Bight there are records of *Sardinella aurita* (= *S. anchovia* of some authors), and there is the possibility that a second species of *Sardinella, S. brasiliensis,* occurs. Since there are no published records of this second species an account of it has not been included. For an excellent description of development of *S. brasiliensis* see Matsuura, 1975.

Alosa aestivalis (Mitchill), Blueback herring

ADULTS

D. 15–20;[1] A. 15[9]–21;[1] C. 7–8 + 10 + 9 + 6–7;[21] P. 14[1]–18;[9] V. 9[1]–11;[9] scale rows between gill openings and base of caudal 46–54; total ventral scutes 31–36,[1] prepelvic scutes 18–21,[1] postpelvic scutes 12–16;[9] 13–14 longitudinal rows between dorsal and pelvic bases;[11] total vertebrae 47 (FHB)–53,[1] precaudal 14–16, caudal 33–35;[21] gill rakers 41–52;[1] branchiostegals 7, 7.[9]

Proportions expressed as percent TL: Body depth 22.1–25.2; head length 18.5–20.6. Proportions expressed as percent HL: Eye diameter 22.0–26.4; snout length 23.4–30.0; interorbital width 21.1–26.4.[9] Proportions expressed as times in SL: Head 3.3–4.6; body depth 3.0–4.6. Proportions expressed as times in HL: Eye 3.0–6.0; snout 3.6–5.8.[11]

Body moderately compressed,[1] elongate;[8] eye small, equal to or shorter than snout; mouth oblique; upper jaw with definite median notch; lower jaw not extending into dorsal profile. Teeth lacking on premaxillaries, sometimes evident on posterior maxillary; mandibular teeth present anteriorly but lacking free points; narrow band of granular teeth on tongue. Scales moderately adherent with crenulate membranous edges preceded by scarcely visible striae.[1] Lateral line not developed.[8]

Pigmentation: Bluish above, sides silvery; upper scale rows with more or less distinct longitudinal lines; a single dark shoulder spot usually present; fins plain, greenish, or yellowish. Peritoneum generally dark.[1]

Maximum length: Ca. 380 mm.[1]

DISTRIBUTION AND ECOLOGY

Range: Nova Scotia to St. Johns River, Florida.[1]

Area distribution: Chesapeake Bay and "virtually all streams tributary to the Bay,"[2] Delaware River, and offshore waters of New Jersey.[3]

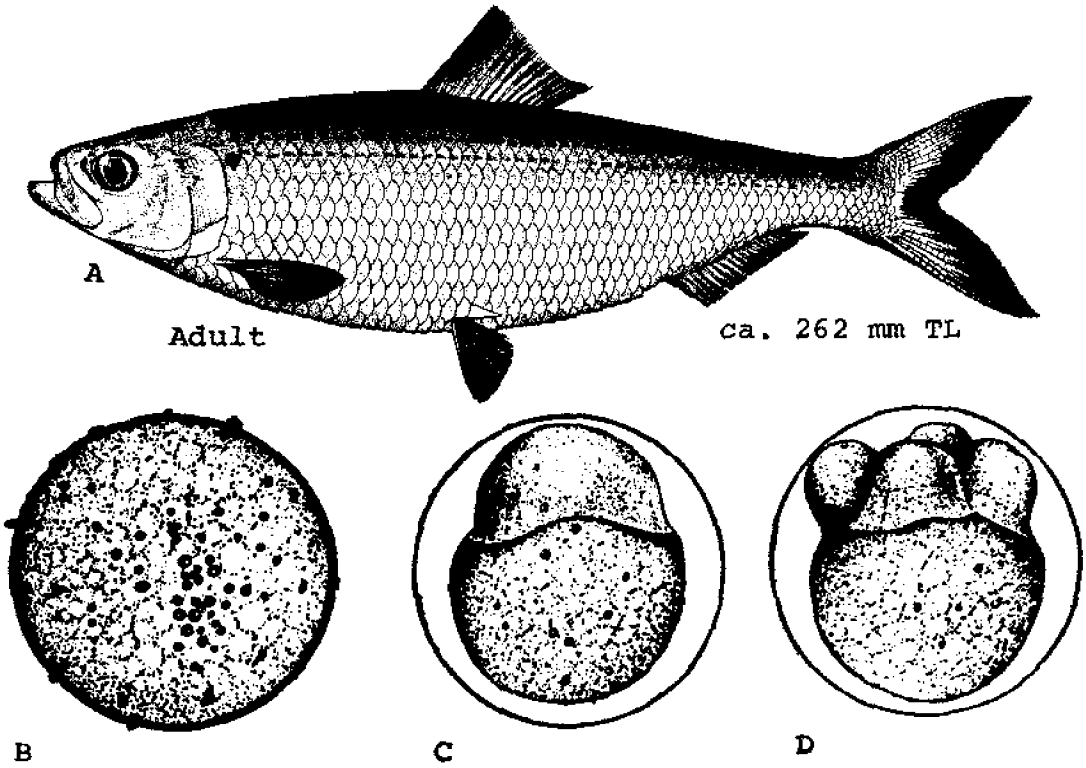

Fig. 35. *Alosa aestivalis*, Blueback herring. A. Adult, male ca. 262 mm TL. B. Egg, ca. 1.0 mm. Mature, unfertilized, waterhardened. Debris sticking to adhesive egg capsule. C. Egg, blastodisc. Yolk granular with small oil globules. Diameter ca. 1.0 mm. D. Egg, 4-cell stage. Diameter ca. 1.0 mm. (A, Goode, G. B., et al., 1884: *pl. 209. B-D, Kuntz, A., and L. Radcliffe, 1917: figs. 87, 88, 90.*)

Habitat and movements: Adults—an anadromous, schooling species typically inhabiting a narrow band of coastal water; entering fresh and brackish water during spawning season; first arrivals at 5 C in vicinity of Connecticut River; upriver movement to spawning areas occurs in late afternoon or at night. Apparently moving to offshore, bottom waters during winter.[1,2,4]

Larvae—fresh and brackish rivers.[1,2,4]

Juveniles—smaller individuals apparently move upstream during periods of decreased flow. Leave fresh and brackish nursery grounds at ca. 50 mm, primarily during mid-September and October at 21–ca. 11 C, in Connecticut. In James River, Virginia, majority collected in surface waters, downstream migration almost complete by November. Some overwintering takes place in Delaware River Estuary and Chesapeake Bay during first and possibly second winters. One and two year olds arrive with or soon after spawning adults.[1,2,4,10,18,22] Experimentally survive transfer from 0 ppt to 28 ppt.[13]

SPAWNING

Location: Fresh and brackish rivers and tributaries, apparently never far above tidewater; also ponds having an outlet to the sea.[1,5] Over bottom of clean swept sand and gravel [10] to boulders, in areas of relatively wide and deep ingress with swift flow. Not ascending freshwater streams as far as alewife, *Alosa pseudoharengus*.[17,18]

Season: Last half of April through first half of May in Potomac River; [1] late April through mid-June, peak last half of May in Delaware River; [10] late April to mid-September in Connecticut.[18]

Temperature: Minimum 14 C; at ca. 27 C spawning apparently ceases; [18] optimum ca. 21 [4]–25.5 C.[17]

Fecundity: 45,800 at 238 mm, to 349,700 at 310 mm.[18]

EGGS

Unfertilized eggs: Fully ripe eggs light amber, semitransparent.[18]

Fertilized eggs: Essentially pelagic, demersal in still water,[20] somewhat adhesive, yellowish, semitransparent; [7] diameter 0.87–1.11 mm [12] (average 1.0 mm); perivitelline space ca. 1/4 egg radius. Capsule relatively thick with inner surface appearing finely corrugated. Yolk granular; oil globules small, unequal, scattered.[7]

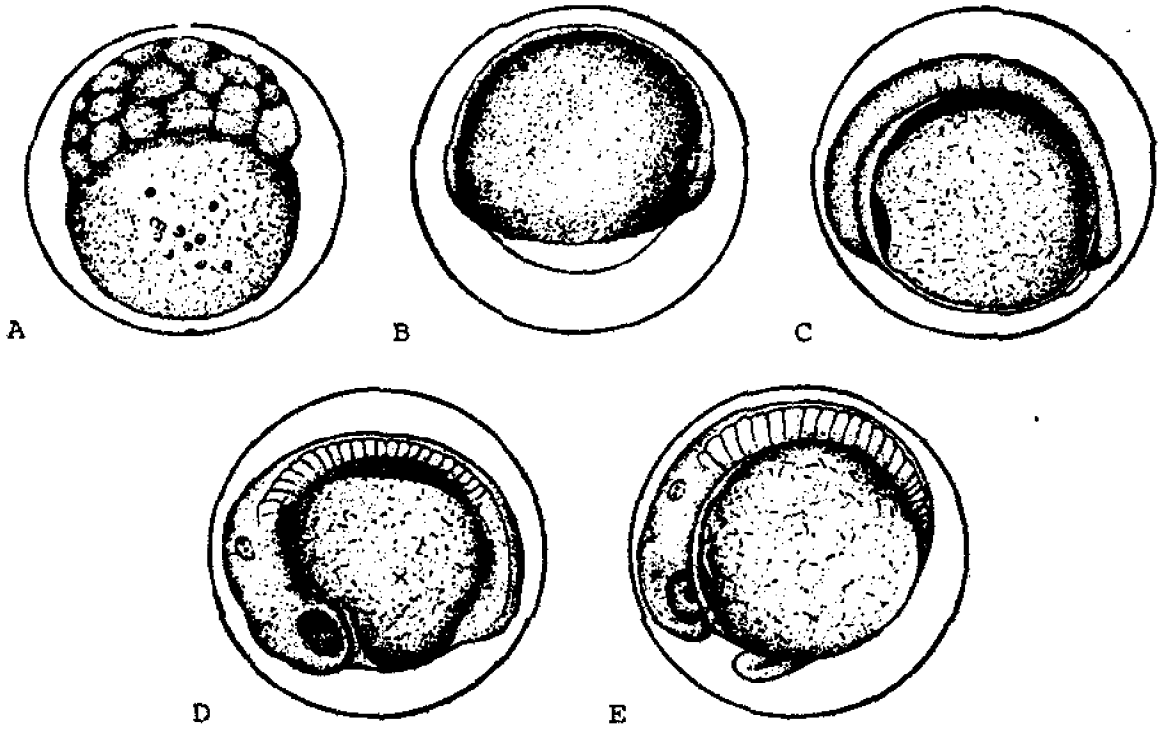

Fig. 36. *Alosa aestivalis*, Blueback herring. A. Egg, 64-cell stage. This and all following eggs ca. 1.0 mm in diameter. B. Egg, early embryo. Germ ring darker at edge of blastoderm. C. Egg, early embryo. Blastopore open; 3 somites visible. D. Egg, 24–26 somite stage. E. Egg, tail-free embryo. (*A-E, Kuntz, A., and L. Radcliffe, 1917: figs. 91, 93–96.*)

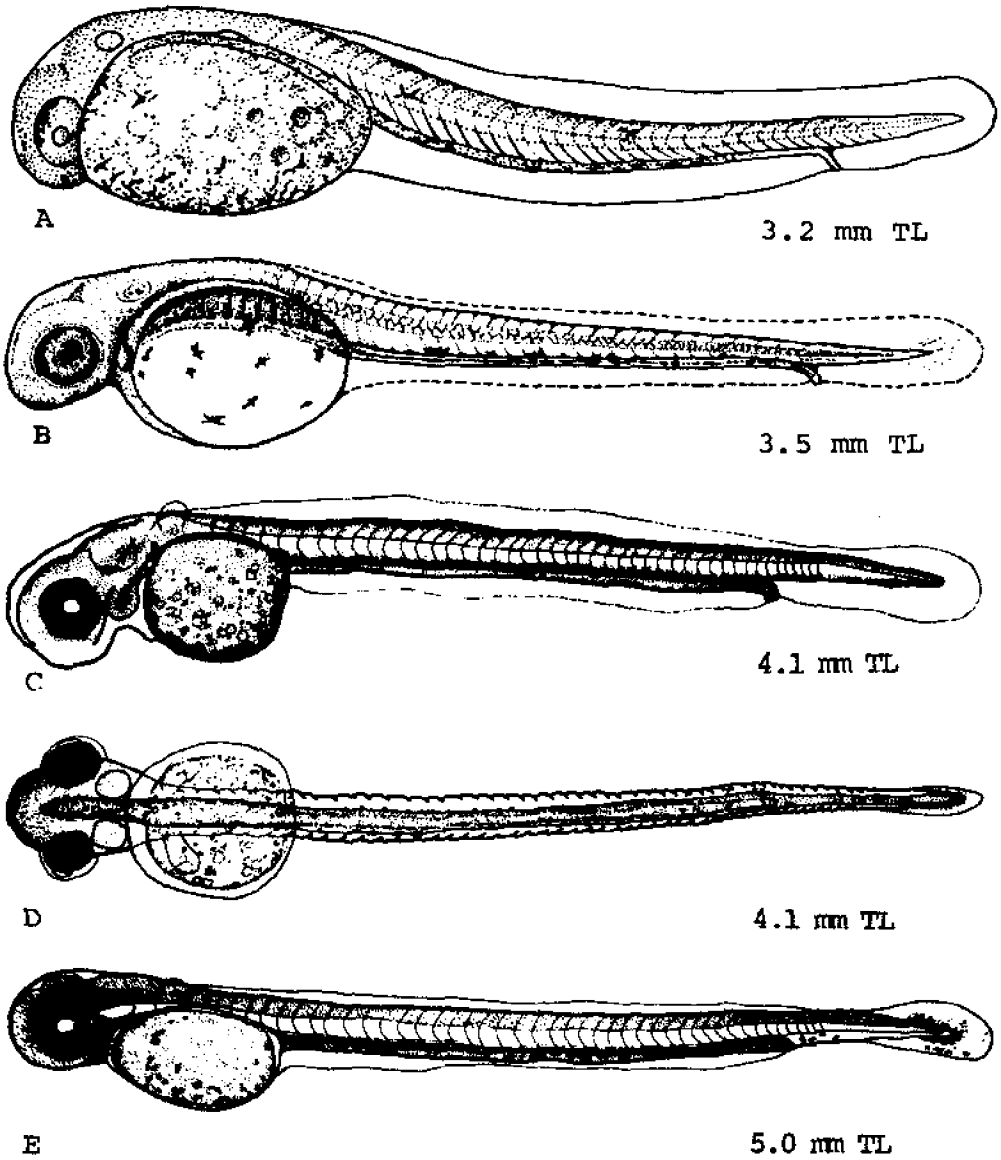

Fig. 37. *Alosa aestivalis*, Blueback herring. A. Yolk-sac larva, 3.2 mm TL. Recently hatched; small oil globules still visible in yolk. B. Yolk-sac larva, 3.5 mm TL. Recently hatched. C. Yolk-sac larva, 4.1 mm TL. Recently hatched. D. Ventral view of "C." E. Yolk-sac larva, 5.0 mm TL. Second day after hatching. (*A, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 21A. B. Kuntz, A., and L. Radcliffe, 1917: fig. 97. C-E, Cianci, J. M., 1969: figs. 12A, 12C, 13A.*)

EGG DEVELOPMENT

At "laboratory temperature."[7]

Fully differentiated blastodisc relatively thick, cap-like. Early blastomeres large and tending to be spherical. Peripheral growth of blastoderm apparent before periblast is well differentiated, but greatly increased following periblast formation and covering more than half the yolk at completion of germ ring and early differentiation of embryonic shield. Embryonic shield long, narrow; embryonic axis, when clearly differentiated, extending more than halfway around circumference of yolk. Three somites visible just prior to closure of blastopore within 16 hours after fertilization. With 24–26 somites present, embryo extends slightly more than 2/3 around yolk; optic and auditory vesicles developed. Just prior to hatching, length of embryo exceeds yolk circumference.

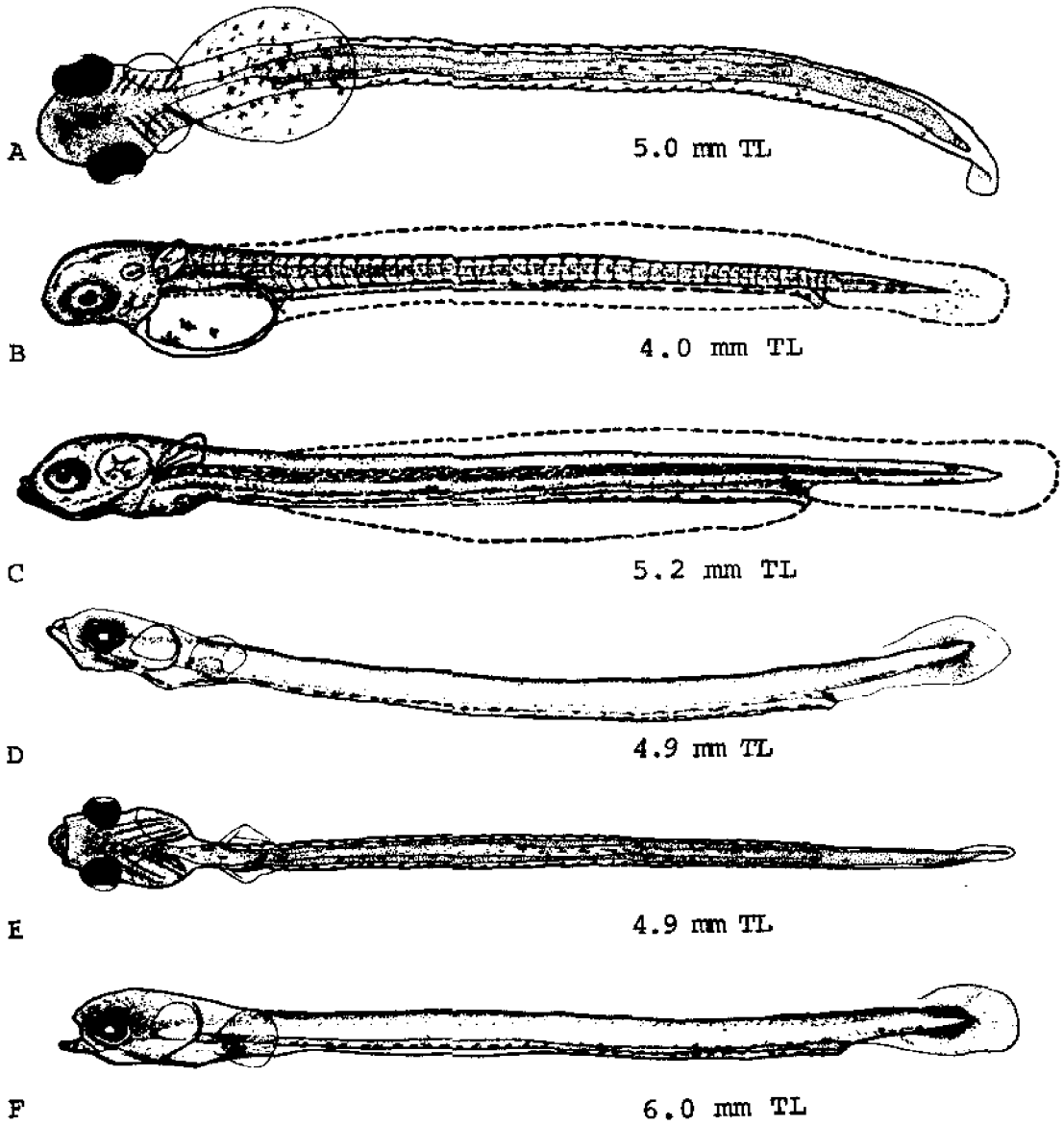

Fig. 38. *Alosa aestivalis*, Blueback herring. A. Yolk-sac larva, 5.0 mm TL. Ventral view. B. Yolk-sac larva, 4.0 mm TL. C. Larva, 5.2 mm TL. D. Larva, 4.9 mm TL. E. Larva, ventral view of "D." F. Larva, 6.0 mm TL. (*A, D-F, Cianci, J. M., 1965: figs. 13B, 14, 15. B, C, Kuntz, A., and L. Radcliffe, 1917: figs. 98, 99.*)

Embryo relatively opaque; slightly pigmented.[7]

At 23.9 C, 8 hours after fertilization, blastula stage.[18]

At 21.8 C, 30.5 hours after fertilization, embryo 3/4 around yolk, tail free in many.[18]

Incubation: Ca. 80–94 hours at 20–21 C;[19] ca. 50 hours at 22 C;[4] 55–58 hours at 22.2–23.7 C.[18]

YOLK-SAC LARVAE

Hatching length 3.1[12]–5.0 mm TL, average 4.3 mm TL. Average length at end of stage 5.1 mm TL. Duration of stage 2–3 days.

Recently hatched larvae, preanal myomeres 37–41 (typically 39).[16] Proportions expressed as percent TL (aver-

ages): Snout to vent 77.50–79.75; head length 11.78–12.40. Proportions expressed as percent HL (average): Eye diameter 31.74–45.10.[16]

Body elongate, relatively slender, head moderately deflected at hatching.[7] Recently hatched larvae with head attached to yolk,[16] not deflected in some specimens at one day;[7] rudimentary mouth evident. Yolk mass initially subspherical, granular, containing small oil droplets;[16] greatest length less than 1/4 TL, markedly reduced at end of first day.[7] Auditory vesicles poorly developed. At second day after hatching (average length 5.1 mm TL) oil droplets absent from yolk mass; auditory vesicles prominent. Three days after hatching (average length 5.1 mm) lower jaw extends beyond upper.[16] Incipient caudal rays apparently formed at hatching. Pectorals initially absent; conspicuous and possibly rayed at one day,[7] fin enlarged by third day.[16] Origin of dorsal finfold relatively far back on body at hatching; dorsal finfold apparently somewhat more narrow at hatching than at one day;[7] in recently hatched larvae ventral finfold narrow, caudal finfold small, rounded.[16]

Pigmentation: At hatching eye completely pigmented, chromatophores scattered over ventral surface of yolk sac. Series of pigment on dorsal edge of gut from behind yolk sac to anus, occurs as elongate chromatophores to myomere 17–19 followed by irregular widely spaced pigment. Series along ventral gut from myomere 18–20 to anus. At 2nd day scattered chromatophores more stellate, irregular, row below pectoral fin; melanophores on upper gut enlarged, becoming stellate near vent.[16]

LARVAE

Size described 4.0–15.9 mm SL.

Preanal myomeres at 4.0–5.9 mm SL 42–44 (usually 43); at 6.0–13.9 mm SL 43–45 (usually 44); at 14.0–15.9 mm SL 42–43. Myomeres between cleithrum and vent at 4.0–5.9 mm SL 41–43 (usually 42); at 6.0–13.9 mm SL 41–45 (usually 43); at 14.0–15.9 mm SL 39–40. Myomeres between insertion of dorsal fin and posterior margin of vent 11–13 ($\bar{x}$ 11.8).[8,16]

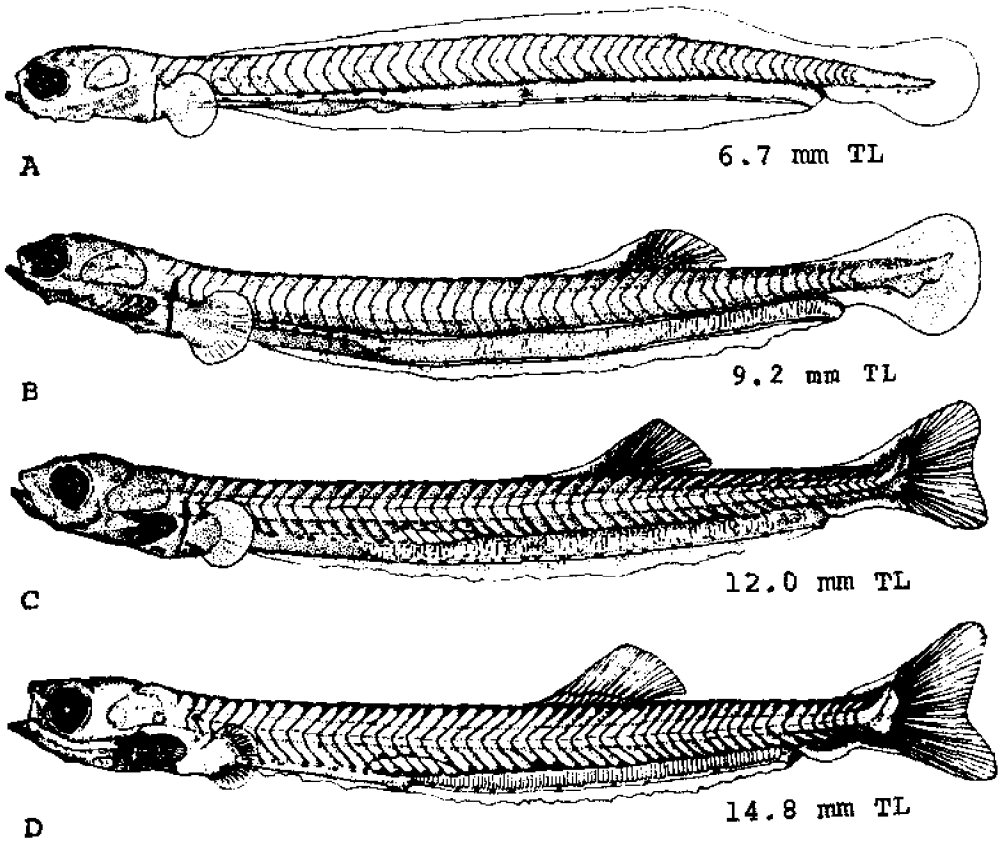

Fig. 39. *Alosa aestivalis*, Blueback herring. A. Larva, 6.7 mm TL, 6.5 mm SL. B. Larva, 9.2 mm TL, 8.9 mm SL. Flexion beginning. C. Larva, 12.0 mm TL, 11.0 mm SL. Flexion complete or nearly so. D. Larva, 14.8 mm TL, 13.3 mm SL. (*A-D, Chambers, J. R., J. A. Musick, and J. Davis, 1976: figs. 5B, 6B, 7B, 8B.*)

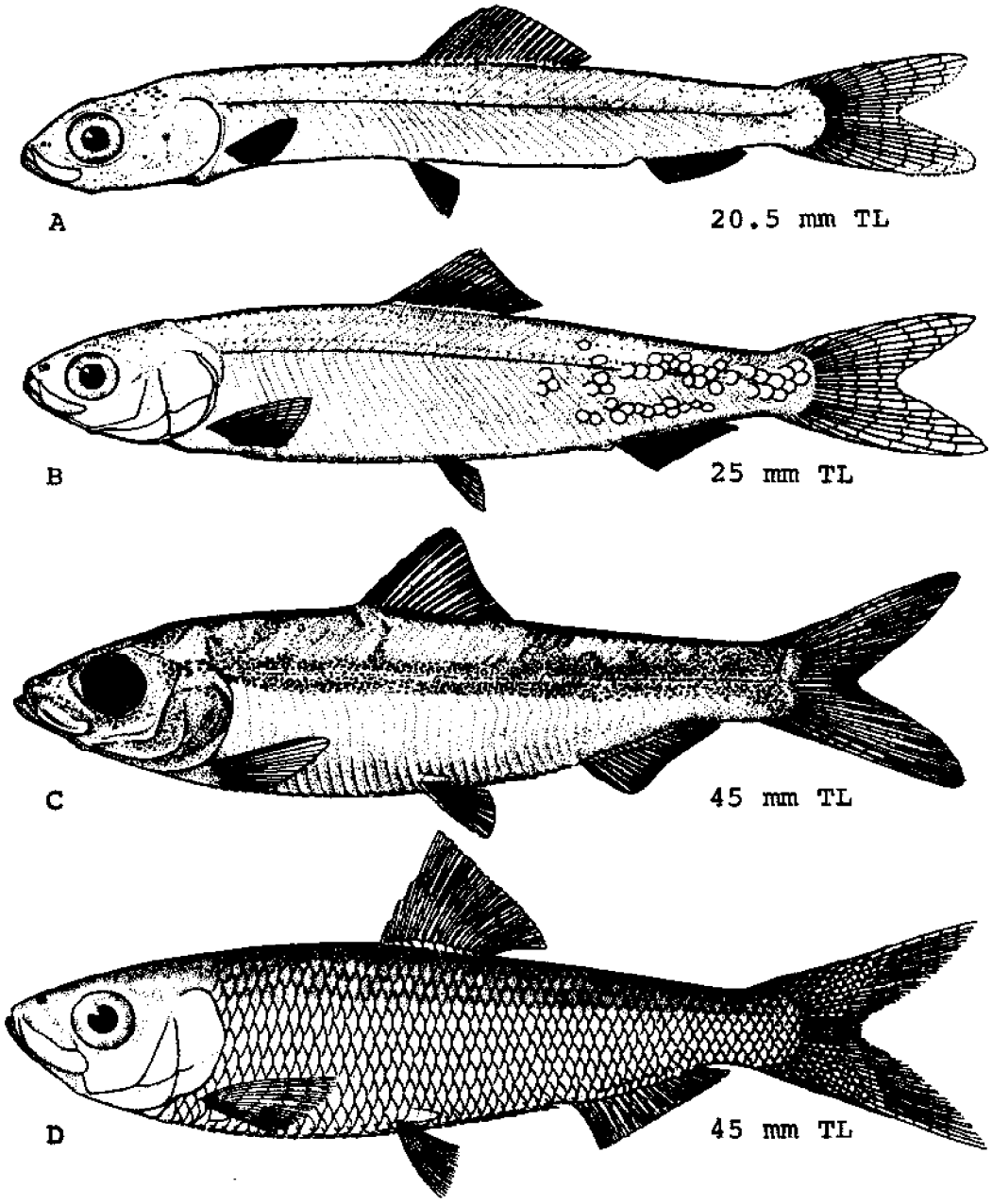

Fig. 40. *Alosa aestivalis*, Blueback herring. A. Juvenile, 20.5 mm TL. B. Juvenile, 25 mm TL. Scales and scutes forming. C. Juvenile, 45 mm TL. D. Juvenile, 45 mm TL. (*A, B, D, Hildebrand, S. F., 1963b: fig. 81. C, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 22D.*)

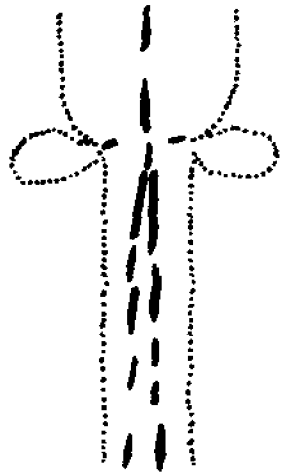

Fig. 41. *Alosa aestivalis*, Blueback herring. Ventral pigment pattern separates this species from *Alosa sapidissima* larvae up to ca. 13 mm TL. (*Leim, A. H., 1924: fig.* 23B.)

At four days after hatching (average length 5.2 mm TL) mouth open, protuberant; auditory vesicles greatly enlarged.[7] At 5 days after hatching (average length 5.4 mm TL) mouth terminal, upper jaw extends to anterior 1/3 of eye; operculum and otoliths prominent; branchiostegals developing. At 6 days after hatching (6.0 mm TL) head broader than body.[16] Ventral finfold deep at 5.2 mm TL;[7] notochord flexion occurs at ca. 9 mm SL; vent has begun forward migration by 14 mm SL, body depth has increased.[15]

Pigmentation: At 5 days after hatching elongate chromatophores at pectoral bases; melanophores along upper and lower gut in distinct rows. At 6 days most anterior melanophores on ventral edge of body below pectoral fin, typically 4, enlarged; small chromatophores above mid-lateral line.[16] By 10.4 mm TL (and possibly smaller) double line of pigment beginning at pectoral bases, diverges gradually so that lines appear to be almost straight.[15,16,28]

JUVENILES

Minimum size described 20.5 mm TL. Two specimens, each 45.0 mm TL, are described in detail and indicate wide variability at this stage[1] (AJL).

Gill rakers on lower limb 28–36 at 30–39 mm SL; 30–39 at 50–69 mm SL; 35–41 at 70–80 mm SL; 38–44 at 90–109 mm SL; 42–48 at 110–129 mm SL; and 42–50 at 130–149 mm SL.[1]

Body initially very slender, its depth increasing with age, 7.5 times in SL at 16.5 mm SL; 5.0 times in SL at 20.0 mm SL. At 20.5 mm TL eye longer than snout; maxillary nearly to pupil. Minute teeth on premaxillary; teeth on free rim of maxillary rather prominent; mandibular teeth with free points.[1] Adipose eyelid present (AJL). Pelvics inserted under origin of dorsal at 20.5 mm TL, considerably further back at 25.0 mm TL. Scales developed posteriorly and scutes evident at 25.0 mm TL.[1] One 45 mm specimen with well-developed axial scales and ventral scutes (AJL), another fully scaled.[1]

Pigmentation: Large chromatophores scattered over head, dorsum, and upper sides at 20.5 mm TL; those of upper sides apparently arranged in definite rows at 25.0 mm TL. Tongue pigmentation along margin when present. Peritoneum usually black.[1] Least developed of two 45 mm specimens with broad mid-lateral band of chromatophores from which irregular blotches extend dorsally; chromatophores also present on head, opercle, and caudal fin (AJL).

AGE AND SIZE AT MATURITY

Minimum age 3;[18] most males at ages 3 and 4, most females at age 4;[14] 250 mm or less.[1]

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Alosa mediocris (Mitchill), Hickory shad

ADULTS

D. 15-20; A. 19–23;[1] C. 9+10+9+7;[6] P. 15–16; V. 9; scale rows between upper angle of gill opening and base of caudal 48–57,[1] longitudinal scale rows between base of pelvics and anterior dorsal rays ca. 16;[4] ventral scutes 33–38; total vertebrae 53 (FHB)–55;[1] precaudal 17, caudal 37;[6] gill rakers 18–23.[1]

Proportions as times in SL: HL 3.4–4.1; body depth 3.0–3.8. Proportions as time in HL: Eye 3.0–5.3; snout 3.7–5.0.[4]

Body moderately slender,[4] elliptical, compressed; mouth oblique; upper jaw with median notch; lower jaw strongly projecting and extending into dorsal profile; upper margin of mandible with no pronounced angle,[1] maxillary broad, rounded posteriorly.[4] Teeth absent in upper jaw, very small on lower jaw and tongue. Scales moderately adherent with longitudinal striae and crenulate, membranous borders;[1] scutes present on midline of belly.[4]

Pigmentation: Grayish green above; sides iridescent silver. Nape green; side of head brassy; tip of lower jaw dusky. Caudal, dorsal, and pectoral fins dusky; pelvic and anal fins plain. Narrow, dark lines along upper sides. Shoulder spot commonly followed by several obscure, dark spots. Peritoneum pale with scattered punctations.[1]

Maximum length: 600 mm.[1]

DISTRIBUTION AND ECOLOGY

Range: Bay of Fundy to Florida.[3]

Area distribution: Throughout Chesapeake Bay;[2] also recorded from New Jersey, Virginia,[1] and Delaware.[5]

Habitat and movements: Adults—marine waters, probably never far from land; also estuaries, tidal rivers and tributaries during late spring and early summer. A schooling anadromous species whose oceanic movements are unknown. Well defined "runs" of adults enter estuaries during spring and, to a lesser degree, during fall in Chesapeake Bay;[2] apparently return to ocean shortly after spawning.[3]

Larvae—no information.

Juveniles—tend to leave nursery areas during early summer; however specimens in age group I found sporadically throughout most of year in Chesapeake Bay and tributaries.[5]

SPAWNING

Location: Tidal freshwater.[3]

Season: Late April through early June.[3]

Time: Possibly dusk to midnight.[3]

Fecundity: Unknown.

EGGS

Location: Apparently broadcast at random; typically demersal although tending to be buoyant under turbulent conditions; slightly adhesive, but easily dislodged by currents.[3]

Unfertilized eggs: Asymmetrical; average diameter 1.12 mm (range 0.98–1.19 mm), average yolk diameter 0.98 (range 0.88–1.08 mm); egg capsule relatively thick, surface appearing finely corrugated; micropyle single.[3]

Fertilized and water-hardened eggs: Transparent, spherical, diameter 0.96 to 1.65 mm, perivitelline space ca. 1/2 egg radius. Yolk, in life, light amber-yellow and densely granular; in preservative, dark amber or whitish yellow, diameter 0.83–1.16 mm; few small oil globules.[3]

EGG DEVELOPMENT

Temperature at time of fertilization 14.4 C; rearing temperature from 2nd hour 18 to 21 C.

1 hour	predominately blastodiscs; few 2-cell stages; blastomeres with fine oil globules.
2 hours	predominately 2- and 4-cell stages.
4 hours	2- to 64-cell stages.
8 hours	16-cell stage to blastula.
16 hours	blastula to headfold stage; about 5 somites present in most advanced embryos.
24 hours	embryonic axis through early embryo; head, trunk, tail, spinal cord, gut, heart, pectoral buds, and ca. 30 somites evident in early embryos.
36 hours	some embryos with tail attached, others tail-free; somites 28–38; notochord and otoliths well-developed; eyes colorless; body pigmentation absent; yolk sometimes with several small oil globules; yolk membrane vascular.[3]

Incubation: 48–70 hours at ca. 16 to 31 C.[3]

YOLK-SAC LARVAE

Average size at hatching 6.1 mm TL (range 5.2–6.5 mm).

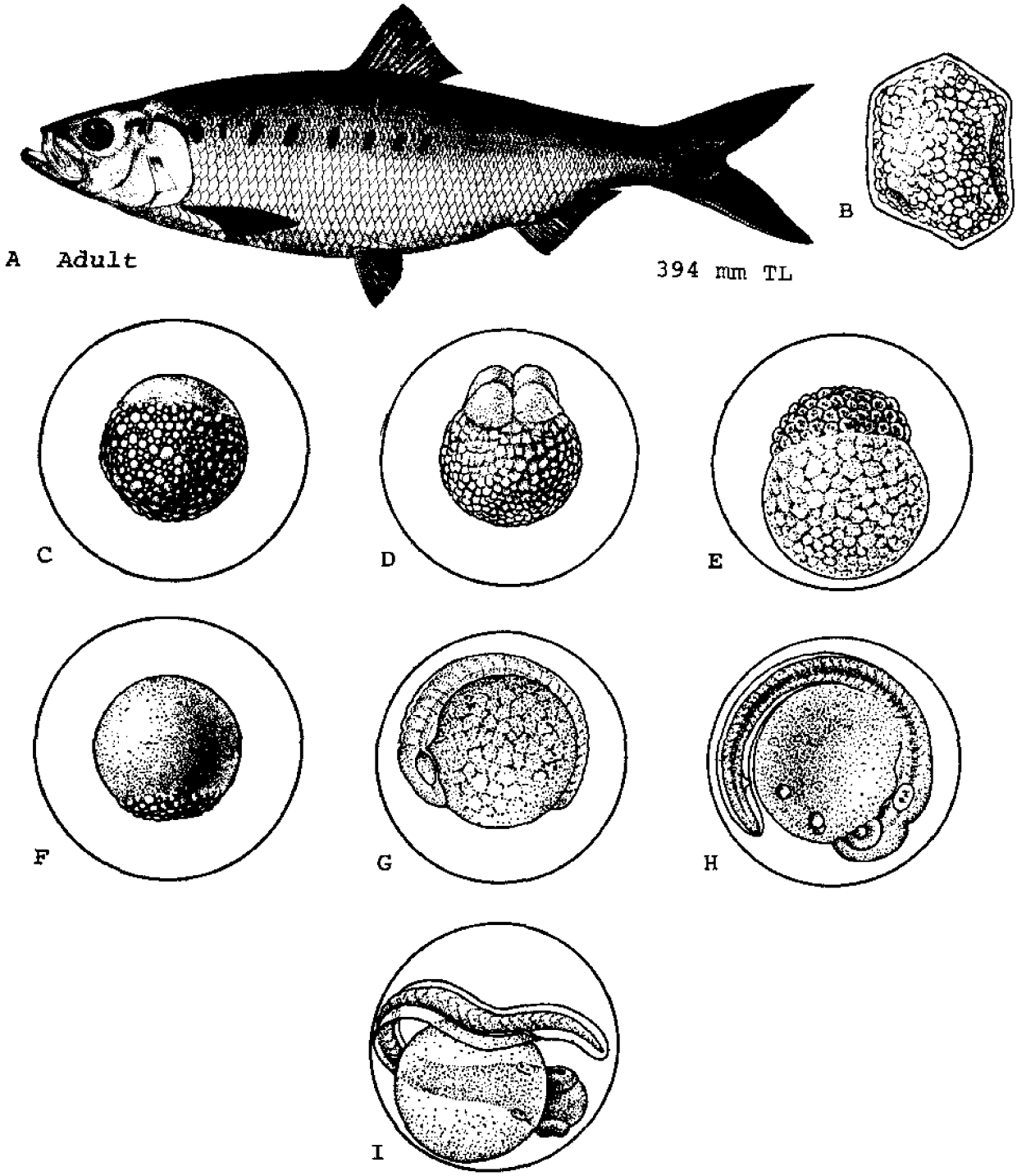

Fig. 42. *Alosa mediocris*, Hickory shad. A. Adult, 394 mm TL. B. Ripe unfertilized egg, diameter 1.1 mm. Asymmetrical appearance typical. C. Egg, blastodisc formed 1 hour. This and all following eggs ca. 1.5 mm. D. Egg, 4-cell stage, 2 hours. E. Egg, morula, 4 hours. F. Egg, blastula, blastopore still open, 16 hours. G. Egg, 30 somites and optic vesicles 24 hours. H. Egg, tail-free embryo, 36 hours. Auditory vesicles, anus, and pectoral buds formed; small oil droplets in yolk. I. Egg, just prior to hatching, 48 hours. (*A, Goode, G. B., et al., 1884: pl. 216a. B-I, Mansueti, R. J., 1962b: figs. 3, 4.*)

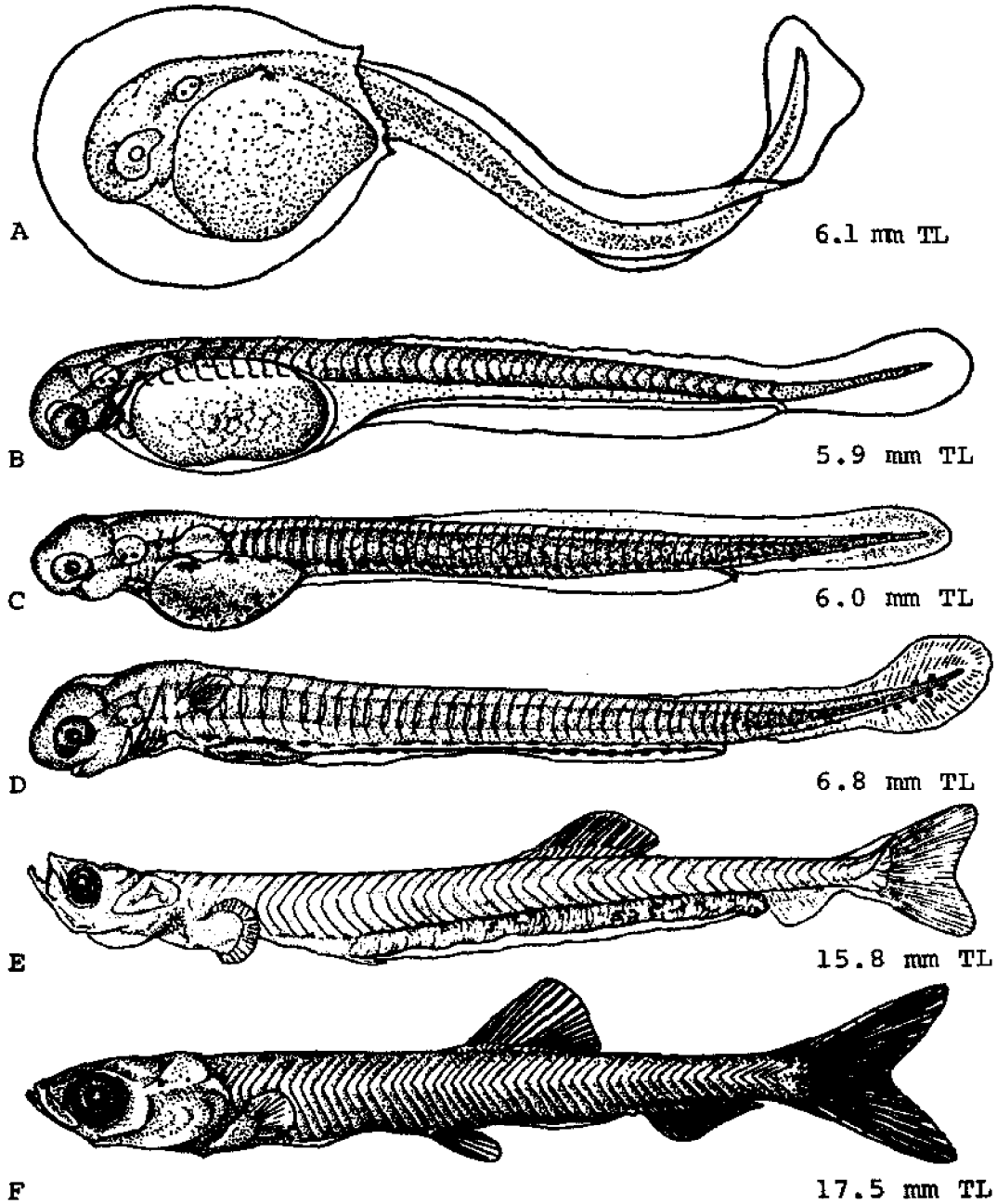

Fig. 43. *Alosa mediocris*, Hickory shad. A. Yolk-sac larva, hatching, 6.1 mm TL, 48 hours after fertilization. B. Yolk-sac larva, 5.9 mm TL, recently hatched. Irregular margin of dorsal finfold typical. C. Yolk-sac larva, 6.0 mm TL, 1 day after hatching. Pectoral buds paddle-shaped. D. Larva, 6.8 mm TL, 3 days. E. Larva, 15.8 mm TL. Intestine with marked striations along entire length. F. Juvenile, 17.5 mm TL. Preanal finfold present. (*A-F, Mansueti, R. J., 1962b: figs. 4, 5, 6, 8.*)

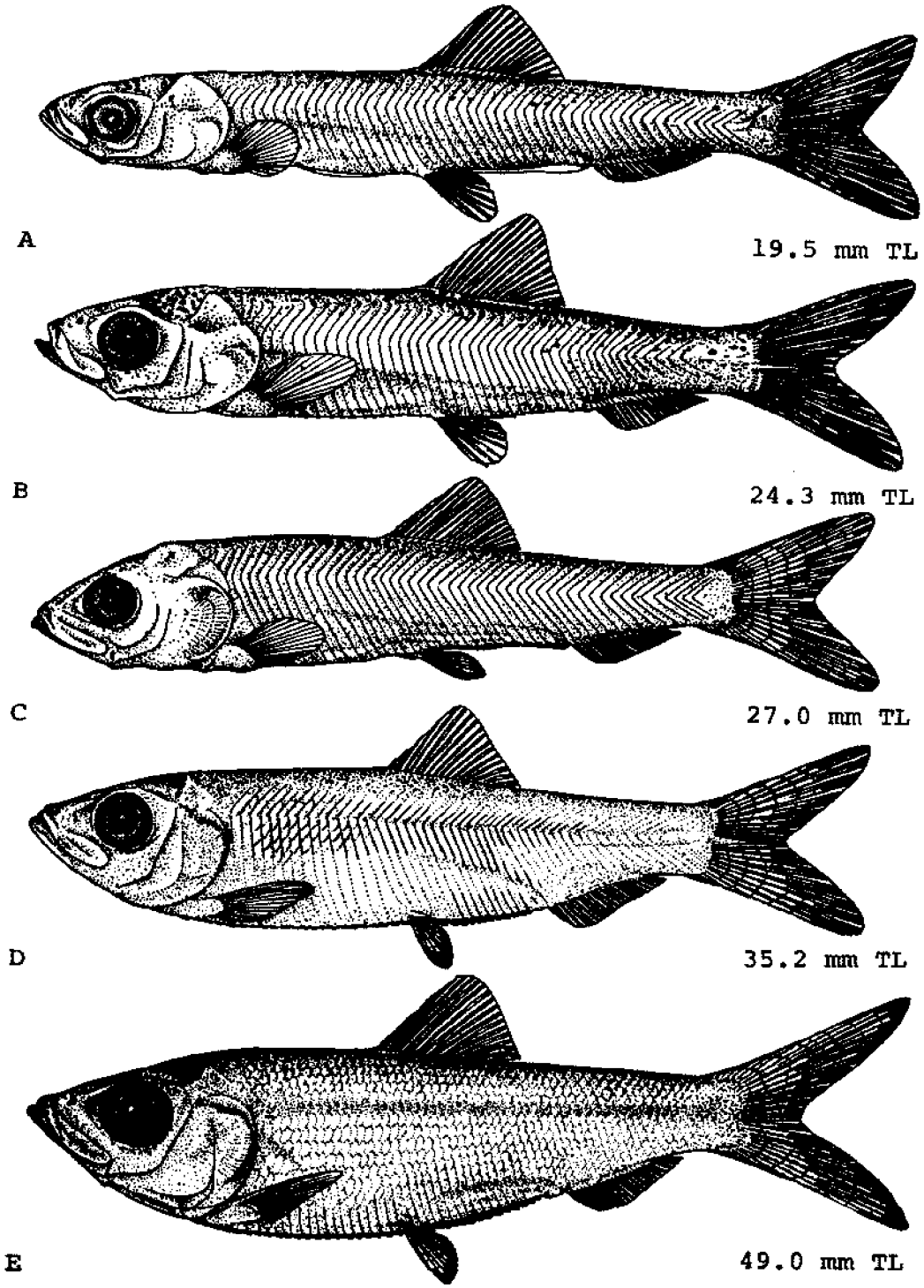

Fig. 44. *Alosa mediocris,* Hickory shad. A. Juvenile, 19.5 mm TL. Preanal finfold present. B. Juvenile, 24.3 mm TL. Scutes formed. C. Juvenile, 27.0 mm TL. Gill rakers visible through operculum. D. Juvenile, 35.2 mm TL. Scales in pectoral region; axial scale formed. E. Juvenile, 49.0 mm TL. Scalation almost complete; light lateral band of pigment present; adipose eyelid formed. (*A-E, Mansueti, R. J., 1962b: figs. 8, 9.*)

Preanal myomeres 37–40 at 1 day, 36–44 at 2 days; 5 branchial arches.[3]

Proportions as percent SL: Depth ca. 13–16; snout-vent distance ca. 80–86; head length ca. 9–10. Eye diameter ca. 40–47% head length.[3]

Yolk large, restricted to anterior 1/4 of body and characterized by granular appearance. Eye large, unpigmented at hatching; hyomandibular, Meckel's cartilage, auditory vesicles present; mouth open, but lacking esophageal connection; cleithrum and gill clefts formed or forming by 2nd day. Pectoral buds prominent at hatching; leaf-like at 1 day.[3]

Pigmentation: Initially limited to few chromatophores along gut. At 1 day, abdomen with small melanophores; 18–20 elongate melanophores along ventral surface of gut between yolk and anus; few dots on dorsal surface; eye darkly pigmented. At 3 days, single line of 18–25 melanophores on upper surface of intestine, bifurcating at yolk and extending to region below origin of pectoral fin; few melanophores posterior to anus and on caudal finfold.[3]

PUTATIVE LARVAE

Size range ca. 6.5–18.0 mm TL. Average preanal myomeres 39 at 6.5–7.0 mm, 38 by end of stage.[3]

Body elongate; anus 4/5 TL from head. Dorsal fin first evident at ca. 9.0 mm, anal at 14.0 mm, and pelvics at 13.0 mm.[3]

Pigmentation: Initially as in yolk-sac larvae; by end of stage, melanophores on ventral part of body from gular region to area above anal fin.[3]

JUVENILES

Minimum size ca. 18.0 mm TL.

Gill rakers on lower limb of first arch 11–20. Total myomeres 50–54; predorsal myomeres ca. 17–26; preanal myomeres 36–42.[3]

Proportions as percent SL: Greatest depth 10.9–20.8; snout-vent distance 74.5–81.8; head length ca. 22–30. *Proportions as percent HL: Eye diameter ca. 20.0–30.6;* mandibular length ca. 42.6–51.6.[3]

Preanal finfold retained to ca. 20.0 mm; scutes evident at 24 mm. Scales first evident ca. 35 mm, originating in pectoral region; pelvic axial scales present or absent. Adipose eyelid evident at ca. 49 mm.[3]

Pigmentation: An ill-defined double row of melanophores along dorsum; caudal fin with melanophores. By 33.0 mm TL dorsum with numerous melanophores; a conspicuous U-shaped blotch behind eyes.[3]

AGE AND SIZE AT MATURITY

Males mature by 287 mm; females 320 mm TL.[3]

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Alosa pseudoharengus (Wilson), Alewife

ADULTS

D. 12[27]–19[2] (usually 13–14[27]); A. 15[12]–21[2] (usually 17–18[27]); P. 13–16[2] (usually 16); V. 10;[27] scales in lateral series 42[2]–54,[12] longitudinal scale rows between base of pelvics and base of dorsal 14;[2] prepelvic scutes 17–21 (usually 19–20);[27] postpelvic scutes 12[2]–17[42] (usually 14–15[27]); vertebrae 46–50; gill rakers on lower limb of first arch 38[2]–46;[46] branchiostegals 7.7.[27]

Proportions as percent TL: Body depth 17.8–21.7; head length 20.3–23.7; anal fin base 10.3–12.0.[27] Proportions as percent SL (based in part on juvenile specimens): Body depth 23.5–35.5; head length 22.6–34.8; eye diameter 5.0–12.0.[2] Proportions as percent HL: Eye diameter 26.1–32.0; snout length 26.9–35.7; interorbital width 15.7–21.6.[27]

Body strongly compressed, deep.[27] Mouth oblique;[2] anterior end of lower jaw thick, heavy, extending beyond upper (closed gape); maxillary extending to below middle of eye;[27] eye large, longer than snout.[2] Dorsal fin origin slightly in advance of pelvic fin; anal fin origin about equidistant between pelvic base and caudal base; pelvic fin usually equidistant between base of pectoral fins and anal fin origin; lower lobe of caudal fin slightly longer than upper.[29]

Pigmentation: Grayish green above; sides silvery; upper scale rows sometimes with more or less definite dusky lines; a dark shoulder spot; fins pale, yellowish, or green; peritoneum pale or silvery, often with dark punctations.[2] Sea run individuals with golden cast on head and upper body.[27]

Maximum length: 380 mm.[2]

DISTRIBUTION AND ECOLOGY

Range: Newfoundland[28] to South Carolina;[14] landlocked populations in the Great Lakes, Finger Lakes in New York,[2] and other freshwater lakes.[8,27]

Area distribution: Virtually all streams tributary to Chesapeake Bay;[7] Virginia,[9] Delaware,[20] and New Jersey.[10]

Habitat and movements: Adults—a schooling species whose oceanic movements are apparently restricted to coastal areas proximal to natal estuaries; maximum depth 110–145 m; maximum distance from land ca. 130 km;[8] sometimes in coastal ponds.[5]

Anadromous, migrations begin in late February or early March in Chesapeake Bay,[2] March in Connecticut,[26] late March[40] to April in Rhode Island,[44] and May in Nova Scotia.[42] Timing of movement into spawning streams may be dependent on local conditions.[44] In North Carolina spawning runs occur primarily from dawn to noon and from dusk to midnight.[34] Entry into streams tributary to Pausacaco Pond, Rhode Island takes place from 1300 to 1800 hrs. only.[40] In the Annaquatacket River, Rhode Island near Hamilton Reservoir, movement into streams generally occurs in late afternoon at low temperatures, early morning at high temperatures, at both periods during peak of spawning run; high midday activity restricted to overcast days; nocturnal movement associated with abnormally high temperatures. Temperatures below 8 C and above 18 C (24 hour average) result in little movement into spawning streams.[44] Peak movement takes place at ca. 13.0 C in North Carolina[34] and 14.0–15.5 C in Rhode Island.[44] Return to sea shortly after spawning.[2,46] In Lakes Ontario and Michigan, inshore movement begins in April, ends in late July and late August respectively; individuals first appear in shallow water during daylight, later mainly at dusk and after dark;[15,21] move towards deeper waters (46–91 m) in September, abundant there from December through March.[36] Taken at temperatures as high as 32 C in Congamond Lake, Massachusetts.[35]

Larvae—remain in vicinity of spawning grounds;[2] forming schools at sizes less than 10 mm, within one to two weeks after hatching.[46]

Juveniles—pass slowly down Chesapeake drainage system until fall when main seaward migration occurs (WLD). Emigration occurs from late June to late October in Connecticut,[40] mid-June or early July to October (continuing in small numbers as late as December) in Rhode Island,[43,46] throughout summer in Gulf of Maine.[8] Migrations take place during daylight hours;[46] related to increased flow, decline in temperatures and precipitation.[43] Some overwinter in Chesapeake[2] and Delaware bays,[31] most go directly to sea.[2] First year or so in salt water tend to remain near surface.[8] Larger juveniles appear in rivers with spawning adults.[40] In Lake Michigan young-of-the-year found at midlevels until late summer or early fall; in large numbers on bottom at depths to 46 m in October and to 36 m in November; age group I essentially pelagic, but occasionally on bottom in substantial numbers in spring and fall; age group II more commonly on bottom;[36] migrate inshore in spring, found in shallow water after dark, in ca. 2–3 m during daylight.[27]

SPAWNING

Location: Large rivers;[8,16] streams only a few feet wide;[1,16] small ponds, including barrier beach ponds;[5] sometimes in rapid water ca. 61 cm deep over coarse

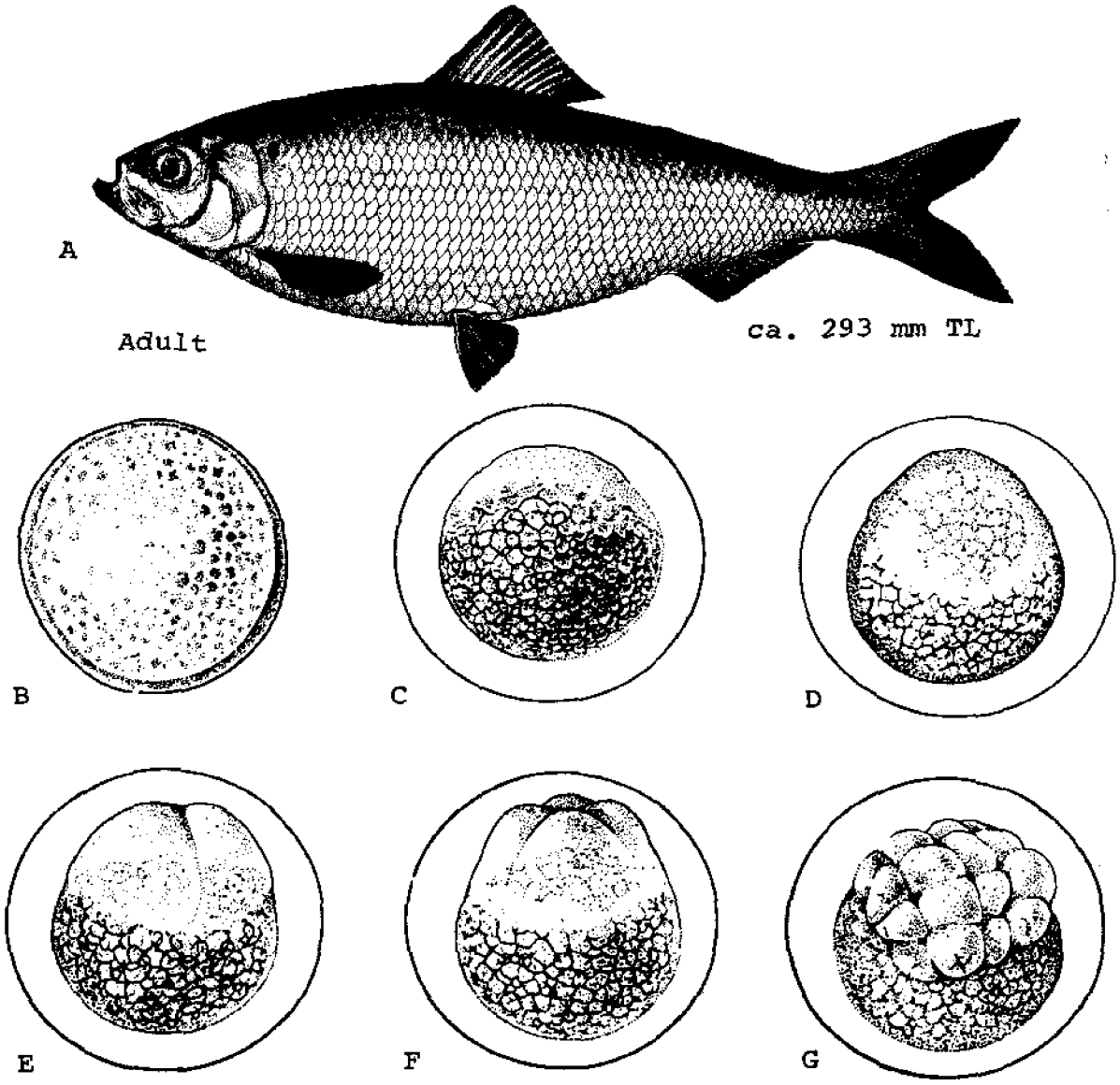

Fig. 45. *Alosa pseudoharengus*, Alewife. A. Adult, female ca. 293 mm TL. B. Egg, ripe unfertilized. Diameter 0.9 mm. C. Egg, blastodisc, ca. 45 minutes. This and all following eggs ca. 1.0 mm in diameter, incubated at average temperature of 20 C. D. Egg, blastodisc, oblique view. E. Egg, two-cell stage, ca. 1 hour. F. Egg, four-cell stage, ca. 1 hour. G. Egg, sixteen-cell stage, 3 hours. (*A, Goode, G. B., et al., 1884: pl. 207. B-G, Mansueti, A. J., and J. D. Hardy, Jr., 1967: figs. 26, B-C5.*)

stones, sand and gravel;[3] usually in sluggish water 15–30 cm deep;[8,18,30] over detritus covered bottom with attached vegetation, sticks or other organic matter; occasionally over hard sand bottom;[46] sometimes at depths of ca. 3 m.[17] In general ascend freshwater streams further than *A. aestivalis*.[39]

Season: Generally precedes *A. aestivalis* by 3–4 weeks;[7] spawning peaks separated by 2–3 weeks.[31] Peak occurs in early April in North Carolina.[34] Season late March through April in Maryland (AJL) with spawning lasting only a few days for each spawning group;[8] early April through mid-May (peak last two weeks in April) in Delaware River;[31] late March or early April to mid-July (peak early May through mid-June) in Connecticut;[40] peak centered around May 1 in Rhode Island;[46] late May to mid-August in Finger Lakes, New York;[6] June through early August in Lake Michigan.[21]

Time: Observed both diurnally [3,17] and nocturnally,[17] but apparently with greatest activity at night.[15,17]

Temperature: Ca. 10.5[37]–21.6 C.[22] Apparently cessation of spawning activity above 27.8 C.[25]

Fecundity: Variously estimated, 2180–10,011 (Lake Cayuga, New York); [13] 11,147–22,407 (Lake Michigan); [21] average 102,800 (Potomac River, Maryland); [1] 48,000–360,000, average 229,000 (Bride Lake, Connecticut).[26]

EGGS

Location: Broadcast at random; demersal,[2] semidemersal [41] or pelagic; [22] within several hours after spawning adhesive property lost and eggs enter water column.[46]

Green unfertilized eggs: Uneven spheres with thin transparent capsules; diameter 0.80–0.95 (average 0.90 mm); yolk diameter 0.07–0.85 (average 0.80 mm); yolk dark amber, opaque, granular, although not as much so as in fertilized eggs.[2]

Fertilized eggs: Diameter 0.80 [22]–1.27 [23] mm; capsule slightly rippled at high magnification. Yolk granular, bright translucent amber to pale yellow, lacking oil globules [2] containing tiny oil droplets.[22]

EGG DEVELOPMENT

At 1.8 mm, embryo with optic cup, partially pigmented, 18 somites. At 2.6 mm embryo with primordial gill arches, 37 somites.[22]

Incubation Time (hours)	Temperature (C)	Development
0	7.8	fertilization
8	9.4	blastula
12	9.4–10.3	gastrula
24	9.5–12.2	early embryo
38	9.5–10.0	tail-bud embryo; eyes and myomeres visible.
46	9.5–10	embryo almost

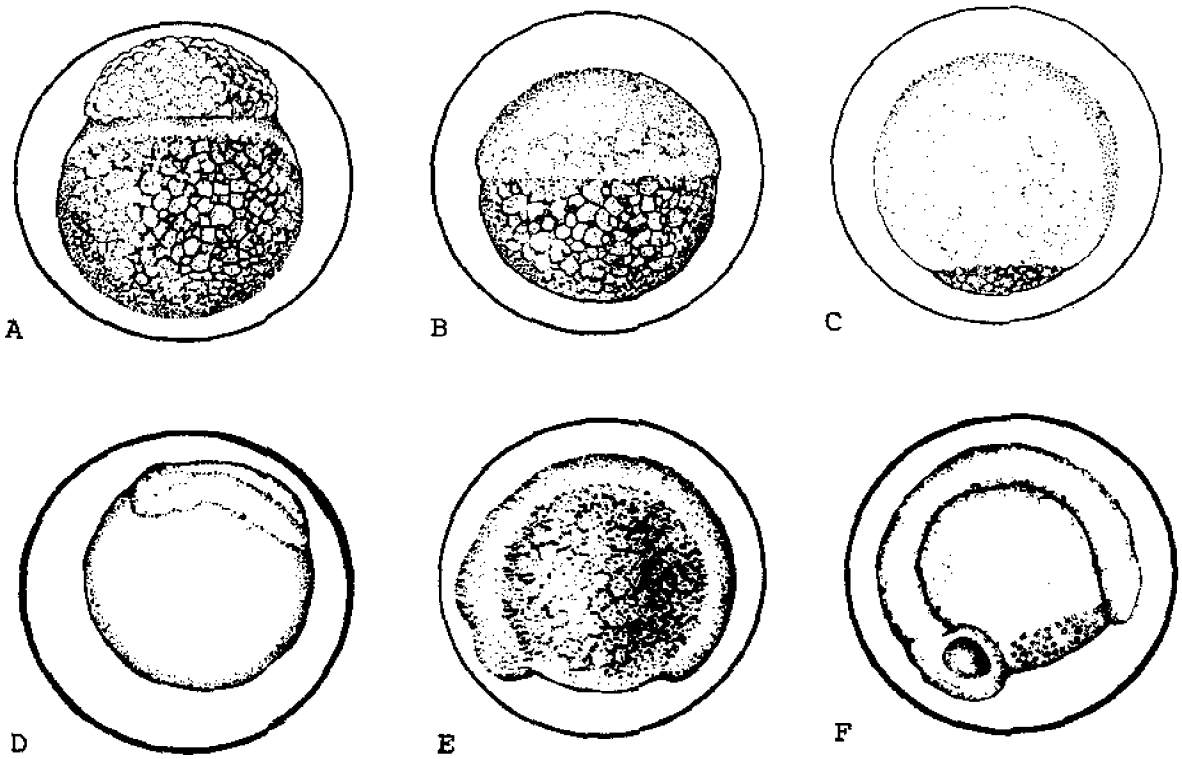

Fig. 46. *Alosa pseudoharengus*, Alewife. A. Egg, morula, 4 1/2 hours. Diameter ca. 1.0 mm; incubated at average temperature of 20 C. B. Egg, early gastrula, ca. 11 hours. Diameter ca. 1.0 mm; incubated at average temperature of 20 C. C. Egg, late gastrula, 12–15 hours. Diameter ca. 1.0 mm; incubated at average temperature of 20 C. D. Egg, length of embryo 0.5 mm. Diameter of yolk 0.76 mm. Diameter of egg 1.06 mm. E. Egg, early embryo, one day. Blastopore closed, brain folds developed. Diameter ca. 1.0 mm; incubated at average temperature of 20 C. F. Egg, oil droplets in yolk, 18 somites, diameter 1.06 mm. (*A-C, E, Mansueti, A. J., and J. D. Hardy, Jr., 1967: figs. 26, C6–C9. D, F, Norden*, C. R., 1967b: figs. 1A–1B.)

		completely encircles yolk.
55	9.6–10.2	tail-free stage; heart beating.
81.5	12.2	hatching begins [37]

At average temperature of 20 C: [2]

45 minutes	blastodiscs.
1 to 3 hours	2- and 4-cell stages.
3 hours	16- and 32-cell stages.
4 hours, 30 minutes	32-cell, 64-cell, and morula stages.
11 hours	gastula; blastodermal tissue around 1/2 of yolk; yolk granulations less distinct.
12 to 15 hours	blastopore formed; yolk paler; less granular.
Ca. 24 hours	blastopore closed; embryo differentiated; yolk no longer granular.
65 hours	tail free; eyes, lenses, auditory vesicles, and 28 myomeres formed.
113 hours	heart, otoliths, pectoral buds, finfold, intestine, and vent formed; brown chromatophores over ventral 2/3 of yolk, sparsely scattered over eye, and in a line along ventral surface of gut; tail completely around yolk.[2]

Incubation: 2.1 days (average), at 28.9 C; 3.7 days (average), at 21.1; [25] 3–5 days at 20.0 C (AJL); 3.4–5 days at 10.0–12.2 C; [37] 6 days at 15.6 C; [2] 15 days (average), at 7.2 C.[25]

Temperature limits: Lower ca. 6.7 C, upper between 29.4–30.6 C; optimum 17.8 C. Percent deformed larvae after incubation temperature below 10.6 C, 69%; above 10.6 C, 1.7%.[25]

YOLK-SAC LARVAE

Hatching length 2.5 [45]–5.0 mm TL,[19] average size at end of stage 5.1 mm TL.[21] Maximum size at end of stage 5.8–6.0 mm TL, duration of stage 2 [37]–5 days (AJL).

Recently hatched larvae, preanal myomeres 37–41 ($\bar{x}$ 39); [37] at 3.3–5.0 mm TL, postanal myomeres 7–8.[22]

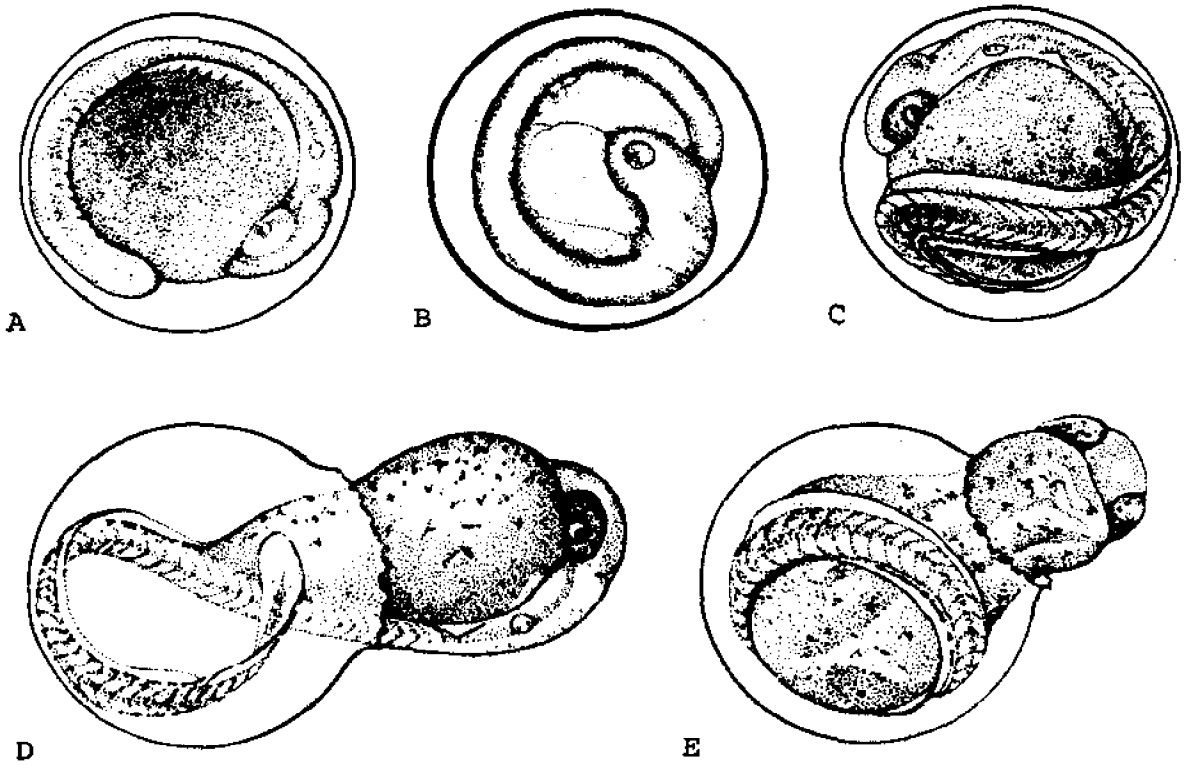

Fig. 47. *Alosa pseudoharengus*, Alewife. A. Egg, tail-free embryo, 3 days. Total myomeres 28. Diameter ca. 1.0 mm; incubated at average temperature of 20 C. B. Late stage embryo. Diameter of egg 1.06 mm. C. Late embryo, 5 days. Pigmentation over eyes and yolk. This and all following eggs ca. 1.0 mm in diameter, incubated at average temperature of 20 C. D. Hatching embryo, ca. 3.5 mm TL, 5 days. E. Hatching embryo, ca. 3.5 mm TL, 5 days. (*A, C-E, Mansueti, A. J., and J. D. Hardy, Jr., 1967: figs. 26, C10–C13. B, Norden, C. R., 1967b: fig. 1C.*)

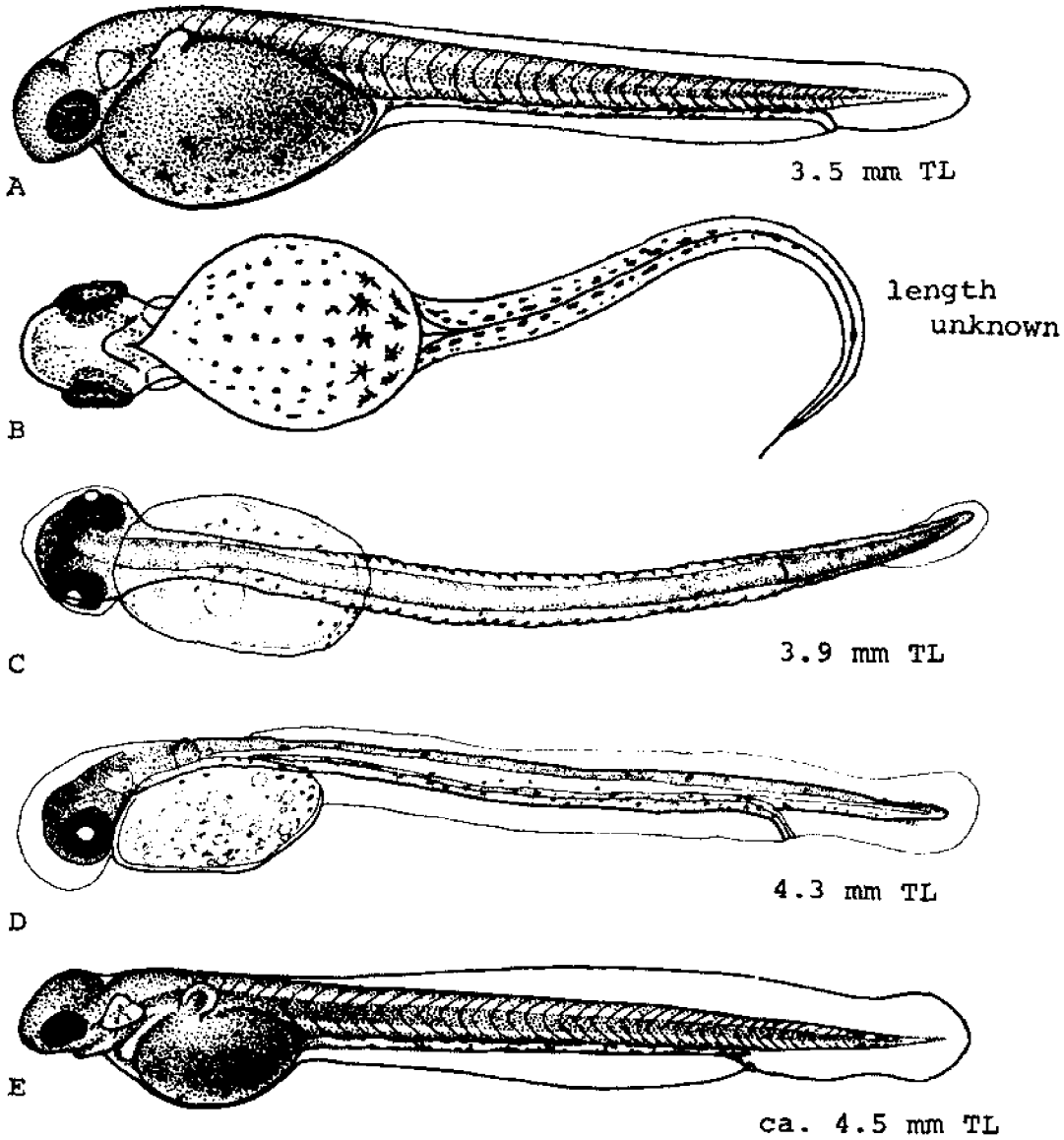

Fig. 48. *Alosa pseudoharengus*, Alewife. A. Yolk-sac larva, 3.5 mm TL, recently hatched. Notochord reticulated. B. Yolk-sac larva, ventral view, recently hatched. C. Yolk-sac larva, 3.9 mm TL, ventral view, ca. 24 hours. D. Yolk-sac larva, 4.3 mm TL, recently hatched. E. Yolk-sac larva, ca. 4.5 mm TL, one day. (*A, B, E, Mansueti, A. J., and J. D. Hardy, Jr., 1967: figs. 27, A-C. C, D, Cianci, J. M., 1969: figs. 2A, C.*)

Proportions expressed as percent TL (at hatching): Head (average) 11.1; snout to vent (average) 79.8. Proportions expressed as percent HL: Eye (average) 37.1.[37] Preanal to postanal length ratio: 4.1–5.1 to 1 at hatching, 3.2–3.8 to 1 by end of stage.[45]

Head deflected at hatching, straight or deflected at 1 day (AJL),[22] straight at 2 days; mouth absent,[87] or barely evident at hatching, nonfunctional at 1 day (AJL), functional at 2 days with maxillary extending under anterior edge of eye.[37] Yolk initially hemispherical, pale amber (AJL), granular; several oil droplets around periphery,[22] or throughout, absent at 1 day;[37] yolk 1/2 absorbed by 1 day (AJL) about as wide as deep at 3 days.[37] Auditory vesicles triangular at hatching, much enlarged by 2nd day (AJL); otoliths visible at hatching. Operculum visible, branchiostegal rays appearing at 1 day.[37] Pectoral fin bud present immediately after hatching,[22] rounded at 3 days.[87]

Dorsoventral finfold complete immediately after hatching, extends from second somite, around tail to vent and on to base of yolk sac,[22] reduced at 3 days (AJL).

Pigmentation: In recently hatched specimens pigmentation pattern of yolk variable, typically with ca. 10 rows of melanophores across ventral half of yolk (AJL). Two chromatophores present below pectoral fin insertion, 3–6 posterior. Row of melanophores along dorsal edge of gut from behind yolk sac to myomere 17–19 and on 3–5 myomeres preceding anus. Series of elongate melanophores on ventral edge of gut from myomere 18–20, to anus. Posterior to vent chromatophores irregularly scattered on body above mid-lateral line;[37] 4–7 chromatophores on caudal fin, usually 2 above notochord, 3–5 below.[22] At 1 day pigment reduced on yolk sac and above mid-lateral line, eye completely pigmented,[37] flecked with gold (AJL); melanophores fewer but more pronounced and in more defined rows on upper and lower gut. At 2 days after hatching chromatophores concentrated along posterior and ventral edges of yolk sac; 2 elongate chromatophores below pectoral fin, chromatophores posterior to vent sparse, small. At 3 days after hatching anterior yolk-sac melanophores form an elongate dash in throat region along ventral surface. Upper gut melanophores often appear as thin extended line.[37]

LARVAE

Size range described 4.3–19.9 mm SL.

Preanal myomeres at 4.0–5.9 mm SL 40–42 (usually 41), at 6.0–13.9 mm SL 40–43 (usually 41), at 14.0–19.9 mm SL 39–41.[32] Myomeres between cleithrum and vent, at

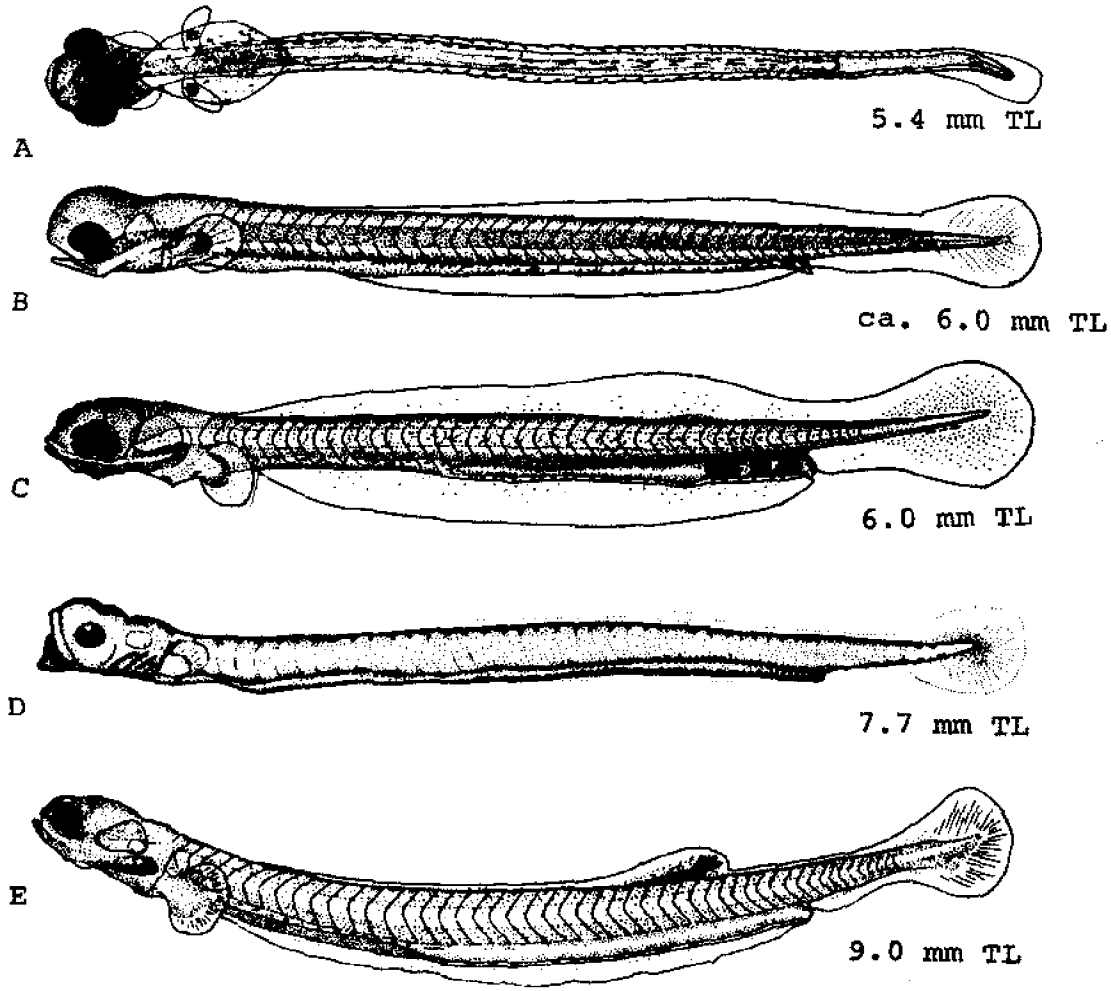

Fig. 49. *Alosa pseudoharengus*, Alewife. A. Yolk-sac larva, 5.4 mm TL, ventral view. B. Larva, ca. 6.0 mm TL. C. Larva, 6.0 mm TL, 5.9 mm SL. D. Larva, 7.7 mm TL. E. Larva, 9.0 mm TL, 8.8 mm SL. (*A, Cianci, J. M., 1969: fig. 4C. B, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 27E. C, E, Chambers, J. R., J. A. Musick, and J. Davis, 1976: figs. 5A, 6A. D, Norden, C. R., 1967: fig. 3B.*)

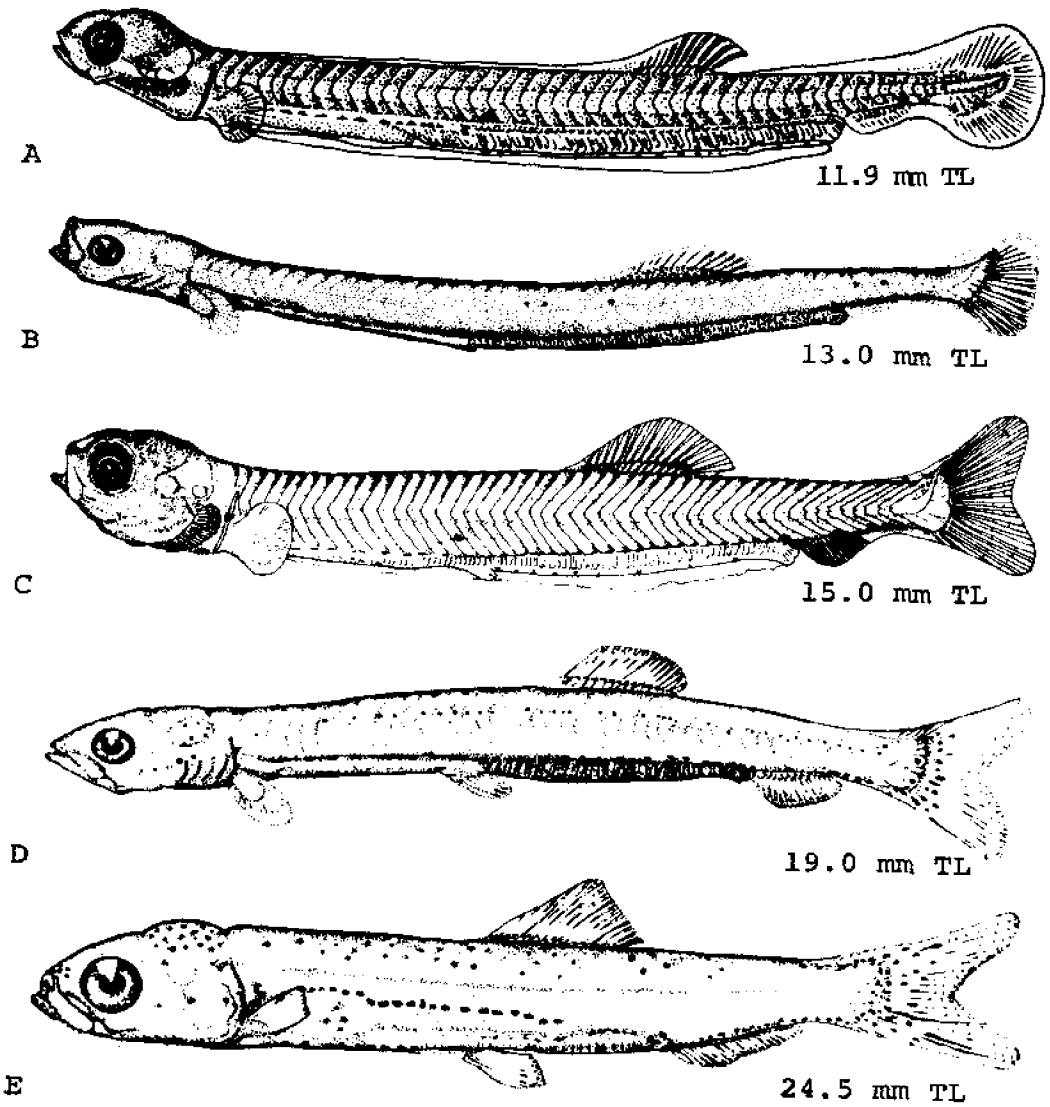

Fig. 50. *Alosa pseudoharengus*, Alewife. A. Larva, 11.9 mm TL, 11.5 mm SL. B. Larva, 13.0 mm TL. C. Larva, 15.0 mm TL, 13.6 mm SL. D. Late stage larva, 19.0 mm TL. E. Juvenile, 24.5 mm TL. (*A, C, Chambers, J. R., J. A. Musick, and J. Davis, 1976: figs. 7A, 8A. B, D, E, Norden, C. R., 1967b: figs. 4, 5.*)

4.0–5.9 mm SL 39–40 (usually 39), at 6.0–13.9 mm SL 38–41 (usually 39 or 40) at 14.0–19.9 mm SL 35–39. Myomeres between insertion of dorsal fin and posterior margin of vent 7–9 ($\bar{x}$ 8.0).[33] Predorsal myomeres 24–27.[22]

Preanal to postanal length ratio ca. 3.5:1 at 6.7 mm TL; ca. 4.0:1 at 14.8 mm TL.[32]

Body long, narrow; head variable, rounded at ca. 6.0[1] mm, flattened by 8th day; lower jaw projected beyond upper at 8 days (AJL), and at 9.0 mm TL;[37] mouth terminal at 6.0 mm (AJL); at ca. 4.5 mm TL maxillary reaches anterior 1/3 of eye,[22] lower jaw with small teeth at 16.5 mm.[19] Notochord flexion occurs at ca. 9 mm SL. Gut straight at 9.0 mm TL,[32] striated at 10.4[37]–15 mm (AJL). At 4.3–11.9 mm TL anus at beginning of posterior 1/5 of total body length;[22] gas bladder visible at 15.0 mm TL[32] and probably earlier (JRC). Caudal and pectorals with or without incipient rays up to 5.4 mm (AJL); preanal finfold retained to 16.5 mm.[10]

Pigmentation: At 6.0 mm, melanophores in a row on dorsal surface of anterior half of intestine and on dorsal and ventral midline of tail near developing caudal fin. At 8 days, ca. 12 melanophores along dorsal surface of anterior half of gut, 22–24 on ventral surface of posterior

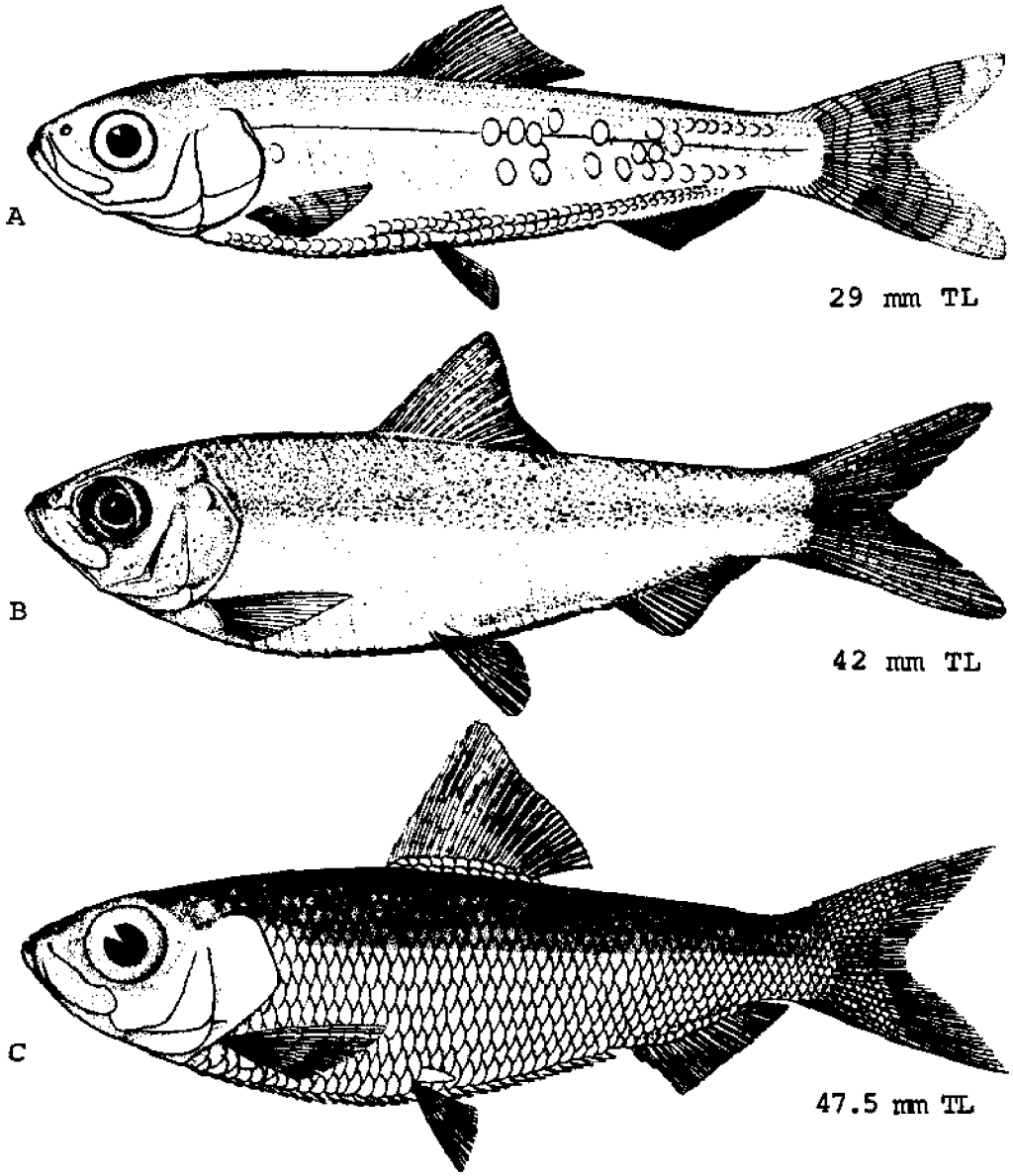

Fig. 51. *Alosa pseudoharengus*, Alewife. A. Juvenile, 29 mm TL, 22 mm SL. B. Juvenile, 42 mm TL, 34 mm SL. C. Juvenile, 47.5 mm TL. (*A, C, Hildebrand, S. F., 1963a: fig. 83. B, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 28B.*)

half of gut; scattered melanophores on lateral body wall and in area behind eye (AJL). At 9.0 mm TL melanophores on upper gut more expanded, caudal melanophores more stellate, 1 large melanophore dorsal to pectoral fin insertion.[87] At 10.4 mm TL melanophores along ventral surface between pectoral fins forming unjoined V.[32,87,47] At 12.1 mm pigmentation increasing along upper and lower gut with small chromatophores reappearing above lateral line.[87] By 19.0 mm pigment increased, particularly in area of gills, otic region and caudal fin; dorsolateral row of chromatophores appearing above lateral line.[22]

JUVENILES

Minimum size described 19.1 mm TL.

At 19.1–32.2 mm TL preanal myomeres 33–42; postanal myomeres 9–14; predorsal myomeres 15–23.[22]

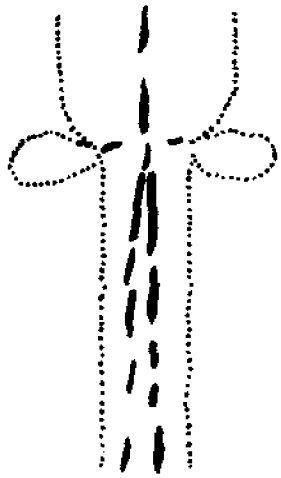

Fig. 52. *Alosa pseudoharengus*, Alewife. Ventral pigment pattern; separates this species from *Alosa sapidissima* larvae up to ca. 13 mm TL. (*Leim, A. H., 1924: fig. 23B.*)

Gill rakers 25–33 at 30–49 mm; 32–36 at 50–69 mm; 30–39 at 70–89 mm; 35–38 at 90–109 mm; 36–40 at 110–129 mm. Body depth 4 times in SL at 29 mm TL; depth adult-like at 100 mm.[2]

At 19.1–32.2 mm TL teeth on maxilla, premaxilla and dentary.[22] At sizes over 35 mm TL gill rakers elongate, closely spaced.[24] Scutes sometimes evident at 22–25 mm TL;[45] scales first evident at 28[18]–29 mm[22] on side of tail along lateral line at about 43rd myomere.[18] At 32.2 mm vent at beginning of posterior 2/5 of body length.[22]

Pigmentation: At 19.1–32.2 mm TL chromatophores increasing on dorsolateral surface from head to caudal fin; pigment on lower jaw, snout tip, top of head, caudal fin and dorsal margin of swim bladder.[22]

AGE AND SIZE AT MATURITY

Freshwater populations mature earlier and at a smaller average size than saltwater populations. In Lake Ontario, males mature at minimum of ca. 1 year and ca. 95.5 mm SL, females at minimum of 2 years and ca. 110 mm SL.[15] Anadromous populations in North Carolina, minimum age 2, most at age 3;[34] in Connecticut, males minimum age 3, most at age 4, females minimum age 4, most at age 5.[38]

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Alosa sapidissima (Wilson), American shad

ADULTS

D. 14 [17]*–21 (usually 18–19)*; [35] *A. 18–25* [17] *(usually 21–22* [35]*)*; C. 7–8+10+9+7; [53] P. 13 [40]–18 [17] (usually 16–17 [35]); V. 8–10; [2] lateral line scales 52–64,[35] scale rows between base of pelvics and anterior dorsal rays 15–16; [4] ventral scutes 34 [43]–40, 19–25 anterior to pelvics, 12 [17]–19 behind; [36] total vertebrae 51 [2]–60,[17] precaudal 18–19, caudal 37–38; [53] gill rakers on lower limb of first arch 59 [4]–76; [5] *branchiostegal rays 7, 7 (rarely 7, 6).*[36]

Proportions as percent SL: Body depth 30.2–48; head length 23–28; eye diameter 3.8–5.7 (may include some *juveniles).*[4] *Proportions as percent TL: Body depth 17.2–*19.4; head length 22.7–24.0. Proportions as percent HL: Eye diameter 27.3–32.0; snout length 26.9–32.0; interorbital width 18.6–21.6.[36]

Body elongate; head broadly triangular; [36] dorsal profile of head nearly straight; [5] mouth oblique; [4] anterior end of jaws about equal with mouth closed; [36] maxillary reaching slightly beyond posterior margin of eye; [5] upper outline of mandible only slightly concave and lacking sharp angle.[7] Teeth small, weak and few in number, on premaxillary and mandible,[36] or absent.[4] Scales large, moderately adherent.[7] Dorsal fin elevated anteriorly, margin slightly concave, origin an eye's diameter or less in front *of pelvics; caudal deeply forked, lobes about equal and* somewhat shorter than head; anal low; axillary scale equal to or little more than 1/2 length of pelvic.[4]

Pigmentation: Greenish or bluish above; [4] *fading to* brown with migration through freshwater; [35] bright silvery on sides; dark shoulder spot sometimes followed by one or more rows of smaller spots; fins pale to greenish,

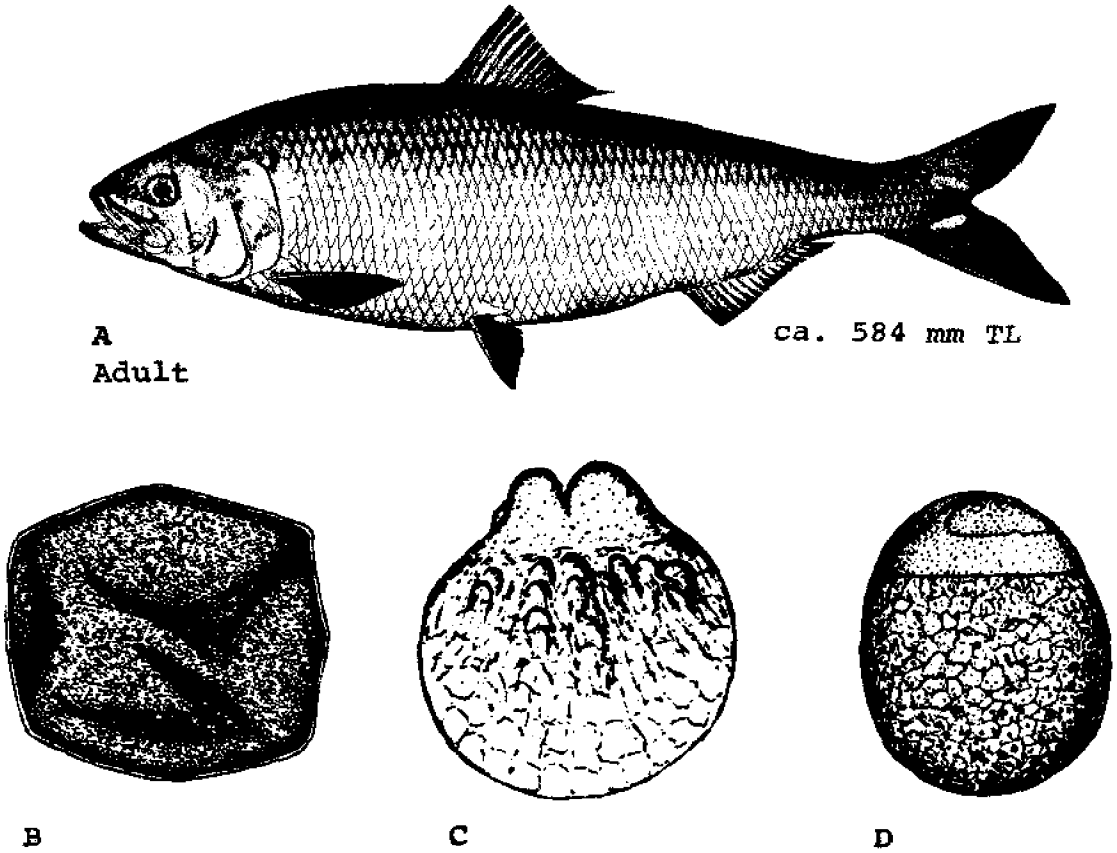

Fig. 53. *Alosa sapidissima,* American shad. A. Adult, ca. 584 mm TL. B. Egg, ca. 1.8 mm. Ripe, unfertilized, not water hardened. C. Egg, 2-cell stage, 1 1/3 hours, egg capsule removed. Diameter ca. 3.5 mm, incubated at 24 C. D. Egg, gastrula, with embryonic shield, egg capsule removed. Diameter ca. 3.5 mm, incubated at 24 C. (*A, Goode, G. B., et al., 1884: pl. 212. B-D, Ryder, J. A., 1887: figs. 68, 78, 101.*)

dorsal and caudal sometimes dusky; peritoneum pale to silver.[4]

Maximum length: Ca. 760 mm.[6]

DISTRIBUTION AND ECOLOGY

Range: Southeastern Labrador [84] to St. Johns River, Florida; [7] introduced on Pacific coast and now established from San Diego, California, to Alaska; [18,27] also eastern shores of Kamchatka, U.S.S.R.[21]

Area distribution: "Virtually all streams tributary to Chesapeake Bay"; [5] New Jersey, Delaware, and Virginia.[6]

Habitat and movements: Nonspawning adults—waters of continental shelf, appearing in schools near surface in spring, summer, and fall; [7] also recorded in brackish estuaries; [4] rarely in freshwater outside the spawning season,[8] however, in Delaware River, many remain upstream well into summer and apparently into the fall.[47] Maximum depth 160–230 m.[35] Maximum distance from coast 177 km.[4]

Spawning adults—anadromous, ascending parental rivers to spawn [10,11,19] with runs of 825 km from sea reported.[33] Repeat spawners virtually absent in rivers of Chesapeake Bay.[44,50] Adults from Connecticut River to Chesapeake Bay migrate northward of Gulf of Maine, those from Canada move southward to same area with both populations remaining there throughout summer and fall. During winter this mixed population scatters throughout middle Atlantic area.[19] Distribution corresponds closely to position of 13.0–18.0 C isotherms.[39] As spawning season approaches schools move shoreward and to native streams.[19] Atypical "runs" may occur in November and December in Chesapeake Bay.[5]

Larvae—fresh to brackish water; [2] most abundant at surface; [54] maximum salinity ca. 7.0 ppt; [2] movements generally downstream.[4]

Juveniles—form schools at 20–30 mm TL and gradually move downstream; [47] movements from spawning grounds to nursery areas influenced by current and rising temperatures.[38] In nontidal waters prefer deep pools well away from shoreline, occasionally found in shallow riffles. In Delaware River, largest juveniles occur furthest downstream during summer; leave nontidal waters at ca. 80 mm, very few present after October.[47] Majority leave Connecticut River in late September and early October, migration complete by early November.[54] Emigrate from streams and rivers as temperatures drop below 15.5 C [39] to ocean,[6] probably joining other migrating juveniles and adults.[39] Some remain in estuarine waters such as Chesapeake Bay for first year, in northern localities tend to stay close inshore for at least first year.[4] One and two year old shad are occasionally taken in brackish and fresh water in Potomac River.[11] Immature shad typically remain in the ocean for three [1] to six [19] years, probably spending winters in middle Atlantic area migrating to Gulf of Maine each summer.[35] In autumn and early winter, may not survive prolonged exposure at temperatures of ca. 4–6 C; [45] upper natural temperature limit may be ca. 30 C.[41] Equilibrium usually not immediately lost until dissolved oxygen level drops below 3.0 mg/l; at 0.6 mg/l, immediate mortality evident.[47]

SPAWNING

Location: Mostly in tidal freshwater, less frequently in nontidal water (WHM); possibly in brackish water in California.[2] Usually in river areas dominated by extensive flats; [13] also over sandy or pebbly shallows; [4,15] frequently near mouths of creeks; [1,5] in water clear to very turbid, in current less than 0.3 to more than 0.9 m/sec, in depths of 0.9–12.2 m.[35] Eggs absent at dissolved oxygen levels less than 5 ppm.[54]

Season: First runs in St. Johns River, Florida in November; [4] earliest individuals arrive in Maryland streams in February, but most abundant in April [1] with spawning activity apparently continuing for "several weeks"; [6] spawning occurs from mid-May to July (peak late May to mid- or late June) in Delaware River.[46,47] Spawning may continue until May or June in California,[24,25] and in more northern localities of the east coast as late as June [23,29,30] or July.[42]

Time: Probably all hours of day and night with greatest activity apparently between noon and midnight [1,2,13] or from sunset to midnight.[26] Spawning probably occurs at night in clear water, begins later during day, or occurs all day in turbid rivers.[46]

Temperature: Peak movement into rivers takes place at temperatures near 18.5 C,[39] few enter at temperatures of 4 C and below.[14] Spawning reported from 8–26 C,[35] generally occurs at 12 [16]–21 C.[35]

Fecundity: 58,534 [52]–659,000.[16] Reports of lower fecundities (25,000–30,000) are apparently in error.[12,32] Mean population fecundity (total annual egg production of the average female): St. Johns River, Florida, 412,000; York River, Virginia, 262,000; Connecticut River, Connecticut, 269,000; St. John River, New Brunswick, 155,000.[50]

EGGS

Location: Demersal,[1,4] or found throughout water column; [54] deposited at random, dropped "loosely and singly to the bottom"; [4] increase in diameter due to water hardening may lodge eggs in bottom rubble.[47]

Unfertilized eggs: Ca. 1.8 mm in diameter; [8] pale amber; with wrinkled egg capsule; micropyle single.[3]

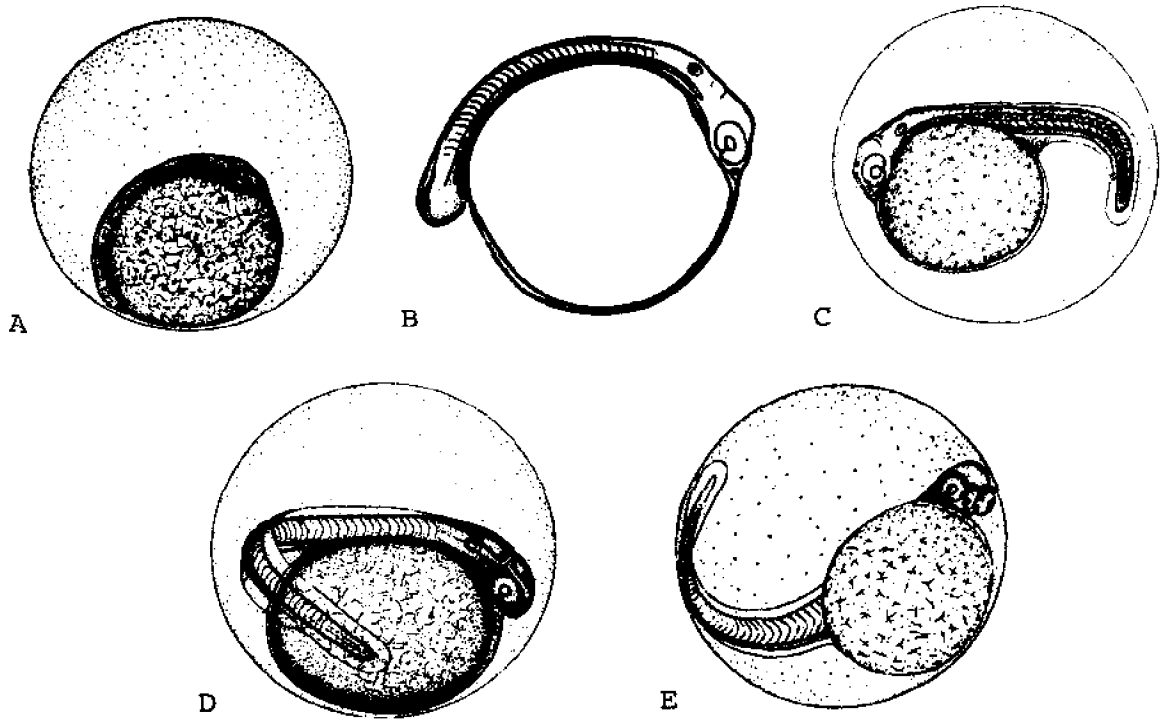

Fig. 54. *Alosa sapidissima*, American shad. A. Egg, just after blastopore closure; 20 myomeres visible. This and subsequent eggs ca. 3.5 mm in diameter, incubated at 24 C. B. Egg, tail-free embryo, egg capsule removed; 32 myomeres visible, heart thickened dark area just posterior to eye. C. Egg, 44 hours. D. Egg, ca. 48 hours. E. Egg, ca. 72 hours. Yolk covered with stellate chromatophores; mouth open; rudimentary gill arches and pectoral buds formed. (*A-E, Ryder, J. A., 1887: figs. 102, 126, 127, 136, 141.*)

Fertilized eggs: Transparent, pale amber or pink,[1] initially adhesive,[47] later nonadhesive,[4] spherical,[3] 2.5[28]–3.8[54] mm in diameter. Yolk distinctly granular; perivitelline space ca. 1/2 egg radius.[15]

EGG DEVELOPMENT

At ca. 24 C:[15]

Ca. 30 minutes	blastodisc formed.
Ca. 1 hour, 20 minutes	first cleavage furrow.
Ca. 2 hours	second cleavage.
Ca. 2 hours, 30 minutes	third cleavage.
4 to 5 hours	morula completed.
Beyond 5 hours	blastula stage brief; blastocoel kidney-shaped when viewed from above, soon becoming crescent-shaped. Three or 4 somites evident at time of closure of blastopore; Kupffer's vesicle, optic and auditory vesicles, choroid fissure evident shortly thereafter; tail bud stage with ca. 32 somites.
44 hours	yolk pigmented and finfold well formed.
Ca. 48 hours	tail recurved and incipient pectoral fins evident.[15]

At 16–17 C:

6 hours	blastula.
20 hours, 30 minutes	late gastrula.
38 hours	early embryo.
42 hours	tail-free embryo.[15]

Incubation: Two days at ca. 27 C,[20] to 17 days at ca. 12 C.[3]

Optimum conditions for development: Temperature ca. 17 C, salinity ca. 7.5 ppt, and darkness.[2]

Maximum hatch and survival of eggs and larvae, 15.5–26.5 C.[39]

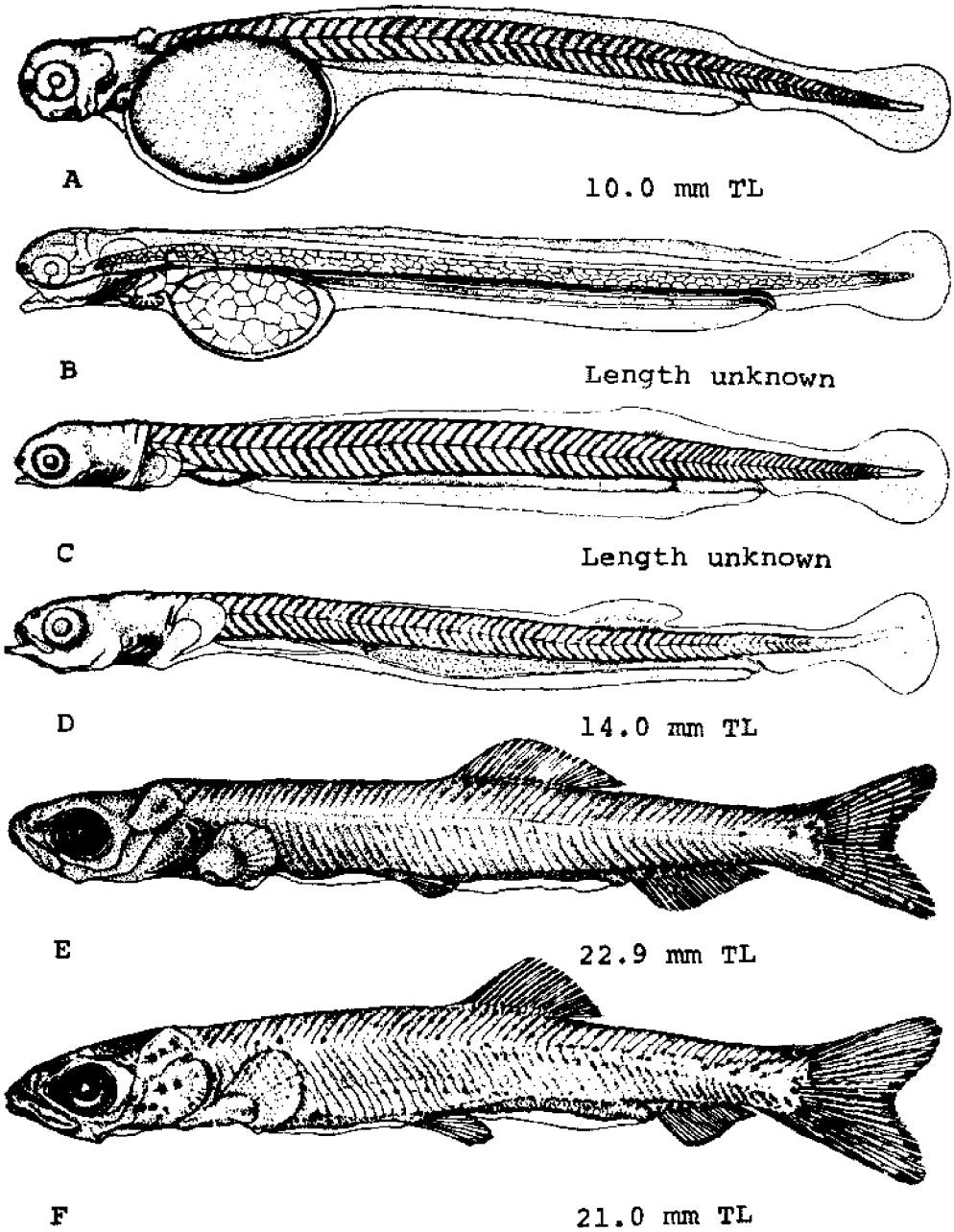

Fig. 55. *Alosa sapidissima*, American shad. A. Yolk-sac larva, 10.0 mm TL, newly hatched. Preanal myomeres 43; pigmentation on yolk and along intestine not shown. B. Yolk-sac larva, length unknown, 3 days. Urogenital system drawn as a dark line over intestine. C. Yolk-sac larva, length unknown, 5 days. Pigmentation of ventral and dorsal surfaces of intestine not illustrated. D. Larva, 14.0 mm TL, 17 days; 9 incipient rays in dorsal; rudimentary gas bladder forming at 18th myomere. E. Larva, 22.9 mm TL, 20.0 mm SL, 12 days. Hatchery reared; D. 17, A. 21; preanal myomeres 43, postanal myomeres 14; sparse pigmentation. F. Larva, 21.0 mm TL, 17.8 mm SL, 18 days. Hatchery reared. (*A-D, Ryder, J. A., 1887: figs. 148–151. E, F, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 30.*)

YOLK-SAC LARVAE

Length at hatching ca. 5.7 [54]–10 mm TL; length at end of stage ca. 9 [4]–12.2 mm TL.[54] Duration of stage 4–5 days at 17 C, ca. 7 days at 12 C.

Body slender, depth in advanced specimens 0.05 of TL.[4] *In newly hatched, yolk subspherical; head detached from* yolk; mouth open but without free passage through esophagus; [3] eyes large, dark, protuberant. By 3rd day, jaws, gill arches, and 2 pairs of recurved teeth in lower jaw forming; incipient rays of pectorals formed; notochord thick, distinctly granular; gut striated; renal apparatus conspicuous, extending from above yolk to anus.[4]

Pigmentation: Body transparent.[4] Yolk sac covered with diffuse network of stellate chromatophores. Mid-ventral line of pigment sometimes present on isthmus. A line of chromatophores along juncture of yolk sac and body and continuing along junction of intestine and body to anus. A closely approximated double line of pigment on ventral aspect of intestine from ca. 18th myomere to anus. A fine network of pigment usually present on lateral surface of intestine, most dense near anus. Stellate chromatophores on lateral surfaces of body, mostly between level of notochord and intestine, extending from yolk to beyond anus. Few spots above and below notochord in area of future caudal fin.[2]

LARVAE

Size range—ca. 9.0 mm SL [51] to ca. 27.0 mm TL (may include juveniles). Duration of stage 21–28 days.[3]

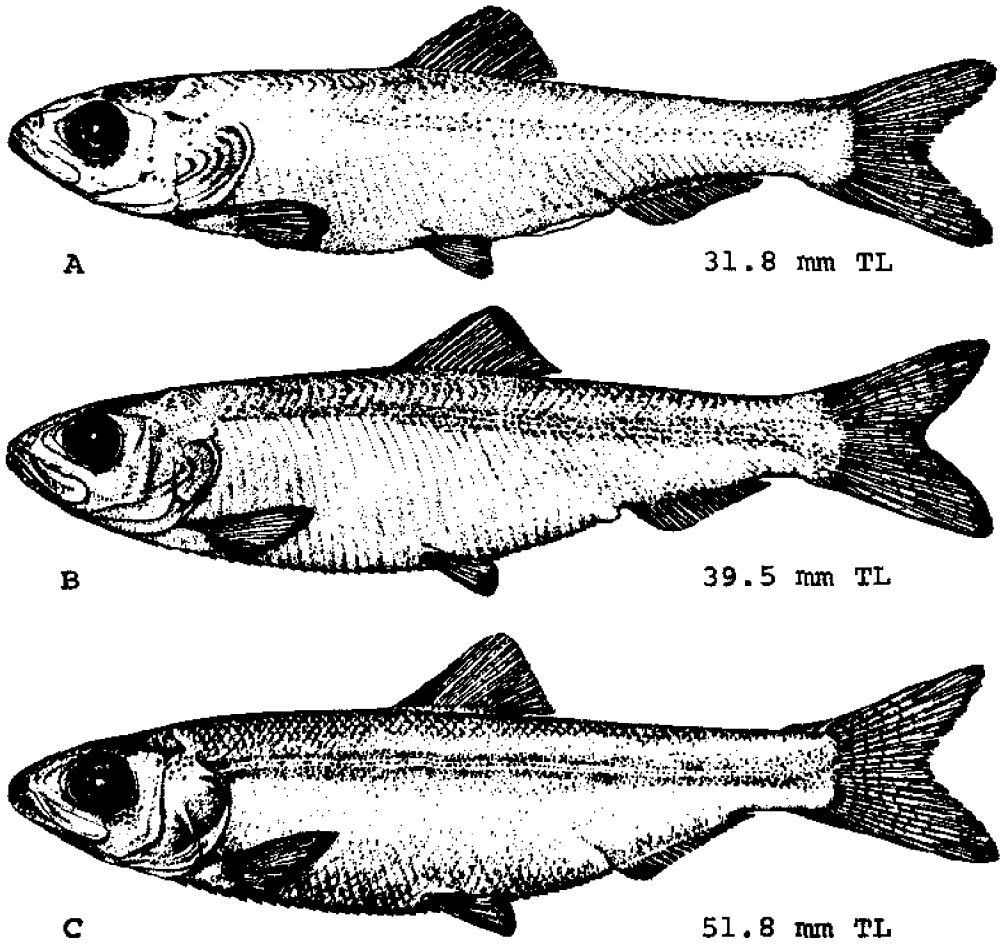

Fig. 56. *Alosa sapidissima*, American shad. A. Juvenile, 31.8 mm TL, 26.7 mm SL. D. 17, A. 21; preanal myomeres 38, postanal myomeres 15; remnant of preanal finfold; scutes forming. B. Juvenile, 39.5 mm TL, 33.5 mm SL; 33 scutes; preanal myomeres 38, postanal myomeres 16; scales forming above mid-lateral region; dark stripe along side. C. Juvenile, 51.8 mm TL, 41.5 mm SL. 37 scutes; almost fully scaled; lateral stripe still evident. (*A-C, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 30.*)

At 21.0 to 22.9 mm TL, pectorals and pelvics still developing; P. 3–15; V. 5–7.[2] Total myomeres 55–57 at 21.0–22.9 mm TL (AJL); preanal myomeres (Chesapeake Bay specimens) 44–50 ($\bar{x}$=47) at 9.0–12.9 mm SL, 45–49 ($\bar{x}$=47) at 13.0–14.9 mm SL, 44–52 ($\bar{x}$=48.3) at 15.0–17.9 mm SL;[48] preanal myomeres (Shubenacadie River, Nova Scotia specimens) 43–47 at 10.5–13 mm TL, 41–45 at 14–16 mm TL, 37–44 at 17–22 mm TL, 34–42 at 23–27 mm TL.[2]

Body long and slender, increasing in relative depth throughout stage. Auditory vesicles still evident at 21.0 mm. Gas bladder evident by 14 mm TL. By 14 mm TL, finfold greatly reduced; anlagen of dorsal fin developed; *incipient caudal rays formed; urostyle directed slightly* upward; rudimentary pelvics evident at 18 mm; preanal finfold retained throughout stage.[2]

Pigmentation: Up to 13 mm TL, two lines of pigment beginning at pectoral bases and continuing along venter and intestine diverge rapidly causing both lines to exhibit a double bending, appearing as short dashes; pigment on isthmus decreased; a line of chromatophores dorsad from base of pectoral; 0–15 chromatophores ventrolaterally between head and caudal peduncle. At 14–16 mm TL, diverging lines of pigment along venter generally terminating at 14th or 15th myomere; chromatophores sometimes present along dorsal wall of intestine between dorsal fin and anus; few chromatophores on caudal fin. Larger specimens highly variable; additional pigment develops on snout, operculum, and dorsal surfaces of head and body. Specimens from freshwater more heavily pigmented than those from brackish water.[2]

JUVENILES

Minimum size 25 to 28 mm TL.[2] (Possibly as small as 20 mm.[15])

Total myomeres 54 at 32 mm (RJM); preanal myomeres 34–47 at 28–32 mm, 32–36 at 33–71 mm.[2] Gill rakers on lower limb of first arch 26–31 at 35–65 mm, 34–43 at 70–125 mm, 48–62 at 190–270 mm, and increasing with growth to ca. 300 mm.[4] Ventral scutes 33 at 39.5 mm, 37 at 51.8 mm.[2]

Greatest depth ca. 3.9 to 4.5 in SL at 26.7–51.8 mm (RJM); average depth 3.5 in SL at 35–100 mm.[5] Ratio between horizontal diameter of eye and distance from most anterior point of eye to tip of upper jaw in specimens 23–47 mm (possibly including some larvae) 0.96–1.28.[3]

At 31.8 mm, adipose eyelid present; opercular apparatus not fully differentiated; remnant of preanal finfold present; axillary scales beginning to form. Scales first evident above mid-lateral region at 34.5 mm, nearly complete at 51.8 mm TL (RJM). Cheek more narrow and deep; angle of upper margin of mandible near middle and

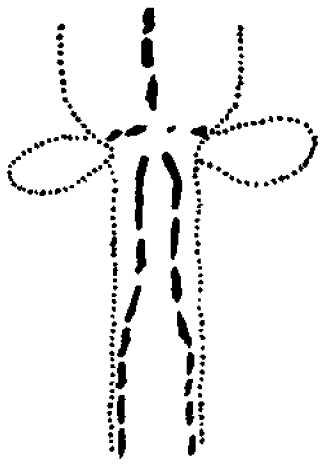

Fig. 57. *Alosa sapidissima*, American shad. Ventral pigment pattern from yolk absorption to ca. 13.0 mm TL. (*Leim, A. H., 1924: fig. 23A.*)

much lower and broader than in other young clupeids. Maxillary reaching middle of eye at 50 mm;[5] median notch on maxillary lacking below 150 mm;[4] teeth developed on anterior part of jaws, persisting to ca. 300 mm.[7] At 40–70 mm, tongue with 6–20 teeth.[22]

Pigmentation: Dorsal and dorsolateral aspects of body and head covered with dense pigment.[2] A 31.8 mm specimen has chromatophores over head, below eye, on opercle, along anal base, on caudal, in a distinct mid-lateral line, and along dorsum (AJL). At 40–70 mm four to six rows of melanophores on tongue.[49]

AGE AND SIZE AT MATURITY

2.35–7 years. Males at a minimum of 2 years, mean age 4.3; females at a minimum of 2 years, mean age 4.6;[50] males ca. 305–447 mm FL; females 383–485 mm FL.[16]

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Brevoortia tyrannus (Latrobe), Atlantic menhaden

ADULTS

D. 18–24 [15] (15–18 branched [28]); A. 18–24 [1] (16–21 branched [28]); C. 7–9 + 10 + 9 + 6–7; [39] P. 13–19 [15] (usually 15–17 [28]); V. 7; lateral scale rows 40–58 (usually 43–53), total predorsal scales 33–46 (usually 35–44),[28] modified scales anterior to dorsal fin 31–43; [2] ventral scutes 28–37 [15] (usually 31–34 [28]), prepelvic 19–21, postpelvic 11–13; [26] total vertebrae 44 [28]–50 [3] (usually 46–48 [28]), precaudal 18–19, caudal 29–30; [39] gill rakers on lower limb of first arch 150 to 160 at 330–360 mm; [1] outer row of gill filaments on ceratobranchial arch 51–66 (usually 53–64); gill filaments at 242.0 mm mean SL, 57.9; pseudobranchiae 28–38 at 220 mm; opercular striations 12–33 (usually 14–27).[28]

Proportions as percent of SL (based in part on juvenile specimens): Body depth 29.9 [28]–40.0; [1] head depth 24.6–29.7; head length 28.8 [28]–36.0; eye diameter ca. 5.0–8.0; [1] mandible length 15.0–19.0; upper jaw length 12.7–16.0; caudal peduncle depth 8.2–10.1.[28]

Body elongate, compressed; head scaleless; maxillary scarcely reaching below posterior margin, or continuing beyond eye; snout quite blunt with prominent median notch, tip of lower jaw projects beyond upper; cheek deeper than long; upper section of opercle with prominent radiating ridges. Scales adherent, exposed parts much deeper than long, posterior margins nearly vertical and strongly fimbriated; [1,37] scale pectinations pointed; [28] row of modified scales on each side of midline of back in front of dorsal fin; low sheath of scales at base of anal and dorsal. Dorsal small, elevated anteriorly, margin concave, inserted about midway between tip of snout and caudal base; origin of anal under or just behind tip of last dorsal ray; pectoral slightly falcate, inserted low on body in advance of opercular margin; lower lobe of caudal slightly longer than upper.[1,37]

Pigmentation: Blue, green, blue-gray, or blue-brown above; sides, venter and fins silvery with strong yellow or brassy luster; [4] anal fin with melanin; [28] dark, round or vertically elongate shoulder spot usually followed by a number of smaller spots sometimes arranged in indefinite horizontal rows. Peritoneum black.[1]

Maximum length: Reported at 500 mm,[1] but sizes above 470 mm are not authenticated.[23]

DISTRIBUTION AND ECOLOGY

Range: Dalhousie, New Brunswick [47] to Everglades National Park, Florida.[48]

Area distribution: "Nearly all sections" of Chesapeake Bay; [5] New Jersey; Delaware; and Virginia.[1,21]

Habitat and movements: Adults—near-surface waters,[17] usually in shallow areas overlying continental shelf, in greatest abundance immediately adjacent to major estuaries. Spring and fall migrations coincide with seasonal shifts in the 10 C isotherm.[26] Northern migrations of older and larger individuals precede movements of younger and smaller. In summer, population south of Cape Lookout, North Carolina generally does not continue northward, those from Chesapeake Bay and north continue to migrate northward throughout most of summer. Southern movement north of Cape Cod begins in September, by November nearly all fish north of Chesapeake Bay are moving southward. A major portion of the population overwinters in offshore waters south of Cape Hatteras, North Carolina; [36] some overwintering occurs in tributaries of Chesapeake Bay.[19] From June to October, population stratified by age and size along entire coast with average age and length increasing from south to north.[36] Salinity range, less than 1 to 36 ppt. Growth and metabolism 10% greater in low salinity than in high salinity.[34] Preferred temperature 15–21 C; [26] avoidance temperature above 26 C.[39] Found in greatest abundance within 24 km of coastline.[36]

Larvae—pelagic,[6] probably spend about one month in waters over continental shelf,[14] entering estuarine waters at ca. 10 mm and larger,[26] in North Carolina, movement occurs in two peaks, one in November and December, and a second and major peak in February and March.[45] Occur in upper Chesapeake Bay tributaries from late May to late June and in November.[29] Early larvae usually at more than 25 ppt, minimum 18 ppt.[26] In estuaries, primarily downriver between fresh and brackish water in salinities less than 1 to ca. 3 ppt; few individuals as much as 54 km upstream from brackish water.[7,34,45] Early larvae, range 0–25 C, most between 15.8–18.5 C.[43] Temperatures of 3.0 C and less appear to prevent entry of larvae into estuaries; [24] acclimation temperature of 15 C and 5.0–20 ppt salinity result in survival time of ca. 2 days at 3 C.[41]

Juveniles—generally pelagic, with smallest size groups farthest up river; [19] as much as 56 km upstream from brackish water in Rappahannock River, Virginia; [9] also among rushes in intertidal zone of Delaware River estuary.[20] Occur in Potomac River in March and April,[45] and in upper Chesapeake Bay tributaries from late May to late June and in November.[29] During June and July at 40–50 mm, generally within 0–15 ppt.[35] Emigrate to sea after first summer, generally in late August in northern estuaries and as late as January in southern waters,[19] however, some overwinter in all major estuaries from Chesapeake Bay to Florida.[26] Those leaving northern estuaries migrate south in fall.[32] Temperatures above 34

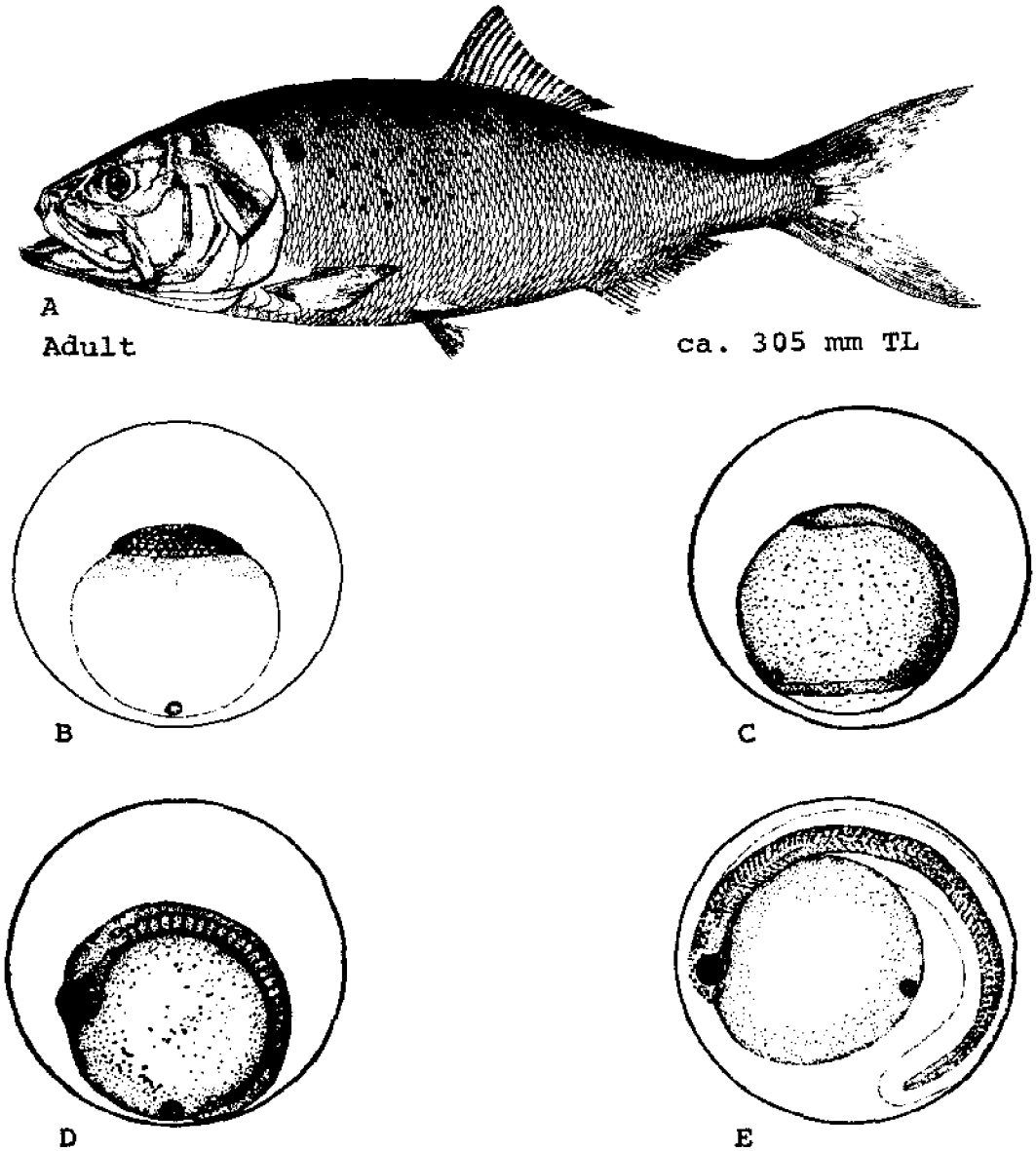

Fig. 58. *Brevoortia tyrannus*, Atlantic menhaden. A. Adult, ca. 305 mm TL. B. Egg, morula. This and subsequent eggs 1.04–1.95 mm in diameter. C. Egg, just before closure of blastopore. D. Egg, early embryo 22–24 myomeres, blastopore closed. E. Egg, late embryo with scattered chromatophores over dorsal surface of body. (A, Goode, G. B., et al., 1884: pl. 205. B-E, Kuntz, A., and L. Radcliffe, 1917: figs. 76–79.)

C and below 6 C result in mortality under laboratory conditions.[38]

SPAWNING

Area: Chiefly at sea, closer to shore in northern parts of range,[1] as much as 64 km offshore from mouth of Chesapeake Bay;[6] eggs have been taken ca. 40 km south of Cape Lookout, North Carolina, and larvae up to ca. 160 km southeast of Cape Fear, North Carolina;[18] eggs from lower Chesapeake Bay[13] and in the Patuxent River north to Benedict.[29] Adults considered as one,[32] two,[30] or possibly four spawning races or populations.[28]

Season: Almost every month in some part of range,[14,16,26] with fall and spring peaks apparently occurring in Chesapeake Bay region.[8]

Temperature: Range 4.4–23.6 C,[29] peak activity 15–18 C.[46]

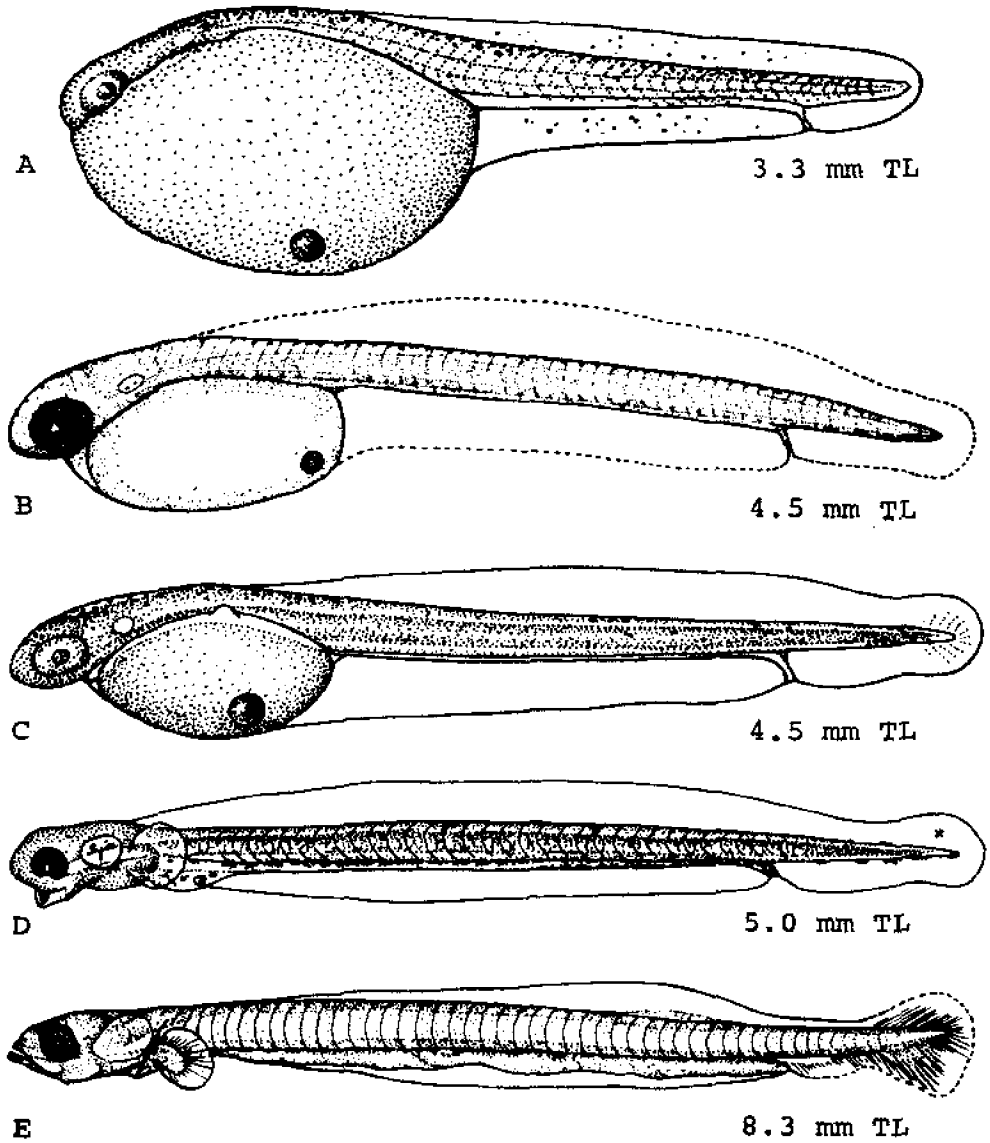

Fig. 59. *Brevoortia tyrannus*, Atlantic menhaden. A. Yolk-sac larva, 3.3 mm TL, 3.2 mm SL, just hatched. B. Yolk-sac larva, 4.5 mm TL, recently hatched. C. Yolk-sac larva, 4.5 mm TL, 4.4 mm SL, recently hatched. D. Larva, 5.0 mm TL, 4.8 mm SL. E. Larva, 8.3 mm TL, 8.07 mm SL. Total myomeres 48; preanal myomeres 40. (*A, C-E, Mansueti, A. J., and J. D. Hardy, Jr., 1967: figs. 31C, E; 32A, B. B, Kuntz, A., and L. Radcliffe, 1917: fig. 80.*)

Salinity: Minimum 10 ppt,[29] usually greater than 25 ppt.[26]

Fecundity: 38,000 to 631,000 eggs per season.[16]

EGGS

Buoyant,[4] spherical, highly transparent,[10] diameter 1.3 (JWR)–1.95 mm [11] (average 1.61 mm [27]), summer eggs somewhat smaller than fall eggs [11] (a reported diameter of 1.04 mm [12] is probably in error, JWR). Yolk light yellow, faintly segmented, 0.9–1.2 mm; [26] single small oil globule 0.11 [27]–0.17 mm [4] in diameter (average 0.14 mm). Egg diameter to oil globule diameter ratio ca. 11/1.[27] Egg capsule thin, horny; [10] perivitelline space ca. 1/2 egg diameter in larger eggs.[26]

EGG DEVELOPMENT

Embryonic axis formed before closure of blastopore. At 22–24 somite stage, tail attached; Kupffer's vesicle con-

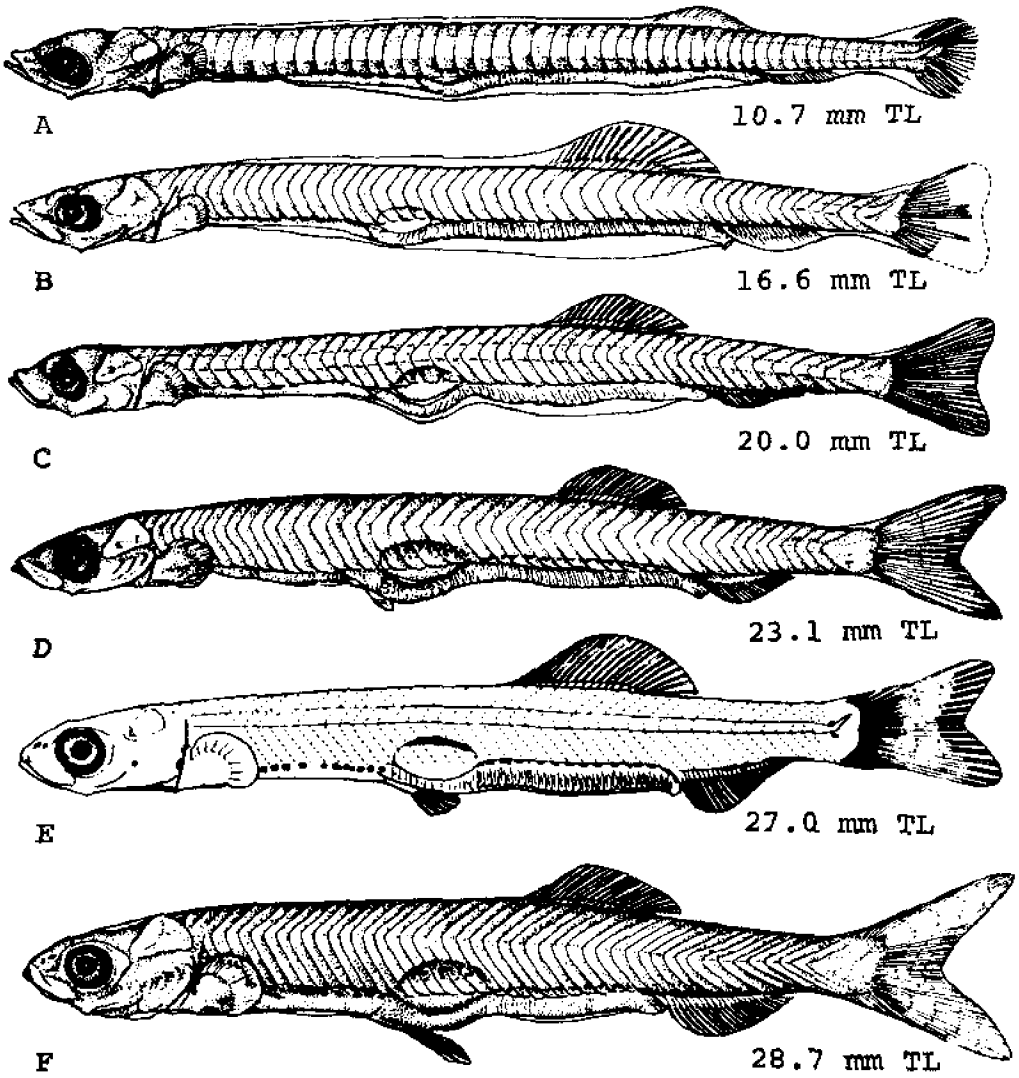

Fig. 60. *Brevoortia tyrannus*, Atlantic menhaden. A. Larva, 10.7 mm TL, 10.4 mm SL. Total myomeres 47; preanal myomeres 37. Gas bladder inflated, depressing intestine. B. Larva, 16.6 mm TL, 15.3 mm SL. Total myomeres 47; preanal myomeres 37. D. 17; A. 18. C. Larva, 20.0 mm TL, 17.9 mm SL. Total myomeres 46; preanal myomeres 38. D. 16; A. 18. D. Larva, 23.1 mm TL, 20.4 mm SL. Total myomeres 46; preanal myomeres 38. D. 18; A. 20. Dark pigment over dorsal surface of gas bladder. E. Larva, 27.0 mm TL. F. Larva, 28.7 mm TL. (*A-D, F, Mansueti, A. J., and J. D. Hardy, Jr., 1967: figs. 32C-F; 33B. E, Lewis, R. M., E. H. Wilkens, and H. R. Gordy, 1972: fig. 1A.*)

spicuous; blastopore closed; otoliths present; and eyes forming. Advanced embryo with elongate slender dorsolateral chromatophores from snout to tip of tail.[10] Just prior to hatching anus 9/10 distance from head to tip of tail (ORS).

Incubation: 42–54 hours at 15–20 C.[40]

YOLK-SAC LARVAE

Hatching length 2.4[12]–ca. 4.5 mm.[10]

At 3.3 mm TL, ca. 35 preanal myomeres.

Head deflected over and attached to yolk; yolk mass large, ovoid; anus less than 1/8 TL from tip of tail; pectoral buds barely visible (AJL). At 4.5 mm head less deflected; yolk mass ca. 1/2 absorbed; anus ca. 1/5 TL from snout tip to tail.[10] Incipient rays in caudal (AJL). Newly hatched larvae with 10 protruding neuromasts along each side, forming primitive lateral line.[50]

Pigmentation: At hatching eye unpigmented. Small, black chromatophores along entire dorsal surface (AJL)

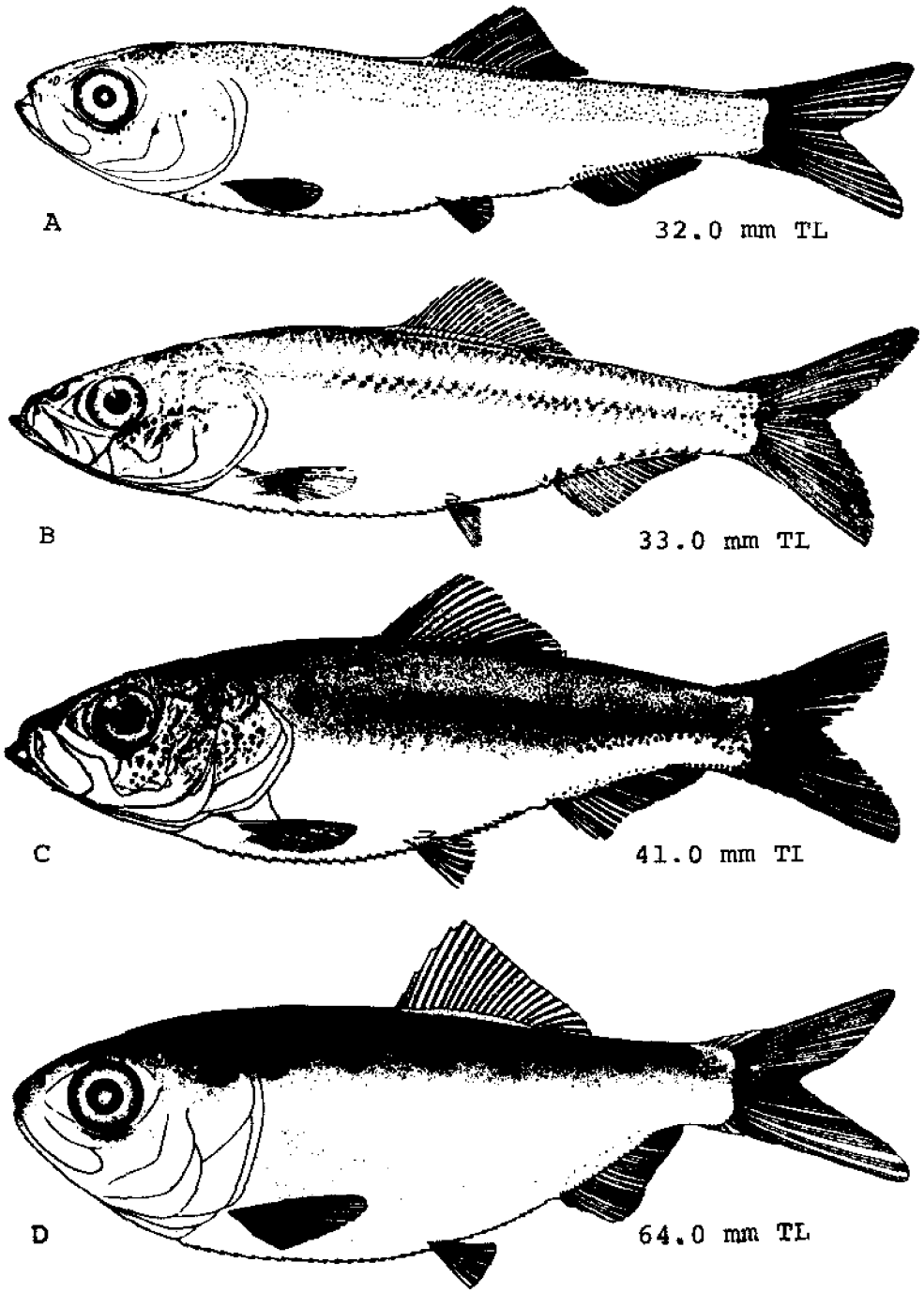

Fig. 61. *Brevoortia tyrannus*, Atlantic menhaden. A. Juvenile, 32.0 mm TL. B. Juvenile, 33.0 mm TL. C. Juvenile, 41.0 mm TL. D. Juvenile, 64.0 mm TL. *(A, D, Lewis, R. M., E. H. Wilkens, and H. R. Gordy, 1972: figs. 1B, C. B, C, Kuntz, A., and L. Radcliffe, 1917: figs. 84, 85.)*

with a fine row of melanophores dorsally near base of finfold;[27] few scattered through dorsal and ventral finfolds (AJL); fine row of melanophores ventrally on body posterior to vent.[27] At 4.5 mm additional pigment on ventral aspect of body posterior to yolk;[10] chromatophores lacking in finfold.

LARVAE

Size range described 5.0–28.7 mm TL (AJL). Size at end of stage up to 30 mm TL.[34]

D. 16–18; A. 18–20 at 16.6–23.1 mm; C. 19; preanal myomeres 37–40; postanal myomeres 8–10 (AJL); myomeres between termination of dorsal fin and termination of intestine 2–3.[33]

Depth ca. 30 times in TL at 9.0 mm, 21 times in TL at 23 mm.[1]

Head shape extremely variable. Choroid fissure retained to ca. 17 mm; auditory vesicle large and more or less triangular at 11.0 mm. Incipient dorsal rays present at ca. 9 mm; anal fin rays evident at 13–20 mm.[27] Gas bladder first evident at ca. 11.0 mm, conspicuously bulged in some specimens (AJL). Gut initially straight;[1] statement that gut becomes convoluted with development[1] is in error, never convoluted (EDH); vent slightly behind a vertical from base of last dorsal ray at 25 mm.[1] Finfold *between dorsal and caudal lost between 8.3 and 10.7* mm; retained anterior to dorsal at least to ca. 17 mm; preanal finfold retained to 28.7 mm but greatly reduced. Dorsal, anal, and caudal differentiating at 8.3 mm; caudal forked at 16.6 mm (AJL); pelvics formed at 20 mm (WFH). Pectorals rounded at 28.7 mm. Notochord initially thick, occupying more than 1/2 thickness of body; urostyle directed upward at 10.7 mm (AJL). Minute teeth on margin of maxillary at sizes above 20 mm (WFH).

Pigmentation: At 5.0 mm, pigmentation along entire dorsal surface of intestine and along posterior half of ventral surface; scattered chromatophores dorsally and in caudal region. At 5.7 mm, chromatophores no longer evident dorsally except near tip of tail; small group of ventral chromatophores in caudal region; and series *along digestive tract from level of pectorals to vent. By* end of stage, additional chromatophores over gas bladder, on nape and opercle; near caudal, anal, and dorsal bases; ventral to pectorals; and in series at dorsal level of notochord (AJL).

JUVENILES

Minimum size described 30 mm TL.[34]

Myomeres between end of dorsal base and origin of anal base 2–4.[45]

Some specimens up to 35 mm with ventral aspect of chest and abdomen rounded and slightly flattened, with greatest depth contained 13 times in TL. Gill rakers increasing with growth of fish;[1] 40–67 at 33–48 mm TL;[45] ca. 60 at 60 mm, ca. 100 at 100 mm,[1] 130–145 at 140–170 mm SL (FHB). Greatest depth ca. 6.7 times in SL at 30–35 mm,[1] ca. 4.2 times in SL at 35 mm (WFH), ca. 3.6–4.0 at 40–45 mm. Cheek not deeper than long;[1] tongue teeth 0–4.[25] Eye proportionately much larger at 41 mm than in adult.[4] Striations on upper plate of gill cover formed by 40–45 mm. Ventral scutes present in *some 30 mm fish.*[1] *Scales present at 33 mm,*[10] *and scale* edges irregular at 60 mm, with blunt serrae at 100 mm; scalation about complete at 40–45 mm, but modified predorsal scales not formed until ca. 125 mm TL; axillary scales of pectoral little developed at 50 mm, ca. 1/2 length of fin at 100 mm.

Pigmentation: At 33 mm, back pigmented; distinct dark lateral stripe; melanophores on dorsal and caudal rays.[10] Specimens 35 mm long with a more or less definite lateral band of dark pigment spots. Silvery lateral band developed at 30–35 mm, blending with silvery abdomen at 40–45 mm.[1] At 41 mm, shoulder spot forming,[10] completed at 75 mm and followed by additional spots by 150 mm.[1]

AGE AND SIZE AT MATURITY

A few at age 1 (180–280 mm), ca. 80% at age 2 (195–320 mm) all at age 3 (over 200 mm).[16]

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Clupea harengus Linnaeus, Atlantic herring

ADULTS

D. 16[1]–22,[75,83] usually 17–19;[1] A. 15–21[76,83] (western North Atlantic), report of 12[75] probably aberrant (FDM); C. 10–13 + 10 + 9 + 8–9;[84] P. 13–21 (spring spawning population), 15[76]–21 (fall spawning population);[76,83] V. 6–10;[59] scales between gill openings and caudal base ca. 56–62, ventral scutes weakly developed, ca. 39–46;[1] vertebrae 23–25 + 32–33 (spawning populations undetermined),[84] total counts 52–59 (spring spawning population),[76,83] 50–59 (fall spawning population);[76] gill rakers 43[53] (spring spawning population), 43[76]–55 (fall spawning population).[76,83]

Proportions as percent SL (may include some juveniles): Body depth 20.0–25.8; head length 22.6–26.4; eye diameter 5.3–7.7.[1]

Body compressed; maxillary rounded posteriorly, not quite reaching middle of eye, its margin with minute serrae. Teeth on lower jaw, tongue,[1] and in oval patch on vomer.[7] Dorsal fin origin about midway along trunk, usually closer to caudal base than tip of snout.[6]

Pigmentation: Body iridescent, bluish above, silvery on sides and belly.[6]

Maximum length: Ca. 450 mm.[1]

DISTRIBUTION AND ECOLOGY

Range: North to edge of polar ice, rarely beyond;[53] in the western Atlantic, Greenland,[21] and Labrador[10] to Cape Hatteras, North Carolina; in the eastern Atlantic, Iceland, Spitsbergen, Novaya Zemlya, White and Baltic seas, and Gulf of Finland,[21] south along coast of Europe to Straits of Gibraltar.[1]

Area distribution: Chesapeake Bay to vicinity of Solomons Island, Maryland[15] and in Patuxent River to Lower Marlboro (WLD); also off New Jersey,[1] Delaware,[10] and Maryland.[14,16]

Habitat and movements: Adults—a pelagic, schooling species found mainly offshore in deeper water[1] but with some populations moving shoreward during spawning season,[1,38] undertake vertical migrations, rising at night and sinking by day.[3,42,43,44] Movements typically local and probably of short range,[1] although specimens of unknown age are known to make long oceanic excursions; e.g., from east coast of Iceland to southern Norway.[5] Fall spawning populations of southern Gulf of St. Lawrence migrate eastward to overwinter in the fjords of southern Newfoundland or in deeper water east of Nova Scotia.[67] Maximum depth about 500 m, but typically no deeper than 55 or 110 m (HCB). Salinity typically ca. 35 ppt,[33] ranging from 0.0 ppt in European lakes[21] to 45 ppt under experimental conditions[33] but not below 2.8 ppt along American coast.[1]

Larvae—initially in vicinity of spawning beds at bottom,[12] making short upward movements and sinking back to bottom;[31,58] may make horizontal movements within 2 hours of hatching[30] and form discrete swarms within 6 hours.[29,30] Vertical movements upward at night with their magnitude increasing directly with size of larvae.[8] Ultimately dispersed by current at lengths of 18[55]–25 mm,[40] e.g., from Georges Bank toward Nova Scotia and New Jersey.[17] Recorded at depths of 7–700 meters,[2] around Georges Bank majority at about 91 m.[74] Experimental optimum salinity 10–15 ppt,[39] but able to withstand 1.4–60.1 ppt for at least 24 hours.[31,32]

Juveniles—drifting with current,[1] *sometimes as far as* 1280 km;[21] initially at surface;[45] inshore after metamorphosis,[31] often in estuaries;[50,62] also in open sea.[21,72] Early juveniles at 37 to 55 m depth.[74] Specimens 90 mm long and longer have been experimentally maintained at a salinity of 45 ppt.[33]

SPAWNING

Location: Vicinity of fjords, bays, straits, and estuaries; also oceanic banks;[1,13,21] greatest concentration of spawning activity off eastern United States at Georges Bank ca. 160 km off Cape Cod;[10] sometimes on slopes of banks situated near underwater "valleys" along which fish approach shore.[53] Usually over rock, pebble, or gravel bottoms; sometimes over clay; probably never over soft mud;[7] in areas with or without vegetation.[6,12] Depth 0.3 m[11] to 240 m;[53] in southern Gulf of St. Lawrence, most occur within 50 m contour.[73] Within the North Sea there appear to be at least 3 isolated breeding stocks within the fall spawning populations.[87] Fall breeding stocks breed farther offshore than spring spawners (Gulf of St. Lawrence).[73]

Season: In eastern North Atlantic a group of fall spawning populations[89] and a separate winter spawning group of populations.[88] In western North Atlantic fall or summer spawning populations, July[73,85]–September[73] or November but peaking in September[74,85] or late August.[74,82] Spring spawning populations peak in May, season restricted.[73] New Jersey and Maryland populations probably fall spawners.[10]

Salinity: 4.0–35.9 ppt[21] with some populations spawning in water that is "nearly fresh."[7] Salinity of 1.7 ppt has been recorded in European spawning grounds,[68] and eggs have been successfully fertilized, developed, and hatched at 52.5 ppt.[32] Many fall spawning populations

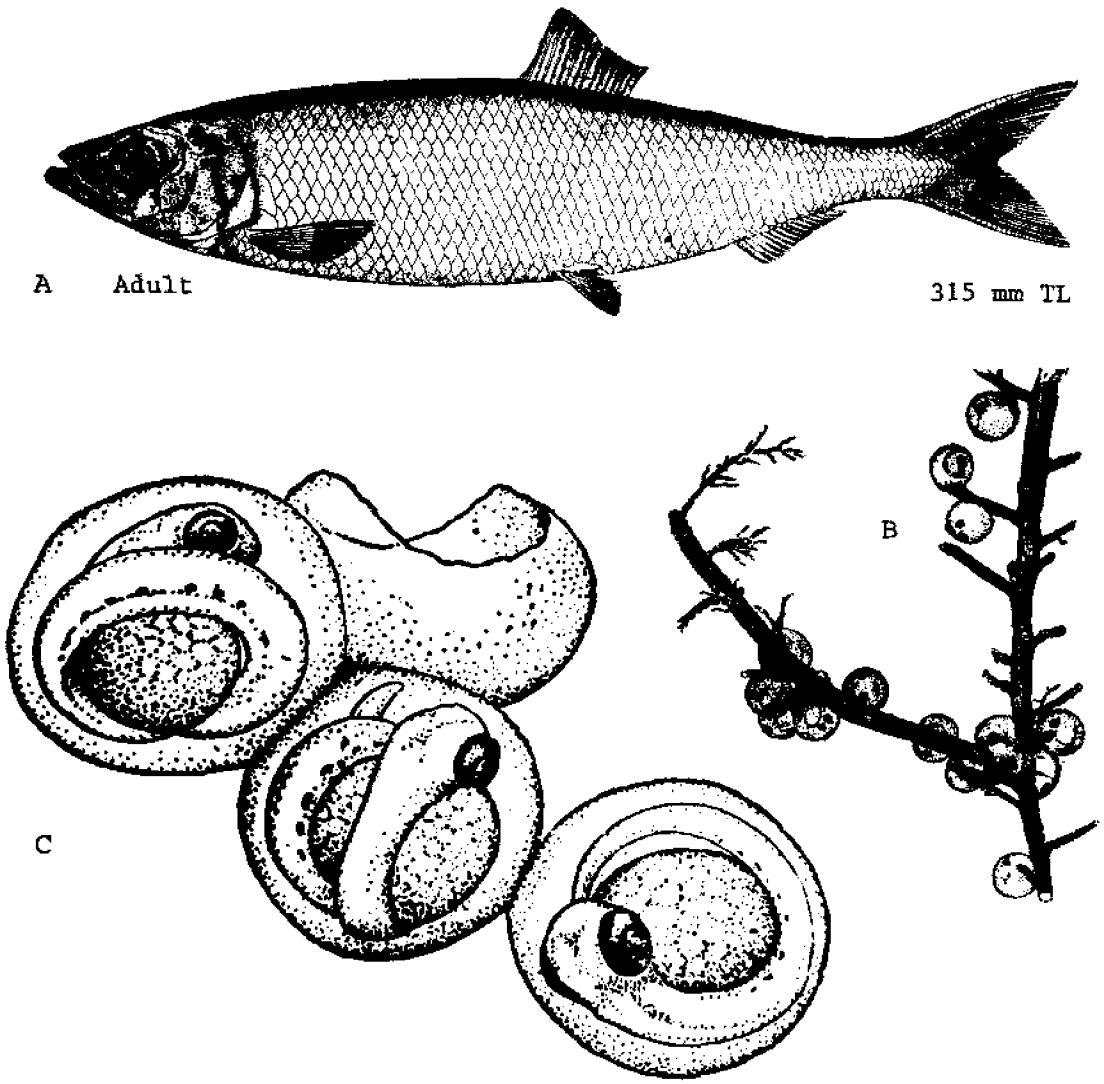

Fig. 62. *Clupea harengus*, Atlantic herring. A. Adult, 315 mm TL. B. Egg clusters attached to seaweed. C. Cluster of eggs containing advanced embryos. (*A, Hildebrand, S. F., 1963a: fig. 66. B, Bigelow, H. B., and W. C. Schroeder, 1953: fig. 42 after Ehrenbaum, E., 1909. C, Berg, L. S., et al., 1949: fig. 121.*)

usually spawn at 33.8–34.1 ppt.[86] In American waters, not below 31.9 ppt or above 33.0 ppt.[1]

Temperature: Spring spawning populations 0–12 C; fall spawning populations 8–15 C.[85]

Fecundity: 3000[53,67]–261,000,[77] with summer-autumn spawners in some areas having significantly higher production than spring spawners.[58,77,90] Considerable interpopulational variation in fecundity with two English coast populations having no overlap in fecundity/length relationships except in smallest sizes.[79]

EGGS

Location: Demersal, adhesive.[1] In western Atlantic sometimes deposited on algae, anchor ropes,[7] and even on free-living animals such as toad crabs, genus *Hyas;*[42] but most often in large "sheets"[9] directly on stones, gravel,[20] and shells[13] in beds which may cover 375,200 square meters.[12] Egg sheets may be 1–9 layers[86] or as much as 35.5 mm thick at center.[9] In English Channel attached to large rocks in long, narrow beds which are oriented with their greatest length lying in the direction of tidal movements;[47] sometimes close inshore[37] and

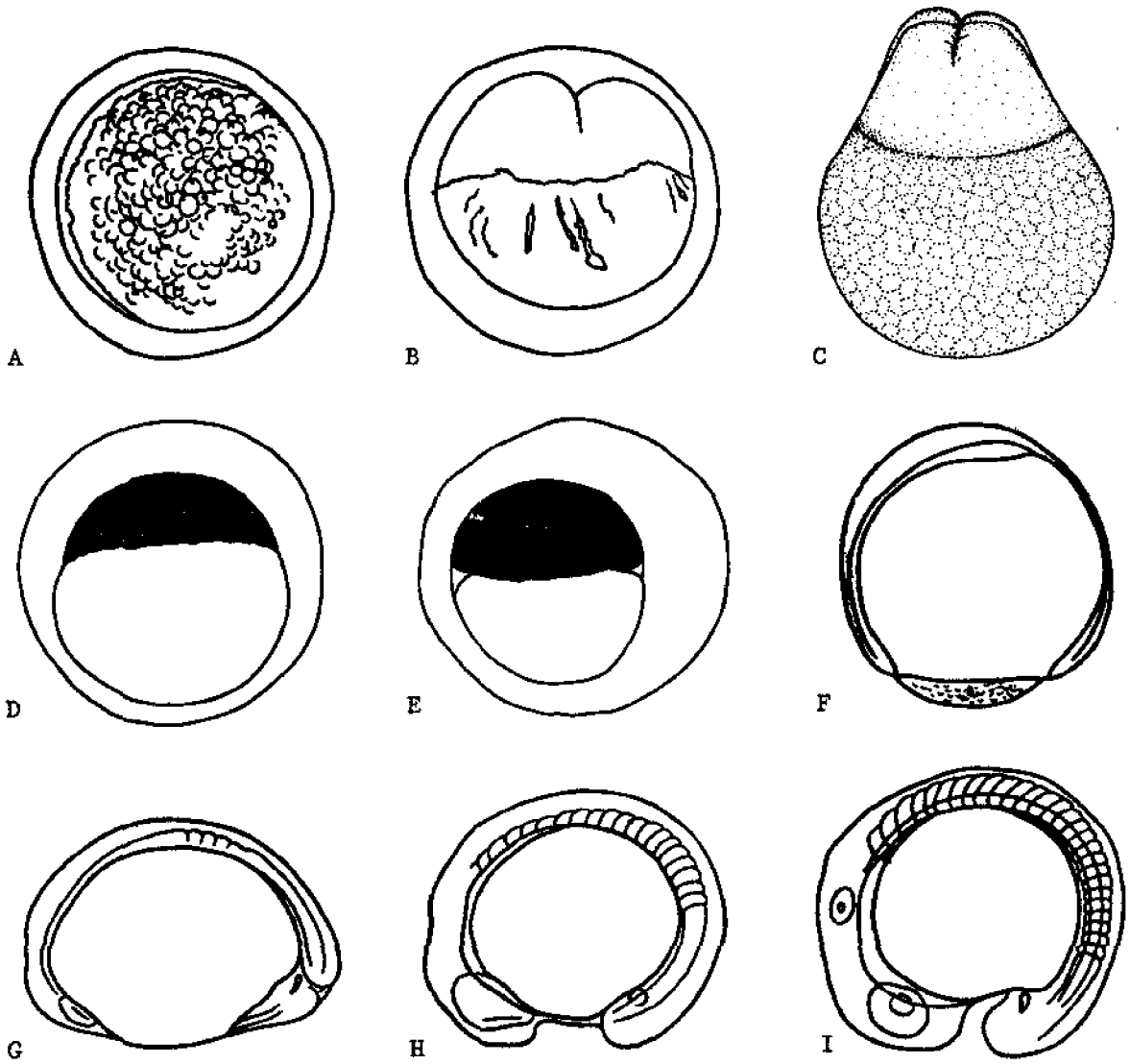

Fig. 63. *Clupea harengus*, Atlantic herring. A. Egg, early blastodisc, 34 minutes at 17 C. Egg diameter 1.12 mm; yolk diameter 0.95 mm. This and all following eggs with granular yolk, although illustrated in "C" only. B. Egg, two-cell stage, 2 hours at 17 C. Egg diameter 1.2 mm, yolk diameter 1 mm; depth of blastomeres 0.55 mm and 0.45 mm. C. Egg, four-cell stage, capsule removed. D. Egg, morula, 8 hours at 11 C. Egg diameter 1.15 mm; yolk diameter 0.9 mm; depth of blastoderm 0.3 mm. E. Egg, blastula, 12 1/2 hours at 23 C. Egg diameter 1.2 mm, yolk diameter 0.75 mm. F. Embryo, 26 hours at 15 C. Embryonic axis visible. This and all following embryos with capsule removed. G. Embryo, 25 1/2 hours, three myomeres, and optic vesicles visible. H. Embryo, 33 hours. Eighteen myomeres, and Kupffer's vesicle visible. I. Embryo, tail bud stage, 38 hours. Twenty-seven myomeres, auditory vesicles visible. *(A, B, D-I, Krevanovski, S. G., 1956a: figs. 21, 23. C, Kupffer, C., 1878: pl. IV, fig. 38, redrawn by Daniel M. Carver.)*

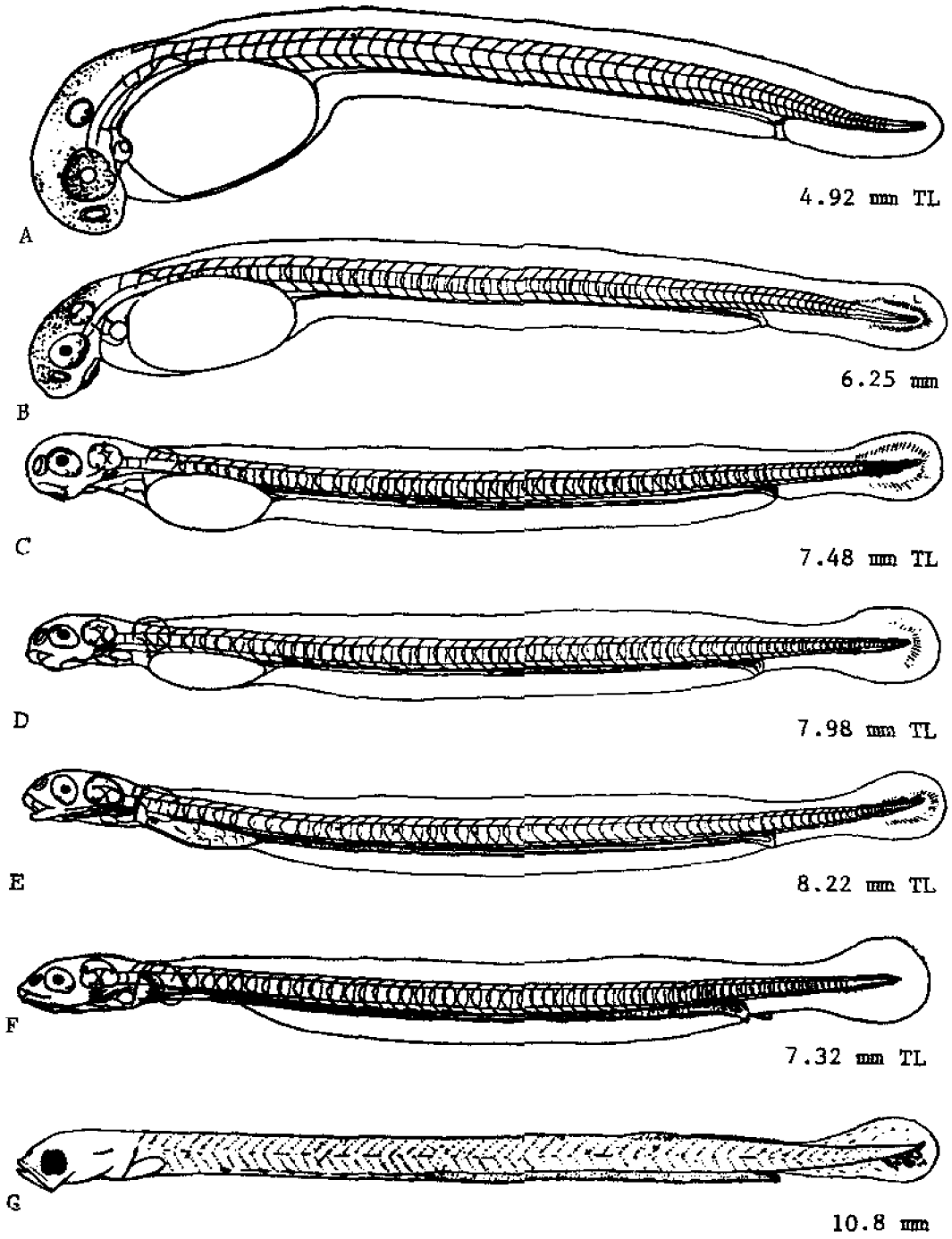

Fig. 64. *Clupea harengus*, Atlantic herring. A. Embryo, 4.92 mm TL, 5 1/2 days, 14.8 C. Melanophores scattered over head. B. Embryo, 6.25 mm TL, 6 1/2 days, 15.8 C. Just before hatching; lower jaw formed; eye pigmented. C. Yolk-sac larva, 7.48 mm TL, 13.2 C. Just hatched, 8 days after fertilization. D. Yolk-sac larva, 7.98 mm TL, 14.8 C. Nine days after fertilization. E. Yolk-sac larva, 8.22 mm TL, 15.8 C. Ten days after fertilization. F. Larva, 7.32 mm TL, 19.7 C. Eleven days after fertilization. G. Larva, 10.8 mm. Incipient rays in dorsal fin. (*A-F, Krevanovski, S. G., 1956a: figs. 26–28. G, Fage, L., 1920: fig. 39.*)

occasionally washed up on beaches.[13]

Ripe ovarian eggs: 0.92[59]–1.7 mm[7] in diameter; transparent;[50] almost globular;[29] egg capsule thick, somewhat bossed;[54] yolk transparent; micropyle single.[29]

Unfertilized eggs: 0.86–1.01 mm, yellow.[55]

Fertilized eggs: Diameter, typically 1.0–1.4 mm in American waters but varying from 0.36 mm in vicinity of Ireland to 3.0 mm in Keil Canal.[21] Size influenced by size of female,[30] time of spawning,[53] and salinity of environment.[32] Yolk granular,[81] mean diameter 0.81–0.92 mm with yolk decreasing 4.4–7.9% of original size during first three hours of development. Perivitelline space ca. 23.2–29.6% of egg diameter.[30] Transparent bluish gray when first deposited, becoming whitish during hatching.[66] *Parthenogenesis occurs.*[28]

EGG DEVELOPMENT

At 17–24 C:[23]

1 hour, 45 minutes	1-cell stage.
2 hours, 5 minutes	2-cell stage.
8 hours, 20 minutes	morula.
14 hours, 45 minutes	early gastrula.
24 hours	closure of blastopore.
25 hours, 30 minutes	eyes forming; 3 somites present.
29 hours	Kupffer's vesicle evident.
31 hours	9 somites.
36 hours	24 somites; auditory vesicles forming.
38 hours	27 somites.
51 hours	45 somites; tail free.
109 hours	59 somites.
120 hours	Kupffer's vesicle no longer evident; incipient pectoral buds visible; pigmentation in eye begun.
174 hours	head not sharply deflected over yolk; pigment developed along lower edge of intestine and above and below body in caudal region.[23] At time of tail-free stage, yolk assumes a somewhat elongate shape, but becomes round when embryo surrounds entire yolk.

Incubation: Ca. 4.3[30] to 56 days,[54] depending primarily on temperature, but with period also lengthened by siltation[30] and decreased salinity.[32]

0.1 C	47–50 days.[4,21]
5.0 C	24 days.[24]
8.0 C	15 days.[71]
12.0 C	10 days.[24]
14.0 C	7.5 days.[24]

Probable time in Gulf of Maine, 10–15 days.[2] Optimum developmental salinity 20–35 ppt.[32]

YOLK-SAC LARVAE

Hatching length 4.0[18]–10.0 mm TL,[40] with larvae hatched at low temperatures tending to be longer and having less yolk. Hatching length also influenced by salinity, with largest larvae produced at 15 ppt.[35] Length at end of stage 6.5[70]–12.0 mm.[37]

Duration of stage varies with temperature and locality: 2 1/2 days at 14.5 C;[25] 4 1/2 to 14 days at 8 C;[24] 50% yolk absorption in 36 days at mean temperature of 5.1 C.[27]

Total myomeres 56[37,49]–67[64] (rarely exceeding 63),[78] increasing during stage.[64] Preanal myomeres 47,[37,49] fixed throughout stage.[64] Four gill arches developed, the fifth forming at hatching.[29]

Depth contained 24 times in TL; vent less than 1/5 TL from tip of tail.[1]

Body very slender;[1] head rounded at ca. 7.5 mm.[23] Yolk mass oval at salinities of 5.9–22.7 ppt, spherical at 33.6–45.0 ppt.[32] Mouth open,[29] nonfunctional at hatching;[31] sometimes functional prior to yolk absorption.[22,37] Eye protuberant; choroid fissure evident. At hatching, gut straight,[31] sometimes with opening from mouth; 2 primitive excretory ducts present; gas bladder not evident.[25] At ca. 6.0 mm, heart a straight tube constricted at middle.[40] Anus fixed in position throughout stage.[64] Pectoral fin distinctly rounded at ca. 7.5 mm. Origin of dorsal finfold initially above pectoral origin; preanal finfold long and wide; by 8.22 mm, finfold reduced in region of future caudal peduncle.[23]

Pigmentation: Body transparent;[1] eye uniformly black[29] or silvery with black pupil.[54] A line of chromatophores between body and intestine on anterior half of body; ventrally along intestine on posterior half; a concentration of pigment in vent region.[23] Few chromatophores on tail; "a little red pigment" located between yolk sac and anus.[45]

LARVAE

Size range described 6.5[70]–34.0 mm TL.[3]

Preanal myomeres 46–47 at 10–20 mm, 41–46 in specimens longer than 20 mm;[37] postanal myomeres 12–13 at ca. 6–14 mm.[81] "Vertebral myomeres" 53–60, not countable until after formation of urostyle;[52] myomeres between anal fin and last dorsal ray at 18–19 mm usually 7–8.[37] Tail less than 1/6 TL in specimens 20 mm and longer.[37,49]

Head becoming elongate at ca. 7.8 mm, but nearly as

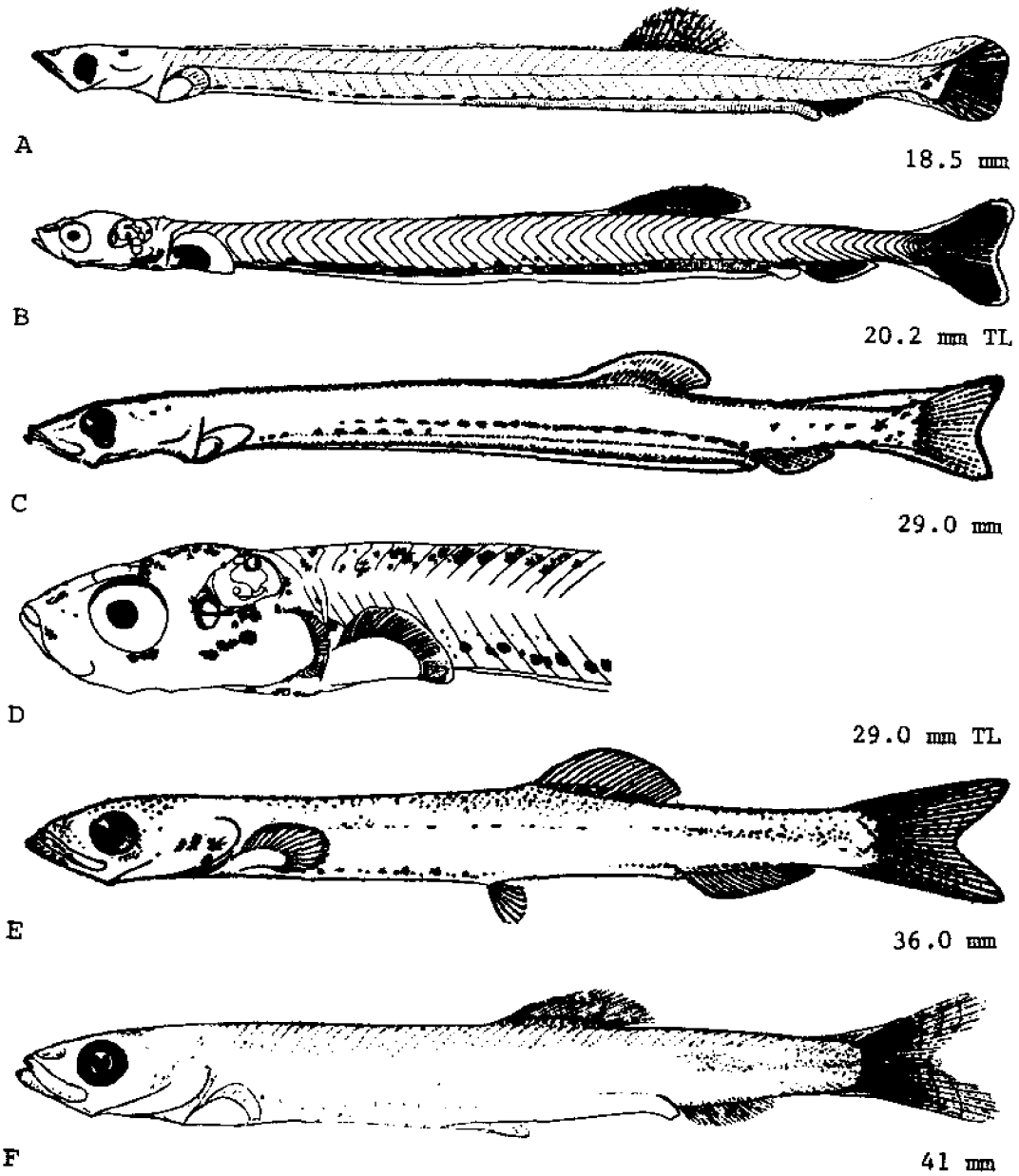

Fig. 65. *Clupea harengus*, Atlantic herring. A. Larva, 18.5 mm; incipient rays in anal fin. B. Larva, 20.2 mm TL. Preanal finfold retained. C. Larva, 29.0 mm. D. Head of larva, 29.0 mm TL. E. Juvenile, 36.0 mm TL. F. Juvenile, 41 mm TL. (*A, F, Fage, L., 1920: figs. 40, 42. B, D, Krevanovski, S. G., 1956a: figs. 30, 31. C, E, Rass, T. S., 1949: figs. 9c, d.*)

broad as long at 10.5 mm. At beginning of stage, anterior margins of upper and lower lips equal and level.[27] Jaw with tooth-like serrations and branchial arches evident at 14.5 mm. Opercle forming at 20 mm. Finfold no longer continuous at 20.0 mm, but remnant retained anterior to dorsal fin to end of stage.[23] Incipient dorsal rays first evident only after yolk absorption,[37] dorsal fin complete by 15[7]–29 mm;[36] anterior migration of fin begins at ca. 27 mm. Anal fin first evident at 16[26]–29 mm;[1] incipient rays at 17.0[3]–20.2 mm; stainable rays at 17.5–20.0 mm;[26] anal fin complete at least by 30 mm.[37] Pelvics first evident at 20.2[23]–29.9 mm,[26] usually appearing near 24th myomere[37] and usually in front of 1st dorsal ray;[48] posterior migration occurring by end of stage.[37] Verte-

bral centra stainable at mid-body at ca. 20 mm; entire column developed at 24–25 mm.[26,35] Urostyle first directed upward in some specimens at ca. 16[52]–17 mm, but usually straight at 18.0 mm, completely oblique at 21 mm or more.[37] Forward migration of anus begins at ca. 22 mm.[23]

Pigmentation: Body transparent. Pigment increased in density at 7.32 mm, especially in region of anus and below pectoral fins. At 20.2 mm, a series of chromatophores ventrally on body; heavy concentration of pigment above anus; few chromatophores at caudal base.[23] At ca. 25 mm, a longitudinal row of black dots on wall of abdominal cavity; fine black spots on dorsal surface, especially on roof of brain.[40] At 29 mm, additional pigment on head and in dorsolateral reigon of body.[23]

JUVENILES

Minimum size described 30 mm TL.[35,48]

Gill rakers on lower limb of first arch 25–36 in specimens 36–70 mm long.[1]

Depth 5.2–9.5 times in SL in specimens 40–70 mm SL.[1]

Premaxilla and posterior supramaxilla developed at 34 mm; late juveniles with minute teeth on maxilla and 3–4 on premaxilla.[34] Dorsal and pelvic fins in final position at ca. 50[74]–55 mm; anus in final position at ca. 40 mm.[37] Pyloric caeca developing at 33 mm,[37] fully developed at 70 mm.[56] Gas bladder evident at 30–35 mm.[22,65] Scales first evident at 24[30]–48 mm;[37] urostyle still evident at 41 mm.[8]

Pigmentation: At 41 mm, pigment over back, along lateral surface on posterior part of body, over gut, along posterior half of venter and on dorsal and caudal fins;[3] at 50 mm, pigment over most of head;[23] at sizes larger than 35 mm operculum silvery.[40] Adult pigment pattern at least by 45 mm in some populations.[50]

AGE AND SIZE AT MATURITY

2[21]–7 or possibly 9 years;[53] in Gulf of St. Lawrence 50% of spring spawning females mature at 5.9 years, 50% of fall spawning females at 7.1 years; in southwest Nova Scotia 50% of spring spawning females mature at 6.3 years, 50% of fall spawning females at 6.5 years.[77] Minimum size ca. 181–185 mm SL in American populations.[19] Length at which 50% of females from Gulf of St. Lawrence spawns varies from 303 mm for spring spawners to 329 mm for fall spawners; in southwest Nova Scotia 50% of the spring spawning females mature at 306 mm, 50% of the fall spawning females at 313 mm.[77]

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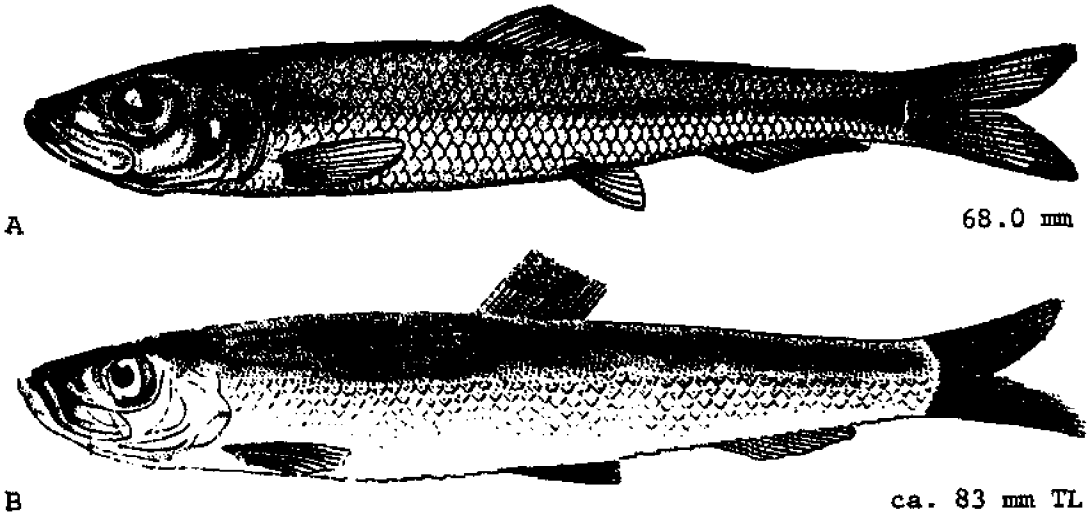

Fig. 66. *Clupea harengus*, Atlantic herring. A. Juvenile, 68.0 mm. B. Juvenile, ca. 83 mm TL. (*A, Rass, T. S., 1949: fig. 9e. B, Prince, E. E., 1907: pl. 8, fig. 5.*)

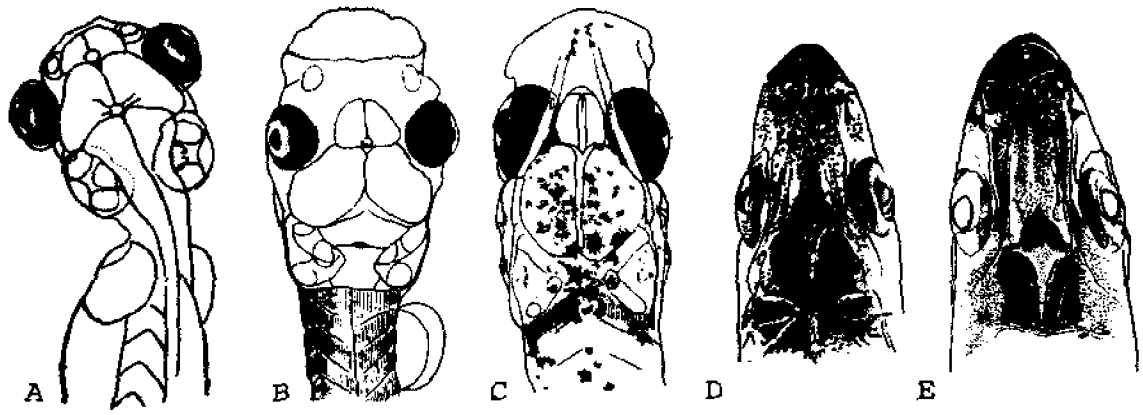

Fig. 67. *Clupea harengus*, Atlantic herring. Dorsal views of head at various stages. A. Embryo, 7.0 mm TL. B. Larva, 18.0 mm TL. C. Larva, 19.0 mm TL. D. Juvenile, 50.0 mm TL. E. Juvenile, 150 mm TL. (*A-E, Krevanovski, S. G., 1956a: figs. 34, 35.*)

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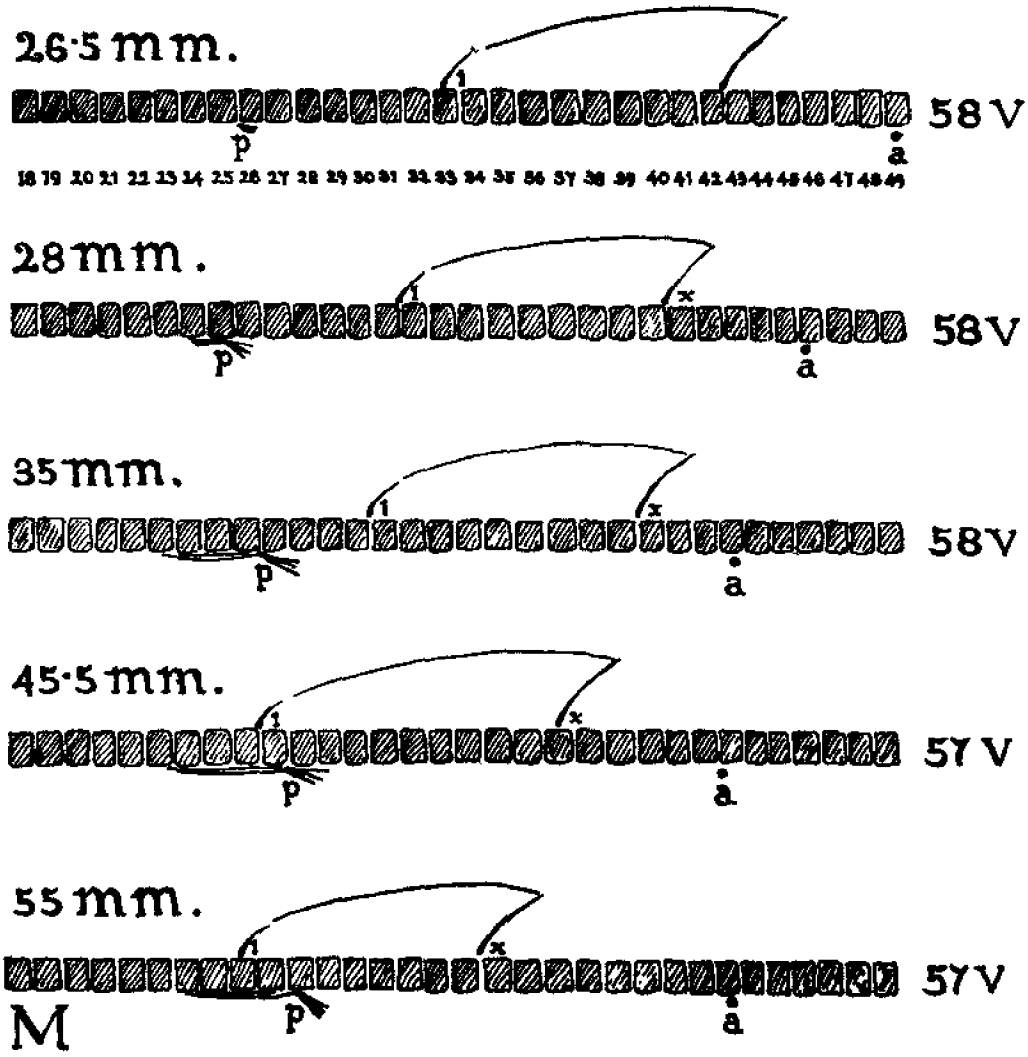

Fig. 68. *Clupea harengus*, Atlantic herring. Shows position of fins and anus to vertebrae in larvae and juveniles of various sizes; p., pelvic fins; 1-x., first and last rays of dorsal fin; a., anus; v., vertebrae; m., metamorphosed specimen or juvenile. (*Lebour, M. V., 1921: fig. 11.*)

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Dorosoma cepedianum (Lesueur), Gizzard shad

ADULTS

D. 10–15;[28] A. 25[7]–37;[25] C. 9–11 + 10 + 9 + 7;[31] P. 14–17; V. 7[7]–10;[30] scales in lateral series 52–70; scales around body 36–45; scale rows between dorsal and anal fins 19–24; ventral scutes 27–32, prepelvic scutes 17–20, postpelvic scutes 10–14;[7] total vertebrae 47[30]–51,[7] precaudal 11–13, caudal 35–39;[31] gill rakers increase with size from 100[30] to over 400;[7] branchiostegal rays 6, 6.[30]

Proportions as times in SL (based in part on juvenile specimens): Head length 3.0–3.9; body depth 2.3–3.1; predorsal length 1.85–2.05; prepelvic length 2.0–2.35; anal origin to caudal base 2.4–2.8; anal base 3.2–3.9; dorsal filament 3.1–6.5.[7] Proportions as percent HL: Eye diameter 20.2–26.4; snout length 16.9–24.2; interorbital width 21.2–26.8.[30]

Body deep, strongly compressed laterally; head devoid of scales;[22] snout rounded,[30] overhanging subterminal mouth; ventral edge of upper jaw distinctly notched,[22] maxillary with 2 supramaxillary bones, teeth absent. Scales comparatively small, cycloid, thin.[7] Last dorsal fin ray elongate,[22] ridge on back before dorsal fin naked.[7]

Pigmentation: Silvery blue above, milky white below, often with brassy or golden reflections; ca. 6–8 horizontal dark stripes along upper sides[7] which are variable in occurrence; shoulder spot often absent in older fish;[22] dorsal fin almost uniform dusky; caudal fin dusky, darkest on outer third; anal fin dusky, lighter basally; top of head, snout, upper jaw and upper part of opercle pigmented; remainder of head silvery.[7]

Maximum length: Ca. 520 mm[7] (average ca. 254–356 mm[1,20]).

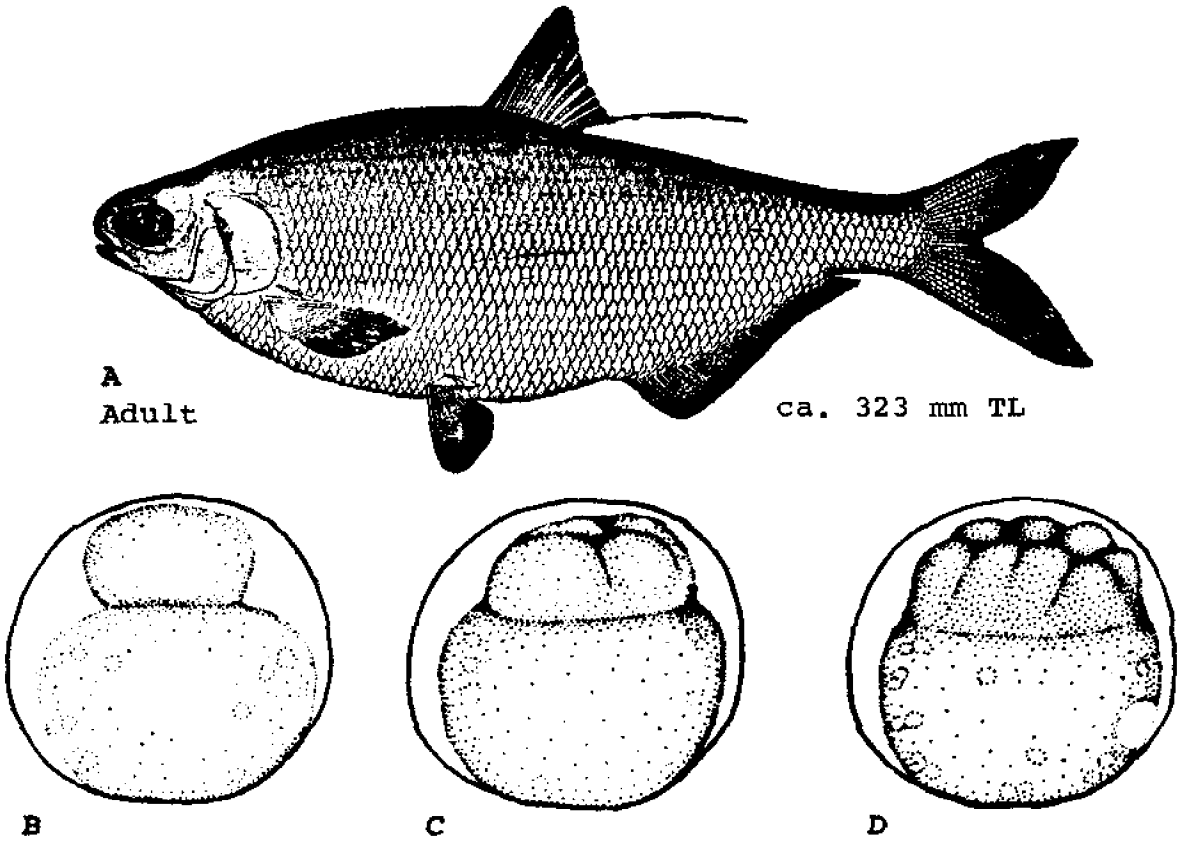

Fig. 69. *Dorosoma cepedianum*, Gizzard shad. A. Adult, ca. 323 mm TL. B. Egg, blastodisc, diameter 0.75 mm. Incubated at 26.6 C. C. Egg, four-cell stage, 3 hours. This and "D" 0.75 mm in diameter. Incubated at 16.6 C. D. Egg, eight-cell stage. Larger oil globules visible. (*A, Goode, G. B., et al., 1884: pl. 217A. B-D, Warner, E. N., 1940: pl 1.*)

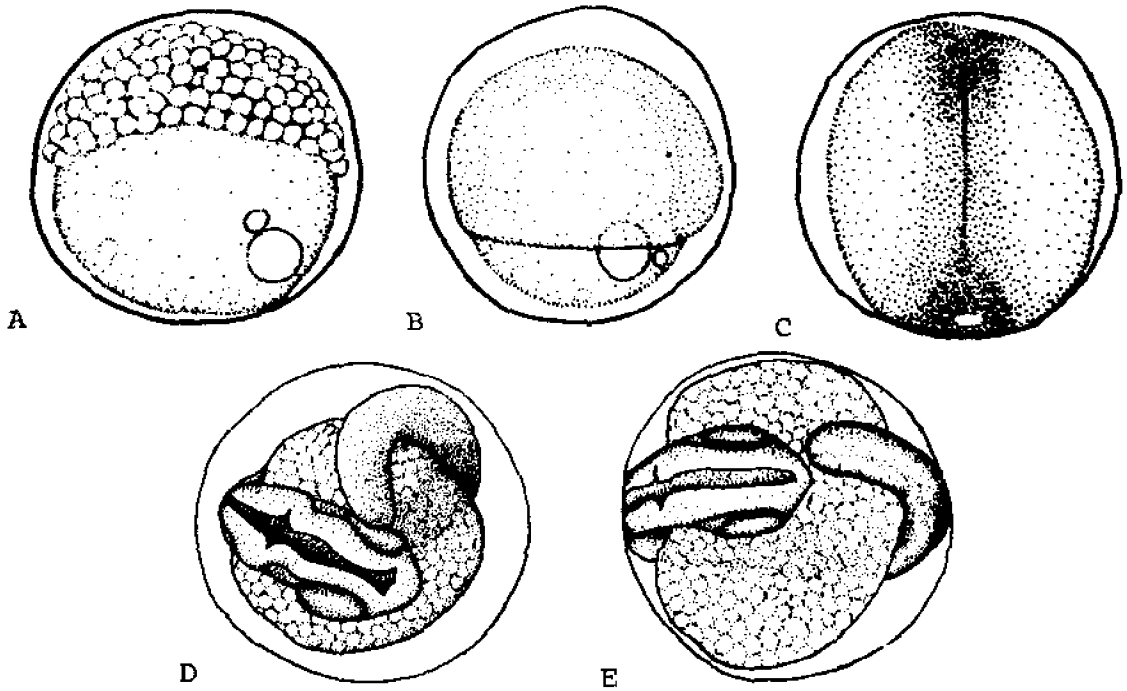

Fig. 70. *Dorosoma cepedianum*, Gizzard shad. A. Egg, morula, 5 1/2 hours. This and all following eggs 0.75 mm in diameter. Incubated at 16.6 C. B. Egg, late gastrula, 15 1/2 hours. C. Egg, embryonic axis 25 1/2 hours. Blastopore closing. D. Egg, tail-free embryo, 60 hours. E. Egg, late embryo, 70 hours. (*A-E, Warner, E. N., 1940: pl 1.*)

DISTRIBUTION AND ECOLOGY

Range: Great Lakes [22] to North Dakota [13] and South Dakota, southwestward across Wyoming and Colorado to Continental Divide in New Mexico and North-Central Mexico, east to Gulf of Mexico, through Mississippi and Great Lakes drainages to Atlantic coast, north to southern New York.[22]

Area distribution: Chesapeake Bay,[11] Delaware River Estuary,[31] Virginia,[8] and New Jersey.[12]

Habitat and movements: Adults—in open quiet surface waters which may be clear to very silty.[1] Concentrated in deeper waters in fall and winter; some in shallow waters throughout year; found over mud, sand, gravel, bedrock and inundated vegetation.[22] Abundant in rivers of Chesapeake Bay region throughout year; and in bay itself in fall.[1] A fall "run" in Chesapeake Bay in September and October,[11] spring "runs" in North Carolina [15] and up Mississippi River.[4] Maximum salinity 41.3 ppt,[26] found in greatest numbers at less than 15.0 ppt.[2] Maximum depth 33 m.[9]

Larvae—at 4.0–5.5 mm TL most abundant in surface waters both day and night; at 6.0–10.0 mm TL strong surface preference during day, dispersed at night, slightly more abundant at bottom; at 10.5–20.0 mm TL highest concentrations at surface in day, changing at night to midwater with lowest numbers at bottom; at sizes greater than 20.5 not taken during day, most numerous at midwater at night (maximum sampled depth ca. 15 m).[27]

Juveniles—in greatest abundance well upstream from brackish water;[8] very young individuals apparently never enter brackish water,[11] taken only in freshwater at ca. 70 mm and less.[24] Reported from beds of spatterdock; close inshore, usually in shallow water,[1] primarily over mud bottom.[16] High mortality rates at temperatures below 2.2 C.[22]

SPAWNING

Locations: Freshwater [19,24] near surface in sloughs, ponds, lakes, and large rivers;[1] observed spawning at 0.15 to ca. 15 m with greatest concentrations at 0.3 to 1.6 m.[22]

Season: Mid-March to late August, but principally during April, May and June in temperate waters of the United States;[1] early summer in area of Chesapeake Bay.[11] Second spawn may occur during late summer in some areas.[22]

Time: Midday.[1]

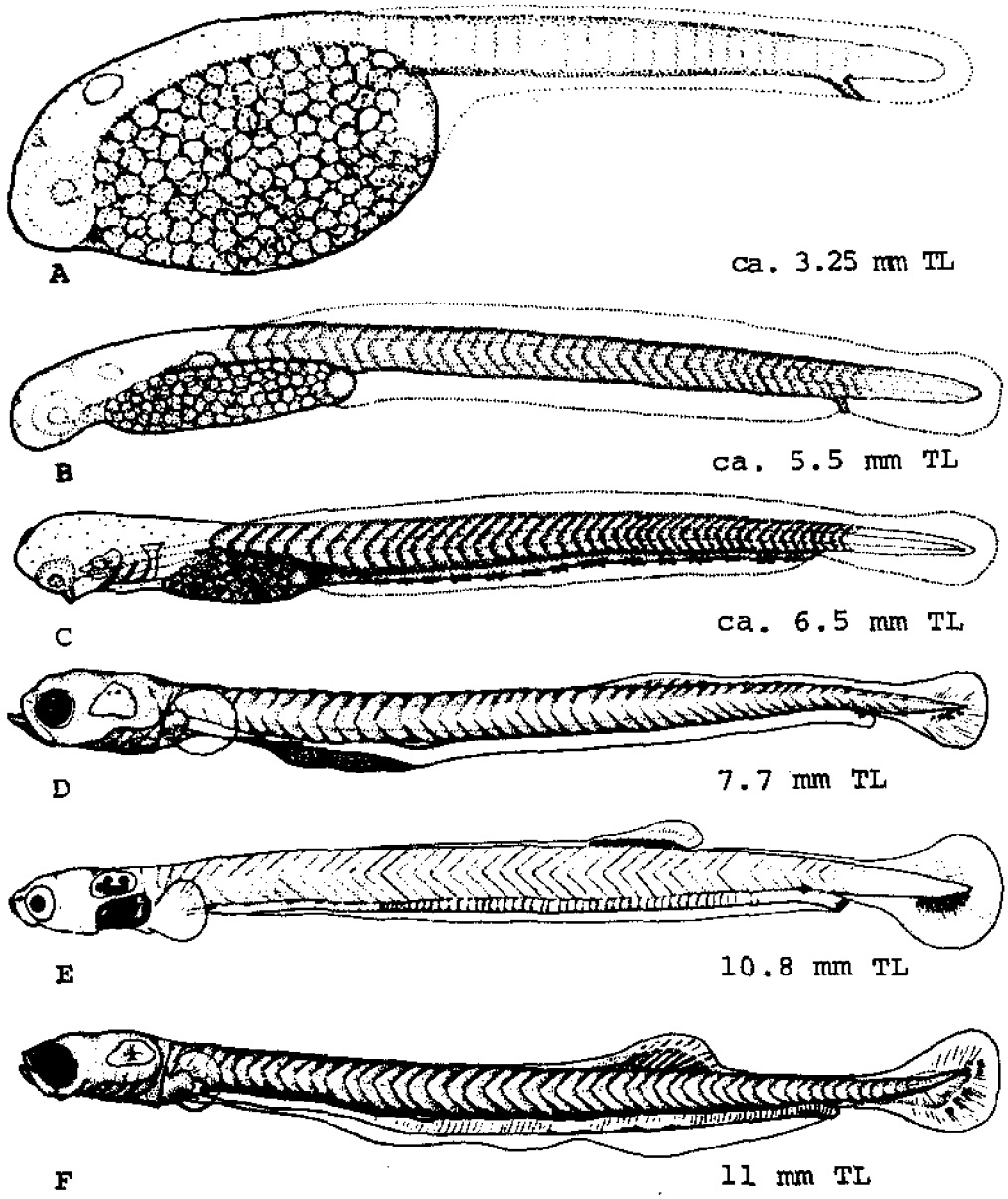

Fig. 71. *Dorosoma cepedianum*, Gizzard shad. A. Yolk-sac larva, ca. 3.25 mm TL, just hatched, 32 myomeres visible. B. Yolk-sac larva, ca. 5.5 mm TL, 3 days old. C. Yolk-sac larva, ca. 6.5 mm TL, 3 days old. D. Yolk-sac larva, 7.7 mm TL. Flexion beginning. E. Larva, 10.8 mm TL. Total myomeres 48, preanal myomeres 44. F. Larva, 11 mm TL. (*A, B, E, Warner, E. N., 1940: pls. 2, 3. C, Miller, R. R., 1960: fig. 3. D, F, Lippson, A. J., and R. L. Moran, 1974: 53, 54.*)

Temperature: 10[1]–28.9 C,[22] usually on rising temperature and most active above ca. 18 C.[1,21]

Fecundity: Range 22,405–543,912; average 59,480 at age group I to 378,990 at age group II; declining with age to 215,330 at age group VI.[5]

EGGS

Location: Demersal; adhesive, attaching to contacted objects.[1]

Unwater-hardened eggs: Irregularly shaped and wrinkled

when first extruded, becoming spherical in water.[1]

Fertilized eggs: Creamy yellow; nearly transparent; 0.75 mm diameter.[1] Egg capsule smooth, tough;[14] micropyle single.[1] Yolk finely granular with single large oil globule and 1–5 smaller ones.[14]

EGG DEVELOPMENT

At ca. 27 C:

15–20 minutes	blastodisc formed.
ca. 1 hour	first cleavage.

At ca. 17 C:

3 hours	4-cell stage.
5 hours, 30 minutes	morula.
25 hours, 30 minutes	closure of blastopore.
33 hours, 30 minutes	2 somites; embryo around 7/8 of yolk; neural keel deep in yolk; optic vesicles and neural cord evident.
43 hours, 30 minutes	9 somites.
52 hours, 30 minutes	17 somites; optic cup formed; caudal region barely delineated from underlying yolk; embryo encircling entire yolk.
60 hours	tail free and overlapping head slightly; three primary lobes of brain distinguishable.[14]

Incubation: Ca. 36 hours to 1 week depending on temperature;[5] 95 hours at ca. 17 C, 36 hours at ca. 27 C.[1]

YOLK-SAC LARVAE

Average hatching length 3.25 mm TL. Maximum size described 6.5 mm.

Total myomeres ca. 32 at hatching, 40 at 5.5 mm. Four gill arches but no filaments at 6.5 mm. Body elongate at hatching; depth, including finfold, 0.2 mm; head flexed downward 90° over yolk. Head straight at 5.5 mm. Yolk mass initially oval and 0.8 mm in length, cylindrical by 2nd day, greatly reduced by 3rd (6.5 mm). Oral plate perforated at 1 day, but pharynx not open into mouth; cartilage of lower jaw forming at 6.5 mm; choroid fissure wide, closed in 1 day. Gut nearly straight at hatching;

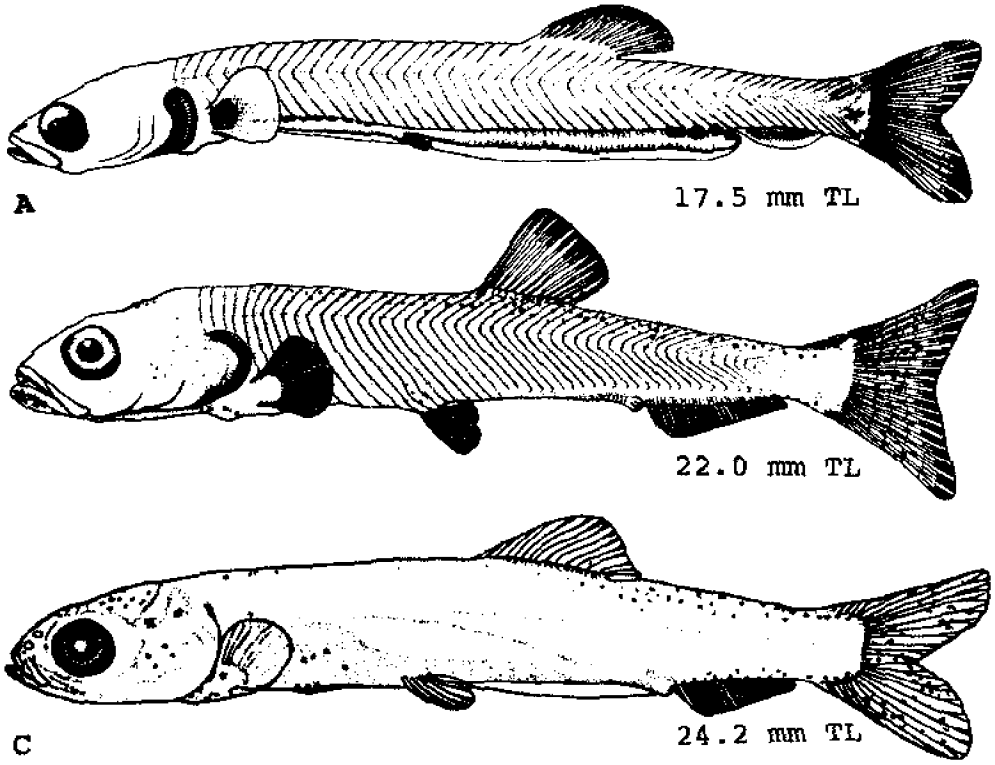

Fig. 72. *Dorosoma cepedianum*, Gizzard shad. A. Larva, 17.5 mm TL. D. 12; A. with 22 incipient rays; total myomeres 49, preanal myomeres 39. B. Juvenile, 22.0 mm TL. C. Juvenile, 24.2 mm TL. (*A, B, Warner, E. N., 1940: pl. 4. C, Lippson, A. J., and R. L. Moran, 1974: 54, after Taber, 1969.*)

anus at margin of finfold at hatching, close to body in notch in finfold at 6.5 mm. Anlagen of pectorals present at 5.5 mm, small and paddle-like at 6.5 mm; finfold slightly constricted in caudal region at hatching.[1]

Pigmentation: Pigment lacking at birth and at 1 day; at 3 days (6.5 mm) a line of chromatophores on each side of body starting dorsad to yolk and extending to preanal finfold.[1]

LARVAE

Specimens described 7.0 to ca. 21.0 mm TL.[25]

A. 22 at 17.5 mm. At 7.0 mm TL and larger total myomeres over 40;[25] at 10.8 mm total myomeres 48, preanal myomeres 44;[1] at 14–15 mm total myomeres 45–50;[25] at 17.5 mm total myomeres 49, preanal myomeres 39;[1] at 16–21 mm 49–52 vertebrae.[25]

Body long and slender. Incipient gill filaments present at 10.8 mm; posterior development of opercle rapid during stage; nostril dividing at 17.5 mm. Internal folds of intestine developing at 10.8 mm; gut 1.5 to 2.0 times TL.[1] Finfold reduced dorsally at 10.8 mm; only preanal present at 17.5 mm. Anal with incipient rays at 17.5 mm; caudal rounded and with 14 incipient rays at 10.8 mm, bifurcate at 17.5 mm; pectoral "paddle-like," more ventral by 10.8 mm, with primitive rays by 17.5 mm. Order of fin development: dorsal, caudal, pectoral, pelvic and anal. Urostyle directed upward at 17.5 mm.[14]

Pigmentation: Additional chromatophores anterior to vent and along each side of dorsal wall of anterior third of gut; scattered over caudal fin and base, and along each side of anal.[14]

JUVENILES

Minimum size described ca. 20 mm.[1]

Gill rakers as low as 90 at ca. 20 mm,[1] greater than 300 at 65 mm SL, ca. 350 at 95 mm.[10] At 22 mm, body minnow-like, cylindrical;[1] mouth subterminal,[25] a few mi-

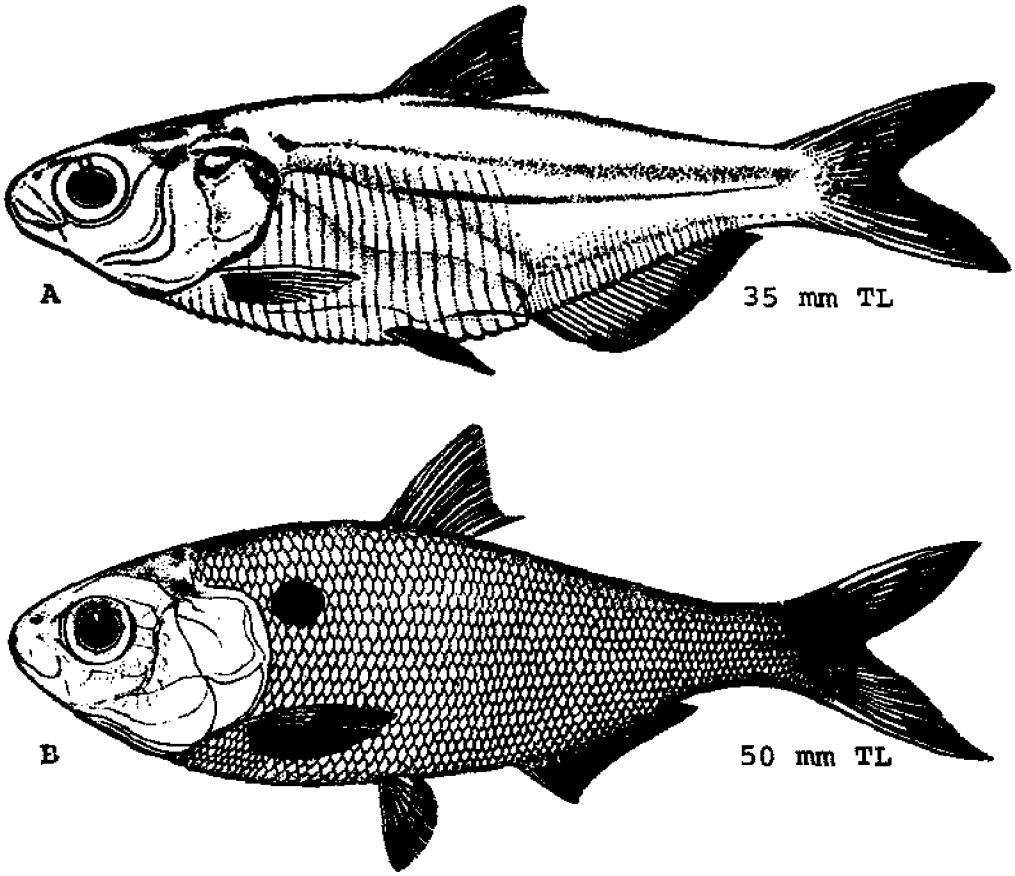

Fig. 73. *Dorosoma cepedianum*, Gizzard shad. A. Juvenile, 35 mm TL. B. Juvenile, 50 mm TL. Last ray of dorsal fin starting to elongate. (A, *Fowler, H. W., 1935: fig. 2.* B, *Fowler, H. W., 1945: fig. 7.*)

nute teeth on lower edge of maxillary;[1] median notch lacking in young.[10] Dorsal filament becoming elongate at ca. 50 mm.[16] Scales apparently not formed, but ventral scutes present at 35 mm;[17] scalation complete at ca. 50 mm.[18] Gut with 4 flexures at ca. 20 mm,[1] caecae arise from duodenum by 27.5 mm; liver, intestine, and gizzard well-developed by 26 mm.[14]

Pigmentation: At ca. 20–26 mm, irregular triangle of chromatophores on crown; ca. 20 chromatophores in 2 irregular rows on lower jaw plus few on lower lip and chin; scattered chromatophores on preopercle and throat; 3 rows on dorsolateral surface; a short fourth row along base of caudal; a row along anal base; and many on caudal fin.[14] Young-of-the-year (up to 114 mm) with dorsal and caudal fins uniformly sprinkled with chromatophores; pectorals and ventrals almost unpigmented.[1]

AGE AND SIZE AT MATURITY

Usually 2nd or 3rd year; some females apparently at 1 year.[5] Typically 178–279 mm.[10]

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Dorosoma petenense (Günther), Threadfin shad

ADULTS

D. 11–15;[28,30] or 16;[11] A. 17–27; C. 9+10+9+6–7;[11] P. 12–17, V. (7) 8;[19] scales 39[30] or 41–48 in lateral series, 16–20 around caudal peduncle; 15–18 prepelvic scutes,[19] 10–12 postpelvic scutes;[30] total vertebrae 43–44, precaudal 11–13, caudal 30–32;[11] gill rakers about 300 at 66 mm SL, 330 at 117 mm SL, 350 at 131 mm SL and 440 at 180 mm SL;[19] teeth absent in adult.[19,30]

Body proportions as percent SL or HL: Head length 26.3[30]–33.9 SL;[19] depth 32.0[10]–41.7 SL;[19] predorsal length 46.2 SL;[10] snout 20.6–24.4 HL; mandible 40.0–47.6 HL; eye 24.4–30.3 HL[19] or 8.6 SL.[10]

Body oblong, elliptical and compressed with a trenchant belly armed with bony scutes, ventral profile more strongly curved than dorsal,[30] mouth terminal,[19] gape to middle of eye. Scales large, thin, deciduous on body, small scales covering base of caudal rays, accessory scales present at bases of pectoral and pelvic fins.[30] Dorsal fin origin over base of pelvic fin; last dorsal rays elongated into a filament,[28] this filament reaching posteriorly beyond a vertical from the end of the anal fin.[30]

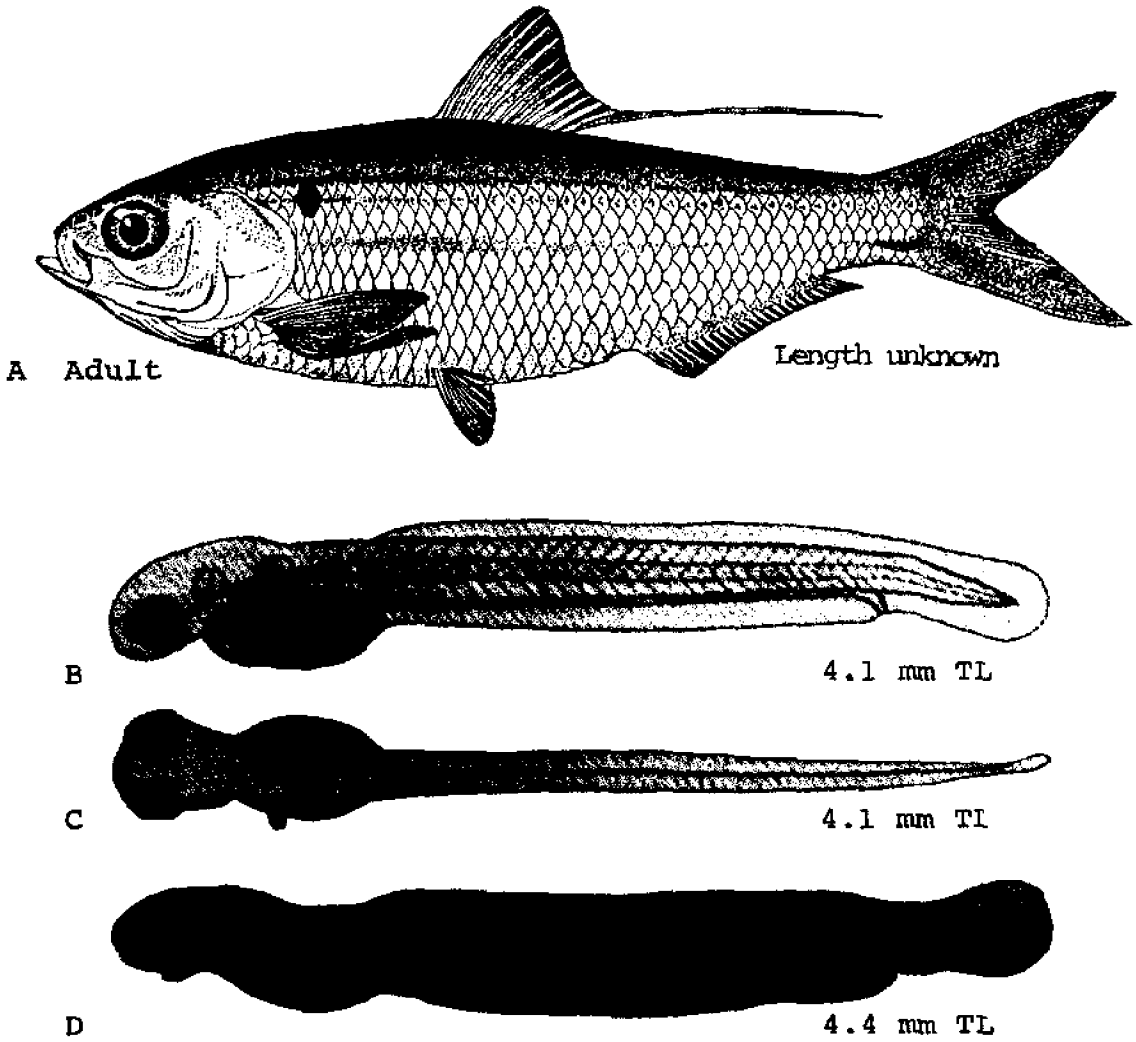

Fig. 74. *Dorosoma petenense*, Threadfin shad. A. Adult, length unknown. B. Yolk-sac larva, 4.1 mm TL. C. Yolk-sac larva, 4.1 mm TL, dorsal view. D. Yolk-sac larva, 4.4 mm TL. (*A, Miller, R. R., 1963: fig. 117. B-D, Taber, C. A., 1969: fig. 5.*)

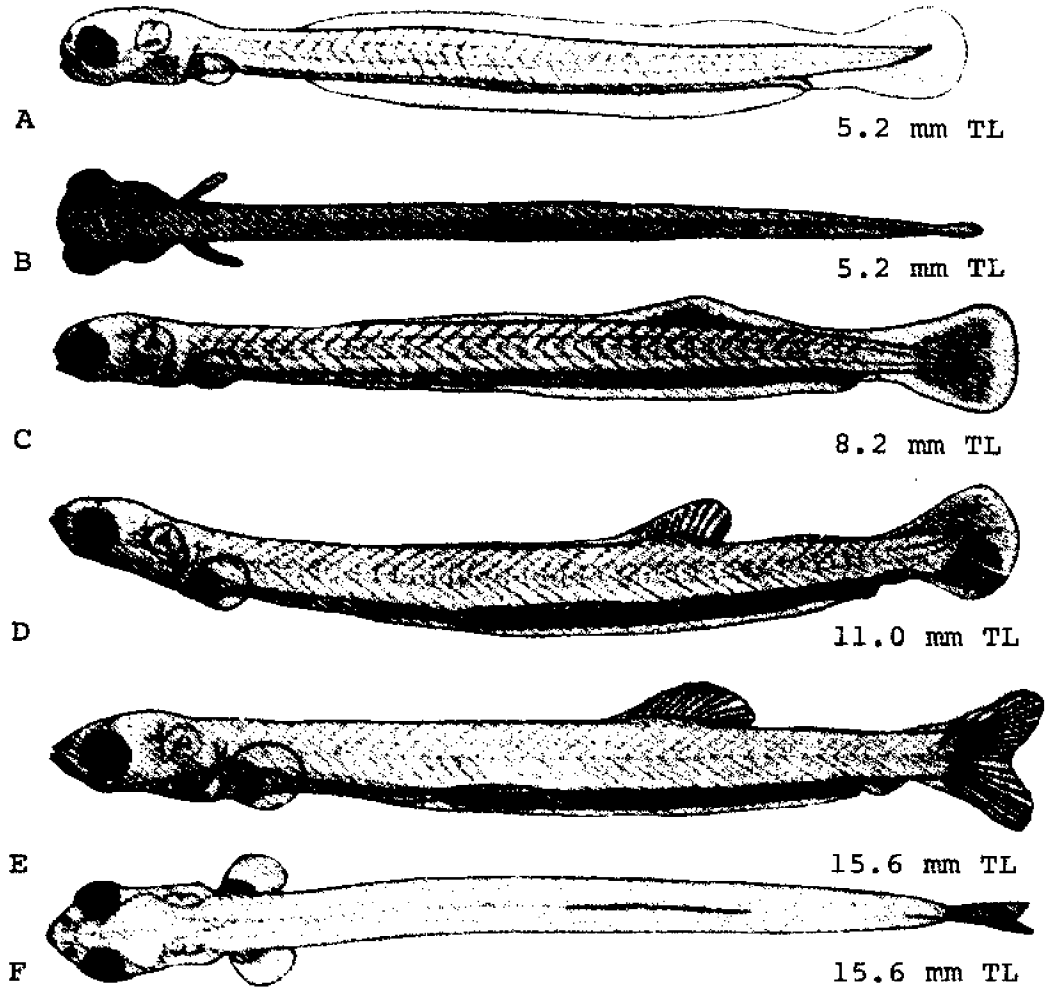

Fig. 75. *Dorosoma petenense*, Threadfin shad. A. Larva, 5.2 mm TL. B. Larva, 5.2 mm TL, dorsal view. C. Larva, 8.2 mm TL, incipient rays indicated in dorsal and caudal finfold. D. Larva, 11.0 mm TL, flexion occurring. E. Larva, 15.6 mm TL, bases to fin rays indicated in anal fin, pelvic bud formed. F. Larva, 15.6 mm TL, dorsal view. (*A-F, Taber, C. A., 1969: fig. 5.*)

Pigmentation: In life body bright silver, especially on sides, opercles and underparts; back and upper sides bluish black or dark olivaceous, washed with gold and overlaid with horizontal rows of dark stripes; a conspicuous round or oval spot behind upper part of opercle; caudal fin with middle portion of each lobe bright golden yellow, fading basally and distally, posterior border dusky; dorsal fin dusky, washed with yellowish olive; anal fin yellow; paired fins yellow basally; a broad golden stripe (often represented only by gilt reflections) in the light band between back and sides; almost no gilt on sides of head.[19]

Maximum length: To 216 mm.[1]

DISTRIBUTION AND ECOLOGY

Range: Ohio River of Kentucky and Indiana westward and southward to Oklahoma, Texas and Florida, along coast of Gulf of Mexico to northern Guatemala and British Honduras.[19] The Ohio River populations of Kentucky, Indiana and Illinois possibly resulting from introduction; also introduced into Virginia, West Virginia, Arizona, New Mexico,[10] California,[1,10,20] Hawaii[14] and Puerto Rico.[22] On the West coast, movements of fishes from the California introductions have resulted in reports as far north as Oregon.[12]

Area distribution: Introduced into James and Rappa-

hannock rivers of Virginia.[28] Reported from Chesapeake and Delaware Canal (MSB).

Habitat and movements: Adults—pelagic, schooling, found in bays, large rivers, reservoirs, lakes and estuaries,[19] prefer the presence of smooth, steep-sided surfaces such as dams, cement-lined pools and riprapped streams,[1] one report from offshore waters;[27] 0 ppt[1,25,30] to 32.3 ppt salinity;[29] in one Texas study 92% of specimens were taken from between 10 and 20 ppt,[24] in Louisiana reported to be most common below 5 ppt;[31] reported from 1.1[1] to 34.9 C,[31] geographic variability in lower lethal temperature limits, in Texas between 12.2 and 14.2 C,[32] in California high mortality below 7.2 C,[18] in Arizona overwintering has occurred down to 5.6 C;[5] occurs in the upper 15 m of the water column.[1]

Larvae—lakes and impoundments;[2,3,5] diel migrations, near surface in daytime, dispersed through midwater and near bottom at night with smallest size at bottom and larger sizes in midwater;[28] probably only in freshwater;[19] surface to at least 15 m,[3] most common at surface;[5,28] common inshore.[3]

Juveniles—occasionally in surf zone in lower salinities;[26] prefer salinities below 15 ppt,[7,19] most common below 5 ppt; reported from 15.5 to 29.5 C.[26]

SPAWNING

Location: Occurs in open water or nearshore in freshwater,[1] over beds of aquatic vegetation,[15,16,33] around floating debris,[17,33] over brush, stumps or other objects projecting from the bottom.[33]

Season: Between April[13,16,17] and July;[3] each age class has a different spawning peak with classes III and IV earliest and each other class peaking sequentially over a 3 to 4 week period; a second spawn may occur under certain environmental conditions.[13]

Time: Spawning reported at about sunrise[15,33] or twice in a day, 0700 and 1500.[17]

Temperature and salinity: Occurs from 14.4[1] to 27.2 C[3] in fresh or nearly fresh water.[7]

Fecundity: 800[8]–21,000 eggs/female,[21] fecundity described by formula $F=3.538 \log L-3.354$ where F is *fecundity in thousands of ova and L is total length in* mm.[4]

EGGS

Location: Adherent to aquatic vegetation,[1,15,16,33] algae,[5] floating debris;[17] nets[33] or planktonic at depths where density equals that of water.[1]

Unfertilized ova: Regarded as mature at 0.53 mm,[11] .68–.75 mm[21] or .74–.94 mm,[18] light yellow, semiadhesive.[21]

Fertilized eggs: 0.75 mm;[6] adhesive.[1]

EGG DEVELOPMENT

Incubation time 3 days at 26.7 C;[1] lower limit for any development between 13 and 15 C, for normal development, 15 C; upper limit for development between 34.2 and 34.4 C.[6]

YOLK-SAC LARVAE

4.1–4.4 mm,[28] yolk absorbed by 3rd day.[1]

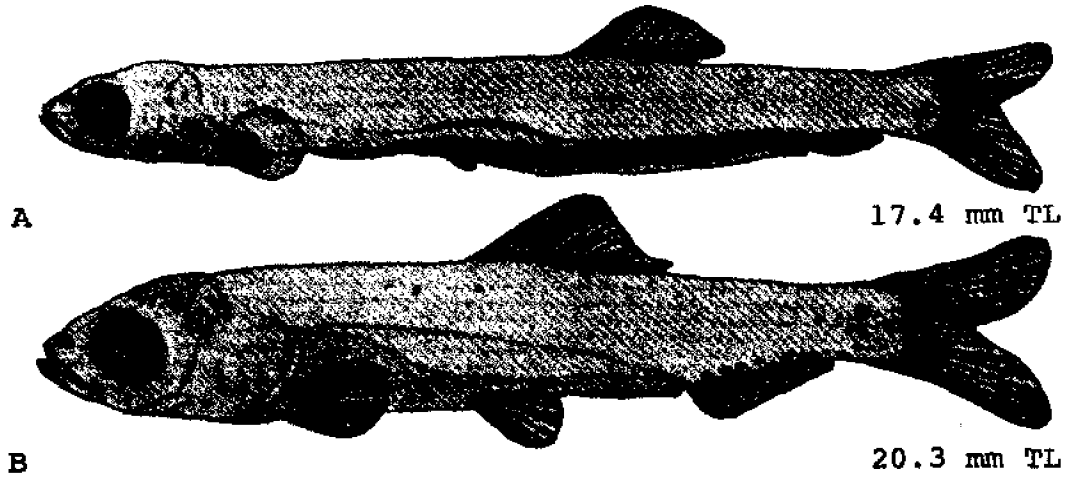

Fig. 76. *Dorosoma petenense*, Threadfin shad. A. Larva, 17.4 mm TL. B. Juvenile, 20.3 mm TL. (*A-B, Taber, C. A., 1969: fig. 5.*)

About 36 preanal myomeres; jawbones forming at 4.4 mm TL; choroid fissure noticeable up to 4.4 mm TL; anus far back on body [28] (most information based on interpretation of illustrations, FDM).

LARVAE

5.2 to 18–20 mm.

About 36 preanal myomeres; [28] at 7–15 mm total myomeres less than 40; [34] dorsal fin rays forming at 8.2 mm TL; anal fin rays forming at 11.0 mm TL; caudal fin rays at 5.2 mm TL; notochord flexion occurring at 11.0 mm TL; anus located far back on body.[28] (All information from Taber based on interpretation of illustrations, FDM.)

JUVENILES

Adult fin ray complement by 18–20 mm TL.

Last dorsal ray beginning to elongate at 20.3 mm TL.[28] (All information based on interpretation of illustrations, FDM.)

AGE AND SIZE AT MATURITY

Mature at 1 or 2 years in some lakes, 2 or 3 in others; [11] age class I spawning females 49 to 55 mm,[18] in general mature between 75 and 126 mm.[22]

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Etrumeus teres (DeKay), Round herring

ADULTS

D. 16[1]–22;[6] A. 9[13]–13;[14] C. 6–7 + 10 + 9 + 6;[15] V. 8;[6] P. 14[1]–17;[6] scales in lateral series 48–56;[13] branchiostegal rays 14–15; gill rakers on lower limb of first arch 27–38; total vertebrae 48–56,[1,6] precaudal 15–17, caudal 32–34.[15]

Proportions as percent of SL: Body depth 16.0–18.5, depth of caudal peduncle 6.7–8.2; head length 24.0–29.0; base of anal fin 5.6–6.9; length of pectorals 14.0–17.0; length of pelvics 8.9–11.5.[1]

Body nearly round, its greatest thickness 80% of depth. Caudal peduncle compressed. Scales deciduous with even edges; scutes lacking. Head low, moderately long; eye with much adipose tissue; maxillary obliquely rounded posteriorly, reaching under anterior margin of eye; gill rakers slender, close-set. Single series of teeth on mandible; row on margin of maxillaries; few on premaxillaries; and very small granular teeth on vomer, palatines, pterygoids, and tongue. Pelvics inserted somewhat posterior to a vertical from base of last dorsal ray; pectorals reaching less than halfway to pelvics.[1]

Pigmentation: Olive green above, silver below.[1]

Maximum length: Ca. 380 mm.[4]

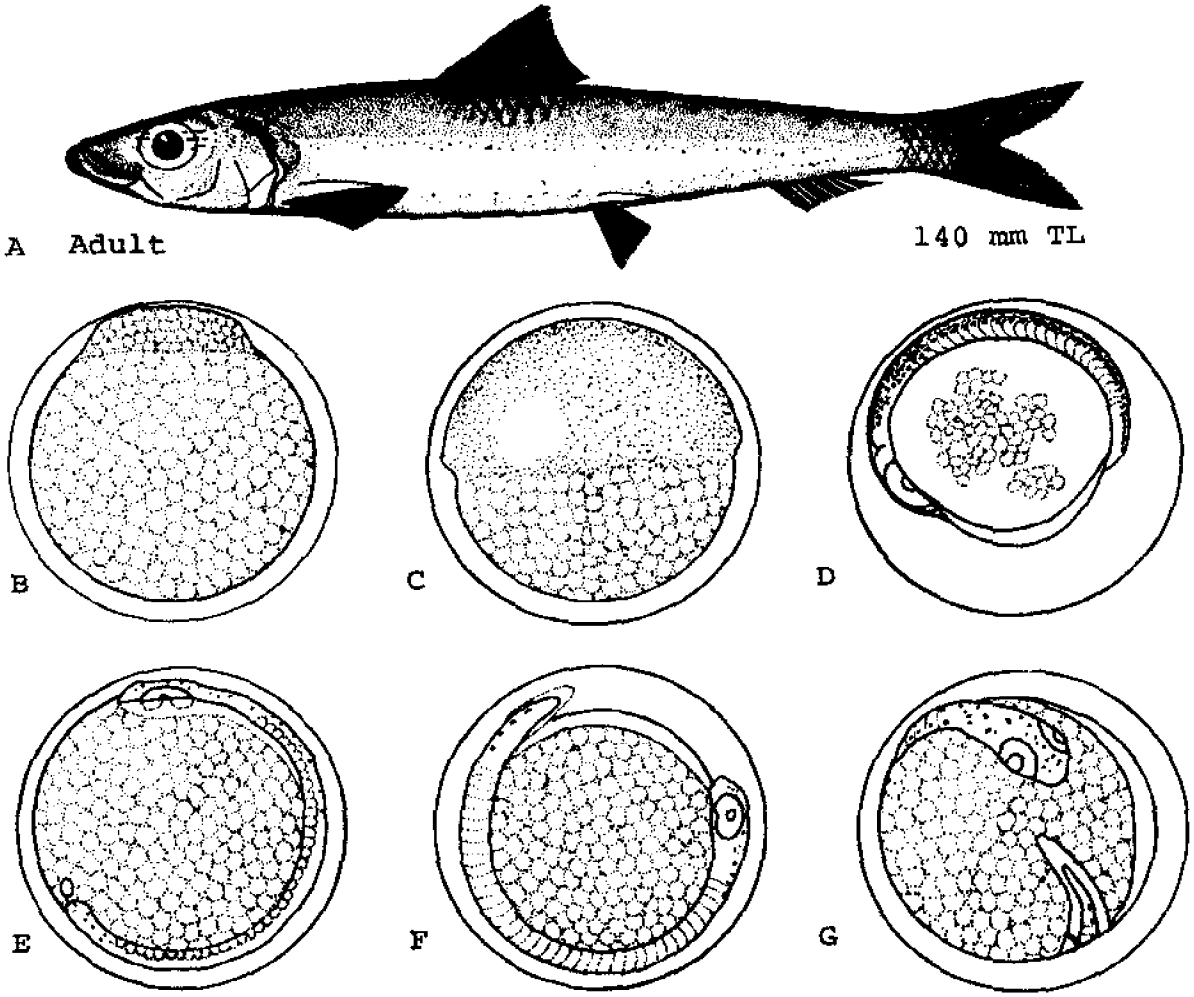

Fig. 77. *Etrumeus teres*, Round herring. A. Adult female, 140 mm TL. B. Egg, showing blastodermal cap. C. Egg, blastula formation. D. Egg, embryo at 25 myomere stage, egg diameter 1.35 mm. E. Egg, blastopore open. F. Egg, tail separation. G. Egg, advanced embryo. (*A, Hildebrand, S. F., 1963a: fig. 62. B, C, E-G, O'Toole, M. J., and D. P. F. King, 1974: figs. 2A-E. D, Uchida, K., 1958: pl. 5, fig. 2.*)

DISTRIBUTION AND ECOLOGY

Range: In western Atlantic from Bay of Fundy to Cape Canaveral, Florida and Gulf of Mexico;[1] the American Pacific coast;[6] central North Pacific near Hawaii;[17] eastern and southwestern coasts of South Africa; south and west coasts of Australia; coasts of Japan, Galapagos Islands, eastern Mediterranean and the Red Sea.[6,10]

Area distribution: One specimen 9.6 km southwest of Cape Charles, Virginia;[2] large schools off New Jersey in some years;[5] possibly off Ocean City, Maryland (taken from stomach of white marlin).[3]

Habitat and movements: Adults—a pelagic, schooling species whose pattern of movement is unknown; primarily an inhabitant of offshore waters although occasionally enter bays and rivers.[1,7]

Larvae—yolk-sac larvae found in surface waters in and around spawning areas; larger specimens occur in mid- to bottom waters.[11] In eastern Gulf of Mexico at $\leq$ 5.0 mm occur at surface temperatures of 20.5–26.9 C (most at 21.26 C) and surface salinities of 34.1–36.8 ppt (most at 35.5–36.5 ppt).[16]

SPAWNING

Location: In eastern Gulf of Mexico primarily between 30–200 m depth contours with slightly over half occurring at depths greater than 50 m.[16] Some spawning may take place beyond continental shelf.[9]

Season: In the eastern Gulf of Mexico from mid-October to the end of May (peak in January and February).[16] In Hawaiian waters from mid-October through mid-July (peak in late April).[17] In Gulf of California larvae most abundant in April.[18]

Time: Evening[17] and night.[16]

Temperature (surface): In eastern Gulf of Mexico, 18.4–26.9 C (most at 21–26 C);[16] in Gulf of California ca. 19.7–23.5 C;[19] in Hawaiian waters ca. 21.5–26.5 C.[17] Off western South Africa eggs have been taken at 16.5 C.[10]

Salinity (surface): In eastern Gulf of Mexico 34.5–36.5 (most at 35.5–36.5);[16] in Hawaiian waters ca. 30.5–36.6 ppt.[17]

Fecundity (at 130–165 mm SL): In eastern Gulf of Mexico, 7446–19,699; relative fecundity (ova per gram of body weight) 150–428 ova/g, mean 296.5 ova/g ($S\ \bar{x}$=33.7 ova/g).[16]

EGGS

Description: Fertilized eggs buoyant[10,11] (specific gravity observed to change during late development[10]), smooth, spherical, transparent;[10,11] diameter 1.17[8]–1.53 mm[17] ($\bar{x}$ 1.29 mm,[8] $\bar{x}$ 1.37 mm[10]); yolk pale yellow,[11] large, lightly segmented;[10] oil globule absent.[8,10,11] Perivitelline space narrow in specimens collected in Japanese[12] and Hawaiian waters[17] and from the southeastern Atlantic near the Republic of South Africa,[10] ca. 10% based on collections from the Gulf of Mexico,[8] moderate (ca. 20–35%) in specimens from waters off the Korean Peninsula.[11]

EGG DEVELOPMENT

Prior to blastopore closure light dendritic melanophores on forehead, between optic cups, on hindbrain region, along dorsal surface on each side of notochord from hindbrain to ca. 1/3 body length, and on tail as light speckling. At tail separation, finfolds develop, body somites extend to caudal region, melanophores are more pronounced on tail, dorsal pigmentation extends almost length of body, ca. 40 countable myomeres present. During late development, anus visible on posterior portion of ventral finfold; dendritic melanophores on dorsal surface begin ventral migration in anterior half of body.[10]

Incubation: 36 hours at 20.5 C;[10] ca. 48 hours at 23–25 C;[17] ca. 50 hours at 21–22 C;[16] 135 hours at 11 C.[10]

YOLK-SAC LARVAE

Hatching length 3.8[11]–4.84 mm TL,[12] 4.5 mm NL;[10] size at end of stage ca. 6.0 mm TL[11]–6.5 mm NL.[20]

At 3.8 mm TL 43+8+ =51+ myomeres; at 4.21 mm TL 44+11=55 myomeres (waters near Korean Peninsula);[11] at 4.84 mm TL 42+12=54 myomeres; at 5.72 mm TL 43+11=54 myomeres (Japanese waters);[12] by 5.0 mm NL 48–50 total myomeres (near Republic of South Africa);[10] at 4.4 mm TL 45 preanal myomeres (Australian waters).[20]

At hatching body slender; head noticeably flexed over yolk.[10] At one day after hatching mouth open, lower jaws forming;[11] at 5.0 mm NL mouth formed; jaws functional;[10] at 6.0 mm TL jaws well developed, teeth present.[11] At 4.4 mm TL incipient rays in caudal fin.[20] Pectoral buds present in newly hatched larvae (EDH). At 4.4 mm TL striations in posterior intestine;[20] at hatching anus ca. 1/6 TL from tail.[10,11]

Pigmentation: Newly hatched larvae—melanophores slightly larger than in eggs;[11] small group of melanophores on forehead, interorbital and cranial regions.[10] Dorsal pigment in two rows, one on each side of notochord, extends from hindbrain to ca. 7/8 NL with pigment near tail turning to sides of body.[10,11] On sides, ca. 10 myomeres ahead of anus, dark pigment group covers 3–4 myomeres; eyes unpigmented. At ca. 4.2 mm $\pm$ TL eye pigmentation begins in some specimens; melanophores scattered from dorsal ridge to sides of yolk, behind this, dorsal pigment lacking; anterior 3/5 of gut pigmented on

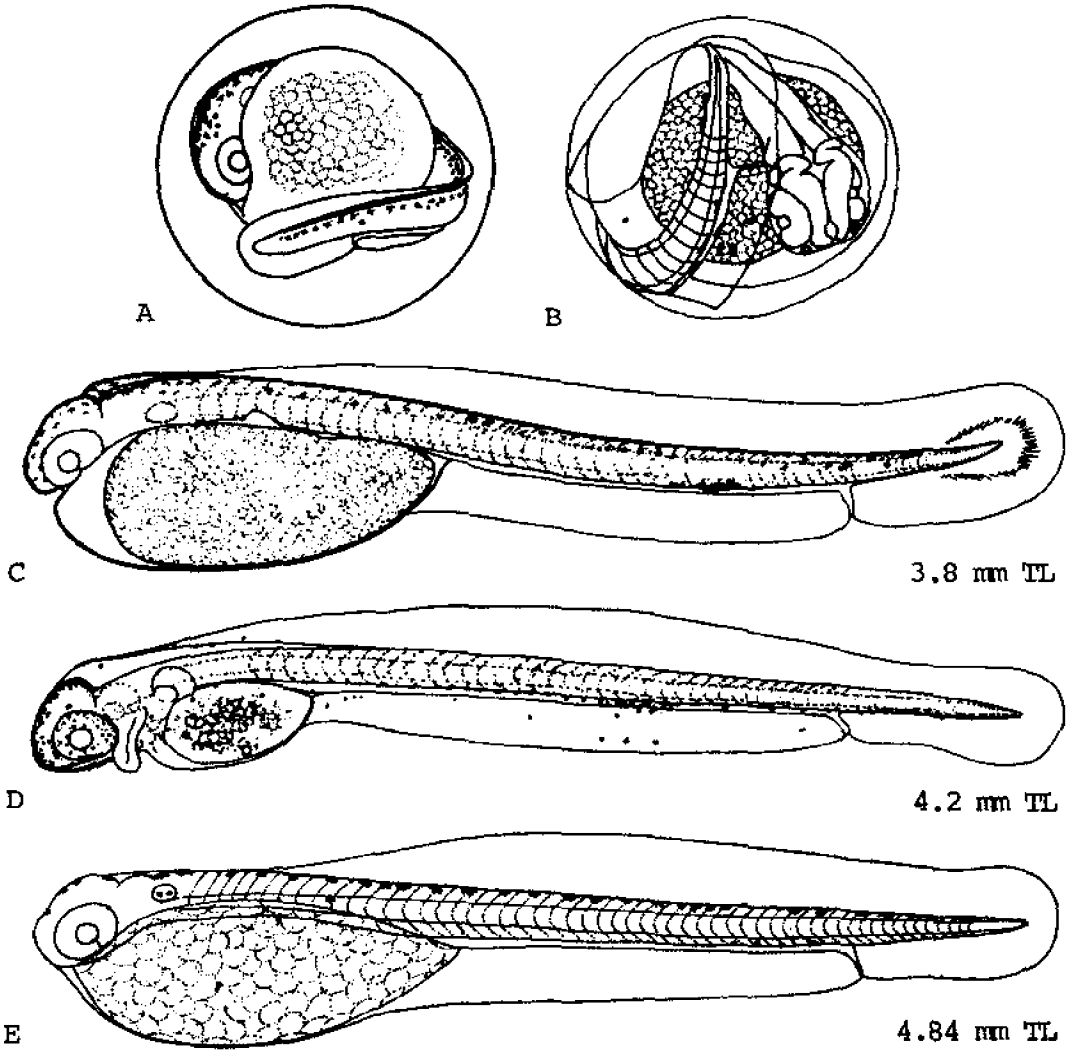

Fig. 78. *Etrumeus teres*, Round herring. A. Egg, advanced embryo shortly before hatching, egg diameter, 1.2 mm. B. Egg, late stage embryo, 1.26 mm in diameter. C. Yolk-sac larva, newly hatched 3.8 mm TL. D. Yolk-sac larva, 1 day after hatching 4.2 mm TL. E. Yolk-sac larva, newly hatched 4.84 mm TL. (*A, C, D, Uchida, K., 1958: pl. 5, figs. 3–5. B, Houde, E. D., and P. L. Fore, 1973: fig. 1A. E, Mito, S., 1961: pl. 20, fig. 7.*)

dorsal surface, posterior 2/5 on lateral surface; preanal finfold with scattered pigment; pigment on ventral surface of tail posterior to anus.[11] By 6.0–6.5 mm NL ventral migration of melanophores almost complete except for a few located between myomeres 30–35; conspicuous band of pigmentation present on lower jaw in specimens from waters near Republic of South Africa,[10] not always present on Gulf of Mexico specimens (EDH). Isolated melanophores visible on yolk sac and ventral finfold between myomeres 30–35.[10]

LARVAE

Size range ca. 6.9–33.0 mm TL.

At 6.9 mm TL 44+12=56 myomeres (waters near Korean Peninsula);[11] total myomeres at 15 mm TL and larger ca. 48–50 (eastern Gulf of Mexico);[8] total myomeres at 18.7–24.0 mm TL 52–53 (Australian waters);[20] at 6.9–23.4 mm TL preanal myomeres 42; predorsal myomeres 25–35; at 15.3–33.0 mm TL prepelvic myomeres 27–29; at 6.9–23.4 mm TL myomeres at pylorus

17–20 (waters near Korean Peninsula);[11] myomeres between end of dorsal fin base and beginning of anal fin base 3–4 (eastern Gulf of Mexico).[8]

Body depth contained 16 to 24 times in SL; snout 1.5 to 2.0 times length of eye.[1]

Snout pointed, elongate; jaws fairly wide at 6.9 mm TL, at 33.0 mm TL, upper contour of snout somewhat round. Forward migration of dorsal fin begins with origin over myomere 36, origin over myomere 26 at end of stage; at 31.0 mm TL dorsal origin above pelvic fin, at 33.0 mm TL dorsal origin anterior to pelvic fin. Caudal base visible at 6.9 mm TL, principal adult fin ray complement evident at 15.3 mm TL. At 15.3 mm TL ventral fins begin to appear below myomeres 30–31. Scale formation begins before 33.0 mm TL.[11]

Pigmentation: At 6.9 mm TL ca. 8 large melanophores in a row on each side of gut anterior to pylorus; posterior to pylorus, melanophores smaller, in two rows, one on each side of ventral midline of gut. One large melanophore evident on gut just above anus, one behind base of pectoral fin, one somewhat anterior to pectoral base, a few near base of caudal fin. At 23.4 mm TL melanophores on pelvic and dorsal fin bases and on anus, pigment increased ventrally posterior to pylorus. At 31.0 mm TL diagonal stripe near base of lower 1/2 of caudal fin quite distinct. At 33.0 mm TL guanin appears on lateral line between dorsal and pelvic fins.[11]

JUVENILES

Minimum size ca. 33.0–35.0 mm TL.[1]

At 39.5 mm TL myomeres 42 + 13 = 55. At 39.6–45.6 mm TL preanal myomeres 41, predorsal myomeres 16–18, prepelvic myomeres 29–30. At 39.6 mm TL myomeres at pylorus 14 (waters near Korean Peninsula).[11]

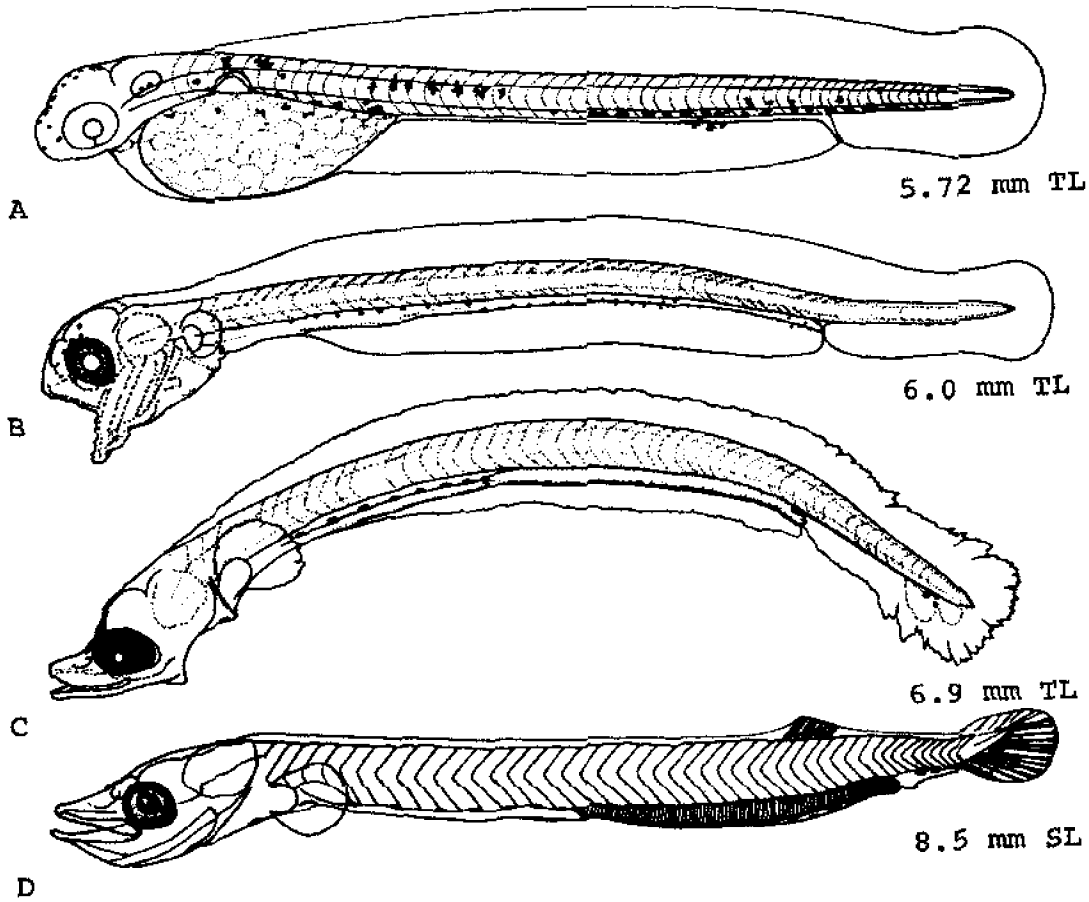

Fig. 79. *Etrumeus teres*, Round herring. A. Yolk-sac larva, one day, 5.72 mm TL. B. Yolk-sac larva, 3 days after hatching, 6.0 mm TL. C. Larva, 6.9 mm TL. D. Larva, 8.5 mm SL. Incipient rays in dorsal and caudal fins. (*A, Mito, S., 1961: pl. 20, fig. 8. B, C, Uchida, K., 1958: pl. 5, figs. 6, 7. D, Houde, E. D., and P. L. Fore, 1973: fig. 1B.*)

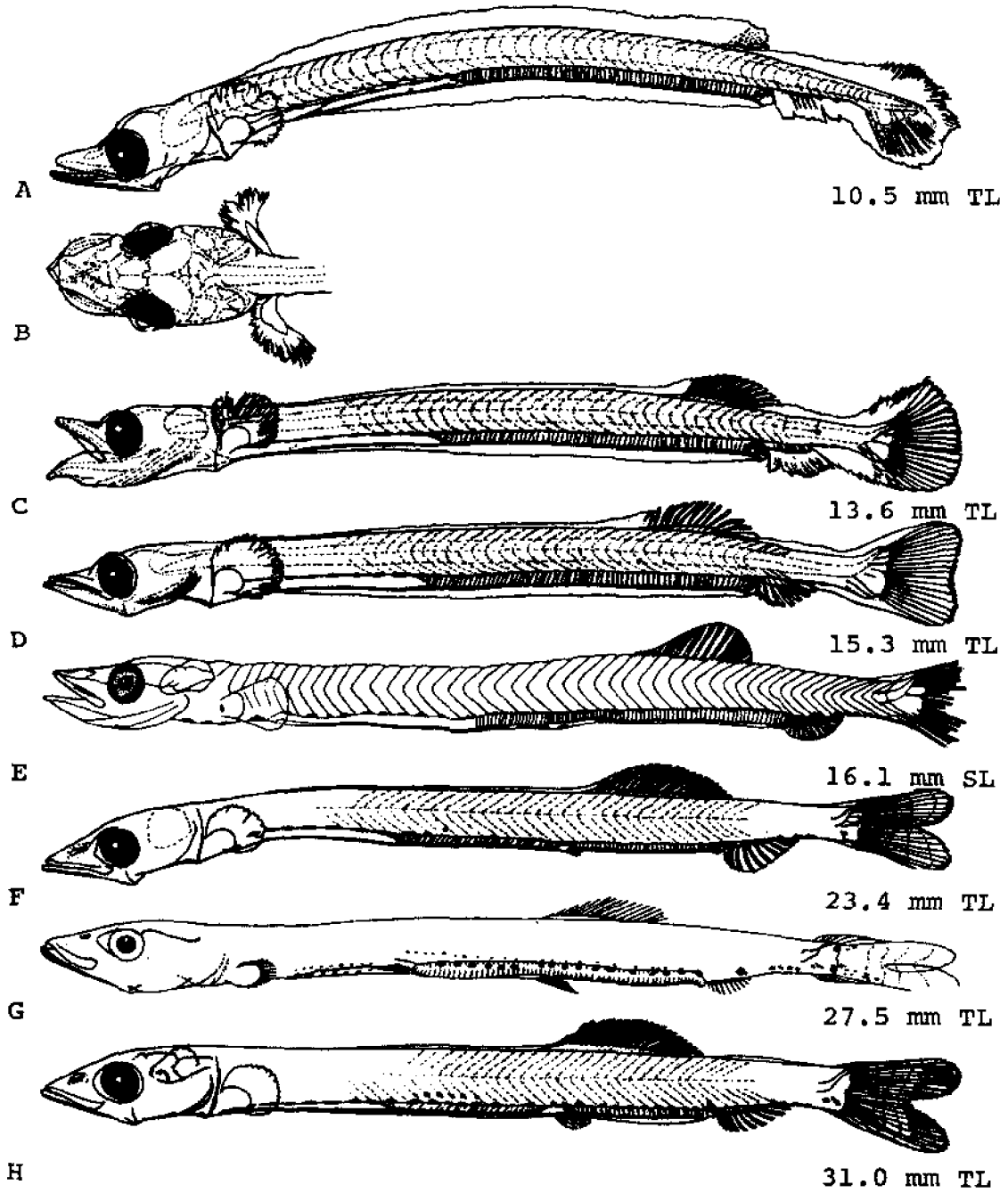

Fig. 80. *Etrumeus teres*, Round herring. A. Larva, 10.5 mm TL. Incipient rays forming in anal fin. B. Head of larva "A." C. Larva, 13.6 mm TL. Incipient rays in pectoral fin. D. Larva, 15.3 mm TL. E. Larva, 16.1 mm SL. F. Larva, 23.4 mm TL. Pelvic bud evident. G. Larva, 27.5 mm TL. H. Larva, 31.0 mm TL. (*A-D, F, H, Uchida, K., 1958: pl. 6, figs. 8–12. E, Houde, E. D., and P. L. Fore, 1973: fig. 1C. G, Hildebrand, S. F., 1963a: fig. 63A.*)

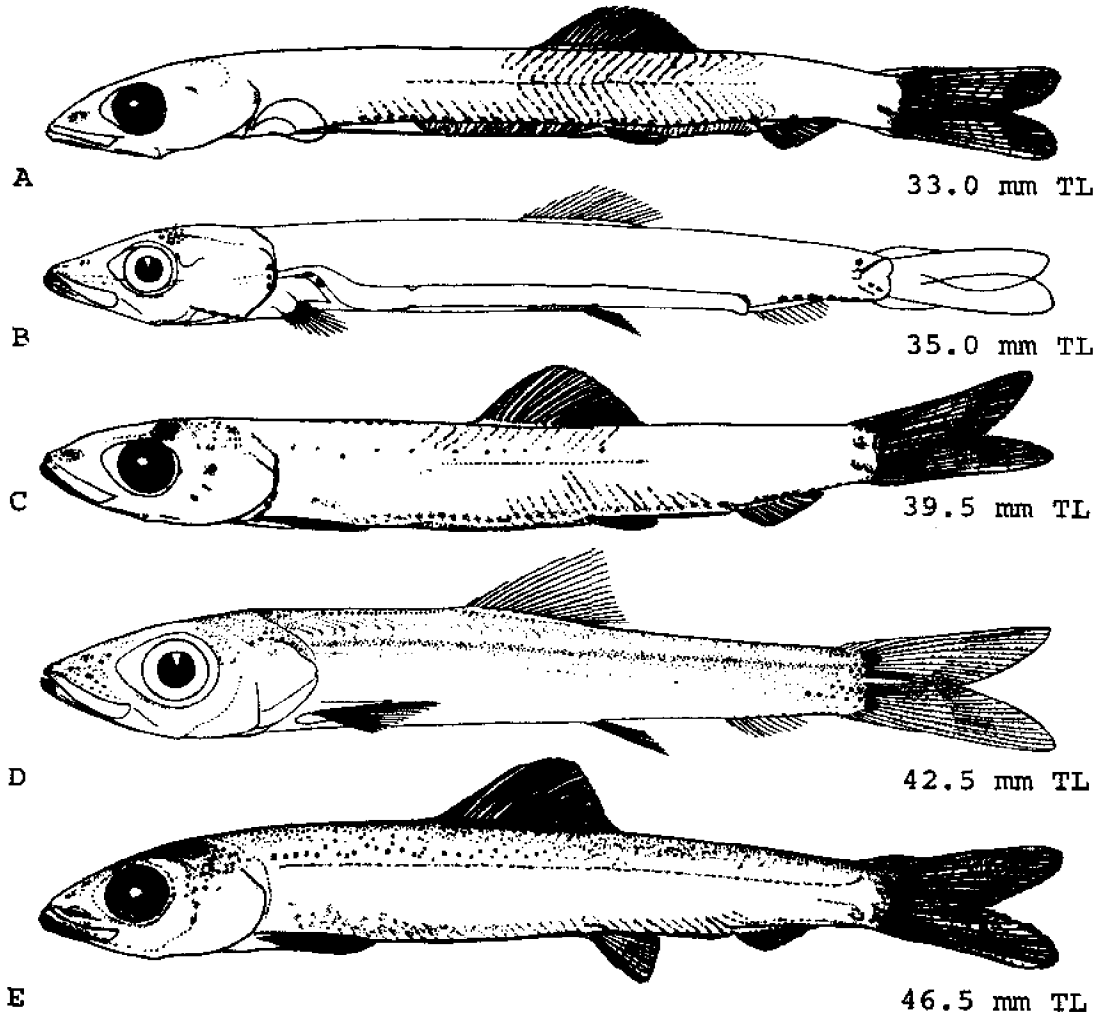

Fig. 81. *Etrumeus teres*, Round herring. A. Larva, 33.0 mm TL. B. Juvenile, 35.0 mm TL. C. Juvenile, 39.5 mm TL. D. Juvenile, 42.5 mm TL. E. Juvenile, 46.5 mm TL. (*A, C, E, Uchida, K., 1958: pl. 6, figs. 13–15. B, D, Hildebrand, S. F., 1963a: fig. 63B, C.*)

Body proportionately much deeper than in previous stage; nostril divided; gut still visible.[1] At 39.5 mm TL to 46.5 mm TL dorsal base on myomere 17–30. At larger sizes a distinct forward movement of dorsal fin evident.[11] At 42.5 mm axillary process of pectoral present, that of pelvic lacking;[1] at 39.5 mm TL to 46.5 mm TL pelvic fin origin on myomeres 30–32, at larger sizes a slight backward movement evident. Anterior tip of pelvic girdle on myomere 26;[11] at 42.5 mm urostyle and gut no longer visible.[1]

Pigmentation: Rows of small chromatophores on dorsum and along upper sides; scattered chromatophores on snout, posterodorsal region of head, caudal peduncle, caudal fin, and ventrally between anal and caudal. General pigmentation scarcely complete at 55 mm TL.[1]

AGE AND SIZE AT MATURITY

In eastern Gulf of Mexico ca. 100 mm TL.[16]

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Opisthonema oglinum (Lesueur), Atlantic thread herring

ADULTS

D. 17[1]–22;[7] A. 20–25;[21] C. 9+10+9+6–7;[22] P. 15–19; V. 8–9; scale rows between gill opening and base of caudal 42–50; vertebrae (total) 45–49,[1,7] precaudal 12–13, caudal 32–36;[22] total ventral scutes 32–36, prepelvic scutes 17–19, postpelvic scutes 13–17;[1,7] gill rakers total ca. 125–158; epibranchial 50–61; ceratobranchial 29–46, hypobranchial 42–62, lower limb 80 (FHB)–100 or more.[16]

Proportions as percent SL: Body depth 30.0–40.0; caudal peduncle depth 8.5–11.0; head length 19.0–28.0; eye diameter 6.0–8.5; maxillary length 8.8–12.0; anal fin base 16.7–21.5; pelvic fin length 8.5–11.5; pectoral fin length 17.0–21.0; length of last dorsal ray 33.3–40.4.[1,7]

Body elongate, rather strongly compressed; ventral outline convex; dorsal outline only slightly convex. Head small; snout lacking definite median notch; maxillary

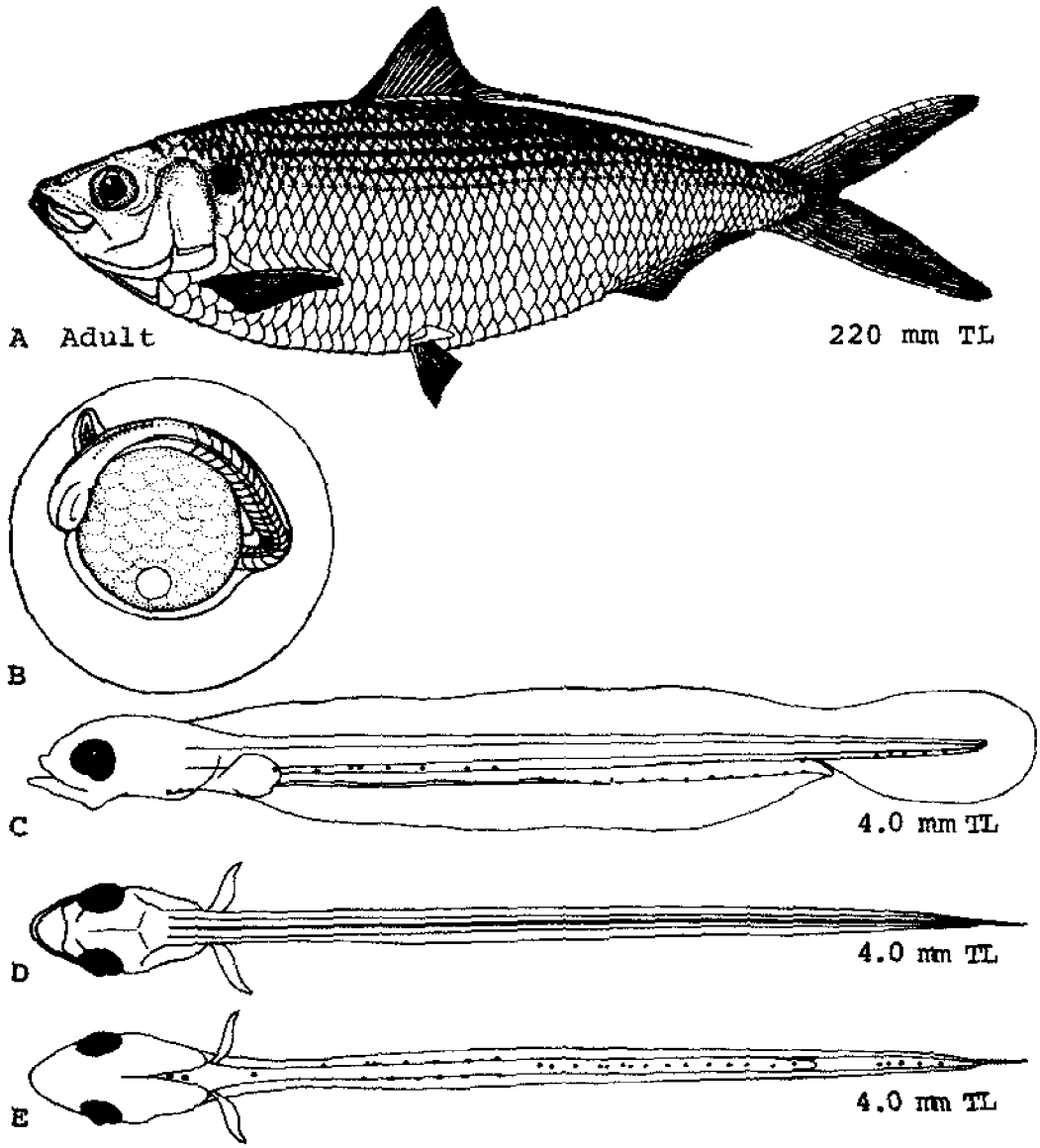

Fig. 82. *Opisthonema oglinum*, Atlantic thread herring. A. Adult, 220 mm TL. B. Egg, late embryo. C. Larva, 4.0 mm TL. D. Dorsal view of "C." E. Ventral view of "C" showing pigment pattern. (*A, Hildebrand, S. F., 1963b: fig. 94. B-E, Richards, W. J., R. V. Miller, and E. D. Houde, 1974: figs. 1, 2.*)

broadly rounded, reaching anterior margin of pupil; mandible slightly projecting, its upper margin forming obtuse angle; jaws toothless; longest gill rakers ca. 1/3 eye diameter. Scales thin, deeper than long, with somewhat irregular membranous edges; predorsal median line scaled to nape; anal and dorsal bases with low sheath of scales.[1,7] Last dorsal ray elongate, more than twice that of next longest ray,[14] often extending to near base of caudal fin;[16] ninth pelvic ray added as flattened segmented ray closely adnate to second ray.[14] Gill rakers increase in number with age.[16]

Pigmentation: Bluish green[16] to silvery bluish above,[17] silvery on sides and below; usually with dark shoulder spot; dorsal scale rows with more or less definite dark lines, fins translucent,[1,7] tips of dorsal fin and caudal lobes dusky.[21]

Maximum length: Ca. 300 mm.[1]

DISTRIBUTION AND ECOLOGY

Range: Gulf of Maine[8] to Santa Catarina, Brazil;[7] also Bermuda[5] and West Indies.[1]

Area distribution: Chesapeake Bay,[2] to Annapolis;[3] Ocean City, Maryland;[6] New Jersey.[9]

Habitat and movements: Adults—a surface schooling species found chiefly in tropical and subtropical waters.[4] Preferred salinity 32–34 ppt. Preferred summer temperature 26–29 C; absent at temperatures below 17 C. Seldom at depths over 18 m, usually in water of 11 m or less, frequently within the upper 3 m of water.[18] In eastern Gulf of Mexico, schools may move northward and possibly offshore at temperatures above 29 C.[15] Annual north–south migrations occur along eastern Gulf[18] and Atlantic coasts.[13] In winter concentrated within 16 km of shore along lower west coast of Florida,[15] usually at distances of 10 km or less.[18]

Larvae—collected in eastern Gulf of Mexico from March through September at surface salinities of 27.3–36.9 ppt and surface temperatures of 18.5–30.9 C; in greatest abundance at surface salinities and temperatures of 35.0–36.5 ppt and 25–30 C. Occur at water depths less than 50 m.[23]

Juveniles—often mixed with schools of juvenile *Harengula pensacolae*[15] and/or *Sardinella aurita*.[19] Reported in small numbers from nearshore and estuarine areas on Florida Gulf coast from June to December; apparently prefer offshore waters.[15] Eight to 10 cm specimens abundant in Beaufort Harbor, North Carolina in August and September;[4] sometimes in great abundance in Chesapeake Bay during summer months.[3]

Juveniles (40–150 mm)—minimum salinity 5.0 ppt, most occur above 15 ppt. Temperature range 5.0–34.9 C (temperature of 5.0 C may be in error, EDH), majority above 20.0 C.[20]

SPAWNING

Location: Reported from straits of Florida;[12] eastern Gulf of Mexico[23] and North Carolina.[1] Based on egg collections, essentially all spawning occurs where depths are less than 50 m, most takes place where water depths are 30 m or less; within 50 km of the coast.[23]

Season: Primarily February to April in Puerto Rico with peak much shorter in some years than in others (FDM); February to September in eastern Gulf of Mexico (spawning in February is restricted to southernmost portions), primarily from April through August.[23] Probably May and June at Beaufort, North Carolina.[1]

Temperature (surface): 22.5–30.3 C, most above 25 C.[23]

Salinity (surface): 32.4–36.8 ppt, most above 35 ppt.[23]

Fecundity: (at 138–175 mm SL) 34,617–67,888.[24]

EGGS

Fertilized eggs: Buoyant;[12] diameter 1.08–1.31 mm ($\bar{x}$= 1.19 mm);[11] chorion thin, fragile, unsculptured, unpigmented. Yolk mass vaguely segmented; at blastodisc stage yolk averages 59% egg diameter, at advanced embryo ca. 53%. Single oil globule present 0.12–0.16 mm ($\bar{x}$=0.15 mm) in diameter.[14] Perivitelline space wide 33%.[11]

EGG DEVELOPMENT

Paired dorsolateral series of tiny melanophores on embryos about to hatch.[14]

YOLK-SAC LARVAE

Eye pigment present within one day after hatching;[12] otherwise undescribed.

LARVAE

Minimum size described 3.8 mm NL, minimum size at end of stage 19.3 mm SL.

Myomeres between end of dorsal fin and origin of anal fin (at lengths less than 16 mm SL) 8–10; predorsal myomeres 19–24;[14] total myomeres 46–48, rarely 49 (EDH); vertebrae 44–46.[14]

Proportions as percent NL (at 4.1–9.9 mm) and SL (at 10.0–19.3 mm): Eye diameter 3.4–5.7; HL 12.0–20.4; origin of dorsal fin to base of caudal rays 30.1–42.3; body depth 4.3–13.5; snout to origin of pelvic fin 41.4–48.2; origin of pelvic fin to base of caudal rays 48.8–60.7; origin

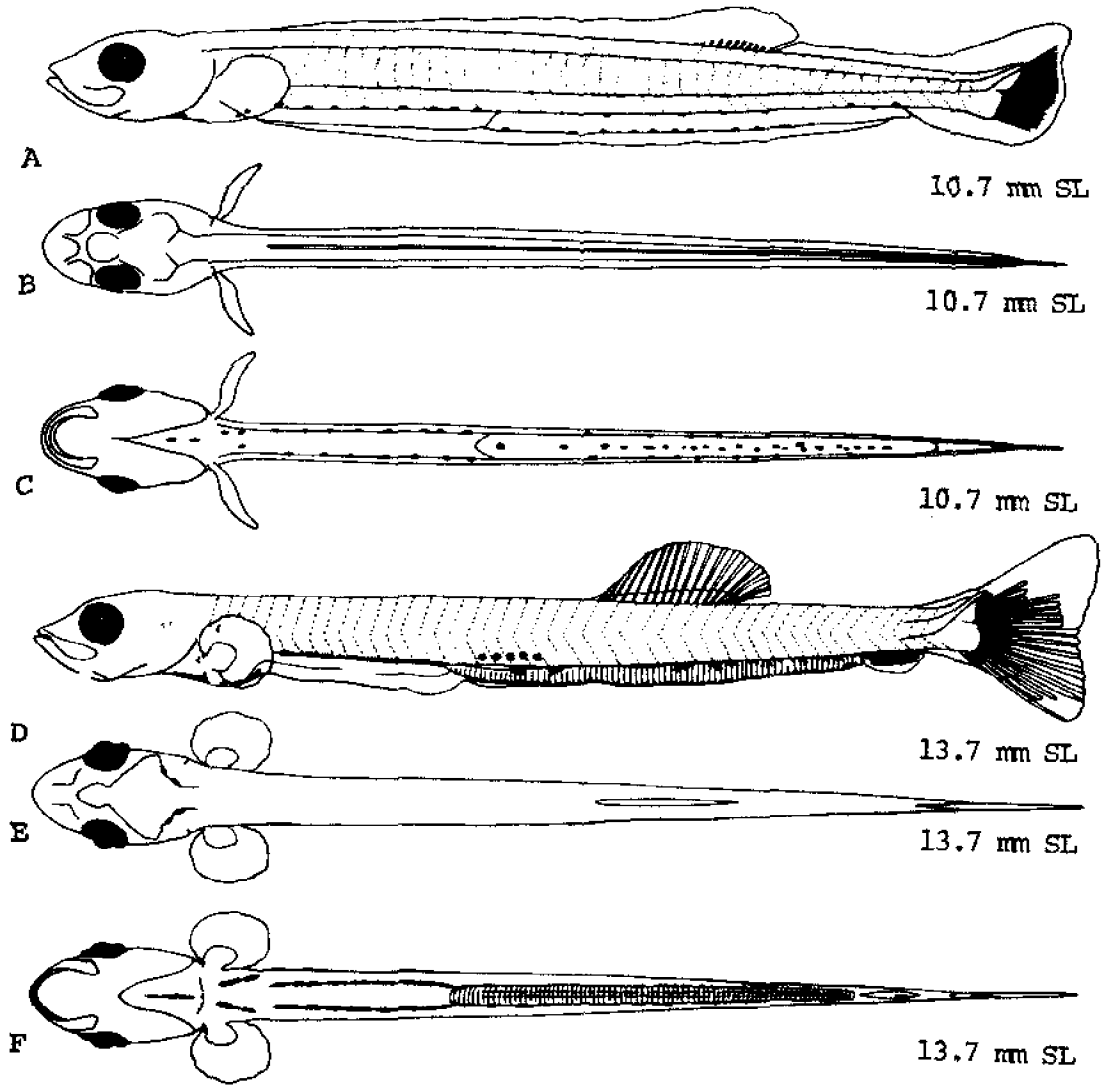

Fig. 83. *Opisthonema oglinum*, Atlantic thread herring. A. Larva, 10.7 mm SL, flexion nearly complete. B. Dorsal view of "A." C. Ventral view of "A." D. Larva, 13.7 mm SL. E. Dorsal view of "D." F. Ventral view of "D." (A-F, *Richards, W. J., R. V. Miller, and E. D. Houde, 1974: figs. 3, 4.*)

of anal fin to base of caudal rays 6.2–15.5. Predorsal length averages over 60% BL up to ca. 17 mm.[14]

At ca. 15 mm and less, body very slender. At ca. 14 mm SL small teeth on ventral edge of maxillaries and anterodorsal edge of dentaries; teeth on basihyal may be limited and variable in occurrence. Dorsal fin develops at ca. 4 mm TL (as with development of caudal fin, this may be a rearing abnormality, fin development in field-captured specimens rarely starts at less than 7 mm SL); rays present at 6 mm SL, countable at ca. 8.4 mm SL; forward migration of fin begins with origin over vertebrae 25 at ca. 15.5 mm SL; minimum adult dorsal fin ray complement first evident at 13.5 mm SL. Anal fin rays countable at ca. 10.5 mm SL; at ca. 15 mm SL forward migration of fin begins with origin under vertebra 38. Caudal fin develops more or less as a lobe at ca. 4 mm TL; rays countable at 8.4 mm SL; between 8.4–10.0 mm SL adult complement evident. Pectoral first fin to form, as small fan-shaped structure, ray areas differentiated soon thereafter but with no apparent relation to location of ossified rays, which first form at ca. 17–19 mm SL. Pelvic fin first appears as a fleshy protuberance, at 13 mm SL 4 rays present. Finfold decreases at ca. 10.0 mm SL, almost lost by 13 mm SL except for remnant beneath foregut.

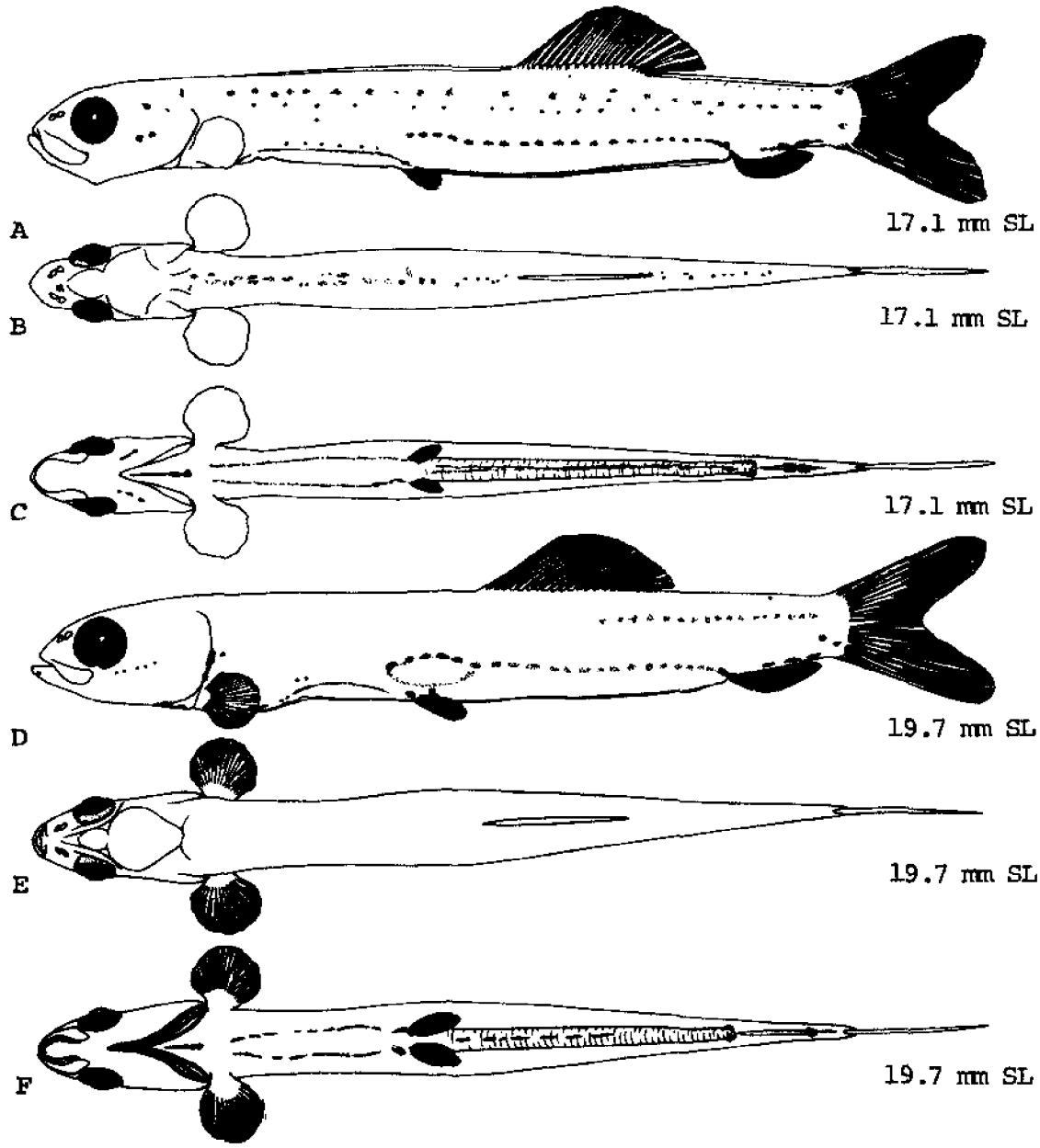

Fig. 84. *Opisthonema oglinum*, Atlantic thread herring. A. Larva, 17.1 mm SL. B. Dorsal view of "A." C. Ventral view of "A." D. Larva, 19.7 mm SL. E. Dorsal view of "D." F. Ventral view of "D." (*A-F, Richards, W. J., R. V. Miller, and E. D. Houde, 1974: figs. 5, 6.*)

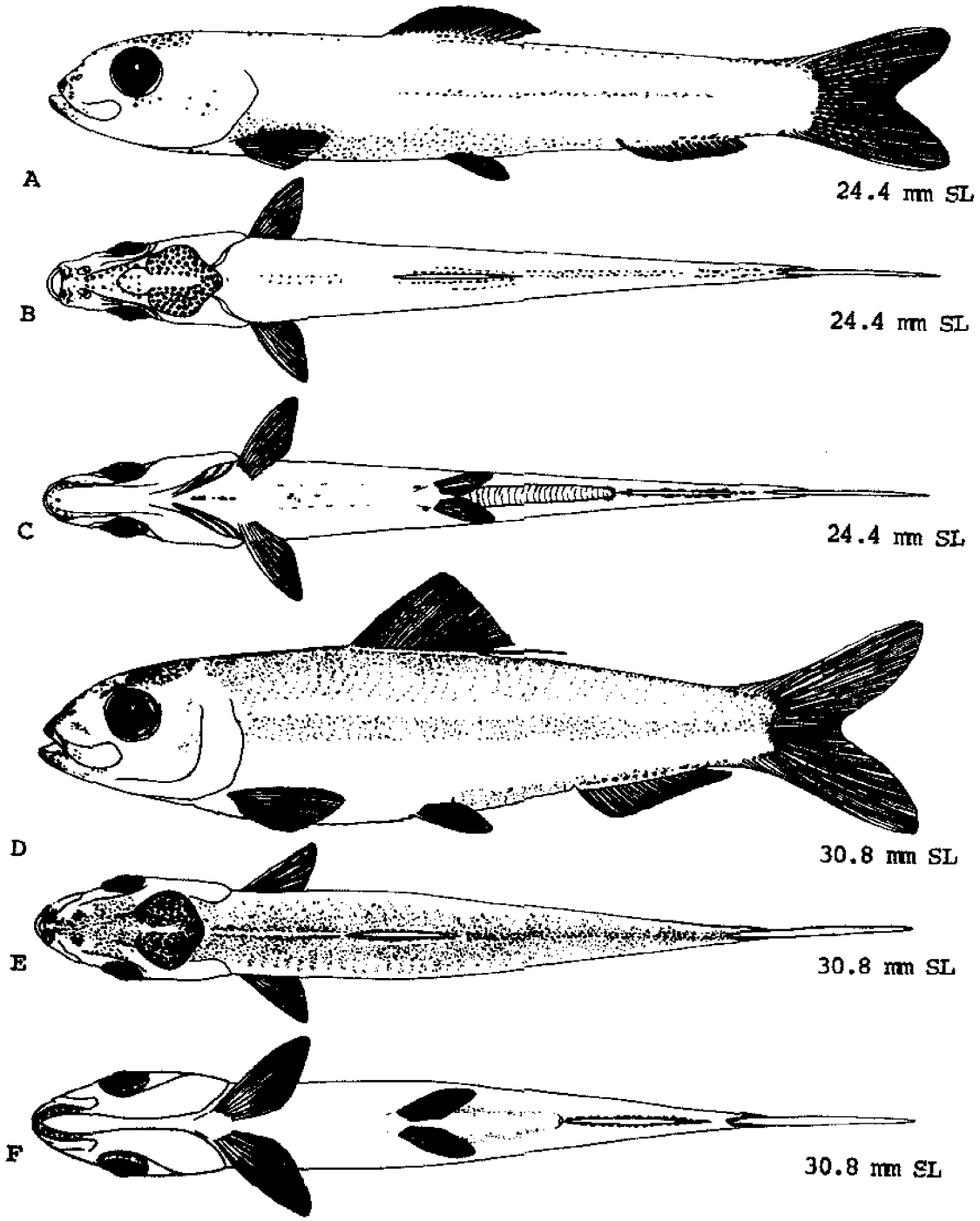

Fig. 85. *Opisthonema oglinum*, Atlantic thread herring. A. Juvenile, 24.4 mm SL. B. Dorsal view of "A." C. Ventral view of "A." D. Juvenile, 30.8 mm SL. E. Dorsal view of "D." F. Ventral view of "D." (*A-F, Richards, W. J., R. V. Miller, and E. D. Houde, 1974: figs. 7, 8.*)

Notochord flexion complete at ca. 10.0 mm SL. At 5 mm SL, foregut and hindgut evident;[14] hindgut possibly ridged or banded at 10 mm or less (EDH); definitely ridged or banded at 13.7 mm SL. Prior to notochord flexion gut length averages 86% BL, after notochord flexion to 15 mm gut averages 92% SL. Definite swim bladder apparent at 15 mm SL. Ossification begins at ca. 10.0 mm SL with maxillaries and dentaries; at ca. 10 mm SL ceratobranchials evident, by 12–13 mm SL partially ossified; gill rakers evident at ca. 14 mm SL; at 15.5 mm SL all vertebral centra partially ossified.[14]

Pigmentation: At 4 mm TL, 1–2 melanophores under heart just anterior to pectoral symphysis, paired row along base of hindgut extending to anus, row on ventral midline posterior to anus, dorsolateral row on each side of foregut. By 10 mm SL, posteroventral row distributed along posterior edge of hypural bones, limited internal melanophores appear dorsolaterally on each side of hindgut, remaining pattern basically unchanged. By 12.1 mm SL limited internal melanophores over posterior centra. By 15 mm SL streaks of pigment along base of isthmus, dorsolaterally along anterior gut, along base of posterior gut, on each side of base of anal fin. Internal melanophores above posterior gut with well defined, broken-lined pattern which had advanced anteriorly forming a slight arch in swim bladder area; one or two individual, or groups, of melanophores above each vertebrae; melanophores on cleithrum near hindbrain; hypural melanophores on bases of lower lobe of caudal fin; by 17 mm SL on both lobes. By 19 mm SL melanophores over anterior vertebrae lost or reduced.[14]

JUVENILES

Minimum size at beginning of stage 19.7 mm SL.

Myomeres between end of dorsal fin and origin of anal fin (at sizes less than 25 mm SL) 5–7.[14]

Proportions as percent SL (at 19.7–30.8 mm): Eye diameter 5.6–7.7; HL 19.8–28.3; snout to origin of pelvic fin 45.7–52.4; origin of dorsal fin to base of caudal rays 46.7–59.2; body depth 13.2–27.7; origin of anal fin to base of caudal rays 15.7–27.3; origin of pelvic fin to base of caudal rays 47.6–54.3. Predorsal length averages 43% SL.[14]

Body generally more slender than in adults in specimens up to 75 mm long. Number of gill rakers increasing with size: 40–50 on lower limb of first arch at 40–60 mm TL; at 40–50 mm SL, ca. 24–35 epibranchial, 22–27 ceratobranchial, and 23–31 hypobranchial.[1] At 20–22 mm SL essentially all bony structures at least partly ossified, by 24 mm SL six ossified branchiostegals present. By ca. 25 mm SL dorsal origin in final position over vertebrae 15–16; at ca. 24 mm SL anal origin assumes final position under vertebrae 33–34; by 23 mm SL pectoral changed into pointed shape of adult. Last dorsal ray 1/2 length of longest ray to ca. 20 mm SL, after about 27 mm longest.[14] Ventral scutes developed at 30 mm or less;[1] Gut ca. 75% SL.[14]

Pigmentation: By 24 mm SL melanophores present dorsally and ventrally on swim bladder, on dorsum, along lateral midline and internally over hypural bones. Internal pigment associated with vertebral column quite pronounced. Some specimens with melanophores medial to left nostril. At 25–30 mm SL melanophores visible over brain and jaws; in increasing quantities on dorsum lateral midline, over gut and in caudal fin rays; by 30 mm SL dorsal pigment increased, foregut pigment lost and melanophores evident in the dorsal fin.[14] At 35–40 mm pigmentation variable; a silvery band, occasionally with small dark spots, generally merges with silvery color of sides, but can remain distinct up to ca. 50 mm. Shoulder spot present in some specimens at 35 mm. Peritoneum black, often visible through body wall.[1]

AGE AND SIZE AT MATURITY

Age at maturity unknown; size at maturity, 135 mm;[17] smallest specimen with ripe eggs in a study performed in Puerto Rico weighed about 7 g (FDM).

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Sardinella aurita Valenciennes, Spanish sardine

ADULTS

D. 15 [13]–20; [1,9,13,16,18,20,25,30,34] A. 14 [13,18]–19 [13,16,18,25] (20 [30]); C. 8+10+9+7; [8] P. 14 [13]–18; [13,16,18] V. 8 [1,13,18]–10; [13,18] scales 42 [4]–51,[16] 17 predorsal,[17] 12–14 in transverse series,[4,25] 18–20 [1,4,25]+13–15 [25] scutes; vertebrae 15–17 [18]+29–31,[8] total 45–52 but usually not more than 49,[16] counts above 49 possibly based on *Etrumeus* (EDH); gill rakers 66–427 depending on size,[13] fine and very slender,[33] curled upward, 0.60–0.66 eye diameter.[1]

Proportions as percent SL: Depth 19.5 [1]–31.1; head length 22.2–27.4; [3] snout length 6.0 [20]–7.8; [1] eye diameter 5.3 [20]–7.1; pectoral fin length 13.9–17.6; pelvic fin length 8.3–9.5; predorsal distance 42.3–45.3; preanal distance 76.0–79.9; [1] caudal peduncle depth 7.7–10.[20]

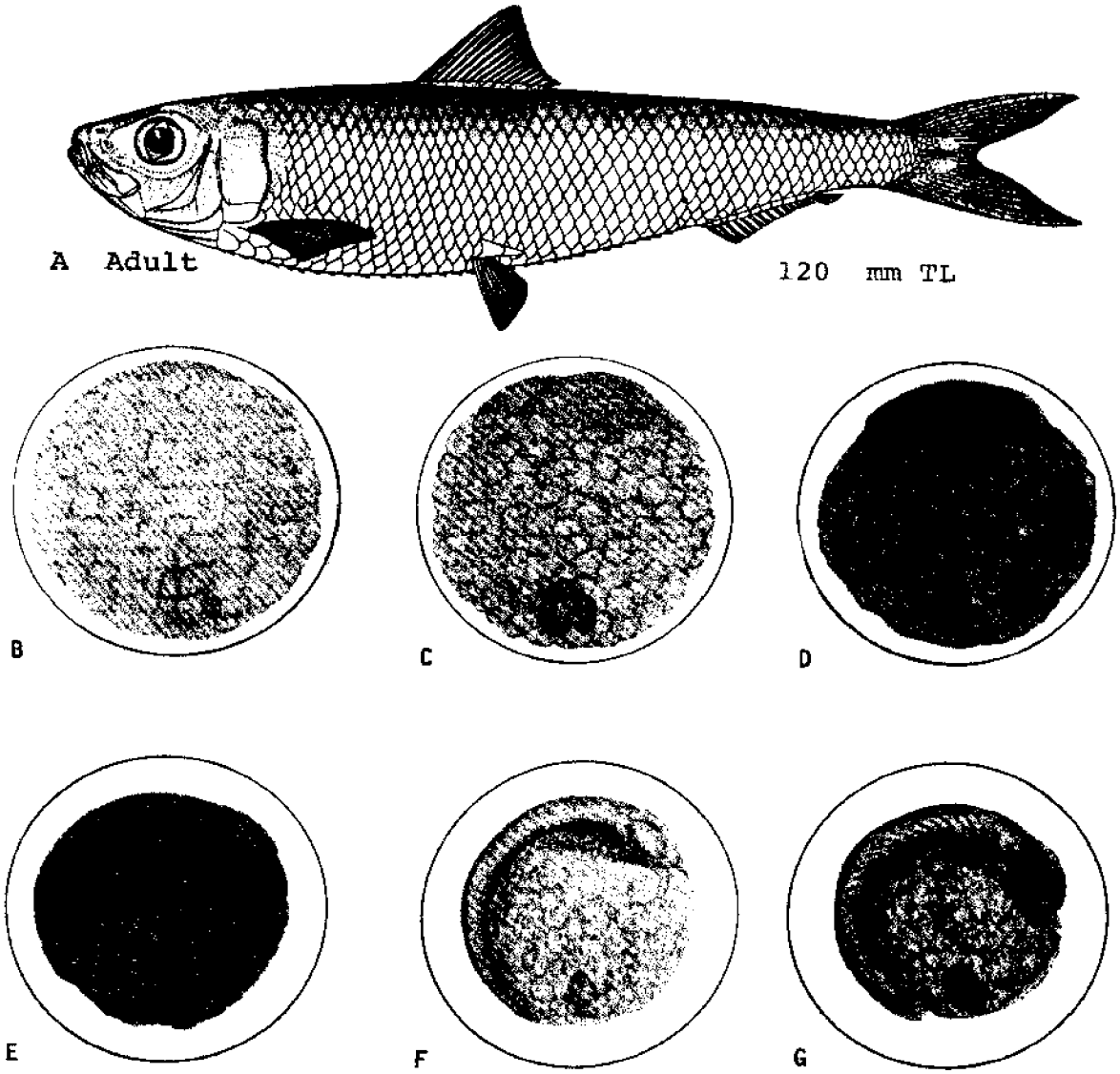

Fig. 86. *Sardinella aurita*, Spanish sardine. A. Adult, 120 mm TL. B. Egg, recently fertilized. This and all following about 1.5 mm. C. Egg, 2-cell stage. D. Egg with complete blastodermal cap. E. Egg, cephalic region becoming better defined. F. Egg, about blastopore closure. G. Egg, earliest development of free tail bud. (*A, Hildebrand, S. F., 1963: fig. 99. B-G, Simpson, J. G., and G. Gonzalez G., 1967: figs. 5a, b.*)

Body elongate,[4,30] compressed,[16,20] oval in cross-section;[9,12] belly not sharply keeled;[12] ventral outline more curved than dorsal outline[20] or about evenly curved;[30] snout long;[3] opercle, preopercle and subopercle entire and smooth.[33] Mouth small,[3] terminal,[16] with lower jaw projecting slightly;[9,16,33] maxillary reaches under anterior third of eye[4,25,30] to border of pupil.[1,16,33] No teeth on maxilla, lower jaw with a few fine teeth on either side of symphysis, basihyal toothplate arrowhead-shaped, basibranchial toothplate extremely slender; fine, granular teeth on palatines, ecto- and endopterygoids.[1] Scales thin, moderately adherent,[20] irregularly shaped,[13] one pointed scale toward rear of dorsal fin base;[9] scutes on belly weakly keeled, especially before pelvic fin base.[3] No lateral line visible.[12] Dorsal fin origin nearer snout tip than to caudal base by 2.0–2.5 eye diameters, its base with a low scaly sheath; pectoral fin tips not reaching pelvic fin bases by 1.66–2.00 eye diameters; pelvic fin bases about equidistant between pectoral fin bases and anal fin origin,[1] slightly behind center of dorsal fin;[3] anal fin origin about 0.5 eye diameters nearer caudal fin base than to pelvic fin bases,[1] last two rays slightly

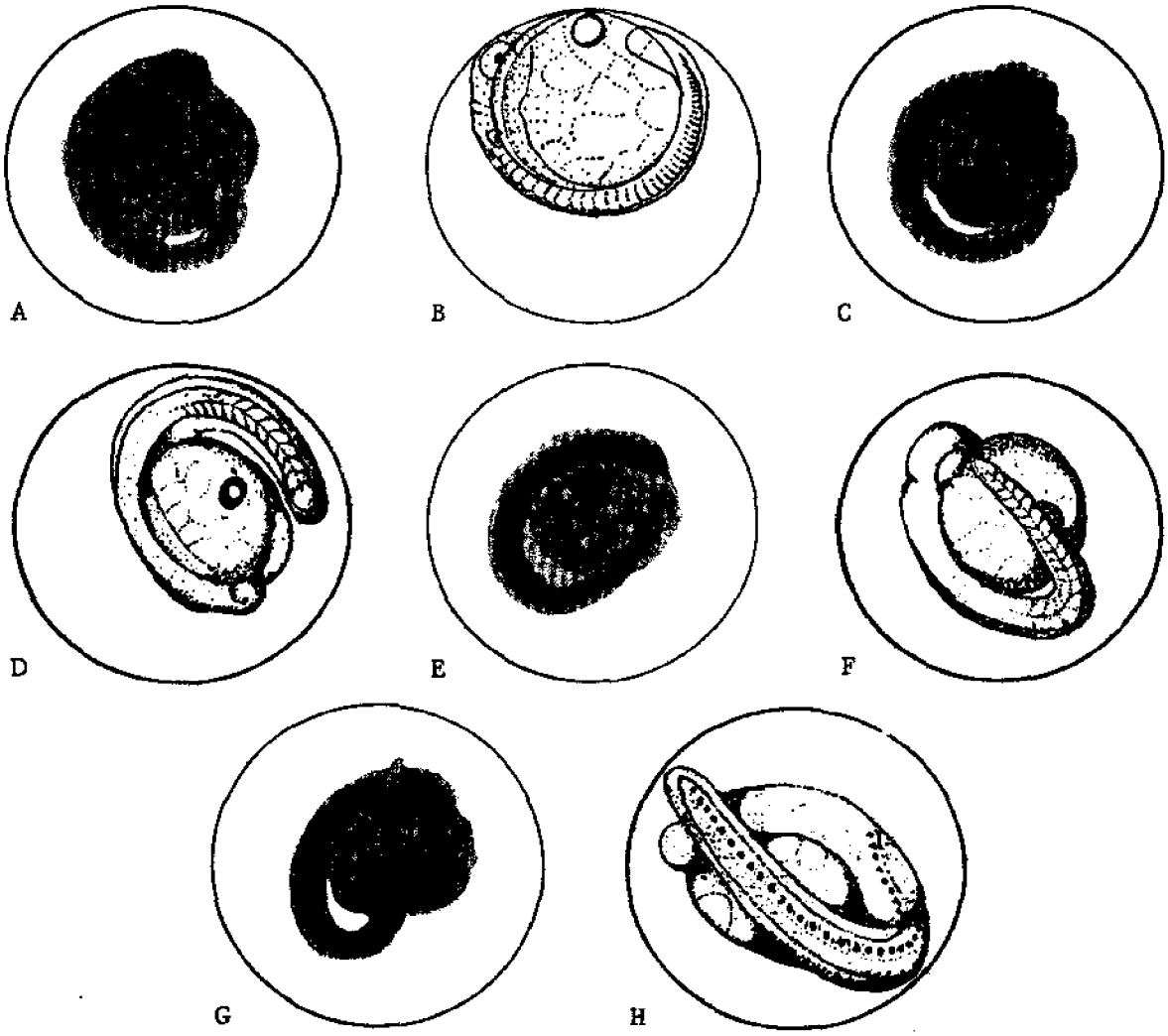

Fig. 87. *Sardinella aurita*, Spanish sardine. A. Egg, embryo about 2/3 around yolk, ca. 1.5 mm. western Atlantic specimen. B. Egg, about same stage as previous, size unstated. Mediterranean specimen. C. Egg, embryo about 3/4 around yolk, ca. 1.5 mm. western Atlantic specimen. D. Egg, about same stage as previous, ca. 1.2 mm. Mediterranean specimen. E. Egg, embryo reaching nearly completely around yolk, ca. 1.5 mm. western Atlantic specimen. F. Egg, embryo reaching completely around yolk, ca. 1.1 mm. Mediterranean specimen. G. Egg, just prior to hatching, ca. 1.5 mm. western Atlantic specimen. H. Egg, probably just prior to hatching, ca. 1.8 mm. Mediterranean specimen. (*A, C, E, G, Simpson, J. G., and G. Gonzalez G., 1967: figs. 5c, 5d. B, Buen, M. F. de, 1932: fig. 1, after Raffaele, 1888. D, F, H, Oliver, M., and F. Navarro, 1952: fig. 1.*)

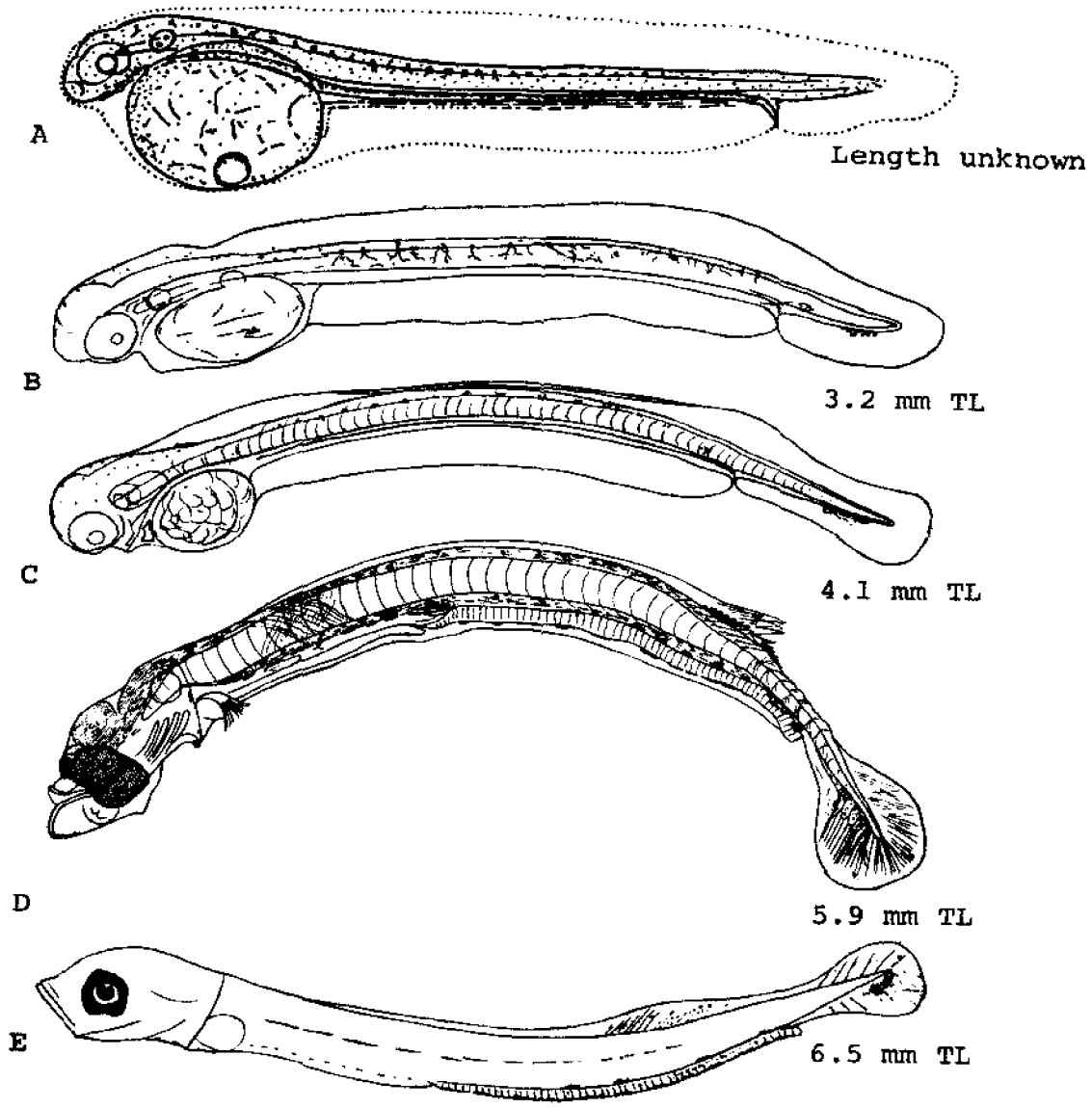

Fig. 88. *Sardinella aurita*, Spanish sardine. A. Yolk-sac larva, length unknown. B. Yolk-sac larva, 3.2 mm TL. C. Yolk-sac larva, 4.1 mm TL, yolk nearly absorbed. D. Larva, 5.9 mm TL, bases for dorsal rays indicated as well as precursors to the urohyals. E. Larva, 6.5 mm TL, dorsal rays indicated. (*A, Buen, M. F. de, 1932: fig. 2, after Raffaele, 1888. B-D, Whitehouse, R. H., 1933: figs. 3, 4, 5. E, Fage, L., 1920: fig. 43.*)

elongate;[9] with a low scaly sheath;[1] caudal fin forked with lobes sharply pointed,[9] a pair of large alar scales on base, a scattering of small circular scales on rest of fin.[1] Adipose tissue covers eye except for a vertical slit about as wide as pupil.[1,9,16]

Pigmentation: Back bluish,[3,9,11,12,30] metallic blue, greenish blue[16] or greenish;[30] lower sides silvery[3,9,11,12,16,30] or golden;[30] a yellow longitudinal streak on upper sides, varying in intensity between individuals;[3,9,12,16] snout tip dark; cheeks silvery white;[16] dark blotch on opercle;[12,16,25,30] yellowish tinge around eyes.[16] Dorsal and anal fins pale brownish[30] with blackish tip;[16] other fins whitish[30] or all fins with membranes yellowish with rays outlined in gray, caudal fin tipped with blackish.[16]

In preservation: Back dark brownish,[1,33] may have blue and violet reflections; sides, lower surface and iris bright, silvery white; tip of snout dusky; dorsal and caudal grayish with other fins whitish,[33] or all fins hyaline except for

speckling at tip of dorsal rays.[1]

Maximum length: Commonly to 15–23 cm,[12] largest reported 38 cm.[31]

DISTRIBUTION AND ECOLOGY

Range: Tropical waters on continental shelf bounded by 30–40° N and S, both sides of Atlantic and in western Pacific from southern Japan, southern China, Taiwan, Hong Kong, and Indo-Australian Archipelago and the Philippines;[16] in the Mediterranean, southern Black Sea,[12,25] and Adriatic Sea;[27] in eastern Atlantic from Spain[9] to Angola; in western Atlantic from Woods Hole to Uruguay[36] including the Gulf of Mexico.[11]

Area distribution: New Jersey.[7,33]

Habitat and movements: Adults—coastal pelagic,[3] offshore in cooler months, inshore in April and May in Africa[31] or September to November at Woods Hole,[10] otherwise nearly nonmigratory.[16] Reported from 24.1–39.3 ppt salinity,[5] most abundant above 34 ppt.[13] Reported from 19.9–32 C[5] and from surface[12] to 100–150 m, deeper during cooler periods.[13] Usually found within the 91 m contour but occasionally out to the 366 m contour.[6]

Larvae—pelagic,[24] reported from surface salinities of 35 ppt (EDH)–42.34 ppt (most common above 35.5 ppt),[19] 17.7–27.06 C surface temperature (optimum 20 C) and from depth of 8–33 m (estimated by FDM based on cable out), mostly in upper 10 m;[21] usually near coast.[16]

Juveniles—school at surface over 18–36 m[16] in shallow waters; *salinity not reported but given as slightly reduced* by autumn rains;[35] reported from temperatures down to 15 C.[13]

SPAWNING

Location: Said to occur near coasts.[16,24]

Season: Occurs throughout the year in Venezuela but mainly from December to April with peaks in January or February;[2,3,14] in eastern Gulf of Mexico essentially year round;[22] in eastern Atlantic and Mediterranean season given as June and July,[24] summer and fall;[16,18,21,23,31] occurs earlier in spring in warmer years and occurs more abundantly in years when rains come in February and April.[29]

Time: Spawning occurs throughout the day but peaks between 1930 and 2300 hours.[14]

Temperature and salinity: Spawns between 18 and 28 C[16] and between 35.6 ppt[31] and 38 ppt salinity.[18,35]

Fecundity: Reported as 3710 to 48,600 dependent on size, with females 125–149 mm averaging 4097 while females 230–249 mm average 41,400.[16]

EGGS

Location: Pelagic[14,18,26,34] at surface to various depths,[18] common at 5–7 m below surface.[14]

Unfertilized eggs: Increase in diameter from 0.988 mm to 1.120 mm with water-hardening.[14]

Fertilized eggs: Spherical,[14,26,34] 0.942[14]–1.40 mm[36] with a mean diameter near 1.1 mm. Chorion thin, unsculptured, translucent; yolk with irregularly shaped granules; usually one large oil droplet with several, usually three, small ones.[14,26] Largest oil droplet ranging in diameter from 0.121[36] to 0.161 mm, mean of 0.145 mm, small ones 0.083–0.094 mm;[14] oil droplet in ventral portion of yolk,[34] yellow;[27,34,36] perivitelline space wide,[14,26,34,37] mean width 0.292 mm.[14]

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

2.3 mm to 4.06 mm.[28]

At 2.3 mm postanal length 20% TL, at 3.2 mm postanal length 18% TL.[28]

At 2.3 mm yolk sac large, oval, yolk segmented;[28] oil droplet located medioventrally,[28,36] disappearing by 3.2 mm[28] or possibly present to 4.0 mm SL (EDH). Otoliths "more prominent" at 4.06 mm. Anus "well back on body."[28]

Pigmentation: At 2.3 mm, a series of melanophores dorsally along whole length. At 3.2 mm pigment more pronounced, a group of melanophores on ventral side of tail near its extremity as well as above anus; dorsal melanophores appear to be migrating ventrally. At 4.06 mm melanophores may still be dorsal.[28]

LARVAE

Reported as 5.9[28] to 16 mm.[16]

At 11 mm 15 caudal rays and about 48 myomeres; 48 vertebrae at 15.5 mm.[21]

Head length 20% TL at 6.5 mm, 18% TL at 11 mm, 14% TL at 15.5 mm, 19% TL at 16 mm; prepelvic length 25% TL; pelvic fin to anus 31% TL and caudal fin 12% TL at 16 mm.[21]

Basal elements of dorsal fin present at 5.9 mm;[28] origin on 28th myomere at 11 mm,[16,21] on 27th myomere at 15.5 mm, on 24th myomere at 16 mm. Anal fin indistinct at 11 mm, developed rays at 15.5 mm.[21] Caudal fin basal elements at 5.9 mm,[28] symmetrical at 10–11 mm, becoming forked at 15–16 mm.[16,21] Pectoral fins well-developed

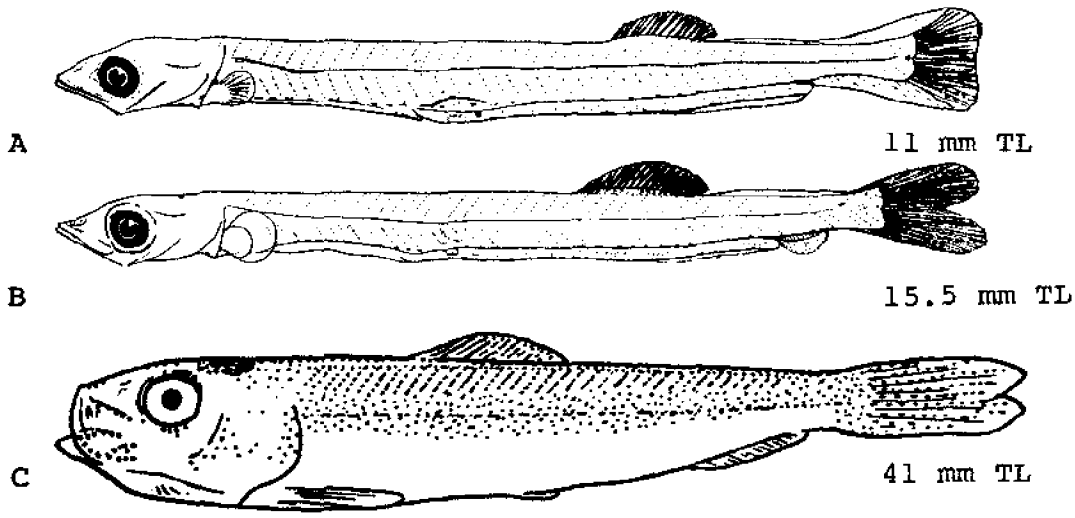

Fig. 89. *Sardinella aurita*, Spanish sardine. A. Larva, 11 mm TL, flexion has occurred sometime between the previous stage and this. B. Larva, 15.5 mm TL, anal fin developing rays. C. Juvenile, 41 mm TL. (*A-B, Fage, L., 1920: figs. 44, 45. C, Buen, M. F. de, 1932: fig. 6, after D'Ancona, 1931.*)

and functional at 5.9 mm[28] but without rays (EDH). Pelvic fins with rudiments at 11 mm,[21] very visible rudiments at 15.5 mm,[16,21] inserted between 14th and 15th myomere. Urostyle fully flexed before 11 mm TL.[21] Gut "fully differentiated" at 5.9 mm,[28] at 11 mm 4 times head length.[21]

Pigmentation: At 11 mm some pigment in dorsal fin, melanophores distributed along base of the anal fin rays.[21] Branchial chamber blackish.[24]

JUVENILES

Descriptions based on specimens 30[16] to 130 mm.[34]

Proportions varying with length. Head length 24.2% TL at 48 mm, 21.1% at 105 mm; predorsal length 37.2% TL at 4–6 cm, 36.1% TL at 9–11 cm; caudal fin 16.2% TL at 30–40 mm, 15.3% TL at 121–130 mm; prepelvic distance 44.7% at 3–4 cm, 42.8% TL at 12.1–13 cm.[34]

Scales reported to appear at 30 mm, especially ventral scutes,[16] but may appear as early as 20–25 mm (EDH).

Pigmentation: Blue and white as in adult but with pigment spots on dorsum and in dorsal and caudal fins.[34]

AGE AND SIZE AT MATURITY

Mature in 2–3 years;[14,32] males ripe at 12 cm in Algeria, 16.9 cm in Spain[16] and 13.5 cm in the Balearic Islands;[34] females ripe at 13.5 cm in Algeria, 19.4 cm in Spain[16] and 12 cm in the Balearic Islands.[34]

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Anchoa hepsetus
Anchoa mitchilli
Engraulis eurystole

anchovies
Engraulidae

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FAMILY ENGRAULIDAE

Anchovies are small schooling fishes found in warm inshore waters around the world. While primarily marine, these fishes are also abundant in estuarine waters, with some species entering freshwater streams and others possibly living entirely in freshwater.

All species share the characteristic features of a rounded protuberant snout, a large mouth and an enlarged maxillary. In life, anchovies are translucent with a silvery, mid-lateral stripe.

This family is composed of 18 to 20 genera and 120 to 130 species (Böhlke and Chaplin, 1968). Within the Mid-Atlantic Region four species have been recorded. *Anchoa duodecim*, the New Jersey anchovy, known only from its type, is not included in this volume. Eggs of the remaining three species, *Anchoa hepsetus*, *Anchoa mitchilli*, and *Engraulis eurystole*, are transparent, elliptical (major axis 0.65–1.66 mm, minor axis 0.50–1.26 mm), lack oil globules and have segmented yolks.

At hatching yolk-sac larvae are long and slender, the anus is near the posterior fourth of the body and the yolk tapers to a point posteriorly. Yolk-sac larvae of *Anchoa hepsetus* are ca. 3.6–4.5 mm TL and lack incipient fin rays as well as definite chromatophores. Those of *Anchoa mitchilli* range from 1.8–3.85 mm TL, have incipient rays in the caudal fin at 3.7 mm TL and, while initially lacking pigment, develop a few chromatophores along the ventral midline below the gut and ventrally between the anus and the caudal fin. *Engraulis eurystole* yolk-sac larvae are 2.0–3.0 mm TL at hatching, have incipient rays in the caudal and pectoral fins at ca. 3.4 mm TL, and at or within eight hours after hatching develop pigment along the dorsal surface of the gut and at the base of the ventral finfold posterior to the vent.

Larvae about 10 mm TL and larger are separable on the basis of the relative placement of the dorsal and anal fins. The anal fin is under the last 5–8 rays of the dorsal fin in *A. hepsetus*, at about the midpoint of the dorsal fin in *A. mitchilli* and under the last 1–3 dorsal rays in *E. eurystole* (Lippson, A. J., and R. L. Moran, 1974).

Anchoa hepsetus (Linnaeus), Striped anchovy

ADULTS

D. 13 [2]–17; [12] A. 18 [2]–24; [12] C. 7–9 + 10 + 9 + 7–8; [18] P. 13 [2]–17; [12] V. 7; [15] scales from upper angle of gill opening to base of caudal ca. 37–43; total vertebrae 40–44,[2] precaudal 21–22, caudal 20–21; [18] gill rakers 15–20 + 18 [2]–25; total gill rakers 34–44.[17]

Proportions as percent SL (at 80–110 mm SL): Body depth 18.9–22.6; head length 26.1–28.9; [17] eye diameter 6.5 [12]–8.0; snout length 4.5–6.1.[17]

Description includes juveniles. Body slender, moderately compressed,[2] belly rounded; snout about 3/4 of eye diameter,[15] projecting much beyond tip of lower jaw; [15] upper part of operculum twice as broad as lower part,[15] its posterior angle ca. 45.[2] Maxilla with tapering tip, slightly [15] to quite pointed, reaching nearly to margin of opercle.[2] Lower edge of maxilla and premaxilla with slightly curved conical teeth; lower jaw with teeth similar

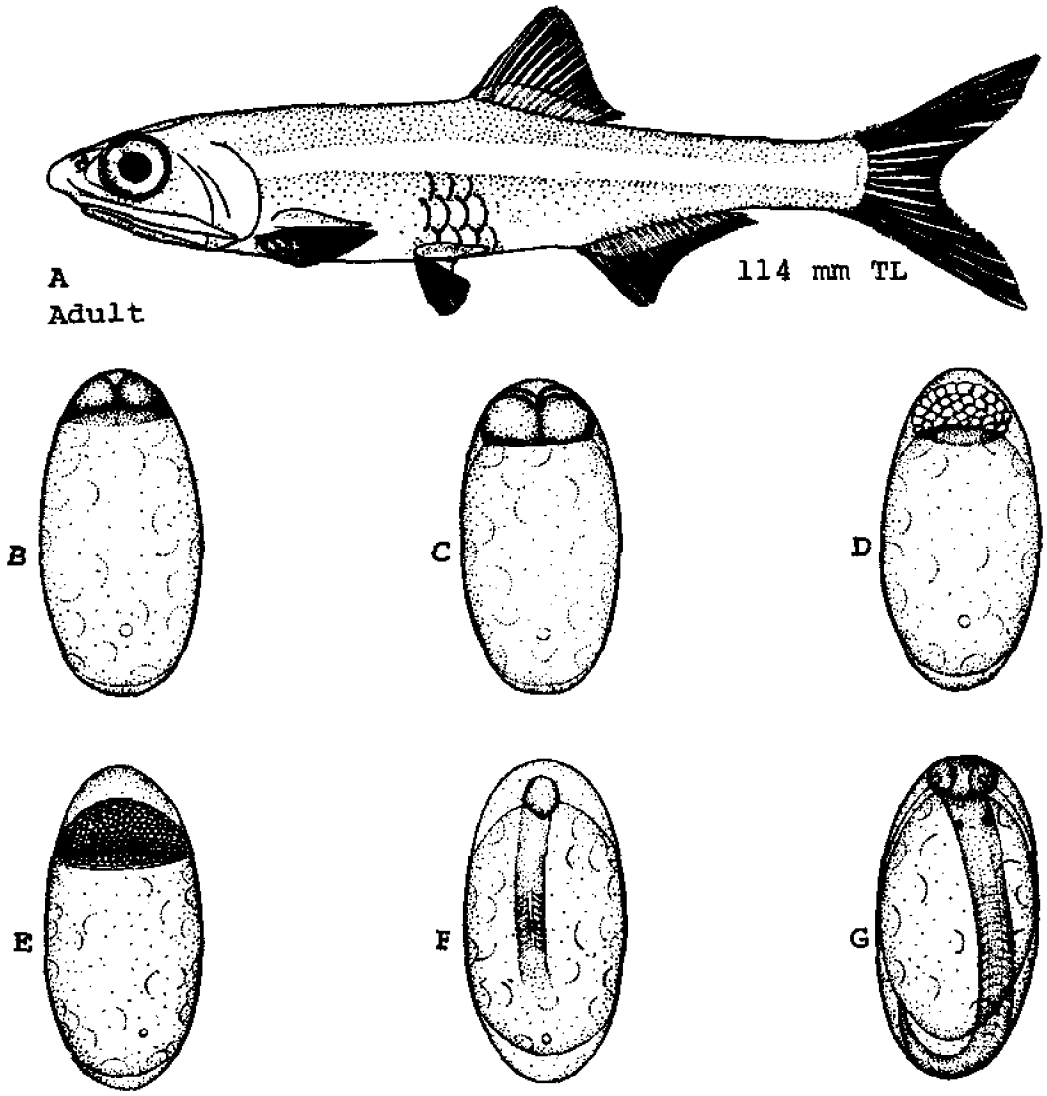

Fig. 90. *Anchoa hepsetus*, Striped anchovy. A. Adult, 114 mm TL. B. Egg, 2-cell stage. This and all following eggs 0.8 mm × 1.5 mm. C. Egg, 4-cell stage. D. Egg, early morula. E. Egg, late morula. F. Egg, early embryo. Eight somites visible; Kupffer's vesicle present. G. Egg, just prior to hatching. (*A, Hildebrand, S. F., 1963b: fig. 40. B-G. Hildebrand, S. F., and L. E. Cable, 1930: figs. 3–8.*)

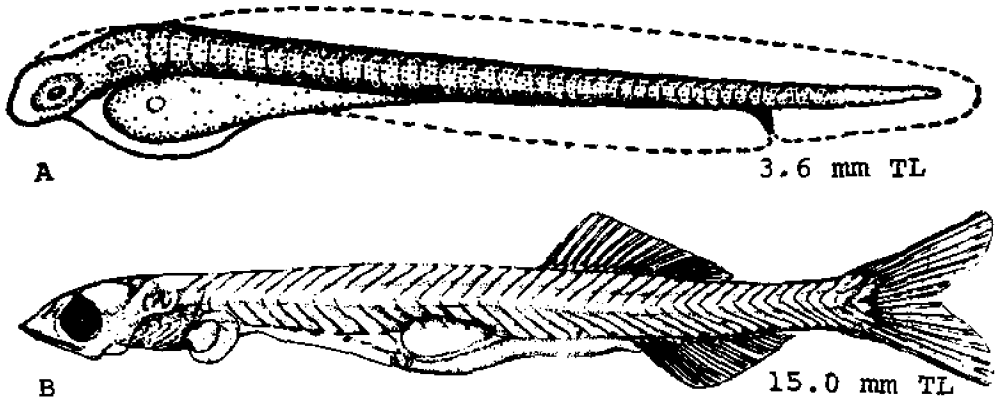

Fig. 91. *Anchoa hepsetus*, Striped anchovy. A. Yolk-sac larva, 3.6 mm TL, newly hatched. Oil globules absent in this species, although indicated in illustration. B. Larva, 15.0 mm TL. (*A, Hildebrand, S. F., and L. E. Cable, 1930: fig. 9. B, Lippson, A. J., and R. L. Moran, 1974: fig. 58.*)

to upper but less curved, first dozen separated from rest by distinct diastema. Single pelvic scute.[15] Origin of dorsal about equidistant between base of caudal and middle of eye;[2] anterior rays of depressed dorsal fin not reaching tips of posterior rays;[12] anal origin below base of eighth or ninth branched dorsal ray; pectoral fin tips falling short of pelvic fin base;[15] pelvics inserted about equidistant between anal origin and pectoral base.[2]

Pigmentation: Body light brown with silvery mid-lateral stripe,[15] expanded posteriorly only at caudal base. Large dots underlying lateral stripe usually show above as thin dark line.[12] Scattered melanophores on ventral surface of snout reaching to mouth and premaxillae.[15] Dark pigment over brain and dorsum of each orbit, two prominent ovate spots on nape.[12] Double line of melanophores on back before dorsal, appearing as broad band in large fish.[15] Small melanophores outline scale pockets dorsally, most evident behind dorsal fin. Melanophores at base of dorsal and anal fins and along dorsal and caudal fin rays.[12] Anterior peritoneum and cleithral region of branchial cavity black. Esophagus, part of stomach and intestine densely pigmented; pyloric caeca and posterior stomach unpigmented.[17]

Maximum length: 153 mm.[2]

DISTRIBUTION AND ECOLOGY

Range: Nova Scotia to Montevideo, Uruguay.[2]

Area distribution: Delaware,[16] Maryland, New Jersey, and Virginia.[8]

Habitat and movements: Adults—usually in large schools near shore; frequently in shallow, grassy areas in North Carolina.[1] Salinity range 2.5[7] to 75–80 ppt.[8] Greatest recorded depth 55–73 m.[2] Oceanic movements largely unknown; apparently withdraws from Chesapeake Bay during winter.[5]

Larvae—salt and brackish water; hatched at surface; statement that majority apparently descend to bottom at an early stage[1] questioned (EDH). Recorded along edge of continental shelf off Delaware and Virginia (ORS).

Juveniles—no information.

SPAWNING

Location: In Port Aransas, Texas from 18 to 49 m, rarely in nearby bays;[14] in Biscayne Bay, Florida at 4 m or less and possibly offshore near Miami (EDH); along outer banks at Beaufort, North Carolina; also in harbor and nearby sounds and estuaries;[1] not more than 16 km offshore (OES).

Season: Late March through July, possibly lasting to September near Port Aransas, Texas;[14] winter and spring months (at least from November through April) in Biscayne Bay, Florida (EDH); mid-April through July with peak activity in May in North Carolina.[1]

Time: Early evening.[1]

Minimum temperature: 16 C (OES).

Minimum salinity: 5 ppt.[16]

EGGS

Ripe ovarian eggs: Ca. 1.2 mm in diameter, white, oval.[11]

Fertilized eggs: Buoyant, transparent,[1] elliptical.[2] Major axis 1.2[9]–1.66 (OES), minor axis 0.7[2]–0.94 mm (OES). Yolk segmented into large cell-like masses,[2] oil globules absent[2,9] (EDH) even though illustrations do indicate a single oil globule.

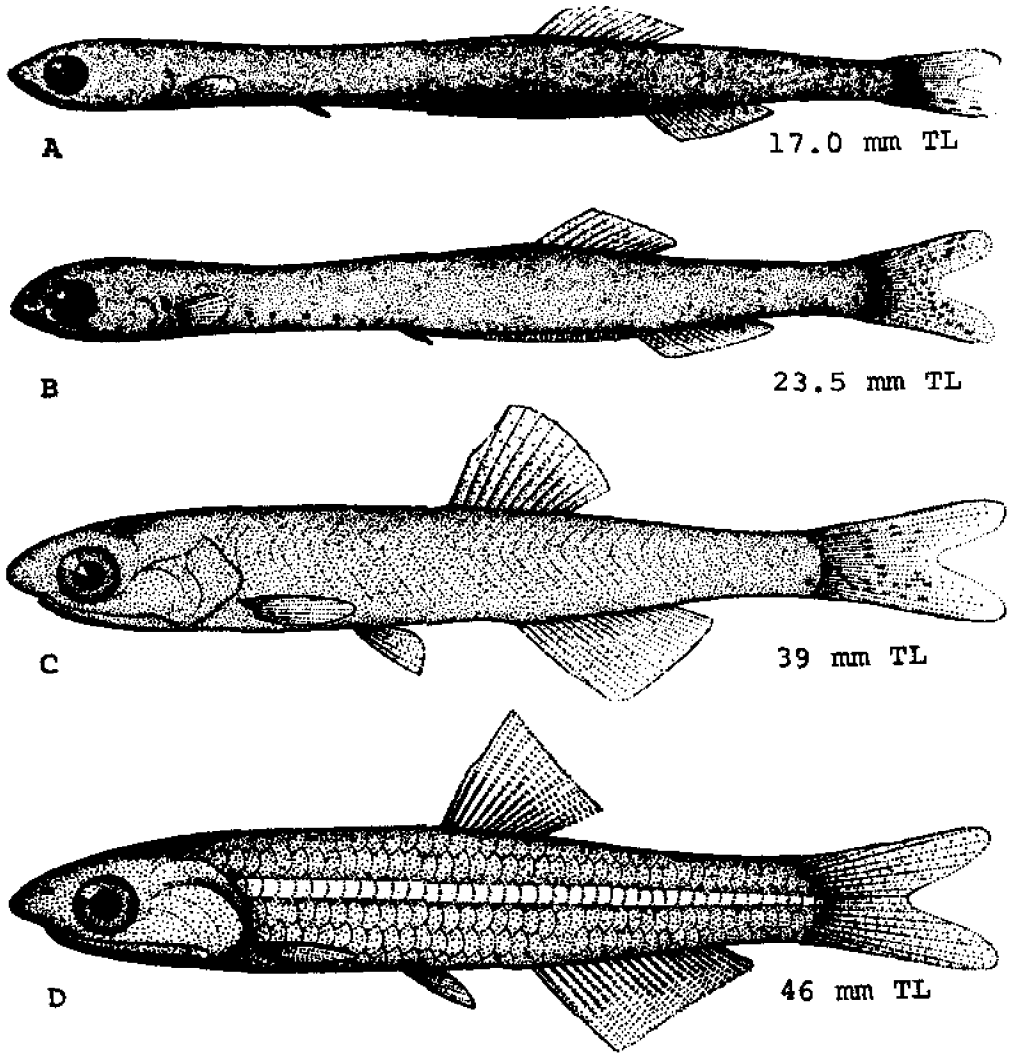

Fig. 92. *Anchoa hepsetus*, Striped anchovy. A. Larva, 17.0 mm TL. B. Larva, 23.5 mm TL. C. Juvenile, 39 mm TL. D. Juvenile, 46 mm TL. Silvery band distinct. (*A-D, Hildebrand, S. F., and L. E. Cable, 1930: figs. 12–15.*)

EGG DEVELOPMENT

Eggs collected before any cleavage occurred, developed at ca. 19–21 C.

Within 1 hour	8-cell stage; early cleavage furrows deep.
12 hours	embryonic axis.
Just before hatching	heart action and embryonic movement apparent.[1]

Incubation: 48 hours at ca. 18.9–21.1 C.[1]

YOLK-SAC LARVAE

Hatching length ca. 3.6–4.0 mm TL. Maximum size described 4.5 mm TL. Duration of stage ca. 24 hours.[2]

Body long, slender,[1] thread-like;[2] head somewhat decurved;[1] dorsal outline slightly concave.[2] Yolk mass elongate, tapering to a point posteriorly. Anus slightly behind beginning of posterior 1/4 of body at hatching. Fins lacking; finfold continuous from first somite to vent and forward over posterior 1/3 of yolk.[1]

Pigmentation: Body highly transparent; slight greenish shade on head, but no definite chromatophores.[1]

LARVAE

Specimens described 5.0-25.0 mm TL.

Body very slender at 5.0 mm, slightly deeper at 10.0 mm,

depth ca. 8 times in SL at 25 mm. Mouth oblique early in stage, gape extending to eye at 5.0 mm, beyond anterior margin of eye at 10.0 mm; mouth terminal, jaw somewhat curved, gape extending beyond posterior margin of eye at 15 mm; mouth slightly inferior, jaw bent upward anteriorly at 25 mm.[1] Myomeres can be seen and counted in larvae at all lengths (statement that myomeres are visible only in posterior region at 10 mm is in error, EDH). Dorsal, anal, caudal, and pectoral fins evident, but lacking rays, at 5.0–6.0 mm. Incipient pelvics at ca. 13 mm; caudal definitely forked at 10.0 mm, definitely homocercal at 15.0 mm; vent posterior to vertical from origin of dorsal. Notochord somewhat oblique posteriorly at 5.0 mm, strongly oblique at 10.0 mm, no longer visible at 15 mm. Gut almost straight, but with striated appearance at 5.0 mm; not invaginated at 10.0 mm, fully enclosed in body wall at 25 mm.[1]

Pigmentation: At 5.0 mm, ca. 5 very small, elongate chromatophores near ventral outline posterior to head. At 10.0 mm, a few chromatophores on midline of chest and along venter from anal base to caudal. At 15 mm additional pigment at upper margin of eye. At 25 mm, a continuous dark line midventrally from gill covers to opposite pectoral bases; 2 or 3 elongate spots behind opercle; a ventrolateral series of chromatophores between pectorals and pelvics; scattered chromatophores on caudal base and fin.[1]

JUVENILES

Minimum size described 30.0 mm SL.[1]

Proportions as percent SL (at 30–70 mm): Body depth 16.4–21.8; head length 27.3–30.5; eye diameter 7.5–8.8; snout length 4.6–5.7.[17] Depth 6 times in SL at 35 mm TL; body very nearly as deep as in adult at 45 mm.[1]

At 35 mm head conical, snout fully developed.[1] Origin of anal under twelfth to fourteenth dorsal ray.[12] Scales evident at 45 mm.[1]

Pigmentation: At 35 mm SL pigment developed on dorsum and a conspicuous brownish area on top of head.[1] Silvery lateral band from level of posterior pectoral tip to last anal ray, maximum width and density at level of anal midpoint. Base of anal rays pigmented. Inside of operculum with scattered pigment; peritoneum densely but not uniformly pigmented; gut black.[17] At ca. 55 mm SL predorsal area nearly devoid of melanophores except for thin middorsal stripe; ovate spots on nape, skull pigmentation divided, appears as four closely appressed dark blotches along midline; melanophores along fin rays of dorsal and caudal fins, around bases of dorsal and anal fins.[12] At 60 mm SL sparsely pigmented silver band extends from opercular border to near caudal base; inside of operculum densely pigmented; anterior peritoneum heavily pigmented but not black; pyloric caeca unpigmented.[17]

AGE AND SIZE AT MATURITY

Ca. 1 year; minimum ca. 75 mm.[1]

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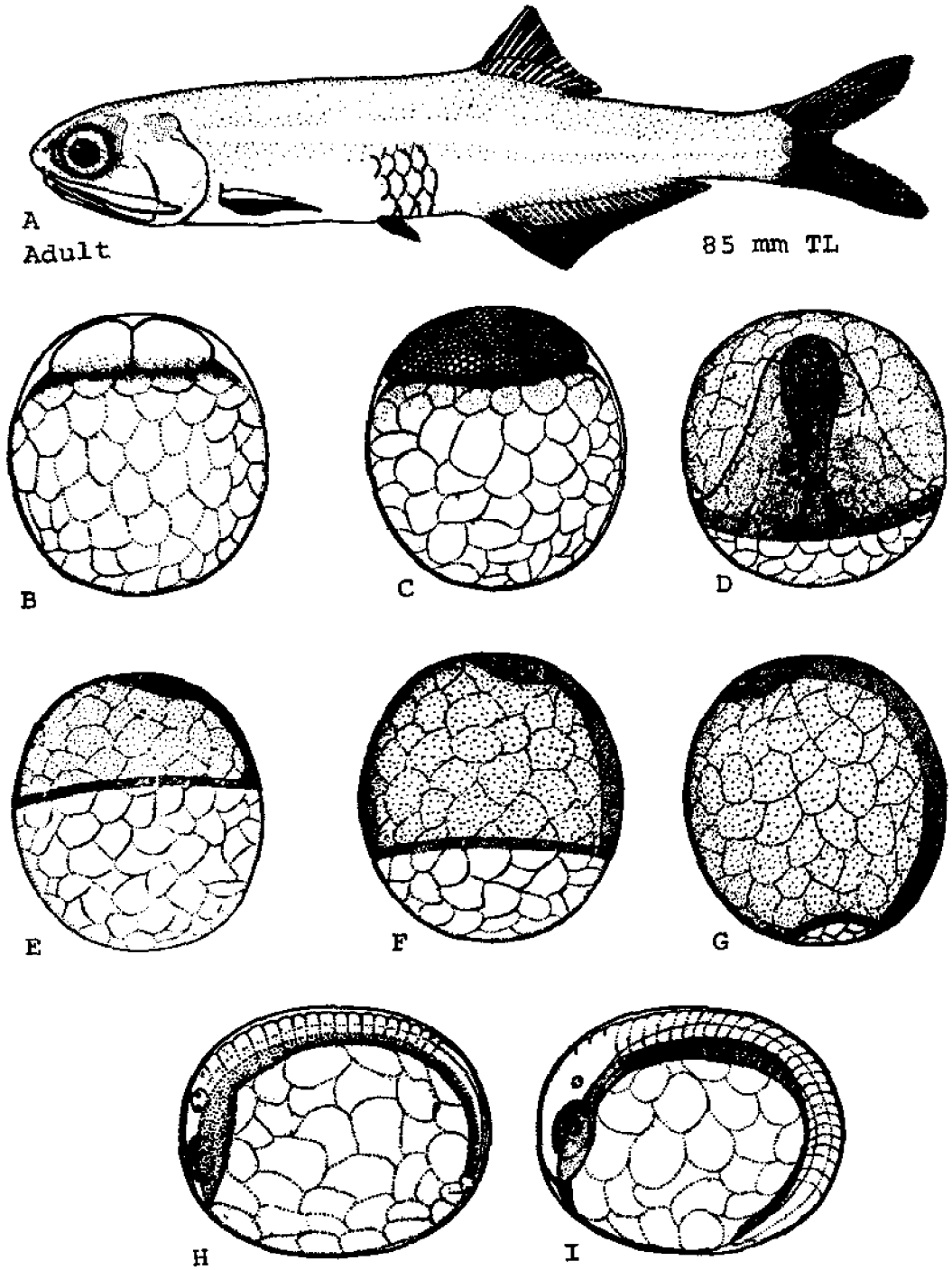

Fig. 93. *Anchoa mitchilli*, Bay anchovy. A. Adult, 85 mm TL. B. Egg, 2-cell stage. Egg sizes are 0.64–1.05 × 0.64–0.92 mm. C. Egg, morula, ca. 5 hours. D. Egg, gastrula. Egg at angle to show formation of embryonic shield. E. Egg, gastrula. Lateral view of "D." Blastoderm about 1/2 around yolk; germ ring distinct. F. Egg, late gastrula. Blastoderm 2/3 around yolk. G. Egg, early embryo just prior to blastopore closure, ca. 10 hours. H. Egg. Embryo with 18–20 somites and Kupffer's vesicle. I. Egg. Embryo with 29 somites. (*A, Hildebrand, S. F., 1963b: fig. 31. B-I, Kuntz, A., 1914: figs. 25, 28, 31–36.*)

Anchoa mitchilli (Valenciennes), Bay anchovy

ADULTS

D. 13–17; A. 23–30;[17] C. 9+10+9+7–8;[25] P. 10–13;[17] scales from upper angle of gill opening to base of caudal ca. 38–44; total vertebrae 38–44,[3] precaudal 19, caudal 21–22;[25] gill rakers 15–20[17]+20–26.[3]

Proportions as percent SL: Body depth 16.0–27.0; head length 22.0[3]–28.0; snout length 3.1[17]–7.3; eye diameter 5.8[3]–9.0.[17]

Body rather slender, moderately compressed; cheek short, broad, about as long as eye, its posterior angle ca. 60°; maxillary pointed, extending nearly to margin of opercle.[3] Anal fin origin posterior to fifth or sixth dorsal ray;[17] pelvics small, not quite reaching halfway to anal origin, inserted nearer anal origin than pectoral base.[3] Vent close to tips of depressed pelvic rays.[17]

Pigmentation: Living specimens greenish above with bluish reflections, silvery below;[3] iridescent green and gold spot over brain and dorsum of each orbit; snout yellow to transparent; narrow silver lateral stripe from head to caudal base, masked by scales; opercular area, eye, jaw, scales and peritoneum silvery.[17]

Preserved specimens light yellow above, lower body and sides of head bright silvery.[3] Melanophore pigmentation highly variable. Dorsal melanophores in reticulated pattern oriented vertically; lateral melanophores often a

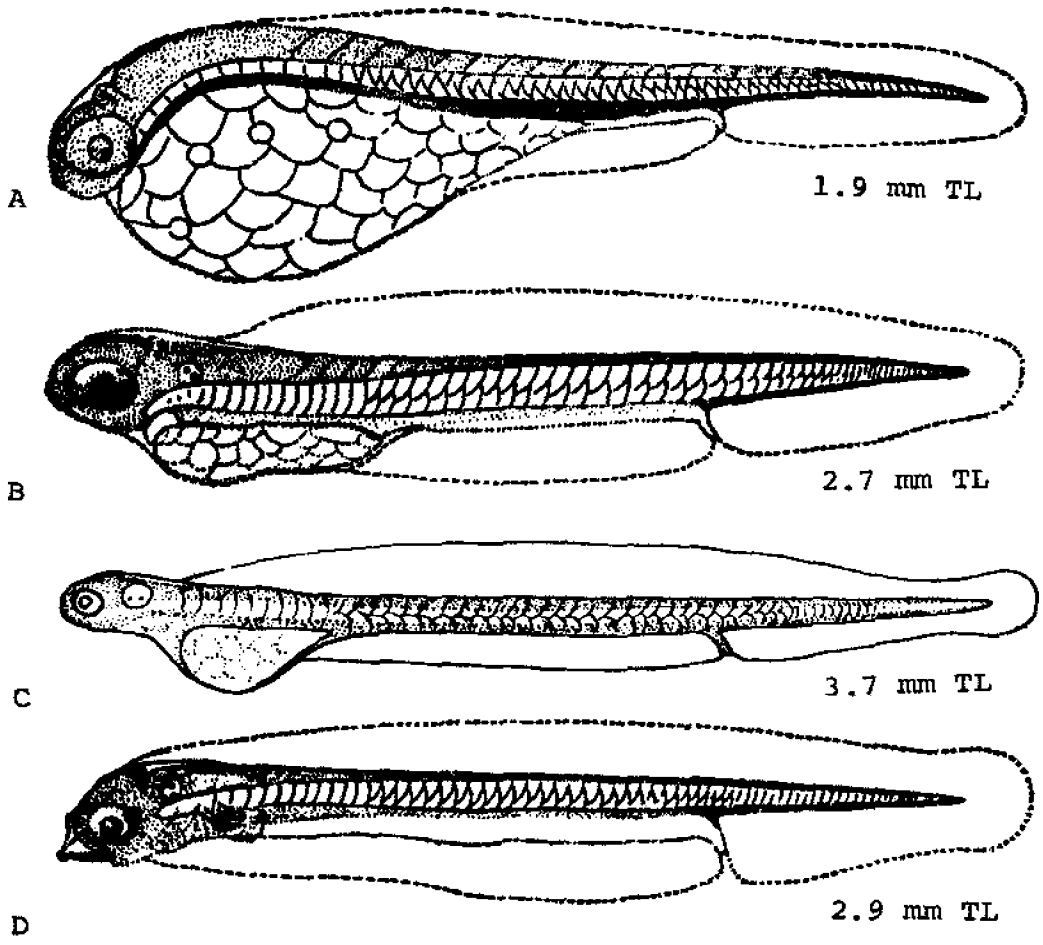

Fig. 94. *Anchoa mitchilli*, Bay anchovy. A. Yolk-sac larva, 1.9 mm TL, recently hatched. B. Yolk-sac larva, 2.7 mm TL, 12 hours. C. Yolk-sac larva, 3.7 mm TL, snout to vent length 2.5 mm; few chromatophores in caudal region. D. Larva, 2.9 mm TL, 36 hours. (*A, B, D, Kuntz, A., 1914: figs. 37–39. C, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 43.*)

narrow vague stripe from caudal base forward, but not reaching head, completely covered by lateral silver stripe in newly preserved specimens. Head anterior to eyes sometimes stippled, prominent black spot over brain. Double row of melanophores from dorsal origin to caudal base; and along anal fin base [17] continuing on ventral midline of caudal peduncle; [3] melanophores along rays of dorsal and caudal fins.[17]

Maximum length: 102 mm TL.[4]

DISTRIBUTION AND ECOLOGY

Range: Gulf of Maine to Yucatan, Mexico.[3]

Area distribution: Chesapeake Bay,[3] New Jersey, Delaware, and Virginia.[4]

Habitat and movements: Adults—euryhaline, 64 km above brackish water in Virginia rivers.[7] Primarily estuarine and coastal waters; in bayous; [9] off sandy beaches; [10,11] in open bays and muddy coves; [8] grassy areas along beaches; [3] around mouths of rivers; [5] and in both shallow and deeper offshore waters.[3] Maximum salinity 80 ppt.[12] Maximum recorded depth 27–36 m.[3] Present in Chesapeake Bay throughout the year, concentrating in deeper water during colder months; [8] oceanic movements unknown, apparently restricted to localized inshore-offshore migrations.[3]

Larvae—predominantly in surface waters of Chesapeake Bay and Delaware River from early May to the middle of October, at ca. 11 C and higher.[18,21] Statement that majority descend to bottom before 12 mm [1] is in error (EDH). In Chesapeake Bay, collected in greatest abundance at 3 to 7 ppt, upstream migration may occur.[18] Very common in Biscayne Bay, Florida at 30–35 ppt (EDH).

Juveniles—euryhaline, ascending rivers in Virginia 64 km above brackish water; [7] also shallow grassy areas and deeper water.[1] Most abundant in brackish water near salt-fresh interface from June to September. Found primarily in deep waters from October to March.[18]

SPAWNING

Location: Typically in water less than 20 m deep,[8] although possibly to edge of continental shelf on basis of putative eggs (OES). In the harbor, estuaries, sounds, and along outer banks near Beaufort, North Carolina.[1] Throughout much of the lower Chesapeake Bay.[18]

Season: May to November and February (based on larvae less than 5 mm) in the western Gulf of Mexico; [19] all year in Biscayne Bay, Florida, uncommon in December and January (EDH); late April to early September in North Carolina,[1] peak activity in July; [2] late April to late September in Chesapeake Bay, peak in July; [18] early June to September in Long Island Sound.[6]

Time: Typically early evening, 1800 to 2100 hours.[1]

Temperature: Ca. 9 C to 31 C with peak above 20 C.[18]

Salinity: In Chesapeake Bay minimum 1 ppt, most at 9 ppt or greater, peak at 13–15 ppt; [18] in Port Aransas, Texas, all spawning occurs at ca. 30–ca. 37 ppt.[19]

EGGS

Location: Found throughout water column at 8–15 ppt, with densities somewhat higher in surface waters (LL III); at 30–35 ppt typically buoyant until hatching (EDH).

Fertilized eggs: Slightly elongate [2] (statement that eggs are occasionally spherical [3] questioned, EDH); highly transparent; [23] eggs apparently smaller as season progresses.[6,15] Yolk segmented into large cell-like masses; [2] oil globules absent; [16] perivitelline space very narrow,[2] becoming larger in eggs from estuarine waters.[18,23]

Size of eggs at various salinities as follows (each range and mean calculated from 30 measurements): [18]

	Major Axis		Minor Axis	
Salinity	Range	Mean	Range	Mean
5 ppt	0.92–1.33	1.12	0.86–1.26	1.04
10 ppt	0.86–1.36	1.05	0.83–1.15	0.98
15 ppt	0.84–1.12	0.97	0.65–1.09	0.90
20 ppt	0.86–1.11	0.95	0.84–0.95	0.89

EGG DEVELOPMENT

At unspecified temperature:

5 hours	cleavage regular and rapid; late morula.
10 hours	blastopore closed and embryo slightly longer than 1/2 greater circumference of egg.

Soon after closure of blastopore, Kupffer's vesicle formed; 18–20 somites present; optic and otic buds visible.[2]

Incubation: Ca. 24 hours at average temperature of ca. 27.2–27.8 C.[2]

YOLK-SAC LARVAE

Hatching length 1.8–2.7 mm.[2] Largest yolk-sac larva described 3.75 mm (WLD).

Snout to anus 2.02 mm at 2.75 mm TL, 2.51 mm at 3.70 mm TL (WLD).

Body elongate, flattened, rather slender. Head deflected downward over yolk at hatching, straight at 2.6–2.8 mm. Yolk pear-shaped, tapering to a point posteriorly; [2] about 10% remains 17 hours after hatching at 28 C and less than 1% remains 25 hours after hatching.[26] Incipient rays in

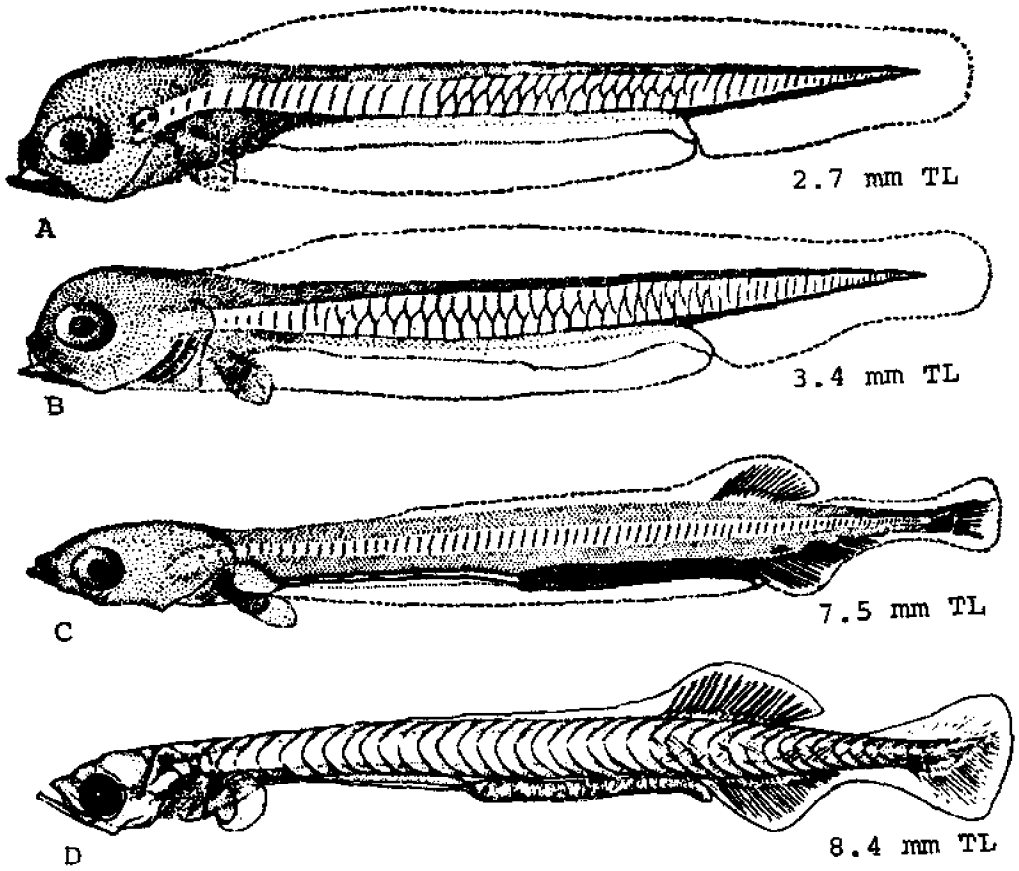

Fig. 95. Anchoa mitchilli, Bay anchovy. A. Larva, 2.7 mm TL, 3 days old. B. Larva, 3.4 mm TL. C. Larva, 7.5 mm TL. D. Larva, 8.4 mm TL. (*A, B, C, Kuntz, A., 1914: figs. 40, 41, 43. D, Lippson, A. J., and R. L. Moran, 1974: fig. 61.*)

caudal at 3.7 mm (WLD). Notochord thick, granular; gut a straight tube.[2]

Pigmentation: Pigment initially lacking;[2] at 3.7 mm, a few chromatophores ventrally between anus and caudal fin (WLD), a few along ventral midline below gut (EDH).

LARVAE

Specimens described 2.7 mm TL[2]–16 mm TL.[8]

At 12.0 mm, D. 15–16; A. 23–31 (NSS).

Depth 12 times in body at 16 mm TL.[8]

Body long and slender. Mouth terminal, apparently functional at 2.7 mm. Finfold somewhat constricted in caudal region at 2.9 mm; relative depths of finfolds decreased by 3.0–4.0 mm.[2] Gut never convoluted, muscular rings develop along hindgut at ca. 5 mm (EDH). Anlage of pectoral present at 2.7 mm; incipient dorsal and anal at 3.0 mm; some specimens with full anal count by ca. 11 mm SL[2] (not at 7.0–8.0 mm TL, VP). Urostyle oblique at 7.5 mm.[2] Transformation into juvenile form begins at 15.5 mm SL (VP).

Pigmentation: Highly transparent, becoming less so with growth. At 3.5 mm, double row of chromatophores along venter (WLD). At 7.0–8.0 mm, a few chromatophores on ventral aspect of thoracic region and at base of caudal.[2]

JUVENILES

Limits of stage unknown (PWJ). Metamorphosis is essentially completed by 22.5 mm SL (VP).

Depth 9 times in body length at 20 mm, 5.5 times at 25 mm.[8]

Projecting snout developed at ca. 20–25 m;[3] maxillary almost reaches lower edge of operculum.[28] Anal origin slightly behind dorsal origin; vent under or slightly anterior to dorsal origin.[1]

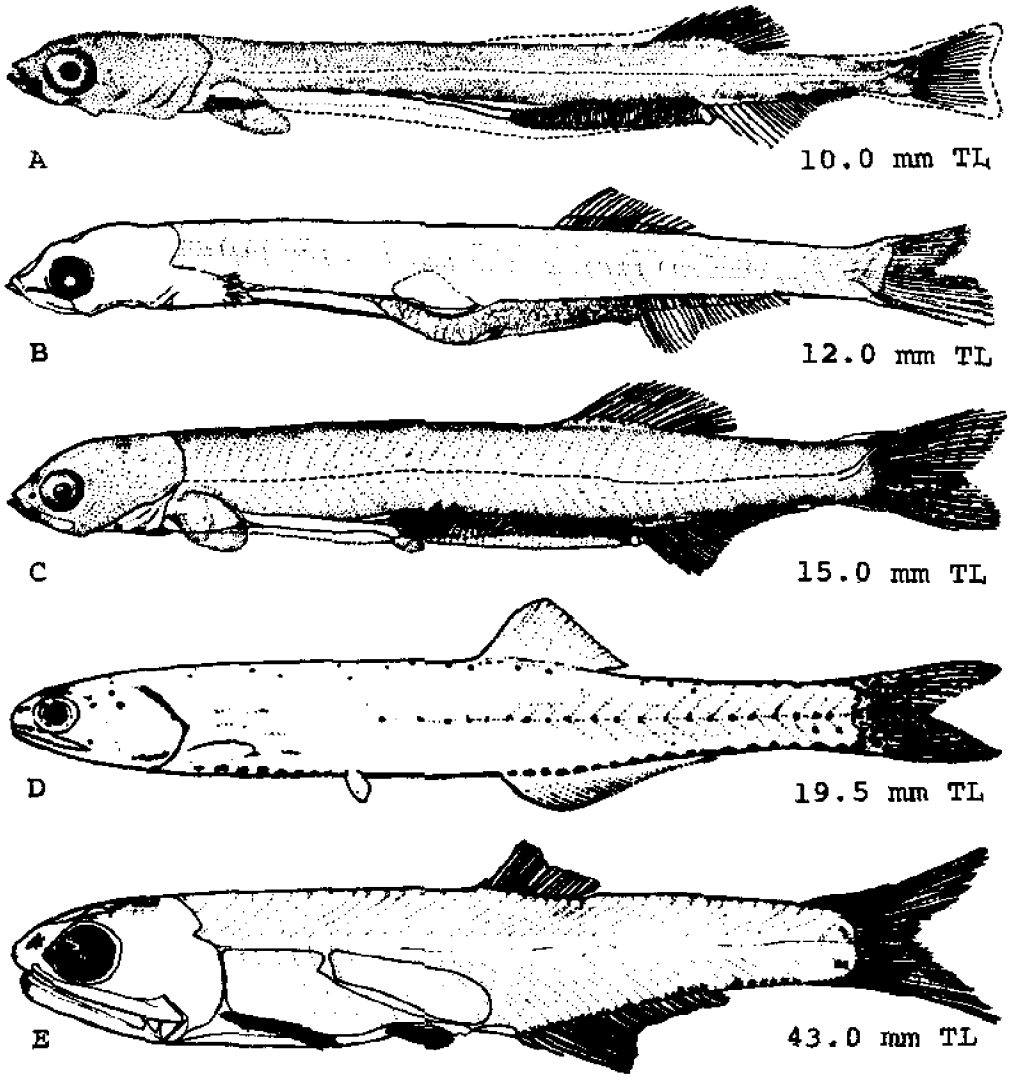

Fig. 96. Anchoa mitchilli, Bay anchovy. A. Larva, 10.0 mm. B. Larva, 12.0 mm TL. Intestine bulging below expanding gas bladder. C. Larva, 15.0 mm TL. Pelvic buds formed. D. Larvae, 19.5 mm TL. E. Juvenile, 43.0 mm TL. Gas bladder visible. (A, C, Kuntz, A., 1914: figs. 44, 45. B, E, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 45. D, Fowler, H. W., 1945: fig. 34.)

Pigmentation: Individuals may remain quite transparent until mature;[3] at 19.5 mm, a series of chromatophores ventrally between operculum and pelvic fins; a similar series from origin of anal to caudal base; mid-lateral row of chromatophores on posterior 2/3 of body; scattered chromatophores on dorsolateral surface; a dark blotch between eyes on top of head; caudal fin heavily pigmented.[13] At 43 mm, a row of chromatophores along anal base and continuing to caudal fin; few chromatophores on head (NSS).

AGE AND SIZE AT MATURITY

Minimum ca. 2 1/2 months (based on putative identification), between 34 and 40 mm.[14]

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Engraulis eurystole (Swain and Meek), Silver anchovy

ADULTS

D. 13–16; A. 15–19;[2] *P. 14*[7]*–16;*[2] *V. 7;*[7] *scales between upper angle of gill opening and caudal base 40–45; vertebrae 43–45; gill rakers 24–28 + 27–33.*[2]

Proportions as percent of SL: Body depth 15.4–19.0; head length 25.0[2]–29.6;[7] snout length 3.85[2]–6.0;[7] eye diameter 5.7[2]–8.5;[7] postorbital distance 13.8[2]–16.7;[7] maxillary length 15.8–17.8; mandibular length 15.0[2]–20.1;[7] anal fin base 12.1[7]–16.0;[2] pectoral fin length 12.5[2]–13.9; pelvic fin length 8.6–9.8; predorsal distance 50.3–53.8; prepelvic distance 48.6–50.0; preanal distance 67.5–73.5.[7]

Body slender, not strongly compressed,[2] belly rounded. *Snout pointed,*[7] *projecting half its length beyond mandible.*[2] Operculum narrow, lower border at an angle of ca. 20° to horizontal, exposed portion of suboperculum with evenly rounded posterior margin; posterior border of gill opening fairly evenly rounded; gill rakers slender, slightly curved, longest two-thirds eye diameter.[7] Maxillary rather narrow, rounded distally,[2] scarcely projecting beyond second supramaxilla, entire lower edge with single series of fine, close set teeth; lower jaw slender, with a single series of teeth continuous except for gap at junction of maxilla and premaxilla. Single unkeeled pelvic scute; alar scales present. Dorsal fin origin nearer caudal base than to snout tip by one-half to three-quarters eye diameter,[7] longest ray failing to reach,[2,7] or surpassing tip of last ray with fin deflexed, last ray above midpoint between pelvic fin tips and anal origin; pectoral tips failing to reach pelvic base by just under one eye diameter; pelvic fin base one-half[7] to nearly one eye diameter before vertical from dorsal origin;[2] anal origin three-quarters eye diameter behind vertical from last *dorsal ray.*[7]

Pigmentation: Light brown with bright silver lateral band, broadening over anal fin (especially large fish); melanophores concentrated just behind head, evident above and sometimes replacing silver lateral band, and speckled on alar scales; fins hyaline.[7]

Preserved specimens pale or bluish above; sides of head *and lower sides sometimes silvery; a silvery lateral band* about as broad as eye in small specimens, becoming obscure along ventral margin in large specimens.[2]

Maximum length: 155 mm TL.[2]

DISTRIBUTION AND ECOLOGY

Range: Lynn Harbor, Massachusetts[8] to southern Florida.[7,8]

Area distribution: Unknown from Chesapeake Bay, rarely taken in coastal waters of New Jersey.[2]

Habitat and movements: Adults—coastal waters; primarily pelagic,[4] often taken at or near surface waters between the 36 and 55 m depth contours during winter and occasionally in bottom trawls in the northern Gulf of Mexico,[6] recorded inshore at Mullet Pond on Shakleford Banks, North Carolina,[4] and in Brigantine Bay, New Jersey; possibly seaward to within the Gulf Stream.[2,5]

Larvae—putative stages from edge of continental shelf off Mantauk and New York (OES).

Juveniles—no information.

SPAWNING

Area: Probably offshore waters.[1] Presence of putative larvae suggest spawning as far south as off the Chesapeake Capes (OES).

Season: July[2] to early August;[1] possibly early spring based on putative larvae taken near edge of continental shelf in April (OES).

Time: Probably during evening.[1]

EGGS

Description: Buoyant,[2] *highly transparent, oblong;*[1] major axis 1.02 (OES)–1.25 mm,[1] minor axis 0.50 (OES)–0.80 mm. Yolk coarsely granular.[1]

EGG DEVELOPMENT

*Unspecified rearing temperature. Embryonic axis evi*dent when blastoderm covers less than 1/4 of yolk. *Shortly after closure of blastopore, somites,* auditory vesicles, Kupffer's vesicle and anlagen of eyes differentiated. When fully differentiated, *embryo lies parallel to* major axis with head deflected sharply over yolk. Advanced embryo, apparently without pigment; extends ca. 2/3 around yolk; notochord thick and vesicular.[1]

YOLK-SAC LARVAE

Length at hatching ca. 2.0[9]–3.0 mm TL; at 1 day, ca. 3.4 mm.[1]

Body elongate; head not deflected over yolk at 8 hours after hatching. Yolk mass elongate, tapering to point posteriorly; more than 1/2 absorbed by first day; gut a straight tube at hatching; anus about 1/4 length of body from posterior end. Dorsal finfold originates just behind *auditory vesicles. Finfold straight-edged in newly*

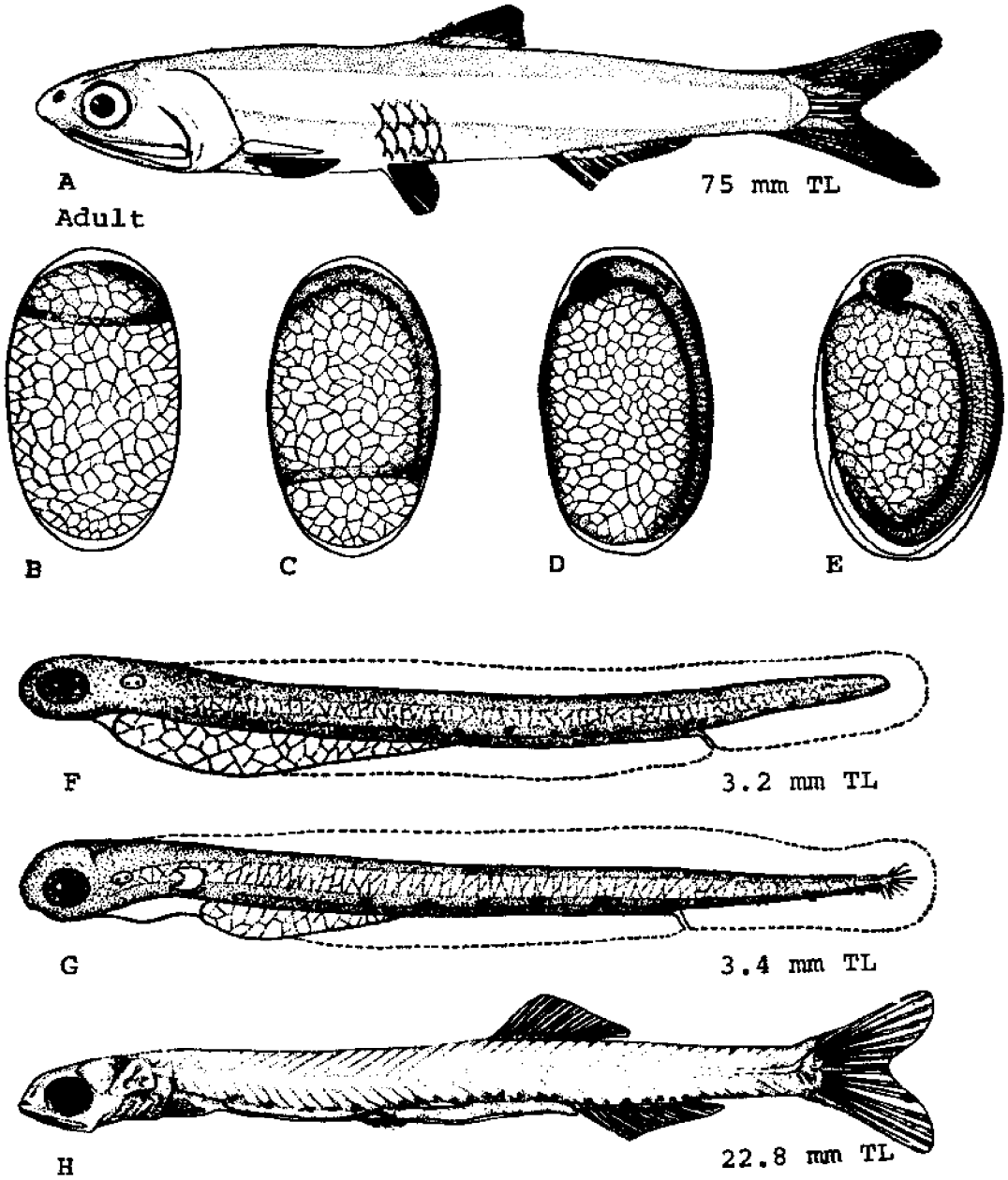

Fig. 97. *Engraulis eurystole*, Silver anchovy. A. Adult, 75 mm TL. B. Egg, embryonic axis forming. This and all following eggs with major axis of 1.15–1.25 mm. C. Egg, early embryo prior to blastopore closure. D. Egg, early embryo just after closure of the blastopore. E. Egg, late embryo. F. Yolk-sac larva, 3.2 mm TL, 8 hours. G. Yolk-sac larva, 3.4 mm TL, 1 day. H. Larva, 22.8 mm TL. (*A, Hildebrand, S. F., 1963b: fig. 44. B-G, Kuntz, A., and L. Radcliffe, 1917: figs. 69–74. H, Lippson, A. J., and R. L. Moran, 1974: fig. 62.*)

hatched larvae; weakly sinuate margin above region of future caudal peduncle in 1 day old fish. Preanal finfold extends forward about halfway across yolk. Incipient rays forming in caudal and anlagen of pectorals present *in 1 day old specimen. Notochord reticulate.*[1]

Pigmentation: At hatching or within first 8 hours, melanophores in series along intestine posterior to yolk and at base of ventral finfold posterior to vent; melanophores considerably larger at 1 day.[1]

LARVAE

Specimens described 4.0–22.8 mm TL.[9]

By 4.0 mm, yolk mass absorbed.[9] At 5.2 mm, body deeper anteriorly. Mouth large, oblique, terminal;[2] gape reaching middle of eye. Opercle well differentiated. Incipient rays forming in dorsal, caudal and anal. Dorsal finfold reduced in front of and strongly notched at posterior region of developing dorsal fin; preanal finfold extending slightly forward to distal end of pectoral fin and almost below anterior end of dorsal finfold. Notochord conspicuously thickened, reticulate.[1] Intestine not convoluted posteriorly; striations due to muscular rings along posterior part of intestine cause a convoluted appearance (EDH).

Pigmentation: At 4–5.2 mm body almost colorless; melanophores of earlier stages less conspicuous.[1] At 22.8 mm TL pigment in series above intestine and along ventral aspect of myomeres to caudal base.[9]

JUVENILES

No information.

AGE AND SIZE AT MATURITY

No information.

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Umbra pygmaea

mudminnows
Umbridae

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FAMILY UMBRIDAE

Mudminnows inhabit small, muddy ponds, slow moving vegetated streams and stagnant pools in North America, Europe and Asia.

These fishes are small, ovate to laterally compressed, with square to somewhat flattened heads and rounded caudal fins. The swim bladder is capable of assimilating atmospheric oxygen.

The family Umbridae is composed of three genera and five species. Within the Mid-Atlantic region one species is known, *Umbra pygmaea*.

This species spawns in algal nests in fresh to slightly brackish waters. The eggs are slightly viscous, have a narrow perivitelline space and contain several oil droplets of various sizes. At hatching the yolk is somewhat flattened, the anus is near the body midpoint and the urostyle extends almost to the tip of the caudal finfold. From yolk absorption to at least 22 mm TL. the prominent extended urostyle is the most outstanding feature of this species. In addition to the extended urostyle, small juveniles (and possibly larger larvae) are heavily pigmented, have a dark basicaudal spot and numerous large chromatophores on the fin rays.

Umbra pygmaea (DeKay), Eastern mudminnow

ADULTS

D. 2–3 unbranched, 12–14 branched; A. 4 unbranched, 5–8 branched;[9] V. 6; P. 12[10]–16;[4] scales in mid-lateral series 28–35, transversely between dorsal and pelvic origins 12–15.[6]

Body depth 4.5 times in TL;[8] eye 3.4–5.0 times in HL.[6]

Body robust, thick, little compressed; head bluntly conic;[20] snout short, equal to diameter of eye; mouth moderate, jaws short,[8] mandible protrudes slightly beyond tip of upper jaw,[20] premaxillaries not protactile.[10] Gill rakers short and numerous. Scales cycloid, lateral line lacking.[8] Dorsal inserted nearer pectoral than caudal base; pelvic inserted just before origin of dorsal, rays of depressed fin reaching to about 3rd anal ray.[20]

Pigmentation: Yellowish green with 10–12 narrow lateral dark stripes; a dark stripe through eye; a black basicaudal bar;[8] lower jaw pale;[13] fins plain.[8] During spawning season, ground color black or gray.[14]

Maximum length: Ca. 152 mm or larger.[6]

DISTRIBUTION AND ECOLOGY

Range: Southeastern New York (ECR) to northeastern Florida[11] (records from New England[2] are doubtful, PWJ); introduced and established in Belgium,[4] France,[12] and the Netherlands.[21]

Area distribution: Tidal tributaries of Chesapeake Bay in Virginia;[19,23] coastal streams and ponds in Maryland (JDH), Delaware[22] and New Jersey.[20]

Habitat: Adults—lowland streams, ponds, pools,[16] and swamps;[17] in heavy vegetation over soft, silty bottoms in sluggish streams,[3] sometimes in slightly alkaline waters (ECP). Maximum natural salinity 4 ppt;[3] experimentally survive at 10 ppt but not at 15 ppt.[3]

Larvae—remain in algal nest for ca. 6 days.[18]

Juveniles—among aquatic vegetation along edges of shallow barrier beach ponds adjacent to Chesapeake Bay (JDH); specimens 15–22 mm TL tend to travel in schools of 10–12 individuals.[7]

SPAWNING

Location: In hollows formed in masses of algae.[17,18]

Season: March and April in aquaria;[4,14] early spring (to at least April) under natural conditions.[5,18]

Temperature: 14–15 C.[4]

Fecundity (at 36.4–90.4 mm TL): 31–2566, average 342 (ECP).

EGGS

Description: Placed in special algal nest[18] and guarded by parents.

Fertilized eggs—diameter 1.4–2.2 mm (average 1.65 mm) based on 6345 eggs (ECP). Slightly viscous;[14] perivitelline space ca. 1/9 yolk radius; yolk with numerous oil globules of various sizes.[1]

EGG DEVELOPMENT

Incubation: 6[18] to 14 days.[14,16]

YOLK-SAC LARVAE

Specimens described 5.4 and 6.0 mm TL.

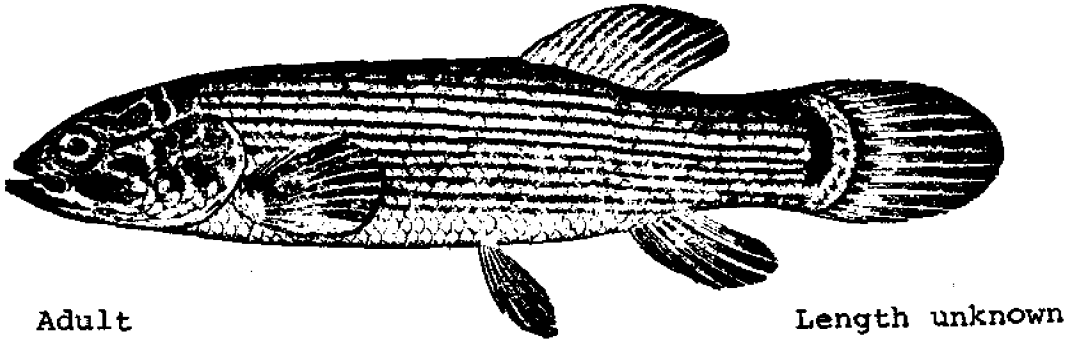

Fig. 98. *Umbra pygmaea*, Eastern mudminnow. Adult, length unknown. (*Jordan, D. S., 1905: fig. 152.*)

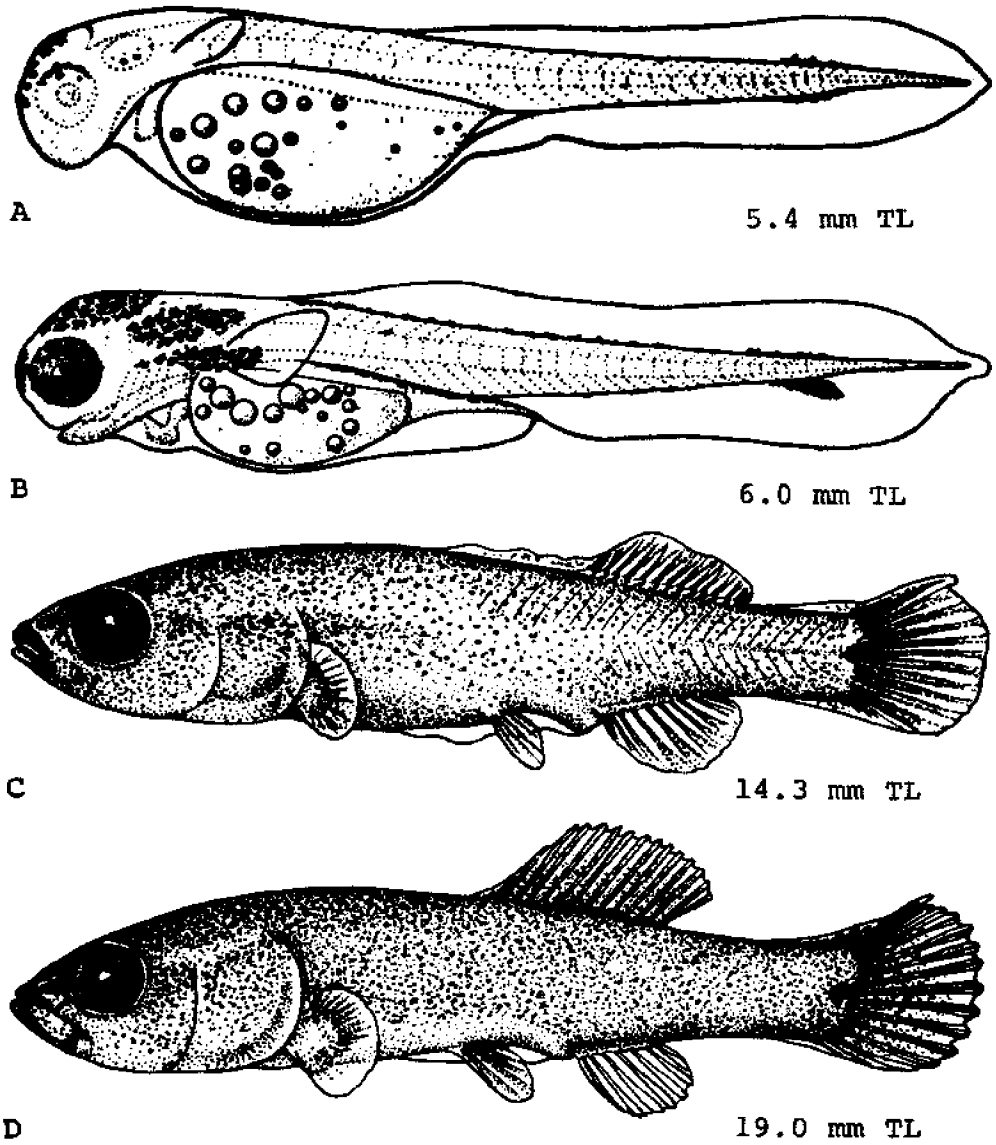

Fig. 99. *Umbra pygmaea*, Eastern mudminnow. A. Yolk-sac larva, 5.4 mm TL, newly hatched. B. Yolk-sac larva, 6.0 mm TL, 3 days after hatching. C. Juvenile, 14.3 mm TL, 12.5 mm SL. Pigment spot at base of caudal and along urostyle. D. Juvenile, 19.0 mm TL, 16.5 mm SL. (*A, B, Breder, C. M., Jr., 1933b: figs. 1B, 1C. C, D, Mansueti, A. J., and J. D. Hardy, Jr., 1967: figs. 47G, 47H.*)

Head deflected downward at hatching, but apparently not attached to yolk; yolk mass somewhat flattened at hatching, more than half absorbed by 6.0 mm. Mouth open at 6.0 mm. Anlagen of pectorals formed at hatching. Finfold apparently continuous around and beyond yolk at hatching; constricted at mid-body and in area of vent and bluntly pointed at posterior end at 6.0 mm. Incipient rays in caudal fin at 6.0 mm.[1]

Pigmentation: Chromatophores on dorsal surface of head and eye, and above and below body in basicaudal region at hatching. At 6.0 mm, chromatophores along dorsal surface of body, in a line between body and yolk, in a heavy blotch ventrally in region of future anal fin, throughout eye, and on top and sides of head and snout.[1]

LARVAE

Specimens described 6.5–10.0 mm TL.

Urostyle turning upward at 6.5 mm. Incipient rays in dorsal at 8.5 mm. Finfold constricted near caudal region and with distinct postdorsal notch at 8.5 mm.[1]

JUVENILES

Minimum size described 14.3 mm TL (JDH).

Body shape similar to adult at 15 mm.[1] Nostril an elongate slit at 22.2 mm. Scales forming at 14.7 mm. Preanal finfold 2/3 distance to opercle at 14.3 mm, to base of pelvics at 21.1 mm; lacking at 16.0 mm. Dorsal finfold forward to a point above pectoral tips at 14.3 mm; reduced to a small remnant at 16.0 mm (JDH). Urostyle external and projecting above dorsal margin of caudal fin at 15.0 mm, gradually absorbed into caudal fin thereafter.[1]

Pigmentation: At 14.3 mm, uniformly and heavily pigmented except in thoracic region, with most dense pigment on head and in region of developing caudal stripe. Rays of fins with numerous large chromatophores. Internal chromatophores visible from eye to opercular region and over gas bladder (JDH). At 15–22, projecting urostyle nearly black.[7]

AGE AND SIZE AT MATURITY

Females 2 years at average size 37.3 mm TL; males 1 1/2 years at average size 34.8 mm TL (ECP).

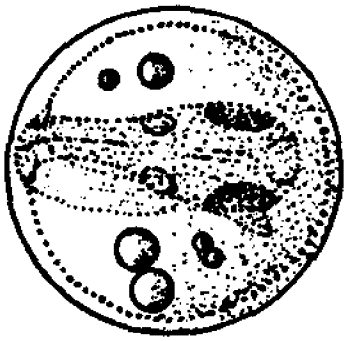

Fig. 100. Umbra pygmaea, Eastern mudminnow. Egg, diameter 1.6 mm, just before hatching. (Breder, C. M., Jr., 1933b: fig. 1A.)

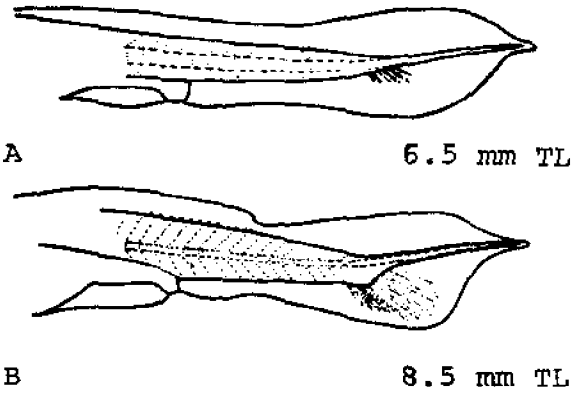

Fig. 101. *Umbra pygmaea*, Eastern mudminnow. A. Tail of larva, 6.5 mm TL, early flexion. B. Tail of larvae, 8.5 mm TL. Prolonged urostyle established. (*A, B, Breder, C. M., Jr., 1933b: fig. 2A, C.*)

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Esox americanus
Esox niger

pikes
Esocidae

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FAMILY ESOCIDAE

The pikes, of which there are five species, all in the genus *Esox*, are primarily freshwater fishes and only rarely enter brackish water. They are limited in distribution to the northern hemisphere, and are found in lakes, ponds, swamps, rivers, and streams from the southeastern United States to northern Canada in North America and from southern Europe eastward and northward to the Arctic Circle in Eurasia.

Members of the family may be characterized as follows: an elongate body, laterally compressed, covered with cycloid scales; the lateral line is complete. The snout is conspicuously produced and flattened above; the jaws are equipped with long, sharp, recurved teeth; there are large patches of cardiform teeth on the vomer, palatines, and tongue. The gill rakers are reduced to patches of sharp denticles; and there are 8 or more pores in the infraorbital canal, 10 to 20 branchiostegal rays, and 43–67 vertebrae.

Spawning takes place in early spring, soon after the break-up of ice, in weedy, shallow water. The large eggs (1.9–2.5 mm in species from the Mid-Atlantic region) are scattered at random. In the regionally abundant species, *Esox niger*, the eggs are initially demersal and attached, but ultimately become free and semibuoyant or buoyant. Within these eggs are a number of widely scattered minute oil globules.

Esocid larvae have a large, oval yolk, and a relatively deep body. A long preanal finfold may be retained, at least in *Esox americanus*, to lengths in excess of 18.0 mm. The anus is far back on the body, three-fifths to four-fifths the distance to the tip of the tail. In *Esox americanus* the pelvic buds are evident at 11.8 mm, while in *E. niger* they have not yet formed at 14.0 mm. Pike larvae are often quite colorful: in those of *Esox niger* the body is chartreuse with a rich pattern of brown melanophores, and chartreuse spots in the finfold.

Esox americanus Gmelin, Redfin and grass pickerel

ADULTS

D. 13 [18]–21; [13] A. 13 [17]–18; P. 8–18; [18] V. 8 [17]–11; [18] lateral line scales 93 [13]–124; cardioid scales between pelvic fins, *E. a. americanus* 6–32, *E. a. vermiculatus* 0–5 (mean 0.5), intergrades 0–26; notched scales in a line between dorsal and anal fin origins, *E. a. americanus* 7–25, *E. a. vermiculatus* 0–8, intergrades 1–22; [18] vertebrae 42 [13]–51; [10] branchiostegals 9 [18]–16 [3] (one side), 19 [13]–31 [3] total; submandibular pores 3:2 to 6:5, usually 4:4.[18]

Proportions expressed as percent TL: Greatest body depth 12.1–18.3; body width 7.7–10.5; caudal peduncle depth 5.6–18.3, length 13.1–16; HL 24.2–31.4. Proportions expressed as percent HL: Eye diameter 13.4–16.0; interorbital width 20.2–23.6; snout length 33.8–41.6.[17] Proportions as times in SL: Greatest depth 5.2–6.1; [2] snout length 7.9–9.5.[10] Postorbital length ÷ snout length: *E. a. americanus* 1.0–1.4, *E. a. vermiculatus* 0.8–1.3, intergrades 0.9–1.2.[18]

Body robust,[3] long, cylindrical, cross-section almost circular [17] with flattened to slightly concave dorsal surface. Head large,[13] flat, naked on top.[17] Right branchiostegal membrane usually overlaps left (*E. a. vermiculatus*).[13] Snout short, broad spatulate,[3] dorsal surface between raised orbits and tip of snout slightly concave (*E. a. vermiculatus*) [13] or convex (*E. a. americanus*). Mouth large,[17] horizontal, lower jaw extending slightly beyond upper,[2] maxillary usually not reaching beyond middle of pupil or to suborbital bar (*E. a. vermiculatus*) or reaching at least to middle of pupil or suborbital bar (*E. a. americanus*).[17] Teeth moderately large, those in front of upper jaw and several along each side of ramus a little enlarged; [6] cheek and opercle fully scaled.[14]

Pigmentation: Olivaceous to black above; [3] belly pale amber [17] to white, sometimes mottled with dark; [3] middorsal band from nape to dorsal fin origin inconspicuous, pale (*E. a. americanus*) or rusty brown (*E. a. vermiculatus*). Sides with 15–23 (*E. a. vermiculatus*) or 20–36 (*E. a. americanus*) olive to black wavy vertical bars separated by paler extensions of what had been lateral band in young, pale area between adjacent bars narrower (*E. a. americanus*) or wider than bars (*E. a. vermiculatus*). Suborbital and preorbital black bars pronounced,[17] suborbital curved back ventrally (*E. a. americanus*) [5] or straight, vertical (*E. a. vermiculatus*),[13] postorbital horizontal; lateral edges of jaws heavily pigmented (*E. a. americanus*) or lightly pigmented (*E. a. vermiculatus*). Pupil yellow (*E. a. vermiculatus*) to yellow-green,[17] iris gold (*E. a. americanus*).[3] Dorsal fin darkly pigmented, others orange to red (*E. a. americanus*) or leading edge of all fins black, remainder dusky to amber (*E. a. vermiculatus*).[17]

Females distinguishable from males (ca. 75% accuracy) by greater intensity and amount of submandibular pigment (*E. a. americanus*).[17]

Maximum length: Ca. 376 mm TL.[25] Larger specimens (up to ca. 483 mm) may be hybrids (EJC).[7]

DISTRIBUTION AND ECOLOGY

Range: *E. a. americanus* occurs from the south shore of St. Lawrence River, Quebec; through the Champlain Valley in southern New Hampshire, Vermont, and New York, south along eastern seaboard to Lake Okeechobee, Florida; [3,8] introduced in mountainous regions of Maryland,[12] and possibly Pennsylvania.[17] *E. a. vermiculatus* is found from the St. Lawrence River near Montreal, south, west of Allegheny Mountains, in Lake Ontario and Finger Lakes drainages of New York, to Louisiana, west to Brazos River in Texas,[17,24] north through Oklahoma,[18] Kansas, Nebraska, Iowa,[17] Wisconsin [19] and Michigan. Introduced in Colorado, Washington and California. Intergrades may occur in Florida, Georgia, Alabama and Mississippi.[17]

Area distribution: Tidal tributaries in Chesapeake and Delaware Bay region, New Jersey [27] (*E. a. americanus*).[1,5,22,26]

Habitat and movements: Adults—in sluggish streams, sloughs, drainage ditches, ponds, lakes, swamps and creeks; usually associated with heavy emergent vegetation over mud bottom; in areas lacking vegetation associated with brush piles, overhanging brush or rocks and boulders; rarely in rivers or areas lacking dense vegetation, unknown from main current, open water or water over 1.2 m deep. At night near surface, above vegetation; often in tea-colored water of pH 4.2–4.9 (*E. a. americanus*),[2,3,18] or rarely found in somewhat acid water (*E. a. vermiculatus*).[13] In winter in dead leaf litter.[18] Maximum salinity 10.15 ppt; [23] final preferred temperature 26 C.[13]

Yolk-sac larvae—possibly attached to vegetation.[17]

Larvae—sometimes in very shallow water in roadside ditches (JDH), also in dead leaf litter.[18]

Juveniles—young-of-the-year in flood pools and rivulets among exposed roots, twigs, leaves, and grass in 7.6–10.2 cm of water.[3]

SPAWNING

Location: Flood plains, grassy banks,[3] sloughs,[19] ditches,[18] and overflow ponds in areas of heavy vegetation, some-

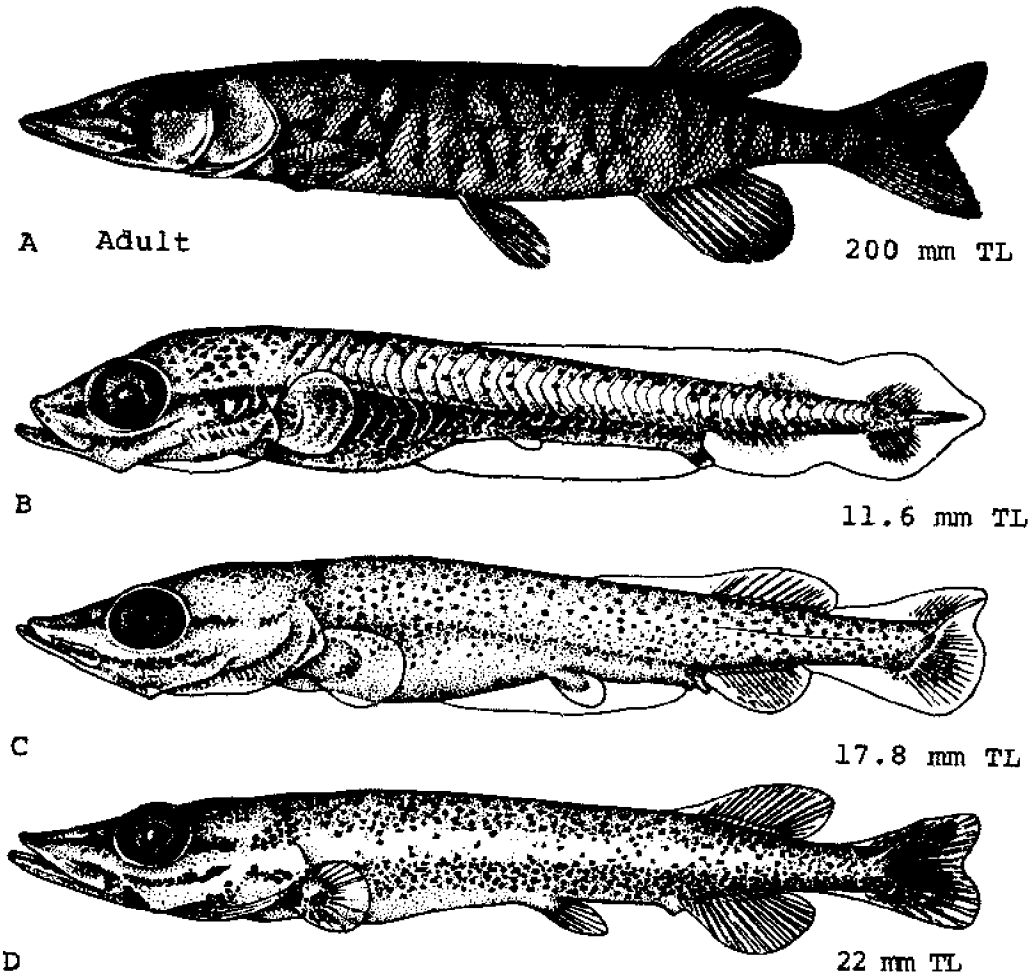

Fig. 102. *Esox americanus*, Redfin and grass pickerel. A. *E. a. americanus*, adult, 200 mm TL, 172 mm SL. B. *E. a. americanus*, larva, 11.6 mm TL, 11.4 mm SL. Preanal myomeres 31; postanal myomeres 15+. C. *E. a. americanus*, larva, 17.8 mm TL, 16.9 mm SL. D. *E. a. americanus*, juvenile, 22 mm TL, 20 mm SL. (*A-D, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 48A-D.*)

times in water less than 30.5 cm deep.[3]

Season: February and March in North Carolina (with spawning possibly lasting one month),[3] April and May in Wisconsin (spawning continues for about two weeks),[19] probably April or May in Ontario.[13] Fall and early winter spawning probable.[13,18,19,21]

Temperature: 1.1–11.7 C.[19]

Fecundity: *E. a. americanus* 3–4 years old, 186–542 ripe eggs (average 269.4).[3] *E. a. vermiculatus* at 168 mm and 325 mm, 625 and 4584 respectively.[19]

EGGS

Location: Scattered in small numbers among aquatic vegetation,[3] not in long strings as has been reported.[18]

Ripe ovarian eggs: 1.6–2.3 mm in diameter;[3,11] golden yellow or amber, clear (*E. a. americanus*);[3] or 1.5–2.4 mm in diameter[19] (reported to average 1.4 mm in diameter), transparent, yellow to amber in color (*E. a. vermiculatus*).[13]

Water-hardened eggs: Yellow (*E. a. vermiculatus*).[18]

Fertilized eggs: Average 1.9 mm (*E. a. americanus*).[17]

EGG DEVELOPMENT

Incubation: 11 days at average temperature of 8.9 C; 14 days at average temperature of 8.3 C; 15 days at average temperature of 7.8 C (*E. a. vermiculatus*);[19] 10–14 days

at unspecified temperature (*E. a. americanus*).[17]

YOLK-SAC LARVAE

Hatching length 5.8–6.1 mm TL (*E. a. americanus*),[17] or 5.0[18]–6.2 mm TL;[17] maximum size described 10 mm TL (*E. a. vermiculatus*).[18] Duration of stage 10–14 days.[17]

By 9.0 mm TL mouth fully developed,[19] at 10.0 mm TL gut partially formed in some specimens,[18] complete in others (*E. a. vermiculatus*).[19]

Pigmentation: At 7–8 mm TL black eye pigment present.[19]

LARVAE

Specimens described 11.6–17.8 mm TL (*E. a. americanus*).

At 11.6 mm, preanal myomeres ca. 31; postanal myomeres 15+; myomeres no longer distinct at 17.8 mm (JDH).

Snout elongates with growth, still quite blunt at 11.6 mm, more elongate at 17.8 mm. Cleithrum and outline of auditory vesicles visible; gill rakers formed and visible through opercle at 11.6 mm; choroid fissure still evident at 17.8 mm. Dorsal finfold extended forward beyond level of ventrals at 11.6 mm, wholly behind ventrals at 17.8 mm. Pelvic buds formed at 11.6 mm; incipient rays in caudal and anal at 11.6 mm, in dorsal by 17.8 mm. Urostyle oblique; caudal finfold bilobed, adjacent to, but not continuous with, dorsal and ventral finfold at 17.8 mm (JDH).

Pigmentation: At 11.6 mm, conspicuously darker below than above; lower fourth of abdomen clear except for heavy, mid-ventral dark stripe. Dorsolateral regions with large brown stellate chromatophores; a mid-dorsal light stripe lacking chromatophores; sides of tail posterior to anus with light and dark chromatophores; a dark stripe along snout and continuous behind eye to pectorals. At 17.8 mm, abdomen conspicuously lighter; mid-ventral line reduced; number of dorsal chromatophores increased and concentrated over brain and in dark band between pectoral fins (JDH).

JUVENILES

Minimum size described 20[3]–22 mm TL (*E. a. americanus*).

Eye proportionately larger than in adult; urostyle still evident; caudal fin lobed; finfold absent at 22 mm TL (JDH). In *E. a. americanus* snout length 8.7 or more times in TL (7.5 times in SL) at sizes less than 150 mm; scales first evident at ca. 50 mm behind head and in lateral band behind pelvics; at 65 mm, scales complete except on venter; vertebral column completely segmented by 65 mm.[16]

Pigmentation: *E. a. americanus:* At 20–22 mm TL sides with scattered stellate chromatophores, denser below than above and enclosing an unpigmented, poorly defined, mid-lateral band which extends from operculum to region above posterior margin of anal fin. Dense stripe on snout and behind eye; vertical band below eye not yet developed. Mid-ventral row of chromatophores still evident; clear area on abdomen much reduced. A conspicuous, bright red blotch at base of caudal fin (JDH). Under 60 mm, a straight to moderately wavy, unpig-

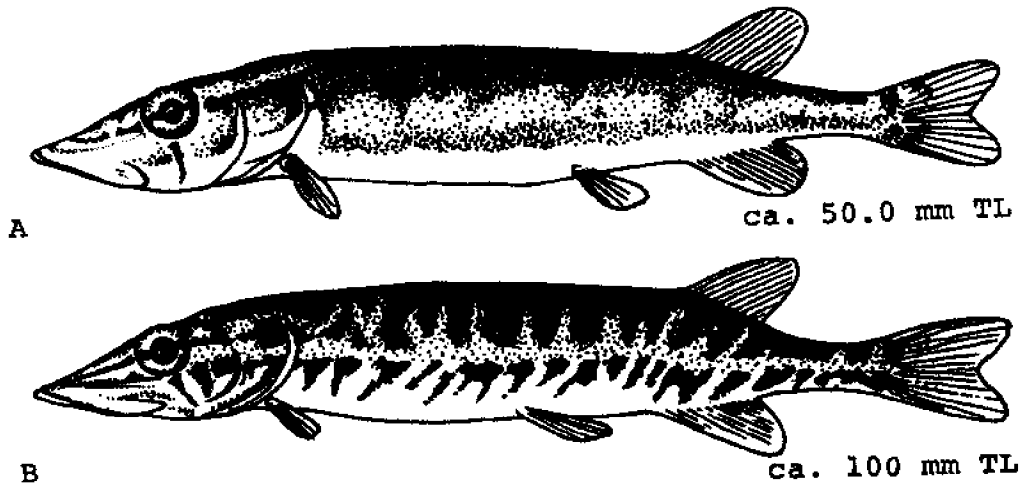

Fig. 103. *Esox americanus*, Redfin and grass pickerel. A. *E. a. americanus*, juvenile, ca. 50 mm TL. Unpigmented lateral band, straight to moderately wavy. B. *E. a. americanus*, juvenile, ca. 100 mm TL. Lateral band changing into adult pattern with vertical bars prominent. (*A, B, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 48E, F, after Crossman, E. J., 1962b: fig. 2.*)

mented lateral band from snout to caudal peduncle, which separates an upper band of olive or black and a lower band of gray. "Young" with red coloring limited to fin bases, and with a lustrous, silver-green mid-dorsal band from tip of snout to caudal base. At 60–100 mm, mid-dorsal and lateral bands inconspicuous; vertical bars forming on sides. Adult pattern developed in excess of 150 mm.[16]

Pigmentation: *E. a. vermiculatus:* At sizes over 20 mm up to 145 mm pigment-free line extends from snout to tail.[18] At 45 mm TL dorsal surface and upper half of sides above lateral line brownish to olive-green; below this, narrow green-gold band from operculum to caudal peduncle, followed by a narrower black line and then by another gold band; ventral surface white. Operculum with gold band bordered by two narrow black lines, upper black line and gold band continuous through center of eye to end of snout, remainder of iris golden, pupil black; suborbital bar visible. Dorsal, anal, and paired fins clear, caudal tip pale red, base black, caudal peduncle with reddish tint. Between 50–140 mm variable black dorsoventral bars evident, usually separated by extensions of light green lateral bar; gold on head disappears except for iris, suborbital bar more pronounced. Adult pattern first appears at ca. 130–140 mm.[13]

AGE AND SIZE AT MATURITY

Possibly 1 year (EJC), definitely 2 years [16] (*E. a. americanus*), or 1 year [19] (*E. a. vermiculatus*). Males 128 mm FL, females 132 mm FL; [3] also reported as ca. 99 mm TL (*E. a. americanus*) [14] or 102 mm (*E. a. vermiculatus*).[20]

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Esox niger Lesueur, Chain pickerel

ADULTS

D. 14–15 principal rays,[36] 17 [19]–21,[32] including rudiments; A. 11–13 principal rays; [36] 15 [19]–19,[32] including rudiments; P. 12–15 (one fin),[36] 25–30 (both fins); V. 18–21 (both fins); [19] scales in lateral line 112–135 [29] (usually ca. 125 [36]); branchiostegals 14–17; [16,23] vertebrae 49–54.[32]

Proportions expressed as times in SL: Body depth 5.3–6.6; [2] snout 6.13–6.83.[32] Proportions expressed as times in HL: Snout 2.2–2.4.[20] Proportions expressed as percent TL: Greatest body depth 11.5–15.5; caudal peduncle depth 4.3–5.9; HL 26.1–28.5; occiput to dorsal origin 40.3–44.4. Proportions expressed as percent HL: Interorbital width ca. 20; eye diameter ca. 14; snout length 44.3–48.0.[36]

Body rather slender, somewhat compressed, deepest near middle. Head large,[2] naked [36] and depressed above, profile slightly concave over snout; snout long, broad,[2] rounded; [36] mouth large, nearly horizontal; lower jaw projecting; maxillary extending to, or slightly beyond anterior margin of pupil. Teeth present on jaws, vomer, palatines, and tongue; lateral teeth on lower jaw and vomer enlarged.[2] Cheek and opercle fully scaled.[20] Gill rakers on lateral and medial surfaces of arches.[36]

Pigmentation: Greenish above, sometimes very dark; [20] venter pale; scales above with golden luster; [2] laterally with light areas enclosed by dark chain-like markings; dark upper side interrupted by light vertical bars; suborbital bar almost vertical or with slight posterior slant; rays of dorsal, anal, pectorals, and pelvics with light interradial membranes,[19] caudal fin base marbled with dark pigment, tips dusky; pupil of eye yellow.[36]

Maximum length: 787 mm.[36] Hybrids of *Esox niger* × *Esox lucius* look very much like *E. niger* but can exceed the maximum length for that species (EJC).

DISTRIBUTION AND ECOLOGY

Range: New Brunswick,[36] southern tributaries of St.

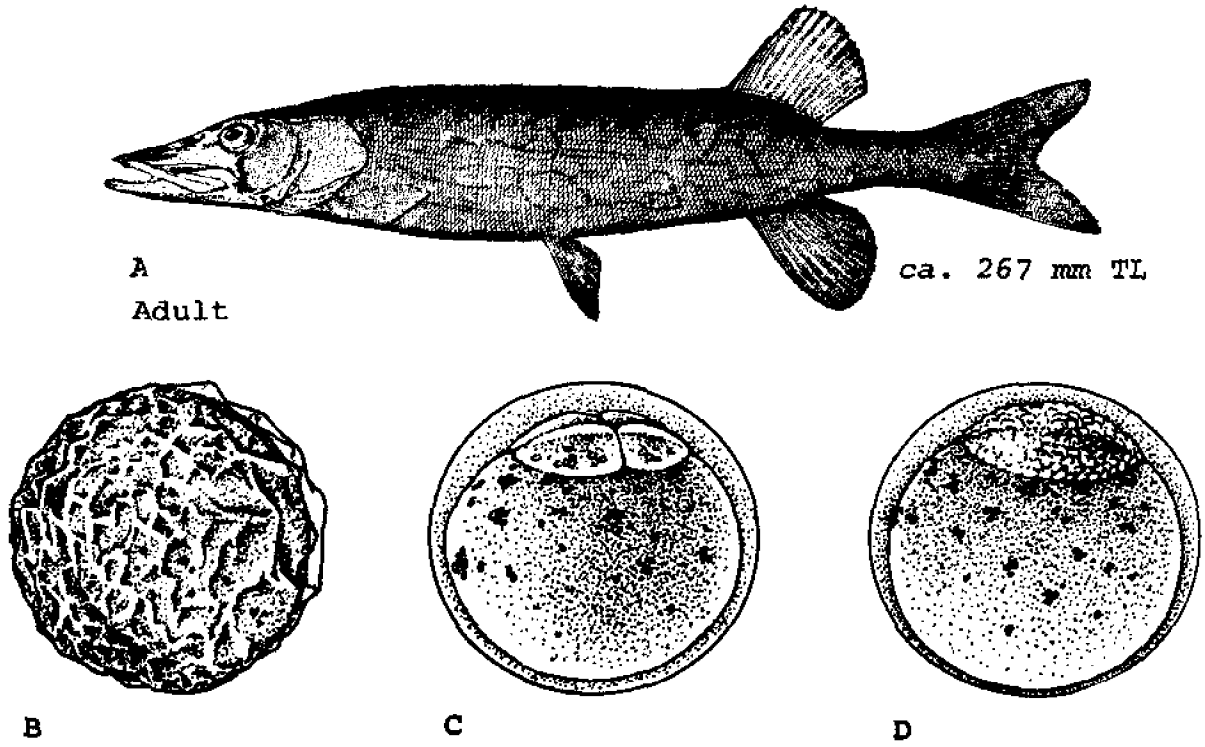

Fig. 104. *Esox niger*, Chain pickerel. A. Adult, ca. 267 mm TL. B. Egg, unfertilized, before water-hardening, diameter 2.0 mm. C. Egg, 2.5 mm, 4-cell stage, 6 1/2 hours at 12–16 C. D. Egg, 2.5 mm, morula, 12 hours at 12–16 C. (*A, Goode, G. B., et al., 1884: pl. 183. B-D, Mansueti, A. J., and J. D. Hardy, Jr., 1967: figs. 49B, C1, C2.*)

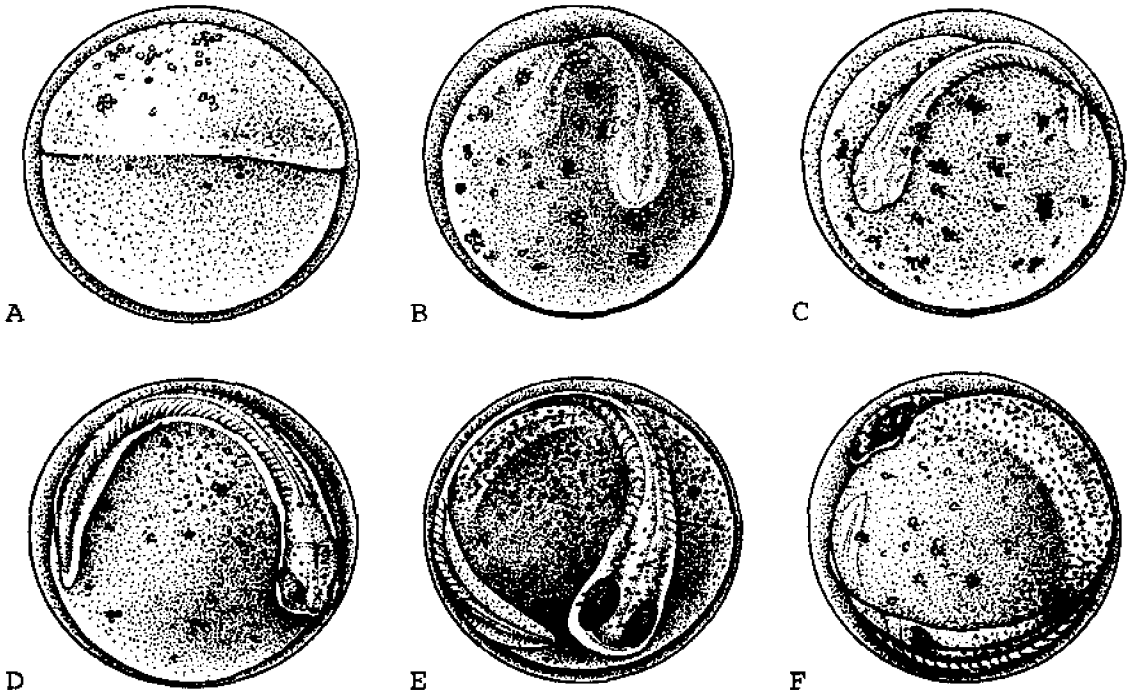

Fig. 105. *Esox niger,* Chain pickerel. A. Egg, gastrula, 1 day. Oil droplets more concentrated under blastoderm in early cleavage, more diffuse in later stages. This and all following eggs ca. 2.5 mm in diameter, incubated at 12–16 C. B. Egg, early embryo, 2 days, notochord formed. C. Egg, early embryo, 3 days, myomeres forming. D. Egg, tail-free embryo, 4 days, ca. 41 myomeres. E. Egg, just before hatching, 5 days. Brown pigmentation intense, embryo with chartreuse coloration. F. Egg, lateral view of "E." (*A-F, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 49C3-C8.*)

Lawrence River and Lake Ontario (rare) drainages south (EJC), east of mountains, to Florida; in Mississippi Valley to Texas, southern Missouri and Alabama; [21] introduced in Nova Scotia (Digby County only),[36] in areas as far west as state of Washington [21] and in Appalachian Mountains.[35]

Area distribution: Throughout area, tidal tributaries of Chesapeake Bay [2,11] and Delaware River; [4,42] New Jersey.[44]

Habitat and movements: Adults—prefer shallow, warm water over mud bottoms with abundant vegetation [17] in lakes, ponds, and sluggish streams; [28,31,41] also found in deep, cold water [37] with little or no vegetation.[17] Migrate to deeper water during winter [3,4,25] undertaking shoreward spawning migrations soon after spring ice disappears.[37] Maximum depth 4.6–6.1 m.[24] Maximum salinity 22 ppt.[31]

Yolk-sac larvae—able to swim when hatched but generally attached to submerged debris or aquatic vegetation,[24] sometimes attached to surface scum,[37] also lying on sides on bottom.[24]

Larvae—hide among vegetation.[10] "Fry" sometimes landlocked by receding water and killed.[24]

Juveniles—at ca. 25 mm, tend to lie motionless near shore or burrow themselves in mud beneath debris.[22] At 28–101 mm SL, near edges of ponds, seldom in water more than 61 cm deep. Larger juveniles present at all depths to 3.4 m, especially at night.[12]

SPAWNING

Location: Usually in water a few centimeters to 3 m deep in coves, mouths of inlets, approaches to outlets, swampy streams, ditches, flooded lowlands,[24] slough areas and shallow tributaries with considerable bottom vegetation; [40] often among terrestrial vegetation; [24] or cattail marshes.[3,7,10,24,28]

Season: Migrations begin at ca. 4.0 C.[24] As early as January in Alabama; [22] February to June in New York; [7] early March [23] to mid-April in Maryland; [11] possibly during late fall in some areas.[18]

Temperature: 5.8 C [23]–18.3 C, usually between 10 and 15.5 C.[24]

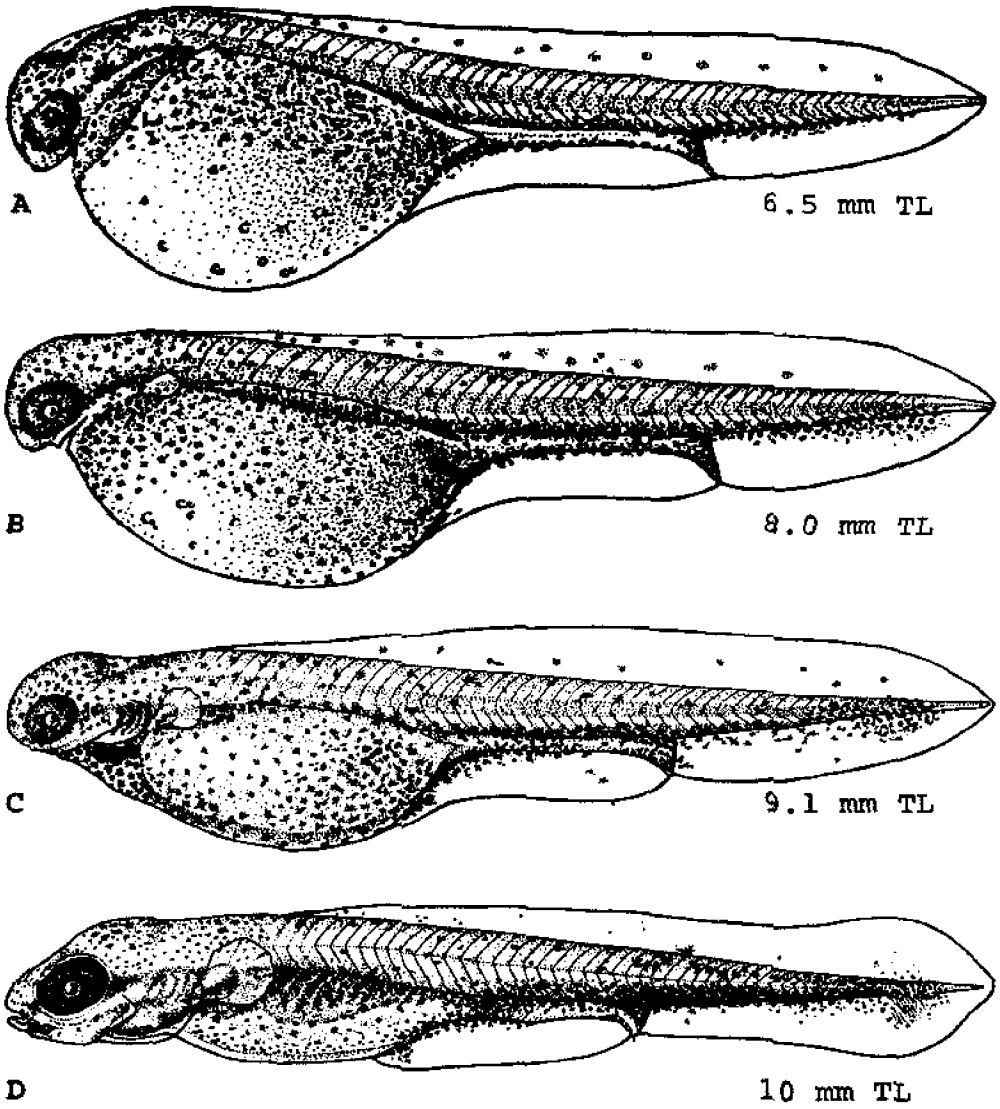

Fig. 106. *Esox niger*, Chain pickerel. A. Yolk-sac larva, 6.5 mm TL, just hatched. Pigment spots in dorsal finfold chartreuse. B. Yolk-sac larva, 8.0 mm TL, 2 days after hatching; 31 preanal myomeres. C. Yolk-sac larva, 9.1 mm TL, 3 days after hatching. D. Yolk-sac larva, 10 mm TL, 5 days after hatching. (*A-D, Mansueti, A. J., and J. D. Hardy, Jr., 1967: figs. 49D, 49E, 50A, 50B.*)

Fecundity: 936 [38]–30,000.[17,30]

EGGS

Description: Demersal when first deposited,[11] but apparently becoming semibuoyant to buoyant at eyed stage;[3,22] temporarily adhesive, but lose this characteristic after water-hardened;[11,24] not deposited in long strings as frequently reported[3,7,25,27,31] but distributed over comparatively large area by vigorous spawning activity.[8]

Mature ovarian eggs: Ca. 2.0 mm[38]–2.48 mm in diameter;[39] yellowish or amber,[22] almost transparent, slightly adhesive, more dense than water.[39]

Unhardened eggs: Bright amber; capsule clear, rugose (AJL).

Water-hardened, unfertilized eggs: Diameter 2.35–2.70 mm, mean ca. 2.5 mm; many small, diffuse oil globules (AJL).

Fertilized eggs: Diameter 2.25–2.95 mm, mean ca. 2.5

mm; yolk diameter 1.5–2.3 mm. Usually spherical, sometimes ovoid (AJL); amber-colored, translucent; egg capsule tough, finely granulated.[11]

EGG DEVELOPMENT

At 12.2–16.6 C:

1 hour, 30 minutes	diameter of blastodisc 1.2 mm; oil globules concentrated in area of blastoderm.
6 hours	2-cell stage.
6 hours, 30 minutes	4-cell stage.
8 hours	8-cell stage.
10 hours	16-cell stage.
12 hours	early morula.
13 hours, 30 minutes	late morula.
ca. 48 hours	early embryo formed; oil globules more evenly distributed; scattered dark brown chromatophores in yolk.
ca. 72 hours	eyes with lens; somites faintly visible.
ca. 96 hours	embryo thicker, extended 2/3 around yolk; tail free and with finfold; 41 somites; brown chromatophores over head, body and yolk adjacent to embryo.
ca. 120 hours (just before hatching)	anus visible; eyes pigmented; heavy concentration of brown and chartreuse chromatophores over embryo and yolk adjacent to embryo (AJL).

Incubation: 5 (AJL) to 12[24] days depending on temperature; 5–6 days at 12.2–16.6 C (AJL); 11 days at 10 C;[18] hatching over period of 2–3 days at ca. 17.2 C.[24]

YOLK-SAC LARVAE

Size at hatching 5.0–7.9 mm TL, mean 7.2 mm (AJL); mean size at end of stage 10.2 mm;[10] duration of stage 6–8 days.[8,10] Preanal myomeres 30–34 by 3rd day (AJL).

Head slightly deflected over yolk at hatching, straightened by 5th day at ca. 10 mm. Yolk more or less oval at hatching, 1/2 absorbed by 3rd day (AJL), or by 8.5 mm.[23] Mouth open by ca. 8.0 mm (AJL). Gas bladder visible on 5th day at ca. 10 mm. Incipient rays in caudal by 9.0[9]–10.0 mm. Pectoral buds present at hatching, flattened by 2nd day or ca. 8.0 mm, fan-shaped and with incipient rays by 3rd day or 9.1 mm (AJL). Notochord granular at 9.0 mm.[9]

Pigmentation: Newly hatched live specimens with dorsal finfold and body chartreuse; dark brown chromatophores scattered over head, dorsolateral region of yolk, along gut, and beneath tail. Pigment increased on yolk and head by 2nd day; extended to ventral region of yolk and increased caudally by 3rd day; eye black at ca. 10 mm (AJL).

LARVAE

Size range described ca. 9.8[24]–14.0 mm TL.

Total myomeres ca. 53–54; snout becoming elongate at beginning of stage; lower jaw definitely longer than upper; eye extended into dorsal profile by 7th day or at ca. 10–11 mm (AJL); choroid fissure visible and auditory vesicles elongate at 11.5 mm.[9]

Anlage of dorsal visible at ca. 14 mm and that of anal at ca. 10–11.8 mm (AJL); pectoral with incipient rays at 11.5 mm;[9] urostyle straight to at least ca. 14 mm (AJL).

Pigmentation: A conspicuous band of pigment through eye at ca. 14 mm (AJL).

JUVENILES

Minimum size described 24.3 mm TL (AJL).

Ratio of TL/snout length 7.0 or less;[12] HL/snout length 2.2–2.5.[14]

At 24.3 mm TL myomeres still visible in thoracic region; scales visible in caudal area (AJL).

Pigmentation: At 24.3 mm TL, dark streak through eye; body chartreuse (AJL). At ca. 25–50 mm, greenish or yellowish throughout with suggestions of dusky punctations; black stripe from tip of snout through eye to margin of opercle; subocular bar downward and obliquely forward from eye.[19,22] With increased size, narrow, pale, vertical bars appear on upper sides;[2] adult pattern appears at lengths of 152–203 mm and over.[13,21,36] In "young" a "pale"[26] or golden mid-dorsal stripe evident.[36]

AGE AND SIZE AT MATURITY

1[10,28]–4 years;[43] minimum length ca. 156 mm.[38]

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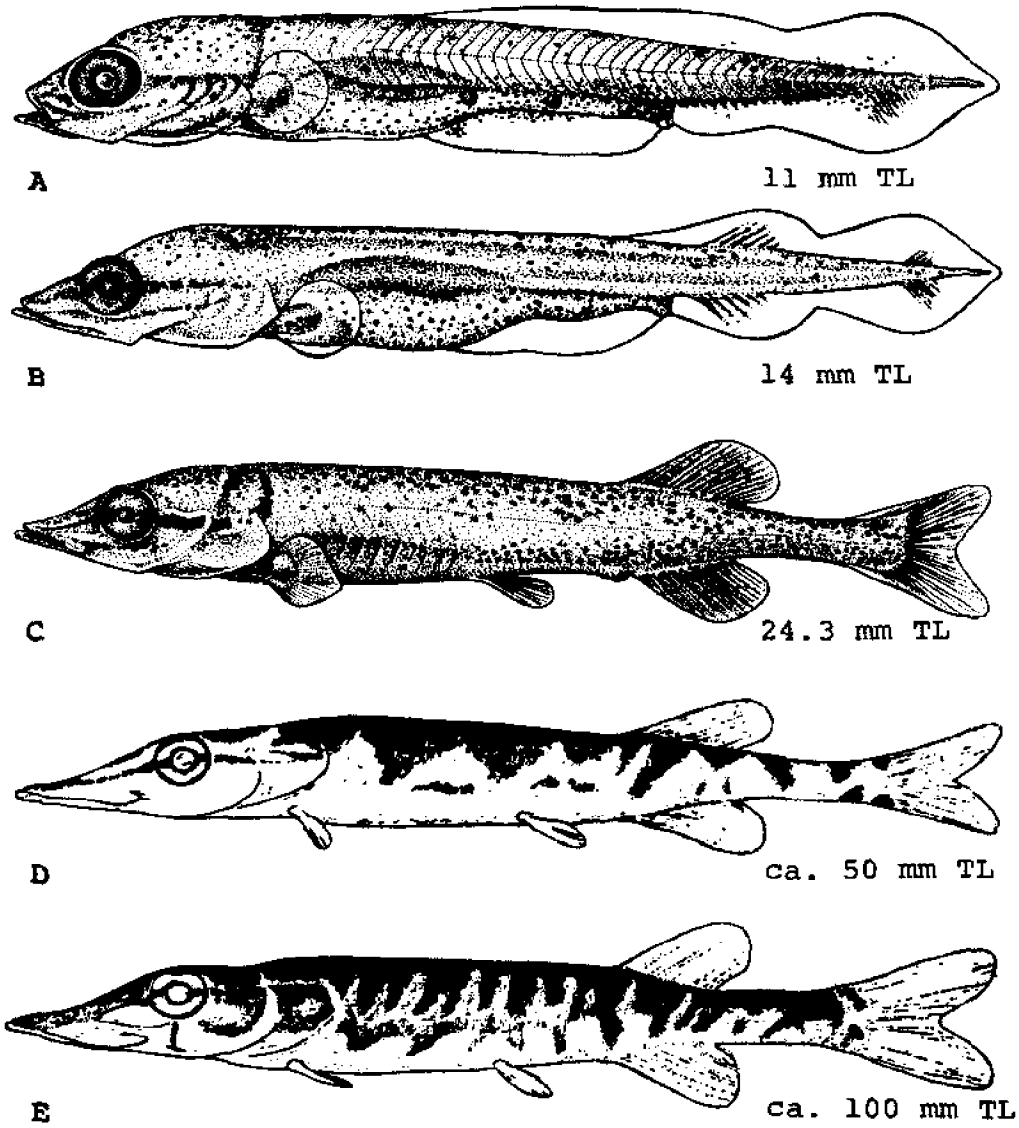

Fig. 107. Esox niger, Chain pickerel. A. Larva, 11 mm TL, 9 days after hatching. Total myomeres 53+. B. Larva, 14 mm TL. Pigment streak through eye. C. Juvenile, 24.3 mm TL, scales on caudal region. D. Juvenile, ca. 50 mm TL, distinctive dorsolateral pigmentation developing. E. Juvenile, ca. 100 mm TL, lateral barred pigmentation pattern established. *(A-C, Mansueti, A. J., and J. D. Hardy, Jr., 1967: figs. 50C-E. D, E, Crossman, E. J., 1962: fig. 2. © Royal Ontario Museum. Used with permission of author and publisher.)*

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Synodus foetens
Trachinocephalus myops

lizardfishes
Synodontidae

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FAMILY SYNODONTIDAE

This family is primarily tropical in distribution with a few species ranging into temperate waters. Capable of burrowing into bottom sediments, lizardfishes are usually associated with a sand or mud substrate.

These fishes have a cylindrical body, wide mouth, numerous sharp teeth and large pelvic fins. Except for one Australian species, an adipose dorsal fin is present (Böhlke and Chaplin, 1968). The air bladder is small in some species and absent in others. Most lizardfishes are marked with saddles, blotches or bands.

The family Synodontidae includes four genera and 35 to 40 species. Two species are known from the area, *Synodus foetens* and *Trachinocephalus myops*.

Eggs of synodontid fishes are spherical with a narrow perivitelline space and an unsegmented yolk. The chorion is, in most species, ornamented with hexagonal facets. In at least some cases, a short spike is evident at each angle of the hexagon.

Larvae are more or less elongate with 49–66 myomeres (Mito, 1961), and a posteriorly placed anus. The most outstanding feature of lizardfish larvae and prejuveniles is the prominent row of ventrolateral pigment spots.

A transformation from prejuvenile to juvenile is accomplished after the assumption of a benthic existence and is probably completed in less than one week. Juveniles lack the prominent ventrolateral pigment blotches characteristic of earlier stages.

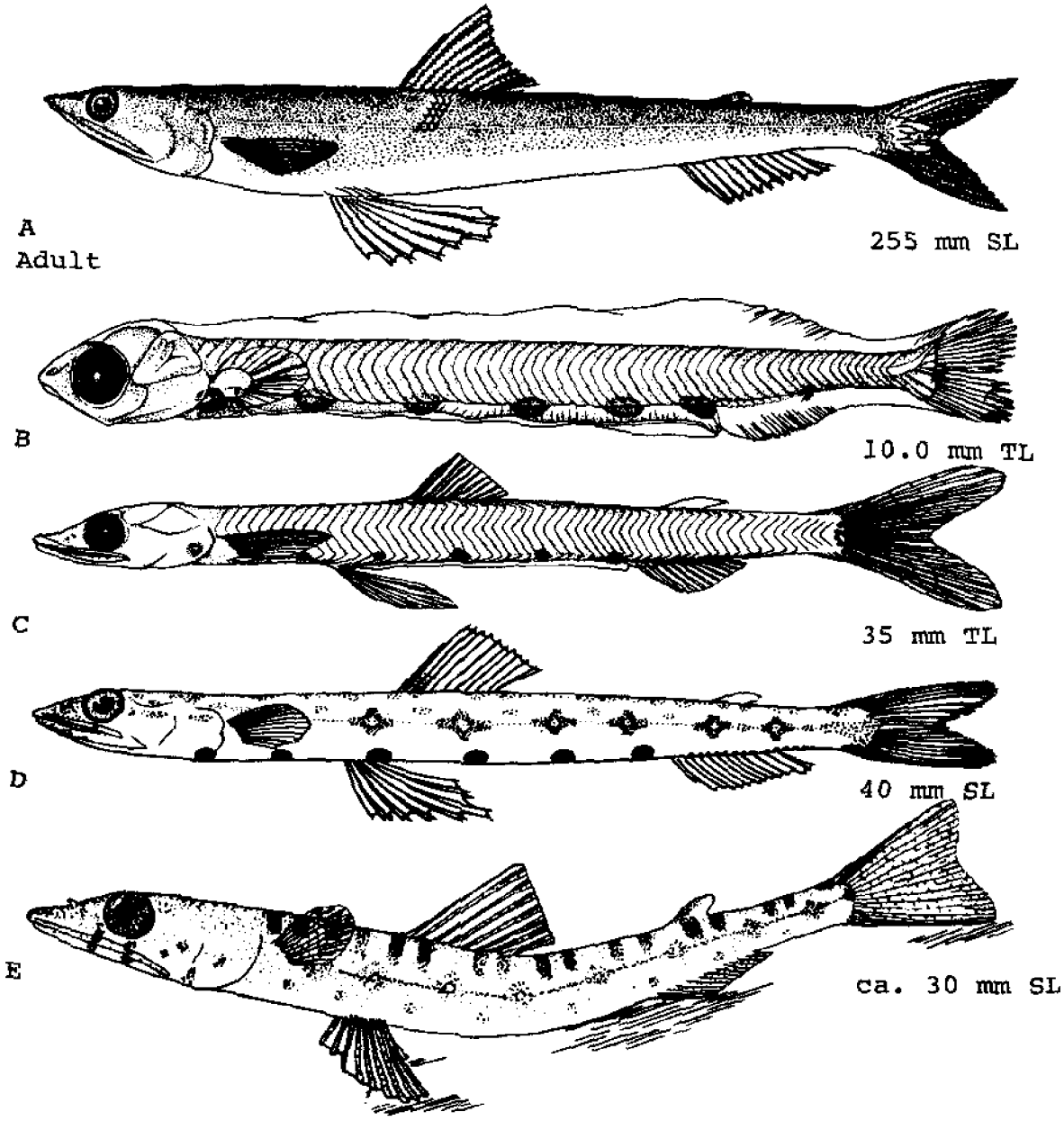

Fig. 108. *Synodus foetens*, Inshore lizardfish. A. Adult, 255 mm SL. B. Larva, 10.0 mm TL, 9.2 mm SL. Dorsal finfold ballooned. C. Prejuvenile, 35 mm TL, 30 mm SL. Total myomeres 58; preanal myomeres 39; postanal myomeres 19. D. Prejuvenile, 40 mm SL. Lateral pigmentation in crosses. E. Juvenile, ca. 30 mm SL. Fish in natural pose resting on bottom ready to strike at food. (A, D, Anderson, W. W., J. W. Gehringer, and F. H. Berry, 1966: figs. 9, 24. B, C, Mansueti, A. J., and J. D. Hardy, Jr., 1967: figs. 52B, 52C. E, Breder, C. M., 1944a: text, fig. 1.)

Synodus foetens (Linnaeus), Inshore lizardfish

ADULTS

D. 9 [13]–13 [14] (usually 12 [28]); A. 10–14 [14] (usually 12–13 [28]); C. 11–12 + 10 + 9 + 11–12 = 41–43; [39] P. 12–15; [14] V. 8; [24] pored lateral line scales 57–64 (reports of 56–65 are in error),[34] predorsal scales 20–30, scales between dorsal base and lateral line 4–6,[14] scales between anterior portion of dorsal fin base and lateral line 5 to 6.5; [36] total vertebrae 56–62; [34] trunk vertebrae 38; [15] branchiostegals 12–16.[35]

Proportions expressed as times in SL (at 126–169 mm): Head 3.9–4.5; depth 6.9–8.45. Proportions expressed as times in HL (at 126–169 mm): Snout 3.2–3.55; eye 6.2–7.6.[28] Proportions as percent of SL: Depth at base of pelvics 9.8–14.4; HL 20.6–26.3; eye diameter 3.4–6.2; anal fin base 9.0–13.9.[14]

Body elongate,[28] cylindrical; [14] head depressed, broader than deep,[1] slightly rugose above,[14] interorbital space concave; [35] snout triangular,[14] pointed, projecting beyond tip of mandible,[28] typically longer than diameter of eye in specimens larger than 200 mm SL; [14] 6–7 oblique rows of scales present on cheeks; [28] top of head naked.[35] Mouth very large, gape extends well past eye; [28] upper jaw projects slightly, premaxillaries form entire margin of upper jaw; large, sharp [35] depressible teeth present on upper jaw,[1] tongue and lower pharyngeals.[7] Scales small [14] (except for patch of large elongate scales present below pectoral base and above pelvic base [28]), lateral line well marked,[14] not keeled. Dorsal fin origin equidistant from center of eye and adipose fin, anterior rays not reaching past tips of posterior rays with fin depressed; [28] anal fin base longer than or equal to dorsal base,[27,37] origin equidistant from end of dorsal base and base of caudal rays; caudal fin lobes of about equal length; tip of pectoral fin not [28] or barely reaching origin of pelvic fin; [27] pelvic fins inserted closer to vent than to snout tip; adipose fin base no longer than diameter of pupil. Anterior nares with prominent dermal flap.[28] Gill rakers rudimentary.[12]

Pigmentation: Color variable with both locality [14] and immediate background; [16] dorsum brownish or olivaceous [1] and with overall greenish cast; [14] mid-lateral line with ca. 8 obscure blotches, variable in occurrence and intensity, fading with growth; [17,36,38] head brownish with light vermiculations on top and sides, pale yellow below; belly white,[17] silvery white,[1] or yellowish, sometimes with brownish punctations; [14] pectorals dusky,[17] yellowish, or light green; adipose with dark spot posteriorly.[1]

Maximum size: Confirmed to reach 405 mm SL,[14] but reported to reach ca. 610 mm.[17]

DISTRIBUTION AND ECOLOGY

Range: Cape Cod, Massachusetts south to Santa Catarina, Brazil; also Bermuda and the West Indies,[14] uncommon north of South Carolina.[28]

Area distribution: Chesapeake Bay north to vicinity of Annapolis; also tidal portions of Patuxent, Choptank,[10] and Potomac Rivers; Maryland seaside [21,22,24] and Indian River Bay, Delaware.[25]

Habitat and movements: Adults—a bottom species [1] found on both shallow and deep sand flats among grass; [3,4,7] inshore in saltwater creeks, rivers, bays, sounds,[14] and deep channels within lagoons; [7] possibly more common over mud than shell or calcareous bottom; [26] also found in open ocean over continental shelf. Migrating northward seasonally, rarely found north of North Carolina from January through May.[14] In southern waters, as in South Carolina, found in deeper coastal waters throughout the year, in shallow water from June to October.[18] Salinity range 4.0 [28]–60.0 ppt [3] (lower limit

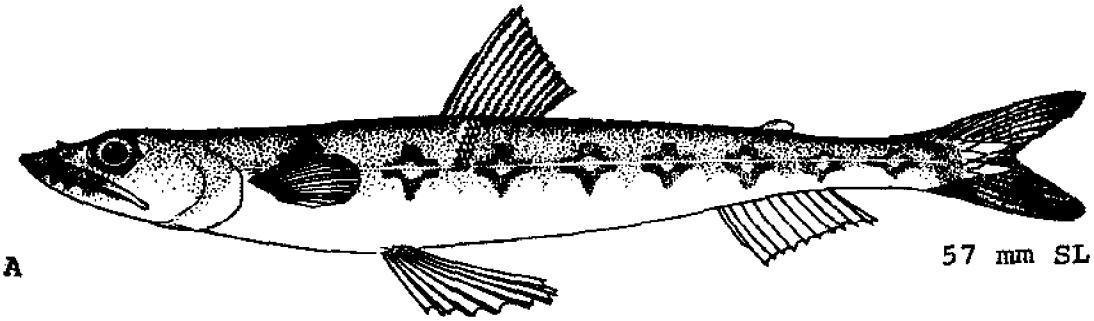

Fig. 109. *Synodus foetens*, Inshore lizardfish. A. Juvenile, 57 mm SL. Lateral crosses still visible. (*A, Anderson, W. W., J. W. Gehringer, and F. H. Berry, 1966a: fig. 25.*)

may include juveniles), described as being more abundant above 10 ppt [29] and 30 ppt.[32] Temperature range 5.0–34.9 C (may include juveniles).[29] Maximum depth 183 m.[37]

Larvae—newly hatched near surface of 27–46 m depths in spring at Port Aransas, Texas; [31] recorded from offshore waters of Virginia in May (WHM).

Prejuveniles and juveniles—apparently pelagic until ready to metamorphose,[9] readily collected from open ocean, usually near land in vicinity of or in shallow water; found at surface at night; collections recorded for February, May [31] to August, November, and December.[11] At 23–45 mm common at Port Aransas, Texas in summer to late September.[31] Transformation to juvenile form probably completed in less than one week and accompanied by assumption of benthic existence and burial in muddy substrate.[8,31] Transforming individuals (36.5–44 mm SL) taken in 22 m depths at Port Aransas, Texas.[31] Specimens less than ca. 50 mm dredged at 15 m off Beaufort, North Carolina.[17] Recently transformed individuals taken at Port Aransas, Texas, nearby bays and offshore at depths greater than 16 m.[31] Specimens 47.1–87.2 mm taken from bayous in vicinity of Tampa Bay, Florida; [3] "young" taken at 137 m; [20] other small specimens from deep sandy flats.[4,7] Salinity 10 ppt to over 30 ppt.[30]

SPAWNING

Location (based on larval collections): At Port Aransas, Texas in 27–46 m in spring, possibly deeper in summer, and perhaps in less than 46 m in fall.[31]

Season: Extends throughout most of year,[31] probably concentrated in spring.[3,6]

Temperature: Unspecified, but said to spawn on a rising or high temperature.[6]

Fecundity: No information.

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

Size at hatching ca. 2.5 mm.[31]

At hatching snout very blunt.[31]

Pigmentation: Three to six ventrolateral spots present which are smaller than interspaces.[31]

LARVAE

Maximum size described 10 mm SL.[31]

At 10 mm TL preanal myomeres 42, postanal myomeres 17 (AJL).

Balloon inflation of the skin present up to ca. 7 [31]–10 mm. At 10 mm TL auditory vesicle large, triangular, about equal to eye (AJL). In some specimens fin rays all well-developed at 10 mm SL.[31] In others at 10 mm TL incipient dorsal, anal and pectoral rays present; pectoral with fleshy base; caudal somewhat bifurcate and apparently with definite rays. Origin of dorsal finfold in occipital region; preanal finfold small, short; urostyle oblique (AJL).

Pigmentation: Six prominent ventrolateral peritoneal spots; a small spot at caudal base and another at anal insertion (AJL).

PREJUVENILES

Minimum size described 15.8 mm TL.[11] End of stage 30.5 [9]–44 mm SL.[31]

Snout usually longer than eye diameter (slightly shorter or equal to on small specimens).[14] Eye 1.8 in snout at 40 mm SL,[23] eye diameter 5 times in HL in "young."[27] Body transparent, subleptocephalic,[9] becoming translucent at 40 mm SL.[23]

Pigmentation: A row of six conspicuous ventrolateral spots of about equal size and equally spaced,[14] with each spot much smaller than the interspace,[11] extending from edge of gill cover [23] to a point just in front of anal origin; snout, lower jaw, and back lightly pigmented; a series of cross blotches developing along lateral line; pigment along anterior base of dorsal; [14] a dark, chevron-like, basicaudal mark with a short, narrow line extending forward from its apex.[11] Just prior to transformation, a pale dorsal pattern develops.[9]

JUVENILES

Minimum size described 30 mm SL.[9]

At 40 mm SL depth 11.5 times in SL.[23] Teeth conspicuous,[14] conical, directed somewhat backward.[23] At 57 mm SL, a flap of tissue on edge of anterior nasal opening.[14]

Pigmentation: In recently transformed juveniles body opaque; internal pigment patches retained but overlaid by dermal pigmentation.[9] At 57 mm SL, ventrolateral spots missing; belly immaculate; ca. 8 very distinct blotches along lateral line arranged as crosses with light centers. Caudal and dorsal pigmented throughout; pigment developing at base of adipose.[14] Color of "half-grown" specimens variable with surroundings; typically

creamy white to pale yellow; dorsal surface crossed by eleven brownish bands or blotches equally spaced, the first between the eyes, all double except the last which lies at caudal base. Ten diamond-shaped spots along lateral line and a second series of spots of lighter shade below and alternating with them. Dorsal, caudal, and proximal half of pectoral same color as body; other fins transparent.[7]

AGE AND SIZE AT MATURITY

No information.

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Trachinocephalus myops (Forster), Snakefish

ADULTS

D. 11 [22]–14; [5] A. 13 [20]–18; [5] C. 13 + 10 + 9 + 13; [22] P. 11–13; V. 8; [5] pored lateral line scales 53–59,[17] scales between dorsal base and lateral line 3.0; [5] total vertebrae 54–57 (mean 55.4),[17] trunk vertebrae 46.[7]

Proportions as percent of SL: Depth at pelvic base 15.5–21.5; HL 25.2–28.6; eye 3.2–6.3; anal fin base more than 23.0.[5]

Body slender, slightly compressed. Head compressed, upper surface strongly rugose; snout blunt and shorter than eye diameter; lower jaw projecting. Scales moderate. Lateral line poorly marked. Large, compressed teeth in narrow band on upper and lower jaw with inner ones larger and depressible; teeth also present on tongue, hyoid bone and palate. Origin of anal fin about midway between base of caudal and insertion of pectorals; [5] dorsal origin slightly nearer snout tip than adipose fin; [21] pelvic separated from anal by less than its length.[19]

Pigmentation: Golden brown above, yellowish below; [15] back with ca. 5 indistinct saddles; sides with ca. 4 faint yellow longitudinal stripes which are indistinct in larger specimens; opercle with black spot at upper angle; pectoral, pelvic and anal fins pale yellowish; dorsal and caudal dusky.[5]

Maximum length: Recorded to 375 mm.[8]

DISTRIBUTION AND ECOLOGY

Range: Warm waters of all oceans but not reported from the eastern Pacific off the American continents; [1,5] in the western Atlantic from Cape Cod south to Brazil.[5]

Area distribution: Off New Jersey at 40°04′ N, 70°33′ W.[4]

Habitat and movements: Adults—reported from inshore habitats [1,2] but apparently more common in offshore waters; over sand, shell, rock and mud bottoms; sometimes burrowed in substrate with only eyes exposed. Depth usually 36–91 m.[5]

Prejuveniles and juveniles—in or near Gulf Stream over

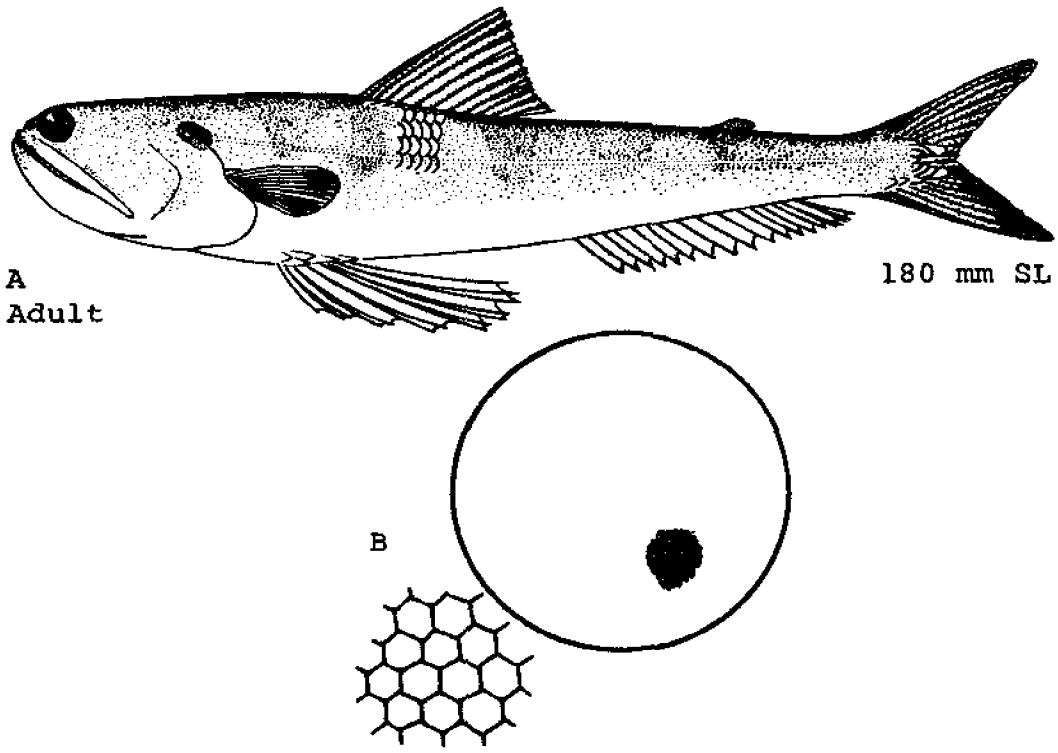

Fig. 110. *Trachinocephalus myops*. Snakefish. A. Adult, 180 mm SL. B. Egg, 1.10 mm with inset showing hexagonal structure of membrane. (*A, Anderson, W. W., J. W. Gehringer, and F. H. Berry, 1966a: fig. 8. B, Rass, T. S., 1972: figs. 1–2.*)

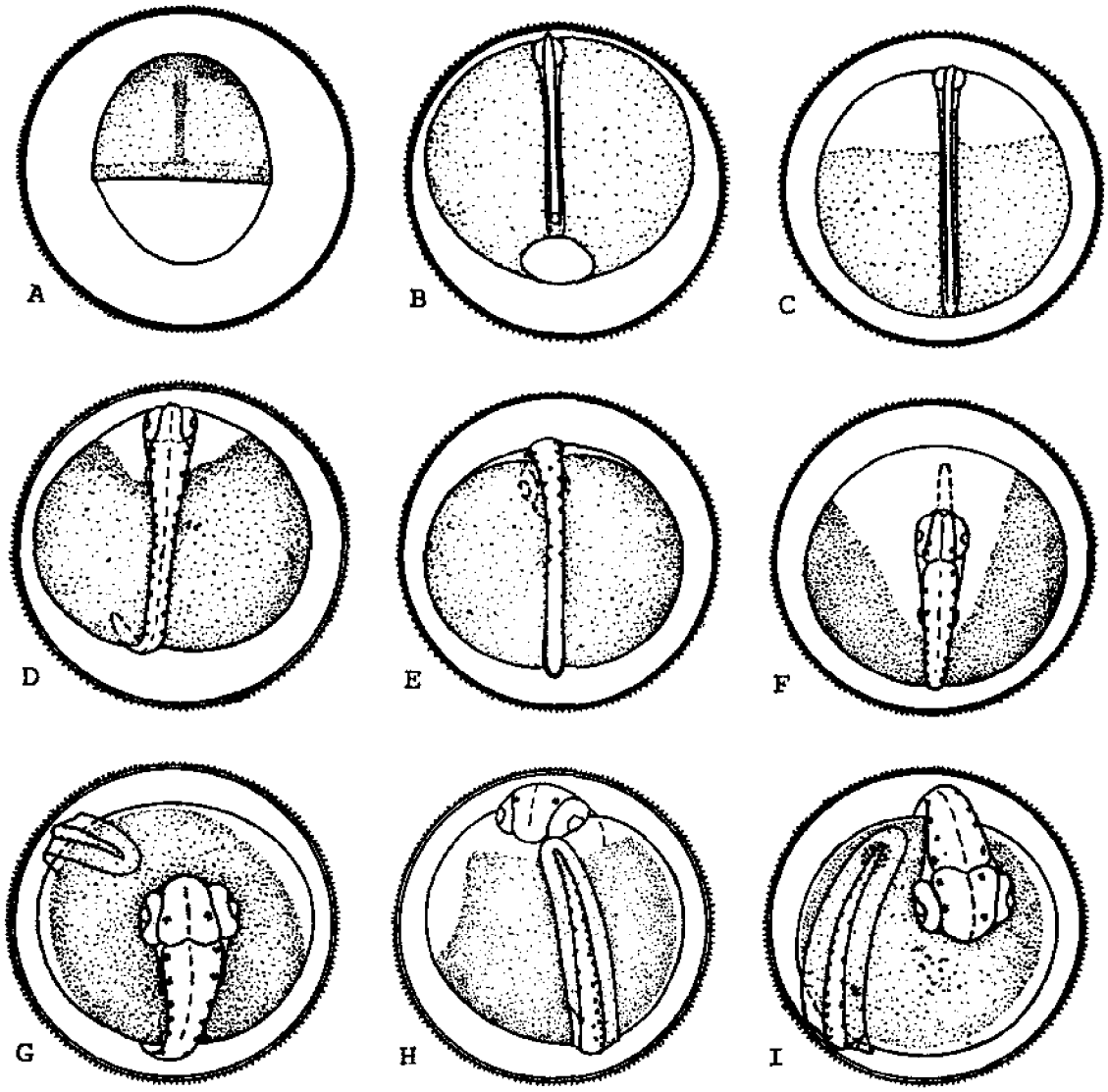

Fig. 111. *Trachinocephalus myops*, Snakefish. A. Egg, germ ring stage. B. Egg, early embryo; blastopore not closed; Kupffer's vesicle evident. C. Egg, embryo covers ca. 1/2 circumference of yolk; somites forming. D. Egg, lens formed, pigment pattern developing. E. Egg, early tailbud-free stage, pectorals forming. F. Egg, embryo covers ca. 3/4 circumference of egg, pigment extending to dorsal surface of head. G. Egg, about same stage as "F," pigment extends to tip of notochord. H. Egg, embryo extends the circumference of yolk. I. Egg, tail of embryo extends to pectoral bud; pigment evident in caudal finfold. (*A-I, Zvjagina, O. A., 1965: fig. 1.*)

more than 1800 m of water;[4] also in coastal waters;[6] sometimes washed ashore during storms.[5,9] Maximum depth: 388 m.[6]

SPAWNING

Location: Ripe or nearly ripe individuals recorded near both islands and major land masses, such as St. Helena,[10] the Grenadines, British West Indies,[11] and off the West African coast.[16]

Season: Probably prolonged; a fully ripe female has been recorded in July,[11] and prejuveniles in July, August, October, and November.[4]

EGGS

Ripe ovarian eggs: 0.78–1.12 mm.[25]

Fertilized eggs: Pelagic,[24] spherical,[18] diameter 0.95–1.25 mm;[25] membrane with hexagonal meshes 0.041–

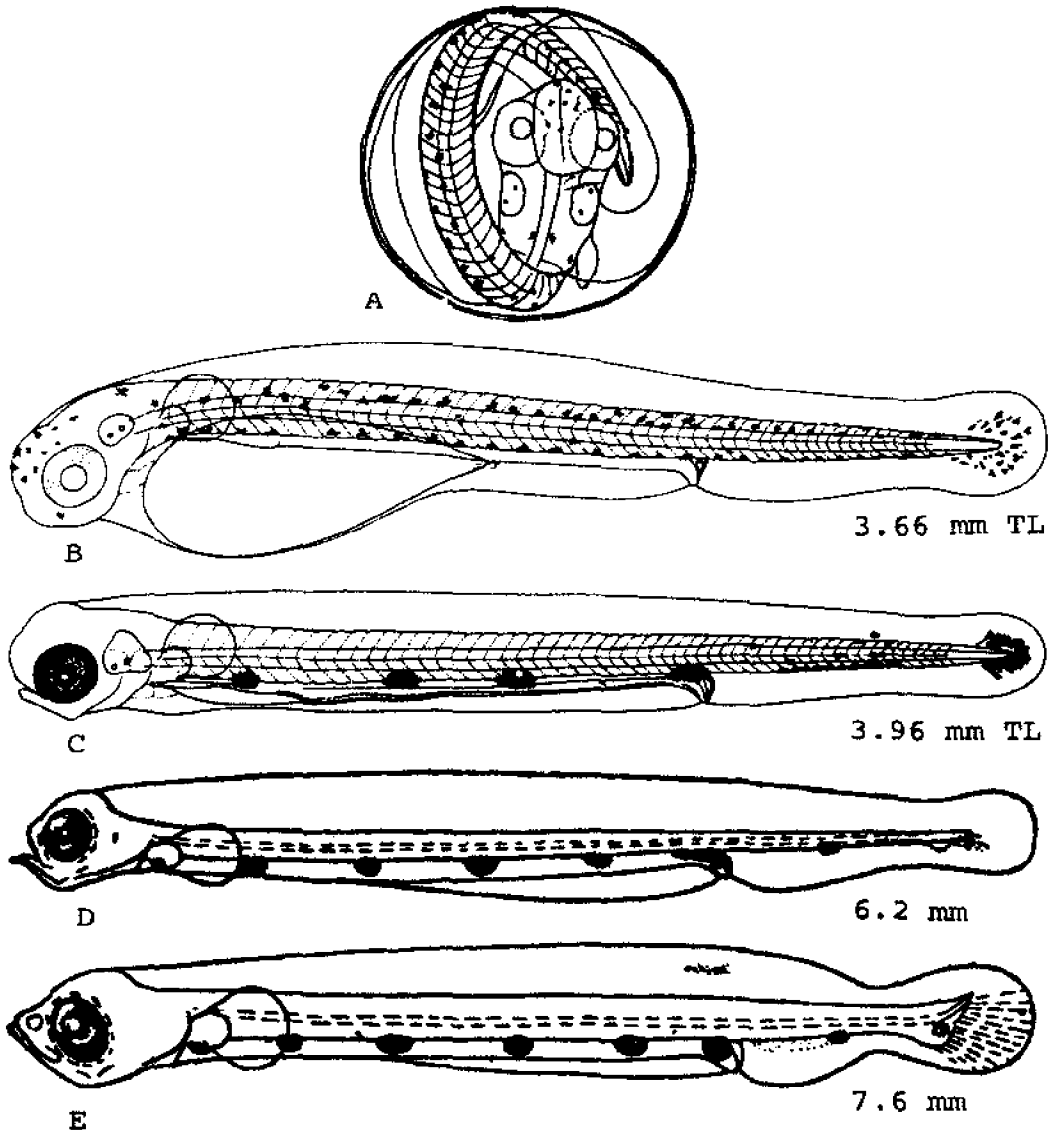

Fig. 112. *Trachinocephalus myops*, Snakefish. A. Egg, late stage embryo. B. Yolk-sac larva newly hatched, 3.66 mm TL, myomeres 33+20=53. C. Yolk-sac larva, 3.96 mm TL, two days after hatching, myomeres 33+21=54. D. Larva 6.2 mm, height of head ca. twice that of body. E. Larva, 7.6 mm, caudal fin with 12–13 rays. (A-C, Mito, S., 1961: pl. 24. D, E, Zvjagina, O. A., 1965: fig. 3.)

0.052 mm;[24] short spike evident at each angle;[25] yolk unsegmented,[18] diameter during early development 0.67–0.94 mm;[25] perivitelline space narrow, less than 15% diameter.[18]

YOLK-SAC LARVAE

Hatching length ca. 3.7 mm TL; maximum size described 4.0 mm TL.

Myomeres 33+20=53 at 3.7 mm TL, 33+21=54 at 4.0 mm TL.[24]

Head deflected at hatching, straight at 4.0 mm; mouth forming at 4.0 mm. At hatching pectoral fins present, yolk tear-shaped. Origin of dorsal finfold over otic capsule at hatching, over vertical midpoint of eye at 4.0 mm TL (based on illustration by Mito,[24] PWJ).

Pigmentation: Newly hatched specimens with small chromatophores lightly scattered in eye; stellate chromatophores on dorsal surface of head; ill defined row of pigment along dorsolateral surface; row of chromato-

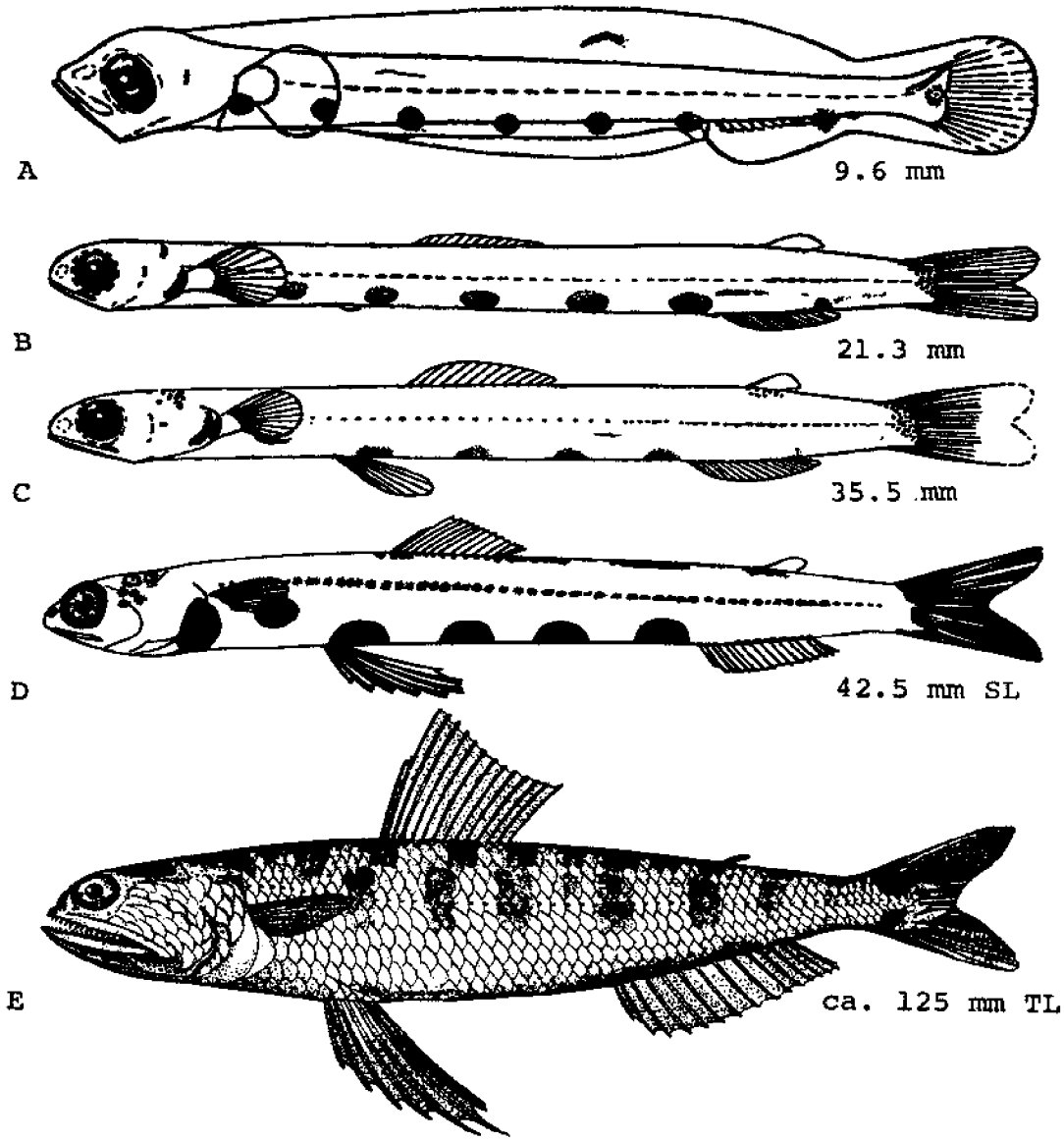

Fig. 113. *Trachinocephalus myops*, Snakefish. A. Larva, 9.6 mm, ventral fins forming. B. Larva, 21.3 mm, adipose fin evident. Pigment on operculum crescent shaped. C. Prejuvenile, 35.5 mm. D. Prejuvenile, 42.5 mm SL. E. Juvenile, ca. 125 mm TL. (*A-C, Zojagina, O. A., 1965: fig. 3. D, Anderson, W. W., J. W. Gehringer, F. H. Berry, 1966a: figs. 8, 14. E, Jordan, D. S., and B. W. Evermann, 1896–1900: pl. 88, fig. 235.*)

phores along ventral aspect of myomeres; scattered pigment in caudal finfold. At 4.0 mm TL eye pigmented; ventral migration of pigment complete except for scattered chromatophores between anus and tip of notochord; four prominent ventrolateral spots visible between pectoral base and anus; posterior to anus, short row of pigment along ventral ridge; pigment on caudal finfold more pronounced (based on illustrations by Mito,[24] PWJ).

LARVAE

Specimens described 6.2–21.5 mm.

At 6.2 mm height of head ca. twice that of body; at 21.5 mm height of head and body almost equal. At 6.2 mm mouth oblique; anterior portion of upper jaw above horizontal midline of eye, by 21.5 mm slightly oblique, below midline. Anal fin with 15 ray bases at 9.8 mm;

lower lobe of caudal finfold with 12–13 rays at 7.6 mm, pelvics forming at 9.8 mm. At 21.5 mm adult fin ray complement evident in dorsal, anal, caudal and pectoral fins; adipose fin evident. Urostyle flexed at 7.6 mm.[25]

Pigmentation: At 6.2 mm six pairs of prominent ventrolateral pigment blotches between pectoral base and anus; large chromatophore midway between anus and tip of notochord at site of future insertion of anal fin; scattered pigment on dorsal and ventral surface of tail, scattered pigment on caudal finfold. At 7.6 mm pigment blotch on pectoral base larger; pigment above anus more rounded; cluster of pigment under urostyle. At 9.8 mm anteriormost ventrolateral pigment blotch extends over edge of operculum. At 21.5 mm pigment on operculum in shape of crescent, remaining preanal ventrolateral pigment oval, pigment near pectoral fin tip somewhat higher than others in series. Pigment evident on posterior dorsal surface of head, at base of adipose fin and on lateral midline from anal fin and back; small melanophores on caudal peduncle near caudal fin base.[25]

PREJUVENILES

Size range described 27–48 mm TL [6,12] or larger.[26]

Branchiostegals 13–14 at 35–42 mm. At 35–42 mm, body depth 10.33–11.50, and HL 5.25–5.75 times in TL: body width 1.25–1.33 times in depth; eye 3.50–3.75 times in HL.[9]

Body slender, considerably less deep than in adult,[4] elongate, slightly compressed, and of almost equal depth throughout; abdomen with narrow smooth band, separating terminations of muscle rings and deeply grooved along each side. Head small with short, rounded snout; interorbital region narrow, concave;[9] mouth nearly straight; lower jaw included; gape extending to just beyond posterior margin of eye; a single row of palatine teeth on each side;[4] pseudobranchiae present; gill rakers minute, tubercular.[8] Lateral line developed at 28[4]–42 mm;[9] at 48 mm, scales of lateral line developed but not imbricated, scales developing on caudal peduncle and posteriorly on body but only indicated by pits on anterior half of body.[12] Urostyle oblique at 29–39 mm.[7] At 27–35 mm, dorsal above myomeres 16–23; anal below myomeres 37–45.[6] Third and 4th dorsal rays, 4th anal ray, and 6th pelvic ray the longest. Adipose fin inserted above 3rd quarter of anal.[9]

Pigmentation: Six pairs of large, preanal, ventrolateral blotches, with the anteriormost partially on opercle, the posterior 4 sometimes confluent below forming a bluish band.[9] At 27–35 mm, body transparent; a semicircle of chromatophores in occipital region, its curve directed posteriorly; a prominent spot at base of adipose fin; scattered chromatophores over head, dorsally between dorsal and adipose fins. At 27 mm TL to 43.0 mm SL, a midlateral row of chromatophores, the anteriormost conspicuously stellate. At 28–43.0 mm, a dark blotch at caudal base; small chromatophores beneath eye, on cheek and in series on each side of posterior half of anal.[4,5,6,9,13,14]

JUVENILES

Minimum size unknown. Specimens described 87.4–137.2 mm SL.

Proportions as times in SL: Body depth 5.2–5.6; head 3.5–3.8; caudal peduncle depth 13.4–13.9; predorsal length 2.4–2.5. Proportions as times in head length: Eye 6.1–6.8; snout 7.2–7.7.[23]

At ca. 125 mm TL eye larger than in adult, mouth less oblique.

Pigmentation: At ca. 125 mm TL blotches developed dorsally and laterally.[3]

AGE AND SIZE AT MATURITY

Ripe female taken 168 mm in length.[11]

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Carassius auratus
Cyprinus carpio
Hybognathus nuchalis
Notemigonus crysoleucas
Notropis amoenus
Notropis analostanus
Notropis bifrenatus
Notropis chalybaeus
Notropis hudsonius
Semotilus corporalis

minnows and carps
Cyprinidae

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FAMILY CYPRINIDAE

Cyprinidae, the largest of the fish families, contains about 10 subfamilies, 275 genera, and 1600 species. Its members are found throughout most of Eurasia, reaching the Arctic Circle in some areas; most of Africa, except the desert regions; and from Alaska and northern Canada to Mexico in North America. The cyprinds are primarily freshwater fishes, occurring in a variety of habitats from quiet ponds to swift flowing streams, and are generally intolerant of brackish water.

In the carps and minnows the jaws are toothless; the pharyngeal teeth are in one to three rows, and there are never more than eight teeth in any one row; the upper jaw is usually bordered only by the premaxillary; one or two barbels are sometimes present; the gill membranes are united; there are three branchiostegals; the lateral line is usually present; and the scales are cycloid and usually restricted to the body. Sexual dimorphism is often striking, and breeding males may be brightly colored and develop nuptial tubercles on the head, body, and fins.

A variety of reproductive stratagems is evident among the cyprinid fishes of the Mid-Atlantic region. The most unusual occurs in *Semotilus corporalis*, which spawns in a pebble nest as much as two meters wide and one meter high. Other species spawn in meadows inundated by spring floods, over muck bottoms, in gravelly riffles and in the abandoned nests of other fishes.

Eggs of the regional cyprinid fishes vary in diameter from a minimum of about 1.0 mm in most species to a maximum of 2.7 mm in *Semotilus corporalis;* the perivitelline space is moderate to broad; and oil globules are usually absent, although there are minute oil globules in the eggs of *Carassius auritus* and *Notropis analostanus* and small oil globules are sometimes present in the eggs of *Cyprinus carpio*. Except in *Hybognathus nuchalis* all are adhesive and attached.

Newly-hatched larvae of the regional cyprinids vary in length from 2.7 mm (in *Notemigonus crysoleucas*) to a possible maximum of 8.0 mm (in *Carassius auratus*). The most striking feature of these larvae is the bilobed yolk: the anterior lobe is generally thick and oval and the posterior lobe is thin and tubular. The anus is always posterior to the midpoint of the body and is generally located at a point between three-fifths and four-fifths of the distance between the snout and the end of the tail. The dorsal finfold is short, extending forward only about two-thirds the distance to the head, and the preanal finfold is typically elongate. Pigment is commonly present on the yolk sac and body at the time of hatching.

Regional larvae have preanal myomere counts of 18–25 (20 or more in most species) and postanal myomere counts of 12–17 (most often 12–15). These counts overlap in many species which, combined with the similarity in body proportions and shape, make identification difficult and often dependent on pigment patterns alone.

Carassius auratus (Linnaeus), Goldfish

ADULTS

D. I [34]–11, 14–20; [33] A. I [34]–11,[33] 5–6; [34] C. 19–20; P. 13 [26]–17; V. 8–9; [34] scales 25 [1,30]–34; [7,30] 5–6 rows above lateral line; [33] vertebrae 28–32; [7,30] gill rakers 37 [11]–50; [7] pharyngeal teeth 0,4–4,0.[30,34]

Proportions as percent SL: Body depth 33 [33]–50; [7] head 28. Eye 29% HL.[33]

Body stout, thick-set, caudal peduncle thick and short.[34] Head scaleless,[26,34] broadly triangular,[34] interorbital space broad, snout longer than eye diameter, maxillary reaching posterior nostril or not quite to eye,[6] barbels lacking on upper jaw.[9,34] Scales cycloid, large. Lateral line complete. Dorsal and anal fins with serrate bony spines, pelvic fins short, broad and thoracic. Nuptial tubercles of male fine, on opercles, sometimes on back and a few on pectoral fins. Hybridize readily with carp, hybrids intermediate in most characteristics.[34]

Pigmentation: Wild-caught specimens olive brown,[8,9] slatey olive,[9] olive green [9,34] with a bronze sheen,[9] silvery,[37] grayish yellowish, gray-silver,[13] through gold (often with black blotches) to creamy white; [34] yellowish white or white below. Cultured forms vary through scarlet, red-pink, silver, brown, white, black and combinations of these colors.[9]

Maximum size: About 457 mm.[5]

DISTRIBUTION AND ECOLOGY

Range: Europe except Scandinavia and temperate zones Asia; [31] introduced throughout the world; [12] in North America, widespread in U.S.,[34] most common in vicinity of Lake Erie, absent from southern Florida,[9] in Canada, the Maritime Provinces, southern Ontario, parts of Alberta and British Columbia.[34]

Area distribution: Fresh and brackish waters of Chesapeake Bay tributaries in Maryland [17] (RJM).

Habitat and movements: Adults—usually a bottom species, but sometimes in schools at surface; [6] shallow water with dense vegetation in warm lakes, reservoirs, rivers, and quiet streams [7,11,12,30] (RJM). Maximum recorded salinity 17 ppt,[10] but apparently unable to withstand prolonged exposures above 15 ppt.[11,14] Lake dwelling individuals move into river mouths to avoid winter O_2 minima.[31]

Larvae—cling to plants [13] or remain quietly on bottom when first hatched; [21] free-swimming after 1–2 days; [28] near surface after yolk absorption.[2]

Juveniles—presumably same as adult (FDM).

SPAWNING

Location: Shallow water among weeds,[1,6] often where willow roots grow exposed in water,[20] also meadows inundated by spring flood.[31]

Season: Intermittently from late March [21] to about middle of August with first spawn of season the largest;[1] peak activity in April and May; individual fish spawn 3–10 lots of eggs at intervals of 8–10 days.[21]

Time: Recorded from just before dawn,[3] to midafternoon,[4] or sunrise to 1000–1100 hours starting again from 1800–2000 or 2100 hours,[31] most often on bright sunny mornings.[34]

Temperature: Ca. 16.4 C [25,29] to 23 C, egg production is abundant in hatcheries at 22–23 C.[13]

Fecundity: 2000 [21]–400,000,[30] average 96,200 in 15–24 cm fishes.[31]

EGGS

Location: Attached singly, rarely in two's and three's, at intervals of ca. 12–25 mm on aquatic plants,[1,28,31] and other fixed objects.[18]

Ripe ovarian eggs: 0.8–1.28 mm.[31]

Unfertilized eggs: Diameter ca. 1.6 mm; [29] outer covering slightly wrinkled, loose; [21] micropyle apparently single.[18]

Fertilized eggs: Spherical; [1,3,21] diameter 1.0–1.7 mm,[6] with smaller fish apparently developing smaller eggs.[29] Eggs just after fertilization slightly oblong; vertical axis 1.05 mm, horizontal axis 1.14 mm.[24] Variously described as transparent,[21,29] semitransparent,[24] pale yellow,[21] yellowish white,[3] cream-colored,[1] and grayish green.[7] Entire surface adhesive until water-hardened and attached.[1] Egg capsule smooth,[21] described as both "thin" [3] and "heavy"; perivitelline space narrow, 0.1 mm; yolk coarsely granular; oil globules 0.01–0.05 mm, sparsely scattered, and tending to disappear during later stages of development.[1] Area specimens comparatively smaller and clearer than carp eggs (JJL).

EGG DEVELOPMENT

At 24–28 C (constant temperature of 25 C following late cleavage stages):

30 minutes	1st cleavage.
45 minutes	2nd cleavage [1] (at which time rhythmic contractions of the egg have been observed [24]).

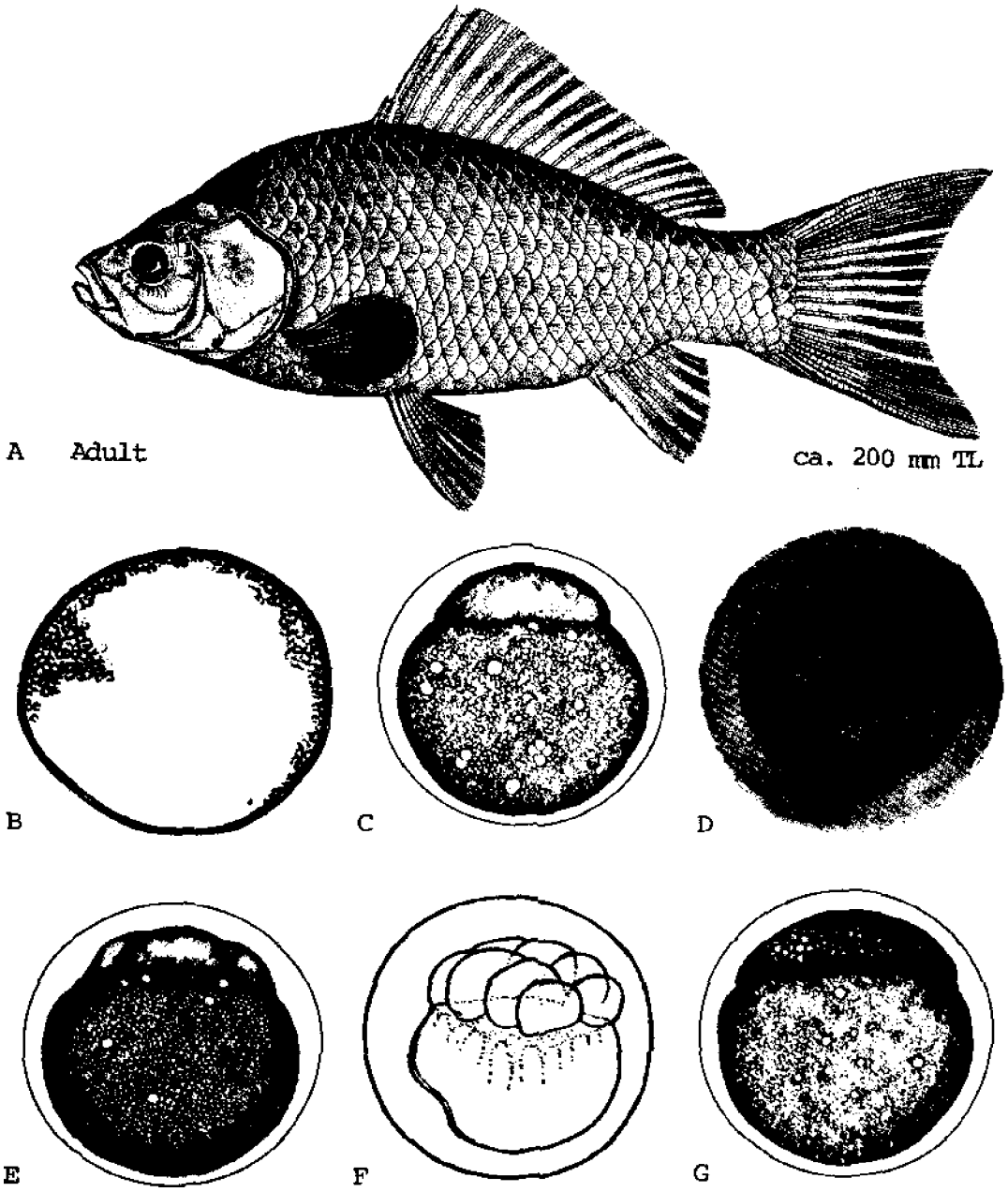

Fig. 114. *Carassius auratus*, Goldfish. A. Adult, ca. 200 mm TL. B. Egg, before water-hardening. C. Egg, blastodisc. Lake Erie wild population. D. Egg, blastodisc, domestic goldfish stock, India. Note the apparently wider perivitelline space than in those eggs from Lake Erie. E. Egg, 4-cell stage, Lake Erie. F. Egg, 8-cell stage, *C. a. cuvieri*. Note the wider perivitelline space. G. Egg, morula, 2 hours at 25 C, Lake Erie. (*A, Goode, G. B., et al., 1884: pl. 231. B, F, Nakamura, M., 1969: pl. 80. C, E, G, Battle, H. I., 1940: figs. 1, 3, 4. D, Khan, M. H., 1929: pl. 1.*)

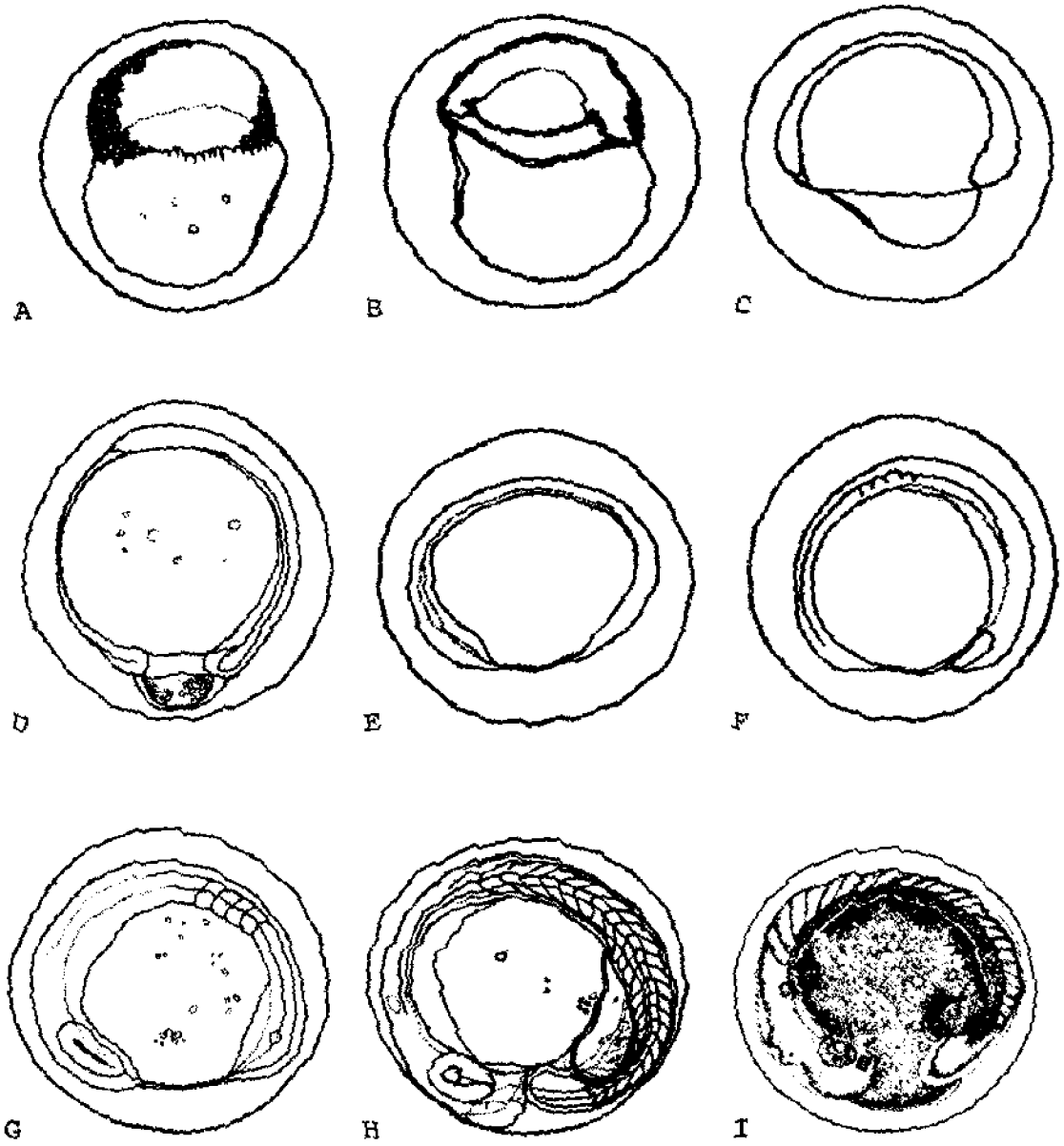

Fig. 115. *Carassius auratus*, Goldfish. *A. Egg*, blastula, *C. a. cuvieri*. B. Egg, embryonic axis formed, *C. a. cuvieri*. C. Egg, embryonic shield reaching about 3/4 around yolk. D. Egg, near blastopore closure, subspecies unknown. E. Egg, cephalization beginning, *C. a. cuvieri*. F. Eggs, optic anlagen, somites forming, *C. a. cuvieri*. G. Egg, about same developmental stage as previous, Kupffer's vesicle visible. H. Egg, otic capsule forming. I. Egg, somites formed further forward than previous. *(A-H, Nakamura, M., 1969: pls. 76, 79. I, Battle, H. I., 1940: fig. 14.)*

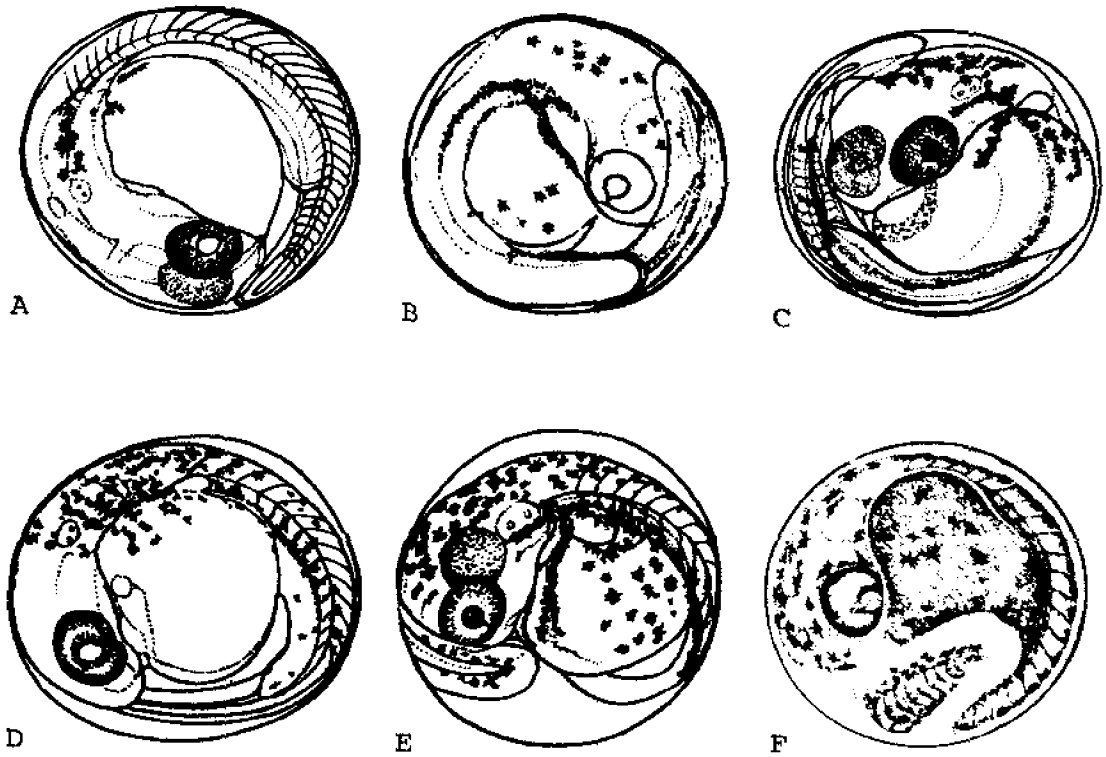

Fig. 116. *Carassius auratus*, Goldfish. A. Egg, late embryo, subspecies unknown. B. Egg, late embryo, *C. a. langsdorfii*. About same stage as previous but eye unpigmented and general pigment pattern distinctly different. C. Egg, late embryo, subspecies unknown. Showing further development of color pattern. D. Egg, late embryo, *C. a. cuvieri*. Showing still a third color pattern. E. Egg, late embryo, *C. a. cuvieri*. Showing further development of color pattern. F. Egg, late embryo, American fish. Color pattern more similar to that of *C. a. cuvieri* than to others shown. (*A-E, Nakamura, M., 1969: pls. 76, 78, 80. F, Battle, H. I., 1940: fig. 16.*)

2 hours	morula.
7 hours	blastoderm extended to equator of egg.
9 hours	blastopore formed.
11–12 hours	axis of embryo nearly encircling yolk, and head region visible as a somewhat oval expansion.
12 hours	3–4 *somites, notochord differentiated.*
15 hours	oval optic evaginations, 8–10 somites.
17 hours	auditory vesicles, olfactory pits, and 18 somites formed.
24–27 hours	tail and head free from yolk; narrow finfold around tail extending anteriorly on dorsal surface to midpoint of body; 25 somites, optic cup, and lens formed; pigment absent.
45–50 hours	embryo longer than yolk circumference; yolk sac divided into anterior spherical or oval division and posterior cylindrical parts; 20–22 + 10–12 somites; pectoral buds formed; stellate chromatophores over head, yolk sac and along dorsum and primitive intestine.
60–65 hours	otoliths and rudimentary semicircular canals formed; dorsal finfold to first myomere; pectorals free from yolk surface; 21–22 + 11–12 somites; heavy, stellate melanophores over head, yolk sac along dorsolateral and ventral musculature, and ventrally over region of intestine; eye densely pigmented.[1]

At 21 ± 1 C: [32]

30 minutes	water-hardened.
1 hour	2 cells.
1 1/2 hours	4 cells.
2 hours	8 cells.
2 1/2 hours	16 cells.
3 hours	32 cells.
3 1/2 hours	morula.
4 hours	blastula, raised from yolk surface.
5 1/2 hours	blastula, flattened somewhat.
7 hours	blastula, beginning to overgrow yolk.

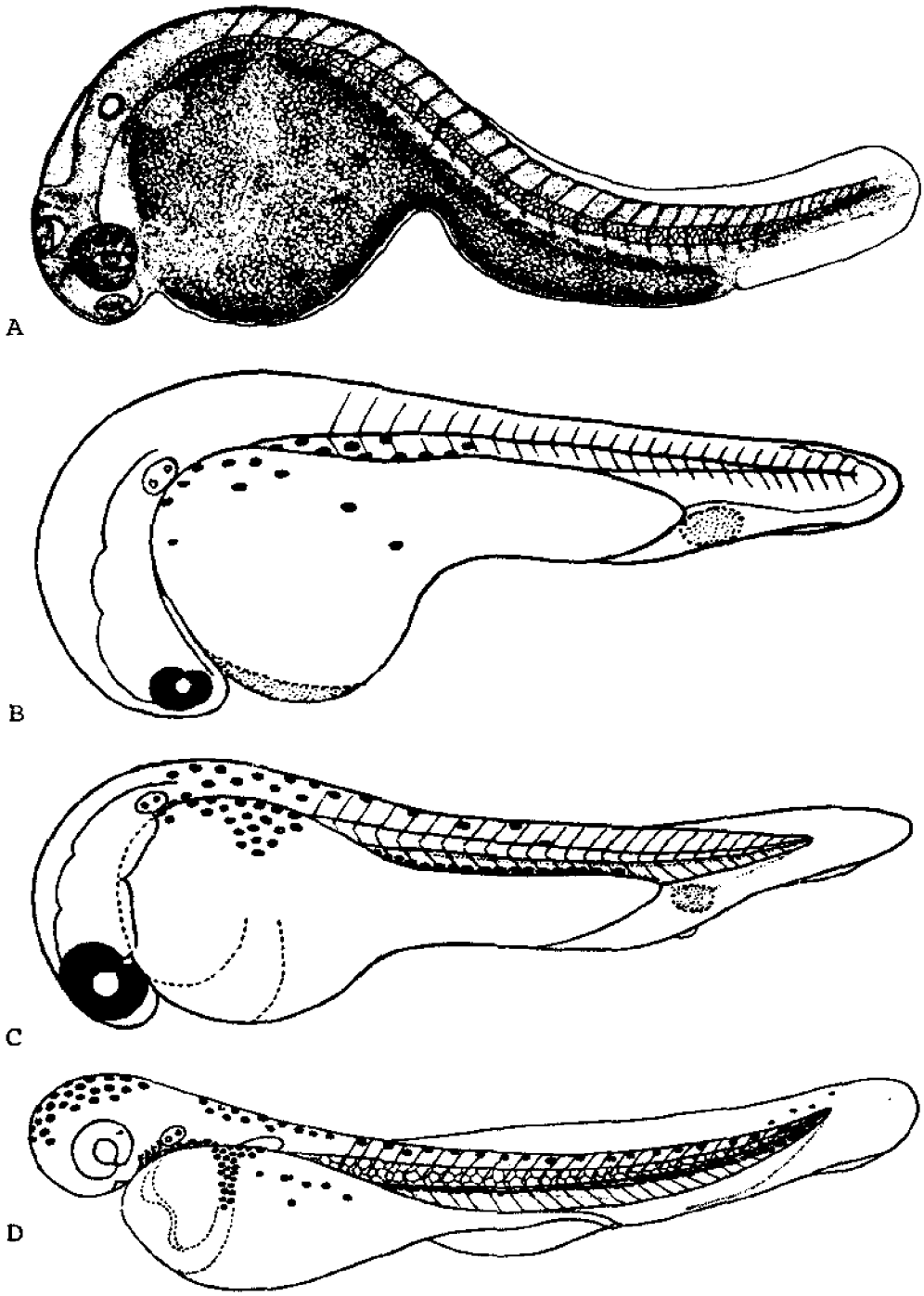

Fig. 117. *Carassius auratus*, Goldfish. A. Embryo removed from egg, 45 hours at 25 C. B. Embryo removed from egg, 50 hours. This and following developed at 21 C. C. Embryo removed from egg, 60 hours. Heart pulsating, circulation evident. D. Hatching embryo, 100 hours. (*A, Battle, H. I., 1940: fig. 15. B-D, Kajishima, T., 1960: figs. 22, 23, 25.*)

9 1/2 hours	early gastrula.
11 hours	middle gastrula.
13 hours	late gastrula.
15 hours	early embryonic shield.
18 hours	late embryonic shield.
21 hours	optic anlagen visible.
26 hours	optic vesicles.
30 hours	optic cups and lens developed.
33 hours	tail bud.
36 hours	retinal pigment begins.
50 hours	melanophores first appear on embryo.
60 hours	heart pulsating.
80 hours	pectoral fin buds appear.
100 hours	hatching.[32]

At an unspecified temperature: [3]

1 hour	cleaved into cells (8 cells shown in figure).
3 hours	periblast visible.
6 hours	periblast cut off from blastoderm, peripheral margin thickened to form a germ ring.
9 hours	(from dorsal view) germ ring seen as a thick triangular area; a plug of yolk cells at blastopore.
10 hours	longitudinal thickening from blastopore to anterior end, the embryonic axis.
11 hours	4 somites visible.
13 hours	8 somites; eyes colorless.
14 hours	13–14 somites; blastopore closed; edges of 15th and 16th somites barely visible; eye colorless; head and tail attached to yolk sac.
16 hours	16–20 somites; otoliths behind the eyes; individuals with 20 somites show movement; head and tail still attached to yolk sac; no heart visible.
22 hours	heart visible but no blood vessels visible; embryo moves; tail detached from yolk sac; brain developed.
25 hours	blood vessels visible; eyes a bit darker; round pigment cells visible.
27 hours	"typical embryonic teleostean circulation"; no gills visible.
32 hours	pigment cells become stellate; eyes darker; anterior vena cava passing through yolk sac with walls studded with white pigment cells; tail elongated.
46 hours	pectoral fins membranous; stellate pigment cells increased; some eggs hatched by 45 hours, hatching tail first.[3]

Incubation: 40 hours [3] to 14 days [4] depending on temperature; 5–7 days (presumably) at 22–23 C; [13] 8–10 days at 15 C, 5 days at 20 C,[6] 40–60 hours at 29 C.[3]

YOLK-SAC LARVAE

Hatching length 3.0 [22]–5.0,[6] possibly to 8.0 mm TL; [23] minimum size at end of stage 6.5 mm TL.[6]

Myomeres 21–22 + 11–12.

Yolk initially with anterior oval and posterior cylindrical sections; almost tubular and much reduced at 5.8 mm; represented by few abdominal granules at 6.8 mm. Head not deflected over yolk, mouth open at 5.8 mm. Mouth much enlarged with lower jaw movable at 6.8 mm. Opercular membrane growing posteriorly over gills at 5.8 mm and well-developed at 6.8 mm; [1] gills visible at edge of operculum by 3rd day. Otoliths enlarged on 3rd day. Heart complex with 6 aortic vessels. Gas bladder apparent within 20 hours of hatching,[3] partially inflated at 5.8 mm. Gut a straight tube, somewhat dilated behind gas bladder at 5.8 mm, enlarged anteriorly at 6.8 mm. Liver reddish yellow, ventral, triangular mass posterior to heart at 6.8 mm.[1] Dorsal first indicated at 5.5–6.8 mm, with incipient rays at 6.2 mm; anal anlage visible at 7.0 mm. Caudal anlage with incipient rays in ventral lobe at 4.5–6.8 mm; caudal more or less truncate at 6.2–6.8 mm, somewhat forked at 7.0 mm. Pectoral buds small at hatching, with incipient rays at 6.2 mm.[1,27] Urostyle oblique at 6.0 [27]–6.8 mm.[1]

Pigmentation: Variable at hatching; melanophores on jaws, dorsal surface of head and back, on sides at level of lateral line, and concentrated on anterior aspects of yolk; heavy subsurface melanophores above gill arches; double or triple series on dorsal surface of intestine,[1] extending beyond vent to tip of notochord. Some specimens light green with guanophores scattered among melanophores,[6] others uniformly covered with black pigment [21] or silvery gray.[25] At 5.8 mm, density of pigment increased, especially in eye; xanthophores developed along dorsal musculature and on head. At 6.8 mm, dense yellow pigment on entire body; melanophores developed on ventral margin of operculum and dorsal surface of gas bladder.[1] At 5 days, round pigment cells along dorsal and ventral edge of notochord.[3]

LARVAE

Specimens described 6.5 [6]–11.6 mm TL.[1]

D. 9 at 9.4 mm; myomeres 22 + 12.[27]

At 7.9 mm, otoliths about equal to size of lens; gills completely covered by operculum; lips with minute, partly pigmented elevations; [27] gas bladder partially divided into 2 chambers.[3,27] Notochord flexion on 6th day after hatching.[3]

Finfold lobed in region of future dorsal and anal at 7.9

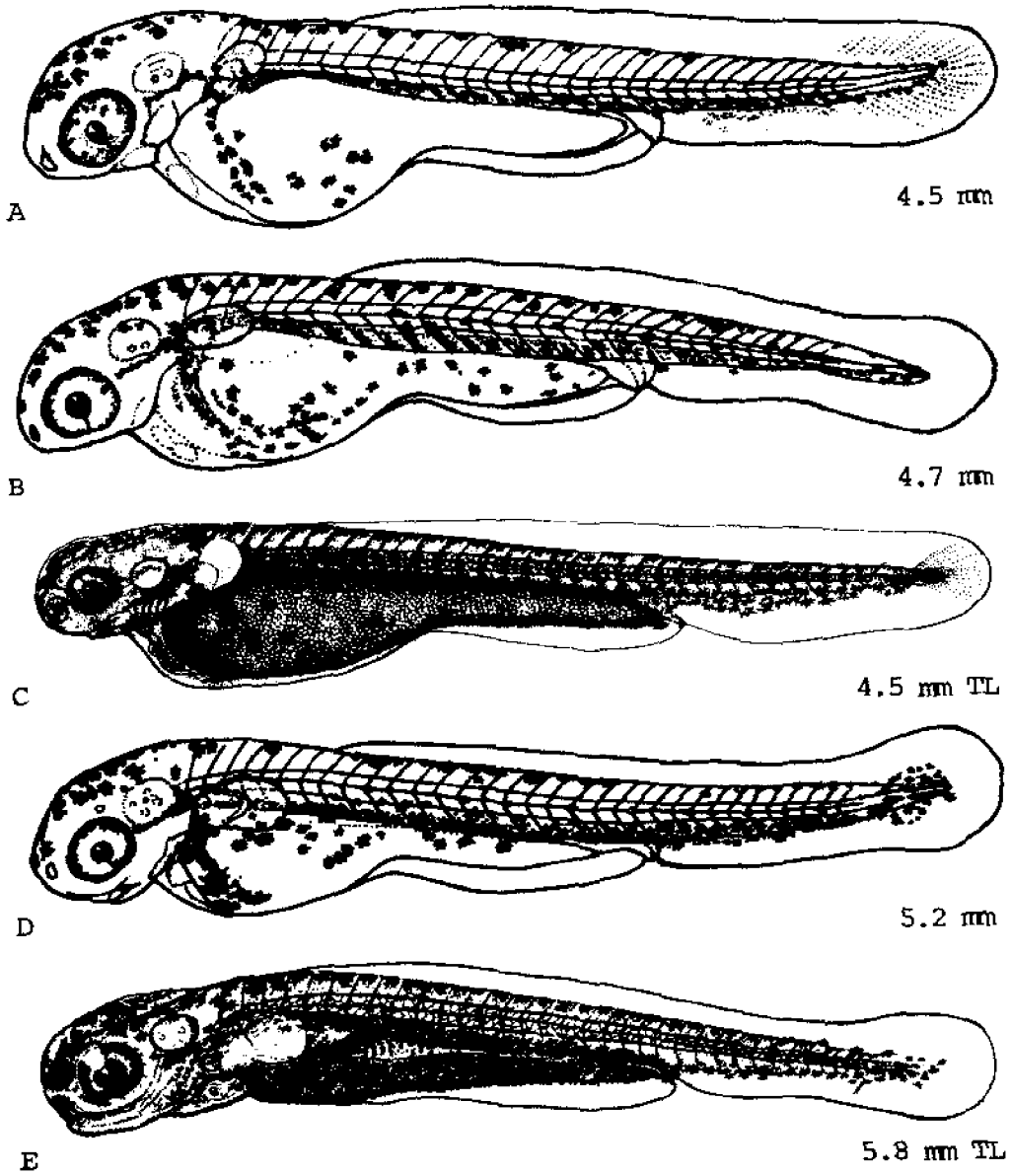

Fig. 118. *Carassius auratus*, Goldfish. A. Yolk-sac larva, 4.5 mm, *C. a. langsdorfii*. B. Yolk-sac larva, 4.7 mm, subspecies unknown. C. Yolk-sac larva, 4.5 mm TL, smaller than previous but jaw appears more developed. D. Yolk-sac larva, 5.2 mm, *C. a. cuvieri*. E. Yolk-sac larva, 5.8 mm TL. (*A, B, D, Nakamura, M., 1969: pls. 76, 78, 80. C, E, Battle, H. I., 1940: figs. 17, 18.*)

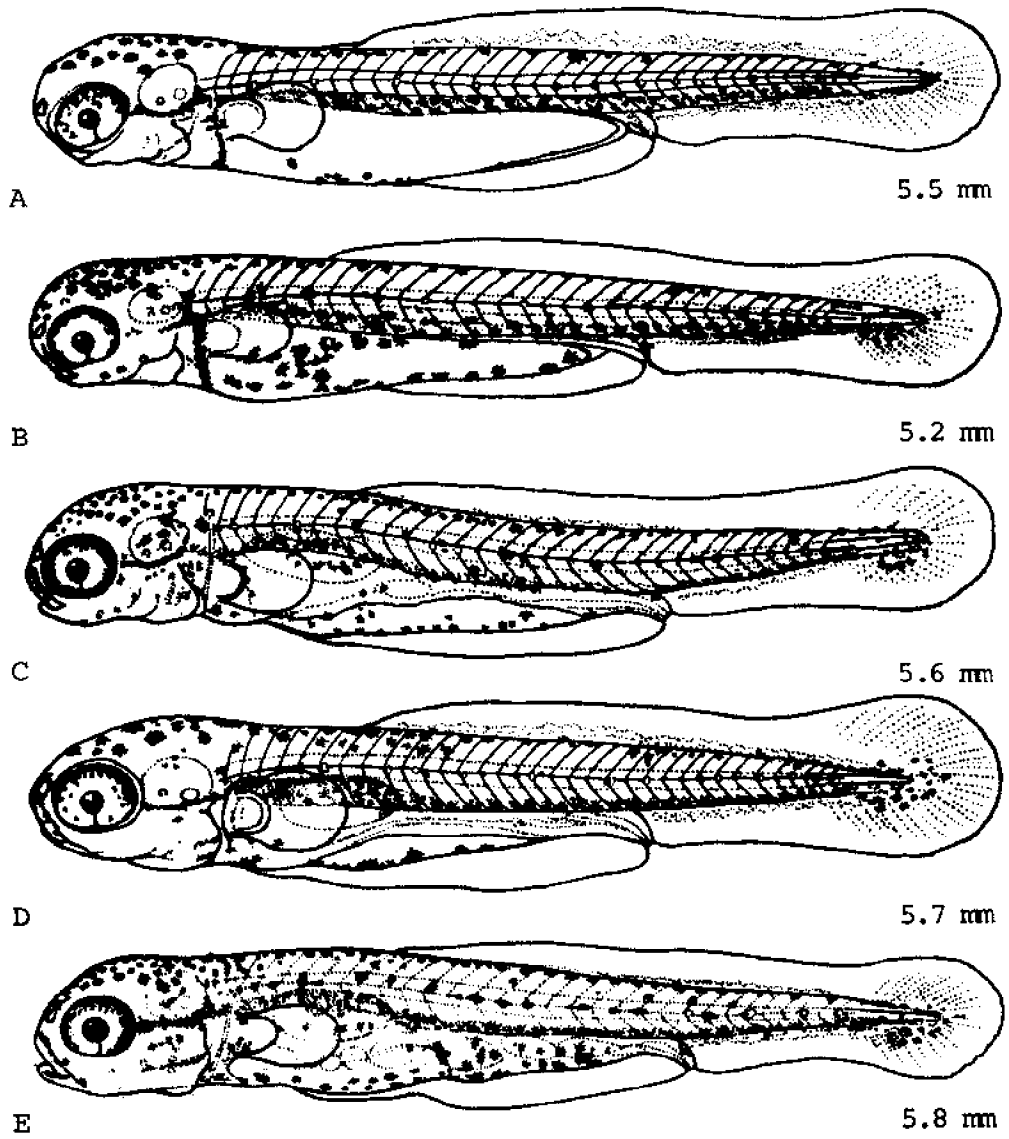

Fig. 119. *Carassius auratus*, Goldfish. A. Yolk-sac larva, 5.5 mm, *C. a. langsdorfii*. B. Yolk-sac larva, 5.2 mm, subspecies unknown. Smaller than previous specimen but yolk more reduced. C. Larva, 5.6 mm, subspecies unknown. D. Larva, 5.7 mm, *C. a. langsdorfii*. E. Larva, 5.8 mm, subspecies unknown. (*A-E, Nakamura, M., 1969: pls. 76–78.*)

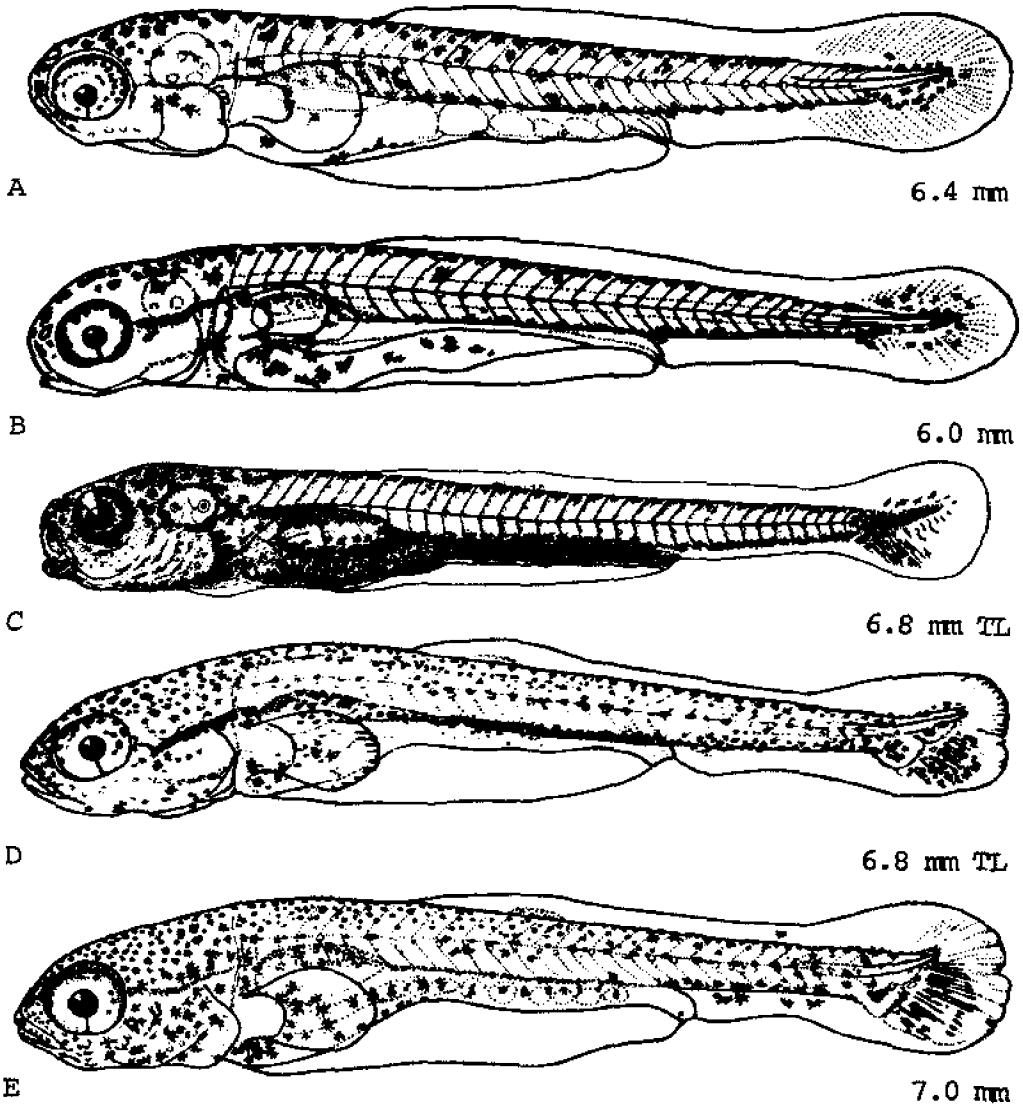

Fig. 120. *Carassius auratus*, Goldfish. A. Larva, 6.4 mm, *C. a. langsdorfii*. B. Larva, 6.0 mm, *C. a. cuvieri*, stage about equivalent to previous. C. Larva, 6.8 mm TL, flexion beginning. D. Larva, 6.8 mm TL, early flexion. E. Larva, 7.0 mm, subspecies unknown. (*A, B, D, E, Nakamura, M., 1969: pls. 77, 79, 81. C, Battle, H. I., 1940: fig. 19.*)

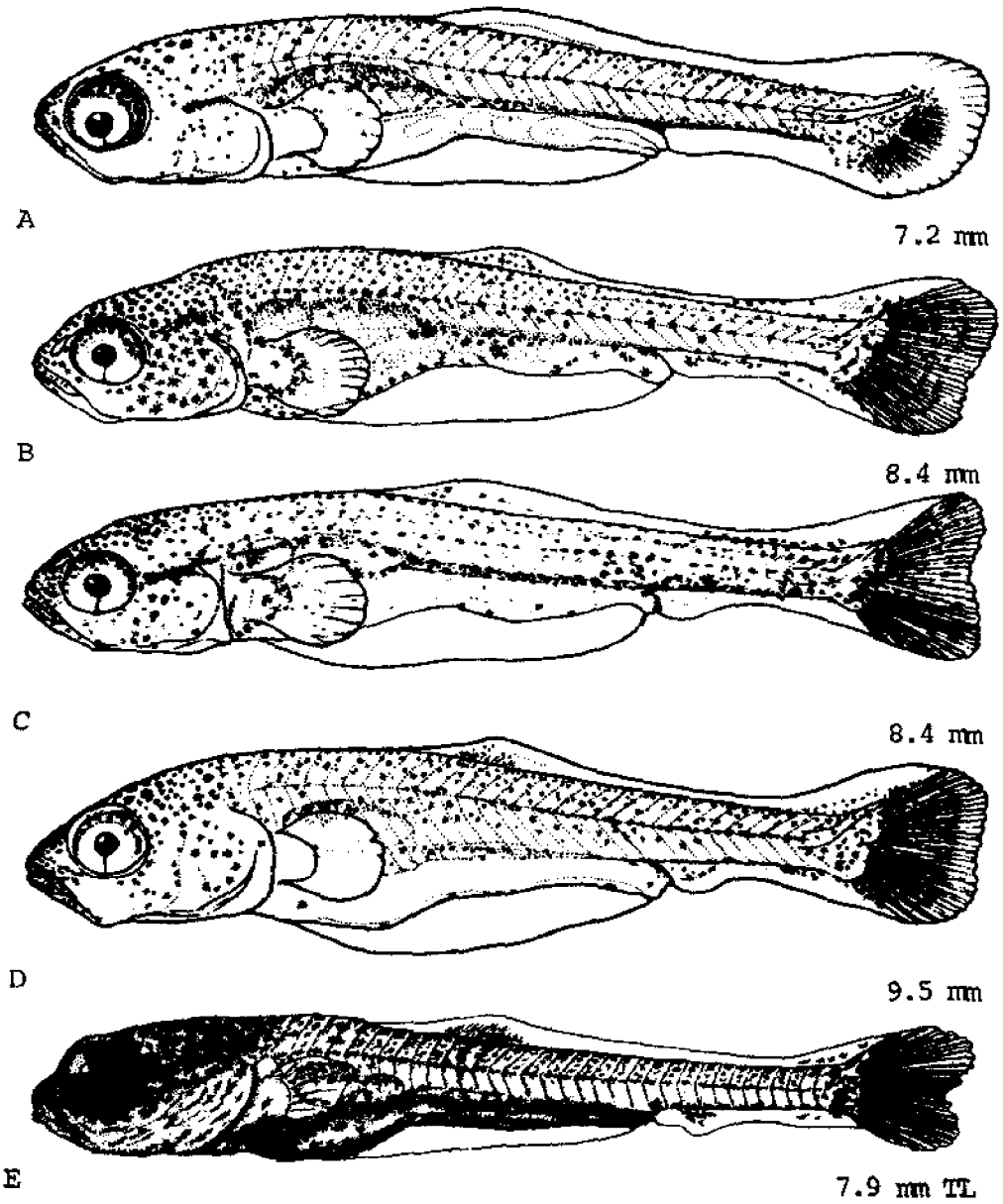

Fig. 121. *Carassius auratus*, Goldfish. A. Larva, 7.2 mm, *C. a. langsdorfii*. B. Larva, 8.4 mm, subspecies unknown. C. Larva, 8.4 mm, *C. a. cuvieri*. D. Larva, 9.5 mm, *C. a. langsdorfii*. E. Larva, 7.9 mm TL, smaller than previous 3 figures but fin ray development well advanced. (*A-D, Nakamura, M., 1969: pls. 77, 79, 81. E, Battle, H. I., 1940: fig. 20.*)

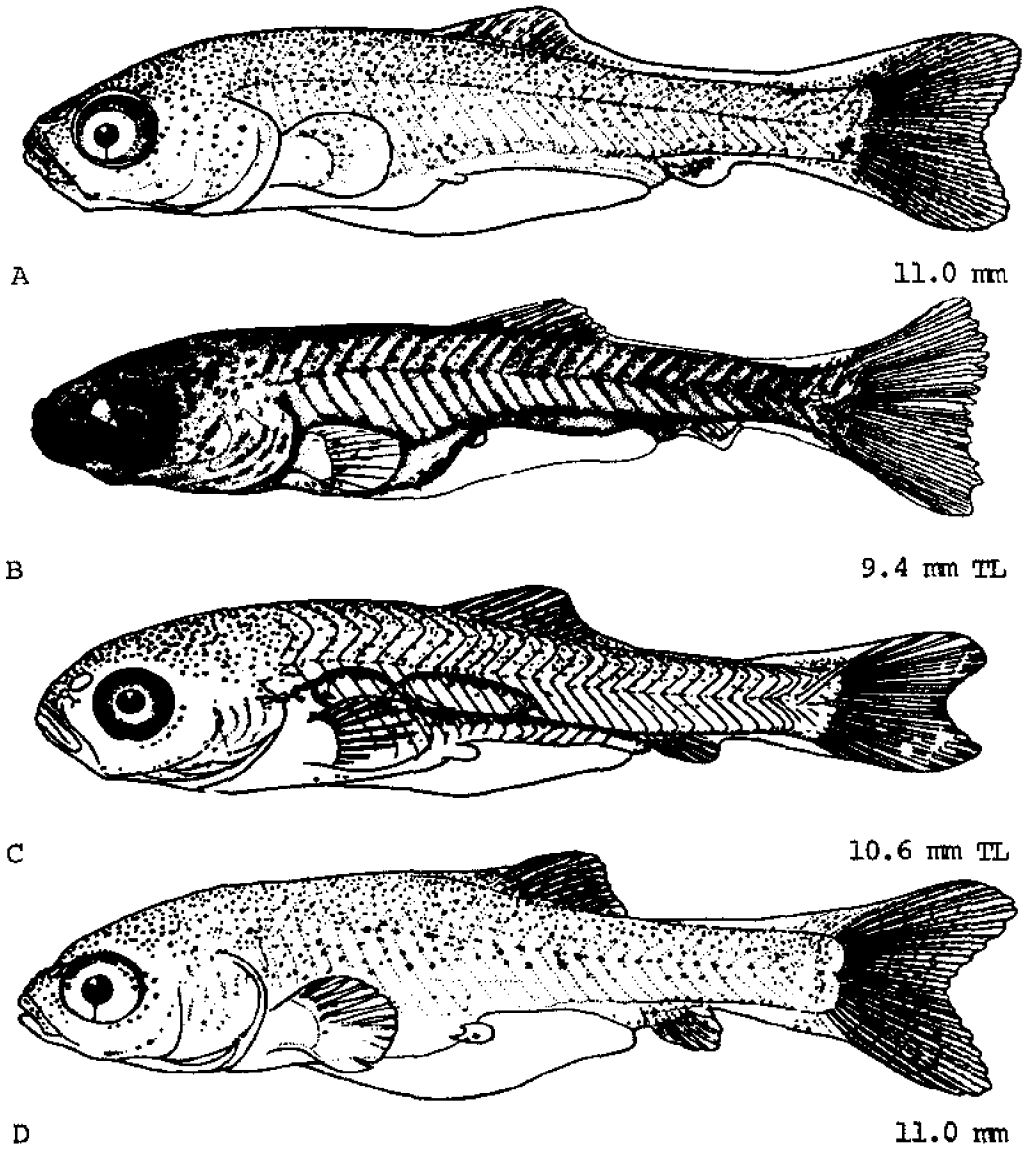

Fig. 122. *Carassius auratus*, Goldfish. A. Larva, 11.0 mm, *C. a. langsdorfii*. B. Larva, 9.4 mm TL. Smaller than previous but anal and pectoral fin rays appear to be more advanced in development. C. Larva, 10.6 mm TL. D. Larva, 11.0 mm, subspecies unknown. (*A, D, Nakamura, M., 1969: pls. 77, 79. B, Battle, H. I., 1940: fig. 21. C, Dmitrieva, E. N., 1957: fig. 6.*)

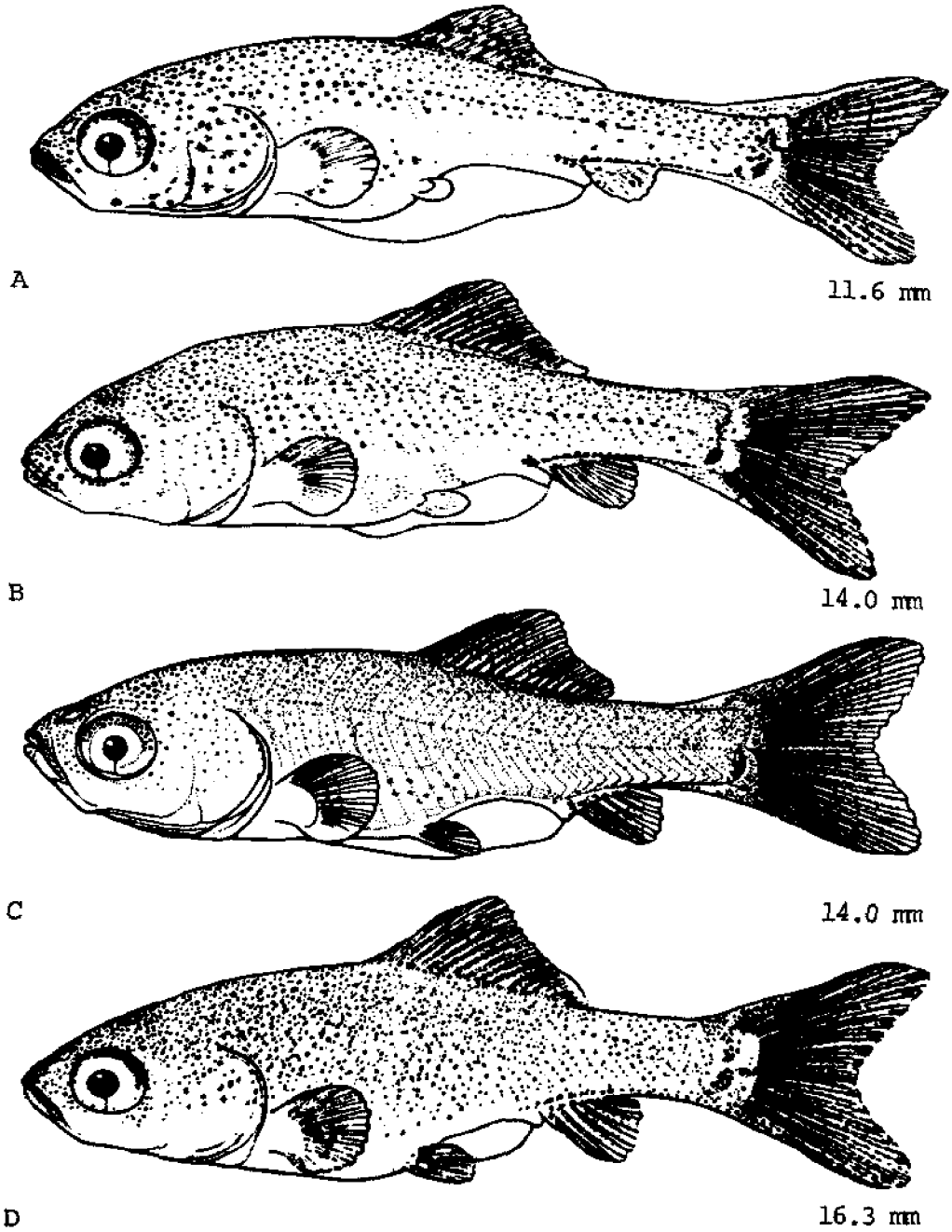

Fig. 123. *Carassius auratus*, Goldfish. A. Larva, 11.6 mm, *C. a. cuvieri*. B. Larva, 14.0 mm, *C. a. cuvieri*. C. Juvenile, 14.0 mm, *C. a. langsdorfii*. D. Juvenile, 16.3 mm, *C. a. cuvieri*. (*A-D, Nakamura, M., 1969: pls. 79, 81.*)

mm; finfold discontinuous from dorsal to caudal at 10.0 mm, discontinuous from anal to caudal at 12 mm;[27] preanal finfold reduced at 11.6 mm. Dorsal rays differentiated and spinous ray developing at 7.5 mm; caudal rays branching at 11.6 mm;[1] pelvics first evident as minute lateral buds at 9 mm, with incipient rays at 10.0[27]–11.6 mm.[1]

Pigmentation: At 7.9 mm, melanophores of head region rounded, those of body stellate; a definite row of external *melanophores along horizontal myosepta*[1] *(this row not* developed in carp specimens, but, like carp, it lacks internal melanophores on horizontal myosepta (JJL)); *elongate melanophores in region of developing dorsal* and anal fins; yellow pigmentation heavy; body iridescent. At 9.4–11.6 mm, opacity increased; ground color greenish yellow to fawn.[1]

JUVENILES

Specimens 12 mm TL,[19] and larger.

At 15.7 mm, body shape and form essentially as in adult.[1] Nostril single at 15 mm,[6] double at 21 mm. At 12 mm scales formed along lateral line with several rows of scales above and below lateral line on anterior 2/3 of body,[19] scalation complete at 15.7 mm in some populations,[1] apparently incomplete at 30 mm in others.[6] At *12 mm preanal finfold retained and extending beyond* pelvics;[19] caudal rays segmented.[27] At ca. 20 mm, dorsal soft rays segmenting and branching, spinous ray serrated. *Serrations increase with age; 8 at ca. 35 mm, 12 at ca. 50,* 12 with "four distal caps not yet fused to rest of spine" at 170 mm. Anal rays segmented at 14 mm, branched at 20 mm; 1st spinous ray serrated at 20 mm with serrations

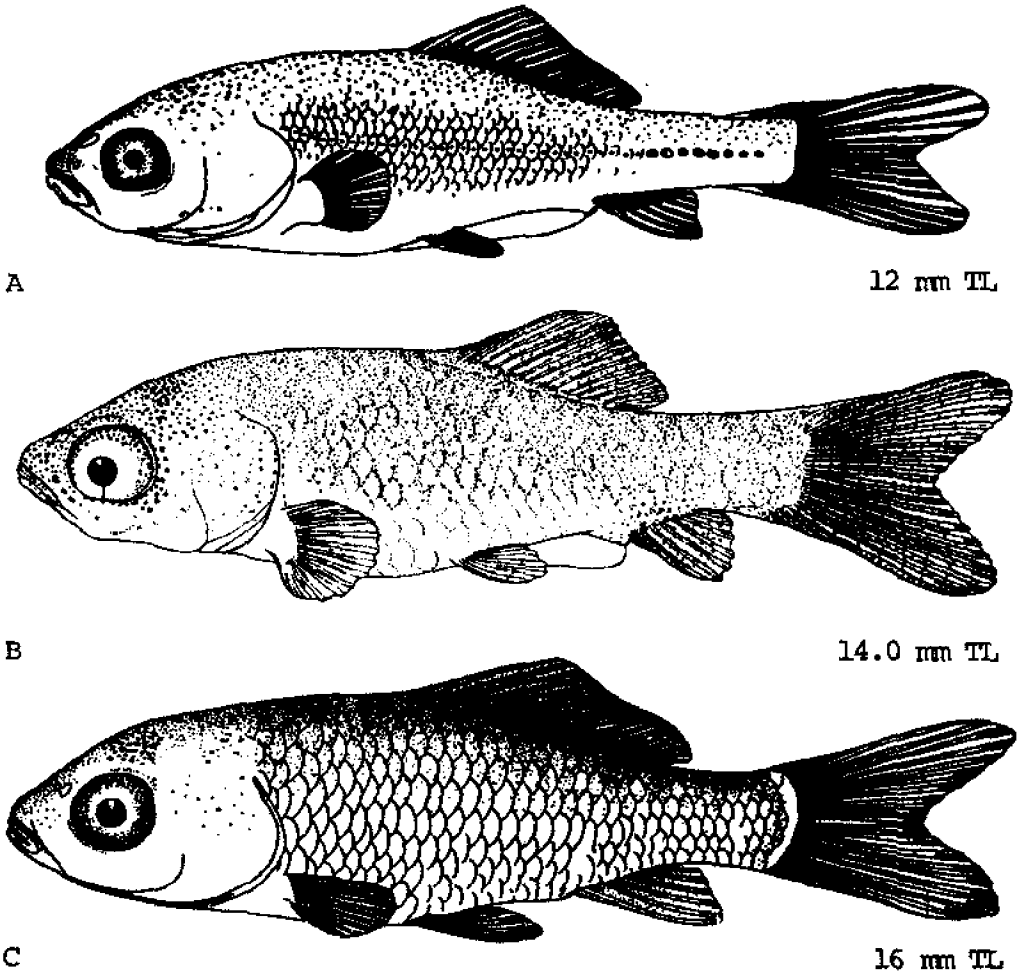

Fig. 124. *Carassius auratus*, Goldfish. A. Juvenile, 12 mm TL. B. Juvenile, 14.0 mm. C. Juvenile, 16 mm TL. (*A, C, Dmitrieva, E. N., 1957: fig. 6. B, Nakamura, M., 1969: pl. 77.*)

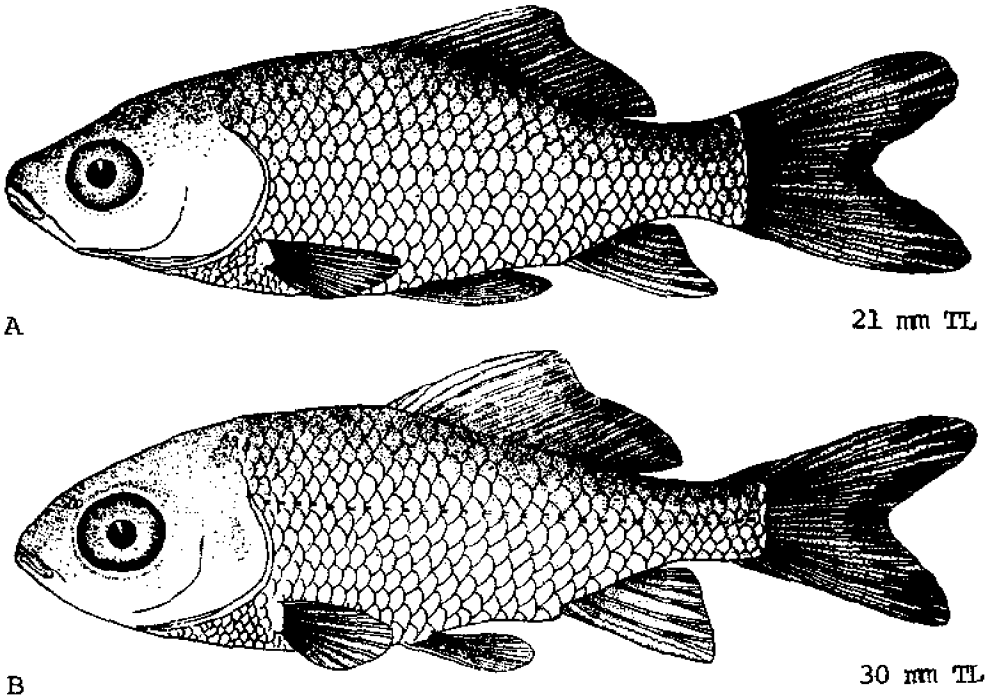

Fig. 125. *Carassius auratus*, Goldfish. A. Juvenile, 21 mm TL. B. Juvenile, 30 mm TL. (*A, B, Dmitrieva, E. N.*, 1957: fig. 6.)

increasing with age. Caudal rays branched at 17 mm. Pelvic rays segmented at 17 mm, branched at 23 mm. Preanal finfold lost at ca. 15 mm.[27]

Pigmentation: At 12 mm scattered chromatophores over upper sides, back, and head.[19] Juvenile pigmentation variable, olive gray[15] to gray-green,[13] becoming adult-like by loss of melanophores and increase in erythrophores and xanthophores.[15] Time required for color change varies with individual[2,21] and never occurs in some specimens.[15] Juvenile pattern may be retained 3[2] to 12 months[13,21,28] or to a length of ca. 25 mm or more.[16]

AGE AND SIZE AT MATURITY

Usually 2[2,8,21]–4 years; also reported at 8 months. Domestic varieties 76 mm long are reported to breed well.[29]

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Cyprinus carpio Linnaeus, Carp

ADULTS

D. I, 18–20; A. I, 5;[50] C. 4–8 + 16–18 + 6–8;[48] P. 14[50]–19;[48] scales in lateral line, 32–41,[13] scales above lateral line 5–7, below 5–7[48] (although scales lacking in some individuals[50]); gill rakers on first arch 21–29; pharyngeal teeth typically 1,1,3–3,1,1; vertebrae 32–39.[13]

Proportions as percent SL in natural population: HL 21–27; interorbital width 8–12; predorsal length 41–49; prepelvic length 41–48; preanal length 70–77; body depth 23–32; pectoral origin to pelvic base 20–26; pelvic base to anal base 26–33; dorsal fin base 36–45; anal fin base 7–11; longest pectoral ray 15–22; longest pelvic ray 14–20; longest dorsal ray 13–20; longest anal ray 14–18. Proportions as percent HL: Length of orbit 12–17; length of shortest barbel 3–12; length of longest barbel 8–22[48] (but in other studies eye 17.7–23.3 percent HL). Proportions as percent TL: Depth 25.8–32.8; HL 23.3–27.2.

Body robust, compressed;[50] a distinct crest behind head. Mouth inferior,[13] toothless;[50] upper jaw with 2 fleshy barbels on each side.[13] Lateral line complete. Dorsal spine distinctly toothed, anal spines with serrations on trailing edge.[50] Spawning males with pearl organs developed on head and pectoral fins; pearl organs lacking in females.[47]

Pigmentation: Typically slaty, golden olive, or olive-green above; lower sides golden yellow; venter yellowish or yellowish white; scales on sides and back with black basal spot; lower half of caudal and anal fin often with reddish hue. Ripe males darker than ripe females. Males dark green to slate gray on dorsal surfaces, dark brown ventrally; females green to gray dorsally, light yellow ventrally.[4,32,47,50]

Maximum length: Ca. 1219 mm.[32] Maximum recorded weight 40.8 kg.[17,19]

DISTRIBUTION AND ECOLOGY

Range: Originally temperate parts of Asia and Europe; now widely introduced in North America and elsewhere.[20,50]

Area distribution: Tidal tributaries of Chesapeake Bay north to Havre de Grace, Maryland;[8,9,27] New Jersey.[11]

Habitat and movements: Adults—a schooling species found in moderately warm, generally shallow waters of rivers, lakes, and reservoirs, usually in association with aquatic vegetation;[4,32] also rocky shoal areas, protected bays over sand, clay, or mud bottoms[24] and, rarely, swift flowing water during spawning runs;[21] capable of surviving in highly polluted water.[53] Reported in salinity of 17.6 ppt in Chesapeake Bay[1] and from "salt water" in Russia and Europe.[10,13,29] Maximum depth ca. 30.5 m.[24,25]

Migrate into lake shallows, stream tributaries, marshes, and drowned flood plains prior to spawning when temperatures reach ca. 10 C.[24,27] In the Danube, however, some individuals are semimigratory (and are, oddly, deep-bodied fish) while others are nonmigratory (and have elongate bodies).[38] Occasional adults may make excursions of up to 1084 km.[21] In Lake St. Lawrence, Ontario, spend late summer and early autumn in marginal marsh areas at depths of 1.5–1.8 m, moving into more shallow water on warm days to feed; as temperatures fall, move into deeper water of lakes and remain throughout winter.[47]

Larvae—initially at bottom, but at less than 5.0 mm attach to aquatic vegetation and other parts of the substrate;[36,44] yolk-sac larvae frequently in water ca. 25–100 mm deep.[24] Larvae at bottom among aquatic vegetation;[36] apparently some "congregation and schooling behavior" is evident at ca. 9.5 mm, but is not "very significant."[46]

Juveniles—at ca. 25 mm, begin to move into slightly deeper water.[14,21] Young less than 1 year old, nonschooling and found in vegetation in shallow water over sand, clay, or silt bottoms.[24]

SPAWNING

Location: Near surface in shallow, weedy areas of lakes, ponds, tributary streams, creeks, swamps, marshes, and temporary flood plains at depths of 7.6 cm to 1.8 m; typically over muck bottoms, and in areas with dense vegetation.[16,17,38,58,46,47]

Season: May (JDH) and June in Maryland;[5] late March to August or possibly September in North America.[6,17,47,53,56] In Russia late May[37] and possibly continuing until September or October;[13] in the Danube early April[38] to July or later;[39] in Israel, March to end of August.[54] Spawning is intermittent, lasting several days to several weeks,[7,38] and two spawning peaks may occur in a single season in some areas.[26]

Time: Throughout the day and apparently to a lesser extent at night,[16,21,38,47] peak activity at or shortly after dawn[42,46] or near midday.[47]

Temperature: Reported range 9[38]–32 C, although typically begins at temperatures of ca. 14–18 C and ceases above ca. 28 C;[37,38,47] in New York ceases if temperature falls below ca. 14 C.[27] Optimum in nature variously reported as 18–20 C,[47] 18–22 C,[13] and 19–23 C, but under laboratory conditions greatest activity apparently at 24–

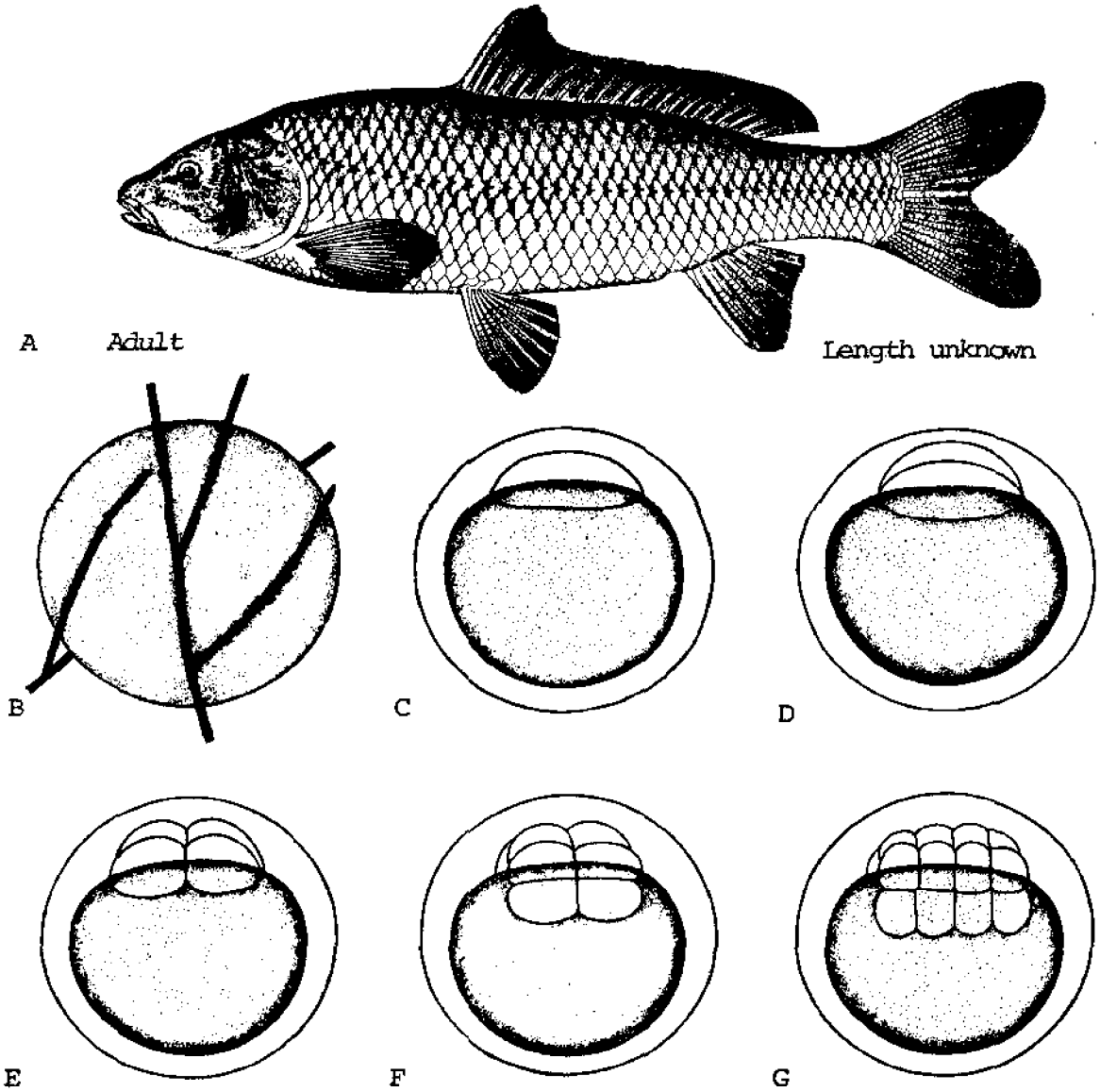

Fig. 126. *Cyprinus carpio*, Carp. A. Adult, length unknown. B. Recently fertilized egg showing method of attachment. C-G. Development of egg. C. Early blastodisc, one-half to one hour. D. 2-cell stage. E. 4-cell stage. F. 8-cell stage, 5 1/3 hours. G. 16-cell stage. (*A, Smith, H. M., 1896: pl. 75. B-G, Hikita, T., 1956: pl. 4.*)

25 C.[47] Specimens transferred from 15–18 C water to 19–20 C water spawned after 10–12 hours of acclimation; others held at 18–20 C spawned after transfer to 28–29 C.[46]

Salinity: Usually in freshwater, but also reported in water exceeding 10 ppt.[13]

Fecundity: Minimum reported 3950;[48] otherwise range 36,000–2,208,000;[47] average for 1 kg fish 150,000,[37] means otherwise stated as 478,753 and 599,000;[38] number of eggs discharged at primary spawning 50,000–620,000;[22] eggs in single spawning act 1500–1600.[46]

EGGS

Location: Deposited in clusters of 500[21]–700[18] in an area about 1.8 m in diameter;[19] typically attached to vegetation (both aquatic and, in flooded areas, terrestrial), roots, twigs, and stones.[38,47,50]

Ovarian eggs: Three batches of eggs develop in ovaries simultaneously; mature ovarian eggs yellowish green,[46] chorion apparently double-layered,[46] diameter ca. 0.8–1.7;[38] ovulated eggs 0.66–1.90 mm, averages varying from 1.04–1.54 mm.[40]

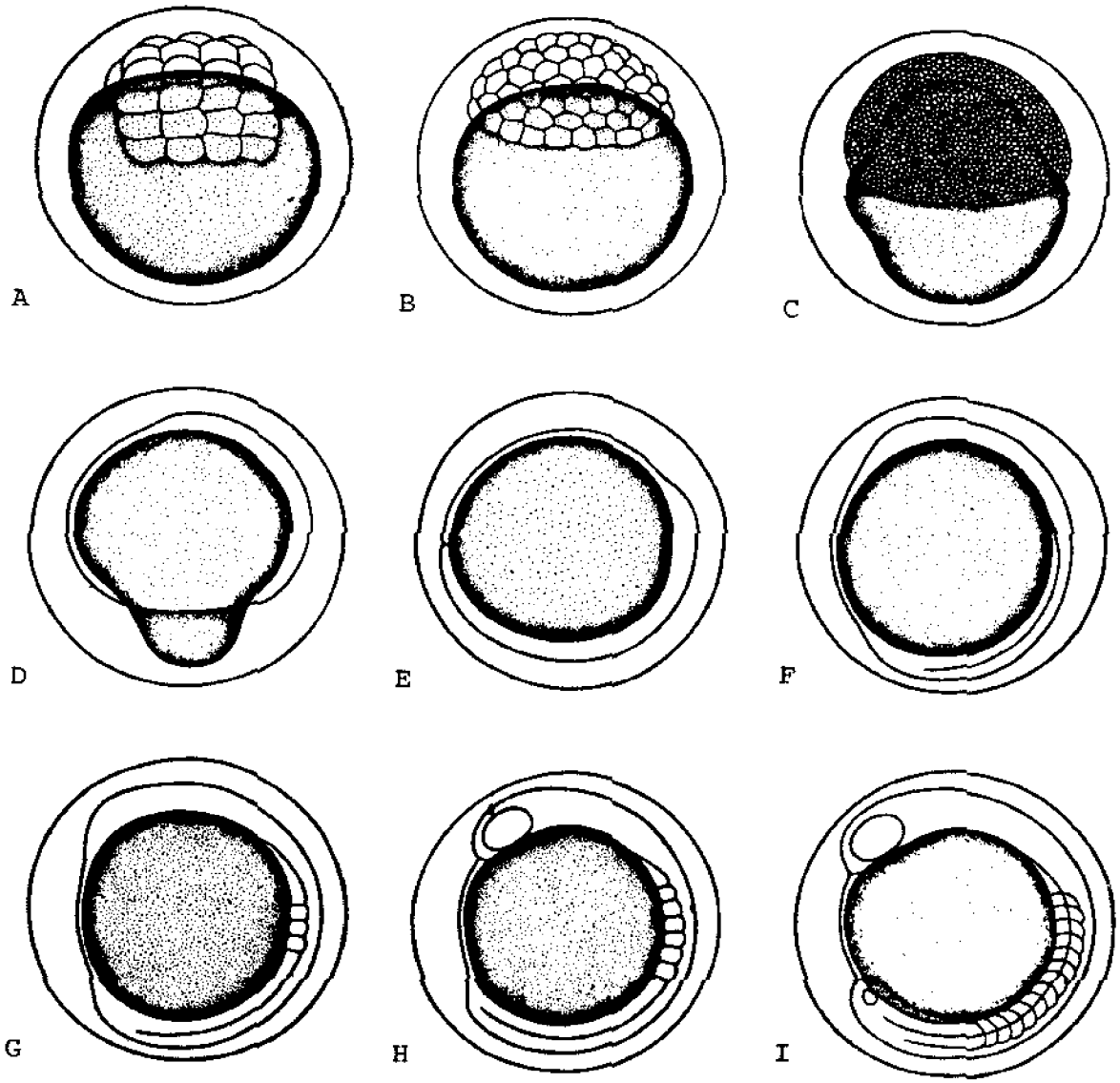

Fig. 127. *Cyprinus carpio*, Carp. Development of egg (continued). A. 32-cell stage. B. Early morula, 10 1/2 hours. C. Blastoderm descending over yolk. D. Blastoderm well below equator of egg, 38 hours. E. Closure of blastopore. F. Body evident. G. 3-somite stage, 65 hours. H. 6-somite stage. I. Tail-free stage, 13 somites, eyes formed, Kupffer's vesicle evident, 80 1/2 hours. (*A-I, Hikita, T., 1956: pl. 5.*)

Unfertilized eggs: Opaque, yellow, spherical; diameter 1.0–1.7 *mm*; chorion smooth, tough.[42]

Fertilized eggs: Diameter 1.0[32]–2.04 mm;[46] average diameters variously reported from 1.26[35]–1.73 mm; egg diameter increasing with increasing length of fish;[43] spherical;[24,46] extremely adhesive when first deposited,[31] but with adhesiveness decreasing as development proceeds;[24,55] variously described as colorless,[2] grayish white,[10,24] yellowish, and extremely translucent[29,31] to slightly transparent;[46] perivitelline space ca. 1/5 egg radius;[2] yolk diameter 1.51–1.73 mm;[43] yolk described as lacking oil globules[46] or with numerous small oil globules.[33]

EGG DEVELOPMENT

Development at 12–25 C:[2,3]

30–60 minutes Blastodisc formed.

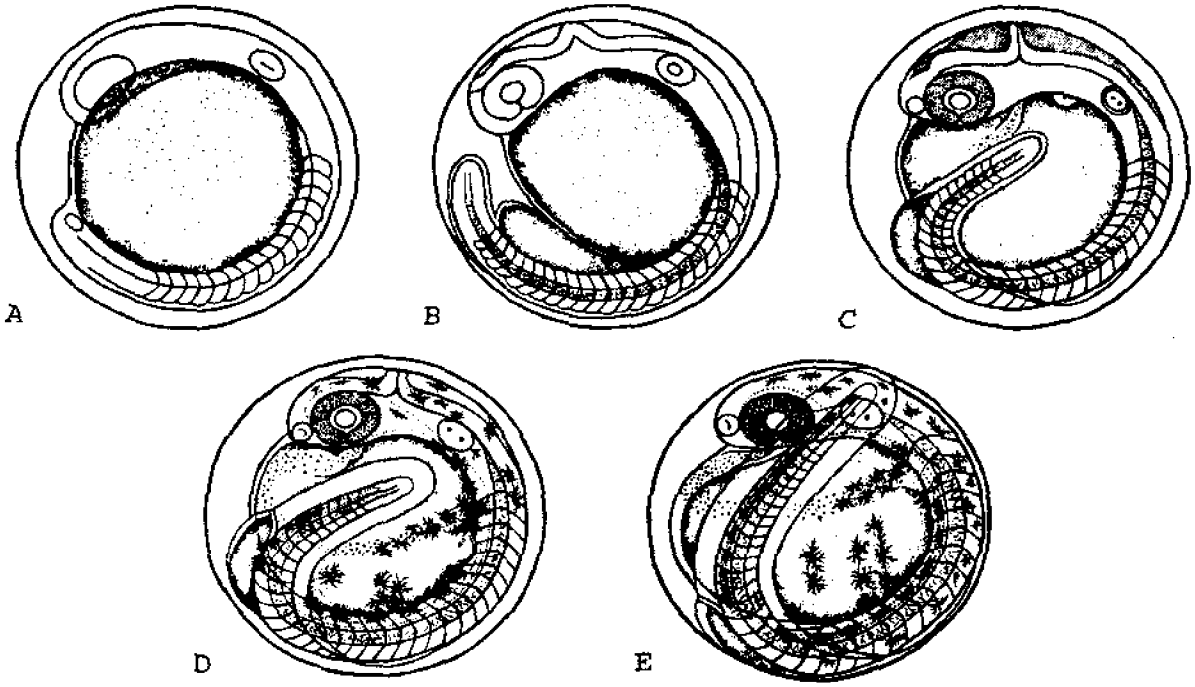

Fig. 128. *Cyprinus carpio*, Carp. Development of egg (continued). A. 16-somite stage, otocyst evident. B. 23-somite stage, choroid fissure developed. C. Advanced embryo, 4 days, pigment forming in eye, otoliths formed. D. Embryo, 5 days, pigment on body and yolk, circulation established. E. Pre-hatching stage, linear pigment pattern on body. (A-E, *Hikita, T., 1956: pl. 6.*)

4 hours, 15 minutes	2-cell stage.
4 hours, 30 minutes	4-cell stage.
5 hours, 20 minutes	8-cell stage.
6 hours, 15 minutes	16-cell stage.
10 hours, 15 minutes	32-cell stage.
10 hours, 35 minutes	64-cell stage.
34 hours	Morula.
38 hours	Gastrula.
63 hours	Embryo formed.
65 hours	3 somites formed.
80 hours, 30 minutes	7–13 somites, optic vesicles, Kupffer's vesicle formed.
95 hours	Kupffer's vesicle no longer visible; 25 somites; auditory vesicles and neural cord formed; embryonic movements noticeable.
101 hours, 10 minutes	Tail free; lens, notochord, and otoliths formed; melanophores on optic cup.
123 hours, 30 minutes	30 somites; circulation established; melanophores on yolk and body.[45]

Development at 13–17 C: [46]

Ca. 10 minutes	Blastodisc formed.
Ca. 30–45 minutes	Blastodisc cap-like.
4 hours	2-cell stage.
Ca. 5 hours, 30 minutes	4-cell stage.
6 hours	8-cell stage.
8 hours	16-cell stage.
Ca. 10 hours	32-cell stage.
15 hours	64-cell stage.
Ca. 17 hours	Morula stage, marginal periblast thickened.
Ca. 20 hours	Blastula, blastocoel well-developed.
24 hours	Gastrula established; germ ring evident, blastoderm over 60–65% of yolk.
Ca. 30 hours	Blastopore closed, neural plate differentiated.
32 hours	Eye developing.
37 hours	Optic vesicles conspicuous, brain ventricles developed, 4–6 somites at mid-body.
38 hours	Kupffer's vesicle formed.

40 hours	Lens placodes formed, embryo around 3/4 yolk, 14 somites.
45 hours	Lens detached.
Ca. 48 hours	Kupffer's vesicle no longer evident, otoliths formed, tail nearly to head, heart pulsations established, pigment developing in eye.
Ca. 52 hours	Pharyngeal folds considerably broadened.
53–55 hours	Nephric tubules established.
Ca. 55 hours	Lateral line organ evident.
56 hours	Circulation established, pectoral buds evident, melanophores increased in eye, 25–30 somites.
57 hours	Five pharyngeal pouches formed, body movement established.
70 hours	Pigment developed on head and yolk, eye with dark black pigment and noticeable iridescence; eye movement established.
78 hours	Liver evident, attachment (secretory) cells developing on yolk and head.
90 hours	Hatching begins (occurring tail first).[46]

t temperature of 19–23 C: [42]

Immediately after fertilization	Egg more transparent, perivitelline space forming.
1 hour	Blastodisc formed.
1 hour, 15 minutes	2-cell stage.
1 hour, 45 minutes	4-cell stage.
2 hours, 30 minutes	8-cell stage.
2 hours, 45 minutes	16-cell stage.
4 hours, 30 minutes	Early morula.
6 hours	Late morula, periblast clearly evident.
8 hours	Blastula stage; blastocoel evident.
9 hours	Blastocoel well-developed.
10 hours	Early gastrula. Germ ring to equator of egg.
12 hours, 30 minutes	Germ ring over 3/4 yolk, embryo elongate, keel of central nerve cord well marked.
13 hours, 30 minutes	Fore-, mid-, and hindbrain developed.
17 hours	Blastopore closed, optic lobes developed.
21 hours	Embryo elevated and well demarcated from yolk, embryo around 3/4 yolk, 5–10 somites formed.
Ca. 32 hours	Kupffer's vesicle, otic vesicles formed; embryo completely around yolk.
Ca. 38 hours	Lens formed, pericardium developed, tail free, movement established in tail.
46 hours	Olfactory lobes developed, heartbeat evident.
58 hours	Pigment developed on margin of eye, otoliths formed. Pectoral buds evident, yolk circulation complete, red blood cells evident, melanophores on dorsal side of body.
78 hours	Hatching. Tremors evident in trunk and tail region, just before hatching.[42]

Comments on development: At a rearing temperature of ca. 21.6 C, "eyed" embryos were noted in 24 hours.[28] Sato noted that, at ca. 24 hours after fertilization, primordia of supraorbital organs and main lateral canal organs are developed; at 41 hours, two additional placodes develop, one behind the optic vesicle and the other in front of the auditory vesicle; at 63 hours supraorbital and main canal placodes begin to divide into distinct cell masses.[39] Swee and McCrimmon found that, under field conditions, water-hardening was complete in 15–25 minutes.[47] Hatching is not synchronous and may take from "a few hours" [42] up to 3.5 days for completion.[46]

Incubation period, 3–16 days at unspecified temperatures.[9,14,29,51,53]

Incubation at various temperatures:

At 15 C	5 days [14]
At 20 C	3–5 days [2]

Incubation at various temperature ranges:

13–17 C	90 hours [46]
14–29 C	76 hours [47]
18–19 C	88 hours [46]
22–23 C	60 hours [46]
24–25 C	70 hours [46]
25–32 C	50 hours [47]

Notes on incubation: Under natural conditions (at unspecified temperature), first hatch at 50–76 hours, 50% hatch at 55–144 hours. A decrease to 11 C or below is lethal to eggs deposited at 17 C or above.[47]

YOLK-SAC LARVAE

Hatching length 3.0–6.69 mm; average length at hatching 4.38–5.70 mm; [24,43,44] length at end of stage 7.0 [18]–9.5 mm; [46] duration of stage 4 [21]–10 days.[14]

Total myomeres 34–36,[46] preanal myomeres 24.[2,3]

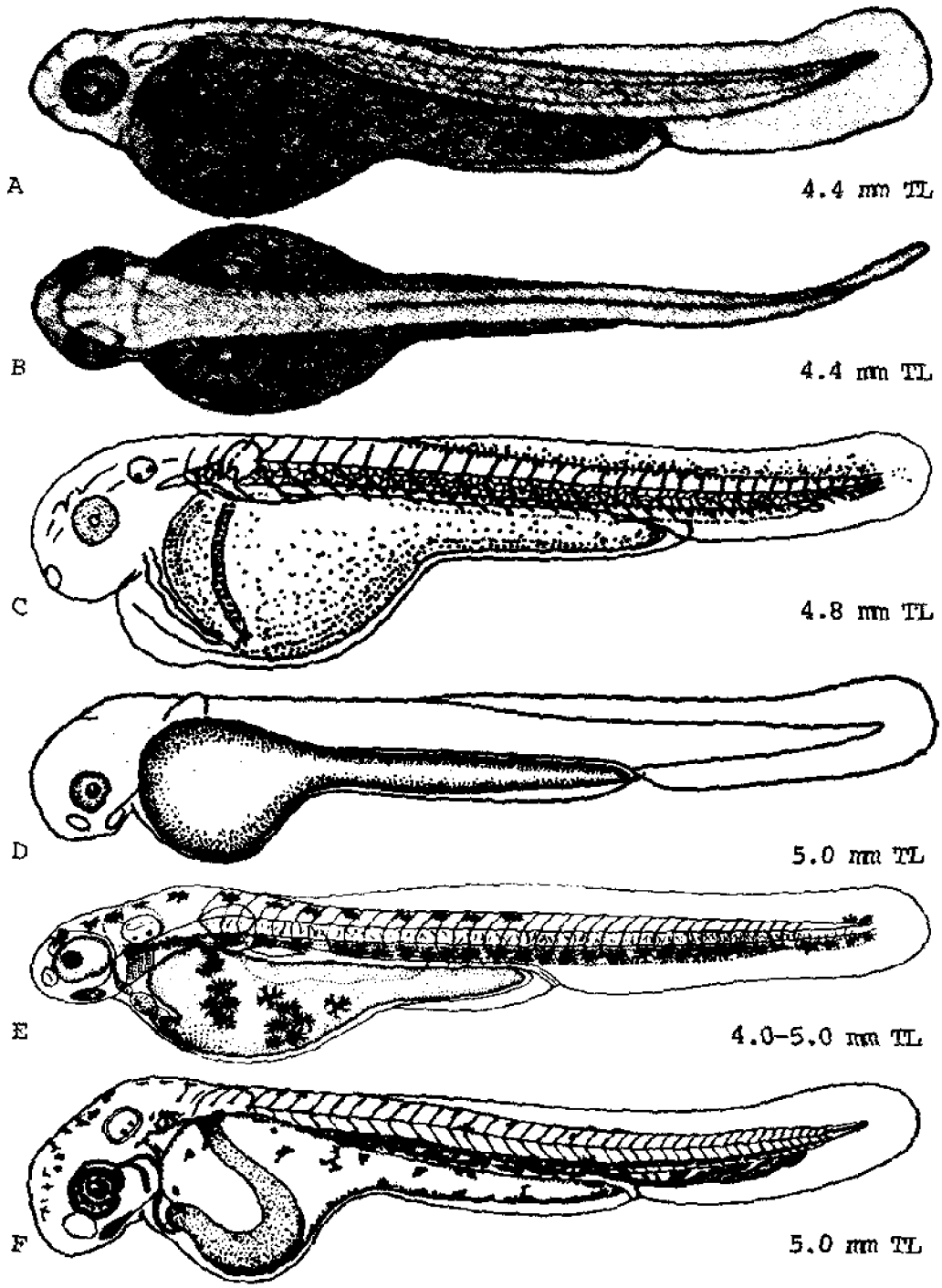

Fig. 129. Cyprinus carpio, Carp. A. Yolk-sac larva, 4.4 mm TL, pectoral buds evident. B. Dorsal view of A. C. Yolk-sac larva, 4.8 mm TL. D. Yolk-sac larva, 5.0 mm TL, emphasizing extremely narrow posterior yolk mass. E. Yolk-sac larva, 4.0–5.0 mm TL, pigment well-developed, yolk somewhat reduced. F. Yolk-sac larva, recently hatched, 5.0 mm TL. *(A-B, Taber, C. A., 1969: fig. 6. C, Hoda, S. M. S., and H. Tsukahara, 1971: fig. 6. D, Vasnetsov, V. V., et al., 1957: fig. 3. E, Hikita, T., 1956: pl. 7. F, Kostomarov, B., 1955: fig. 50B.)*

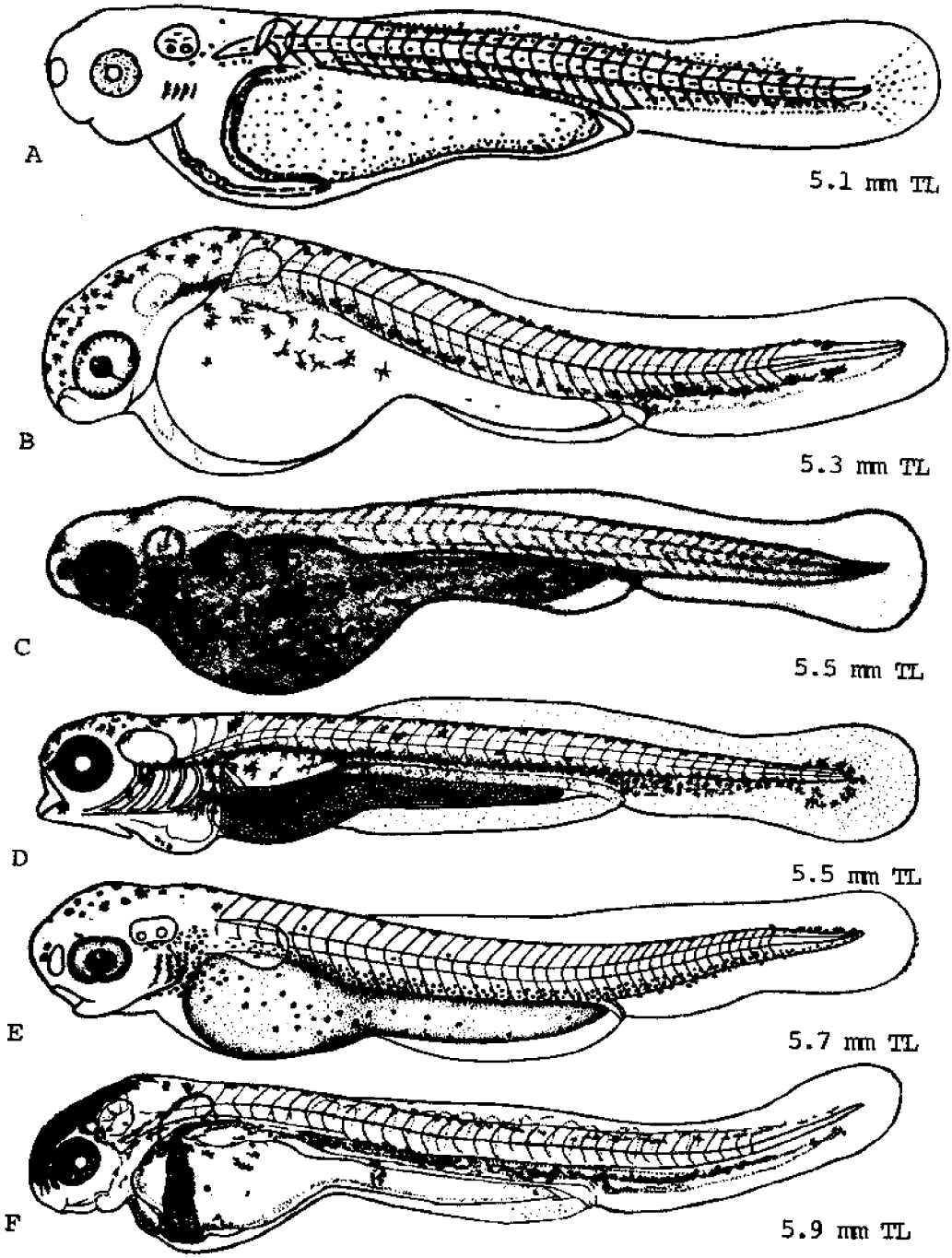

Fig. 130. *Cyprinus carpio*, Carp. A. Yolk-sac larva, 5.1 mm TL. B. Yolk-sac larva, 5.3 mm TL. C. Yolk-sac larva, 5.5 mm TL. D. Yolk-sac larva, 5.5 mm TL, yolk reduced, mouth open. E. Yolk-sac larva, 5.7 mm TL. F. Yolk-sac larva, 5.9 mm TL. *(A, Hoda, S. M. S., and H. Tsukahara, 1971: fig. 6B. B, Nakamura, M., 1969: pl. 82. C, Taber, C. A., 1969: fig. 6. D, Smallwood, W. M., and M. L. Smallwood, 1931, fig. 1. E, Bragensky, R. Y., 1960: fig. 1. F, Balon, E. K., 1958: fig. 2.)*

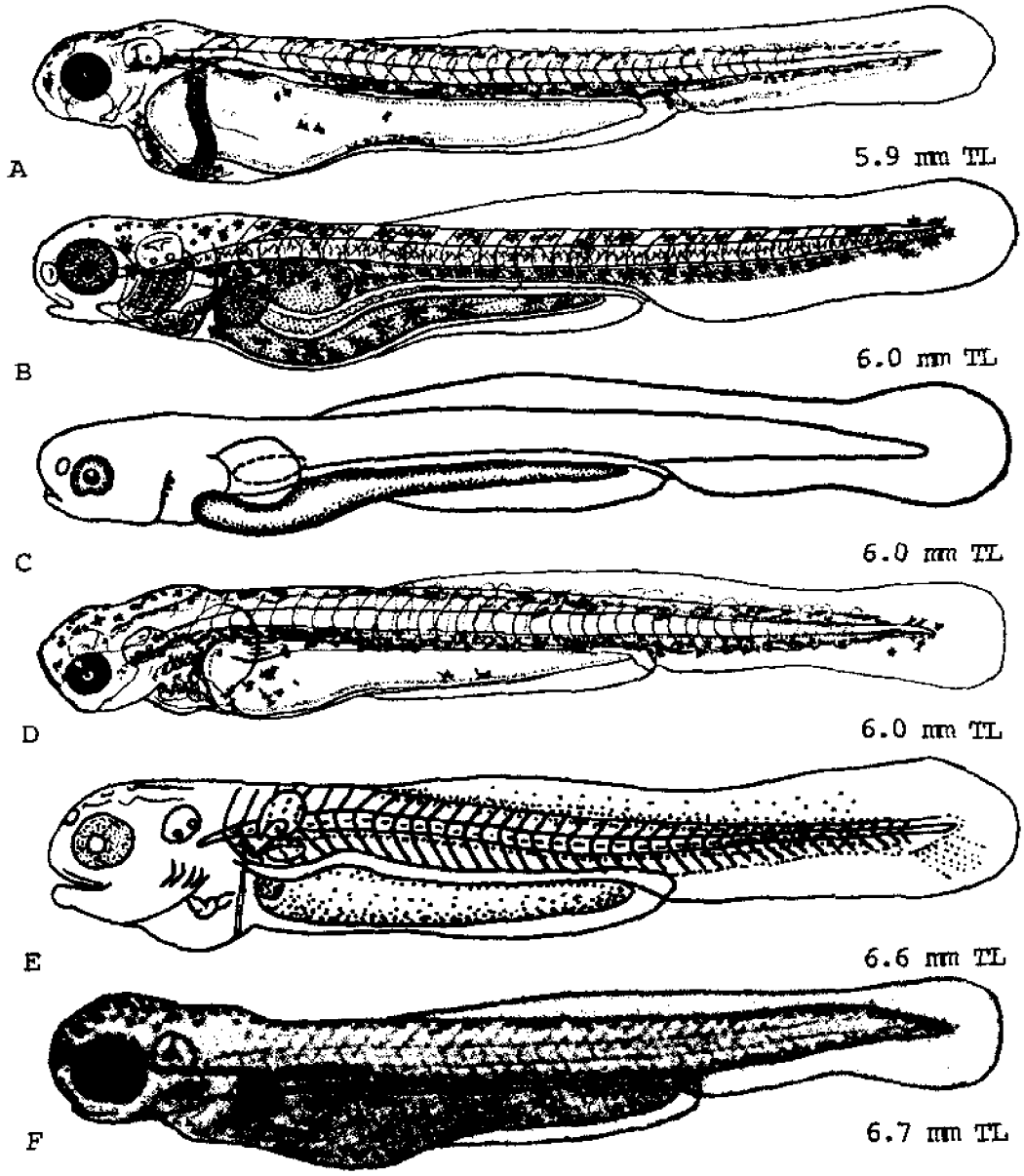

Fig. 131. *Cyprinus carpio*, Carp. A. Yolk-sac larva, 5.9 mm TL. B. Yolk-sac larva, 6.0 mm gas bladder evident. C. Yolk-sac larva, 6.0 mm TL, pectoral fin expanded. D. Yolk-sac larva, 6.0 mm TL. E. Yolk-sac larva, 6.6 mm TL, incipient caudal rays evident. F. Yolk-sac larva, 6.7 mm TL. (*A, D, Balon, E. K., 1958: fig. 3. B, Hikita, T., 1956: pl. 8. C, Vasnetsov, V. V.,* et al., *1957: fig. 3. E, Hoda, S. M. S., and H. Tsukahara, 1971: fig. 6. F, Taber, C. A., 1969: fig. 6.*)

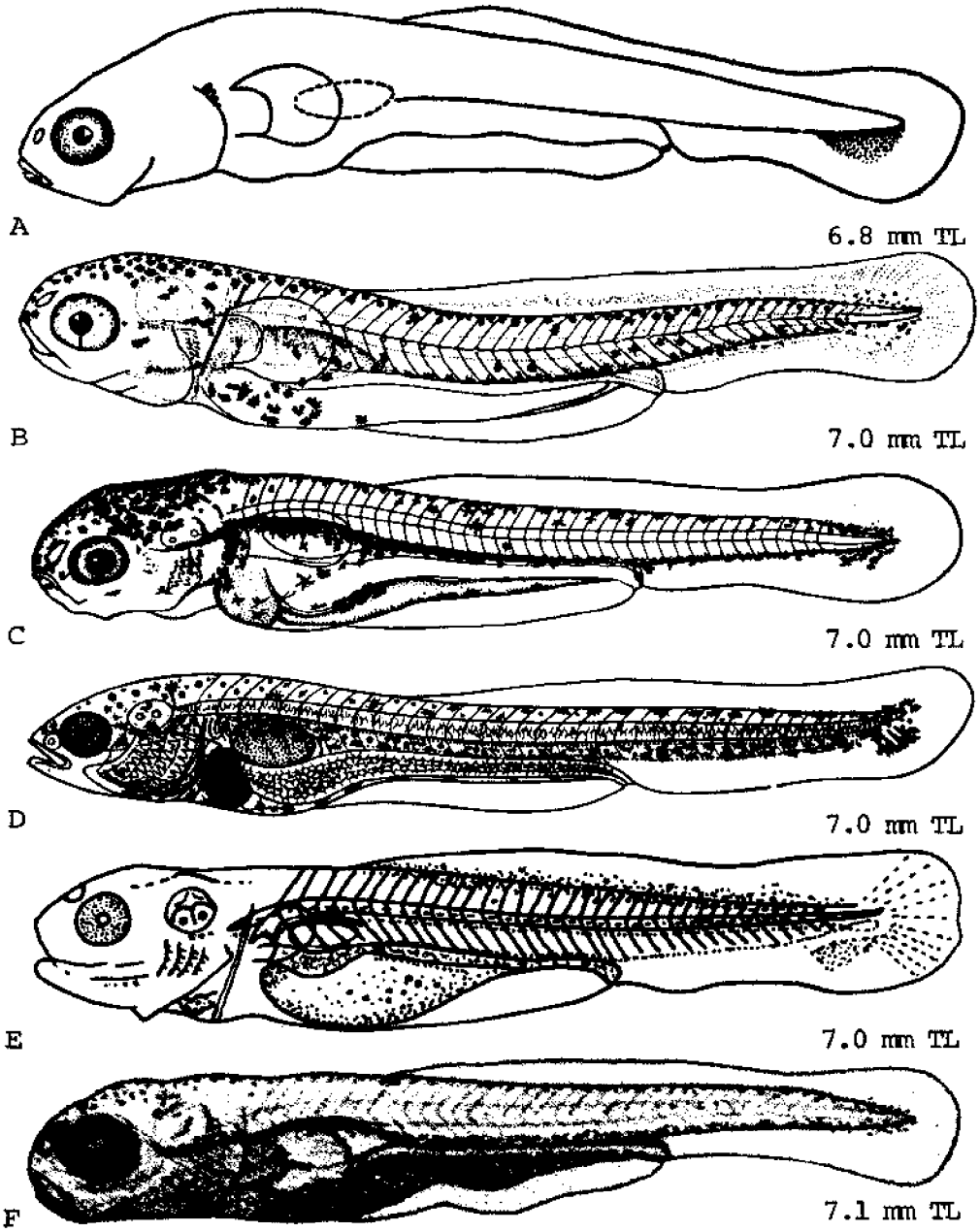

Fig. 132. *Cyprinus carpio*, Carp. A. Yolk-sac larva, 6.8 mm TL, gas bladder distinct. B. Yolk-sac larva, 7.0 mm TL, choroid fissure still evident. C. Larva, 7.0 mm TL. D. Yolk-sac larva, 7.0 mm TL. E. Larva, 7.0 mm TL. F. Larva, 7.1 mm TL, nostril divided. (*A, Vasnetsov, V. V.*, et al., *1957: fig. 3. B, Nakamura, M., 1969: pl. 82. C, Bragensky, R. Y., 1960: fig. 2. D, Hikata, T., 1956: pl. 9. E, Hoda, S. M. S., and H. Tsukahara, 1971: fig. 6. F, Taber, C. A., 1969: fig. 6.*)

Yolk mass elongate, initially round or oval anteriorly, cylindrical behind,[2,3,46] nearly half absorbed at 1 day;[42] yolk apparently granular;[46] head slightly deflected[2,3] or straight[18] at hatching, characteristically straight at 1 day;[42] mouth open[3,46] or closed at hatching, definitely opened at 2nd day (6.5 mm);[42] at 5.6–6.7 mm mouth shifted forward;[46] jaw evident at 5.7 mm,[18] movable at ca. 7.0 mm;[42] at hatching nasal opening single, rounded,[46] at 5.7 mm elongate;[18] pharyngeal teeth evident at 5.1–6.8 mm.[45] Origin of dorsal finfold near 3rd myomere at hatching; preanal finfold narrow.[30] Pectorals initially small, rounded,[46] incipient rays developed at 5.5 mm.[30] Gas bladder (but probably posterior part only, JDH) evident at hatching[2] or by end of first day[42] at length of 5.5–6.0 mm; filled at ca. 7.0 mm.[44] Liver developed at 4.0 mm, spleen at 5.0 mm.[42] Anus open on 2nd day just after opening of mouth.[42] First center of ossification on operculum at 6.2 mm; at 6.3–6.7 mm mandibular arches, basioccipital bones, branchial arches, and a few caudal rays ossified.[52] At 24 hours all placodes of lateral line organs with distinct cell masses; lateral line organs hair-like at 7.0–7.7 mm. Urostyle beginning to flex on some individuals at 7.5–7.7 mm.[46]

Pigmentation: At hatching transparent,[41] eye with some pigment[2] (fully black by at least one day[42]). Melanophores sometimes lacking;[46] when present, on head and anterior half of dorsum, along dorsal surface of alimentary canal, above and below urostyle, and over anterior half of all of yolk sac;[2] yellow tints sometimes along mid-dorsal ridge; blood yellow. At 5.1 mm pigment developing along lateral line;[46] at 5.3 mm pigment along both dorsal and ventral line;[45] and at 5.5 mm pigment developing on gas bladder.[53] At 6.0 mm anterodorsal surface of gas bladder silvery.[46] At 6.3 mm back of head and body light greenish yellow. At 6.5–6.8 mm, melanophores posteriorly on head and along mid-dorsal line.[2] At 7.0 mm density of pigment increased over head, on dorsal surface of gas bladder, and in region of urostyle. At 7.0–7.7 mm melanophores and yellow pigment well-developed on head and along mid-dorsal surface of body; also on pharyngo-esophagus and air bladder; blood red.[46]

LARVAE

Size range 7.0[41] or possibly smaller[43] to 19.0 mm.[45]

D. 6 at 10 mm,[6] ca. 16 at 11.5 mm; A. 4 at 11.5 mm; P. ca. 4 at 12.2 mm;[18] preanal myomeres 18–25; postanal myomeres 12–13.[2,6]

Body stout. Head relatively small; mouth moderate,[6] sucker-like at 9.0–10.0 mm;[8,28] fleshy and papillated at 11.0–16.0 mm. Mandibular barbels evident at 18.5–19.0 mm.[46] At ca. 8.5 mm otic capsule enlarged, closer to eye.[42] At 9.6–10.5 mm a distinct hump behind head. Dorsal fin outline becoming evident at 7.8–9.5 mm;[46] dorsal with incipient rays at 9.0[2] to ca. 15.0 mm[42] (5 rays over vertebrae 13–17 at 9.3 mm SL);[52] dorsal complete at 20–21 mm.[44] Anal with 4 rays under vertebrae 26–28 at 10.8 mm,[52] rays complete at 20.0–21.0 mm.[44] Caudal fin beginning to form at 7.7[18]–8.5 mm;[42] first rays evident at 8.2[18]–10.0 mm;[42] fin forked or forking at 9.6[46]–10.5 mm, and with segmented rays at 12.2 mm.[18] Pectorals variously described as round and without rays at 10.0 mm,[6] with incipient rays at ca. 15.0 mm,[42] and "complete" at 12.0–13.0 mm.[44] First appearance of pelvic buds described by various authors as from 9.5 to ca. 15.0 mm;[2,42,45,46] pelvics complete at 19[45]–21 mm.[44] Sequence of fin development typically caudal, dorsal, anal, pectoral and pelvics.[57] Scales first evident at 16[44]–18 mm;[46] first scales developed anteriorly just below lateral line. At 7 days lateral line organs as in adult.[39] First vertebral column ossification at centrum of 7th vertebra at 7.0 mm SL; hypurals beginning to ossify at 7.4 mm SL;[52] 7 hypurals formed at 9.6 mm. Weberian ossicles ossified at 9.0–9.5 mm.[46] Urostyle distinctly oblique at 8.2 mm.[42] Anterior chamber of gas bladder developed at 9.6[46]–12.0 mm, gas bladder completely filled at 15.0 mm.[44] Gall bladder and pancreas evident at 7.0 mm.[42]

Pigmentation: At ca. 8.0 mm often with a dark streak just below midline of body extending forward to opercular region where it branches to form a "Y".[49] Lacks internal melanophores on horizontal myoseptum,[58] a pigment characteristic of native cypriniform fishes from the study area (JJL). At 9.0 mm, density of pigment increased over gas bladder;[18] skin with a yellowish hue, and a dark spot developing at base of tail.[28] At 10.0 mm, stellate chromatophores on both jaws, top of head, fins, middorsal part of body, and, to a lesser extent, on sides to region of lateral line; subsurface chromatophores in double series along lateral line, ventrally to anus, on gills, and dorsal surface of intestine.[6] At 10.5 mm, pigment increased laterally and longitudinal rows of chromatophores developed on caudal base;[2] at 11.5 mm, density of pigment increased over entire body. At 15.0 mm pigment concentrated in a definite blotch over head.[18]

JUVENILES

Minimum size described, 19.0 mm.[45]

At 30.75 mm, preanal myomeres 19, postanal myomeres 17.[6]

Body stout.[6] Nasal opening constricted at 22.5 mm, divided at 30.0 mm.[18] Development of barbels variable; in some individuals all barbels evident at ca. 22.0 mm,[46] in others a single set of barbels to lengths of at least 30.75 mm.[6] At ca. 50.0 mm gape halfway to eye, pharyngeal teeth developed.[42] In some individuals scales first evident at ca. 20.0 mm;[42] scales complete at 22.0[44]–30.0 mm.[18] Preanal finfold retained to maximum length of 19.0 mm.[45]

Pigmentation: At 30.75 mm, chromatophores over head

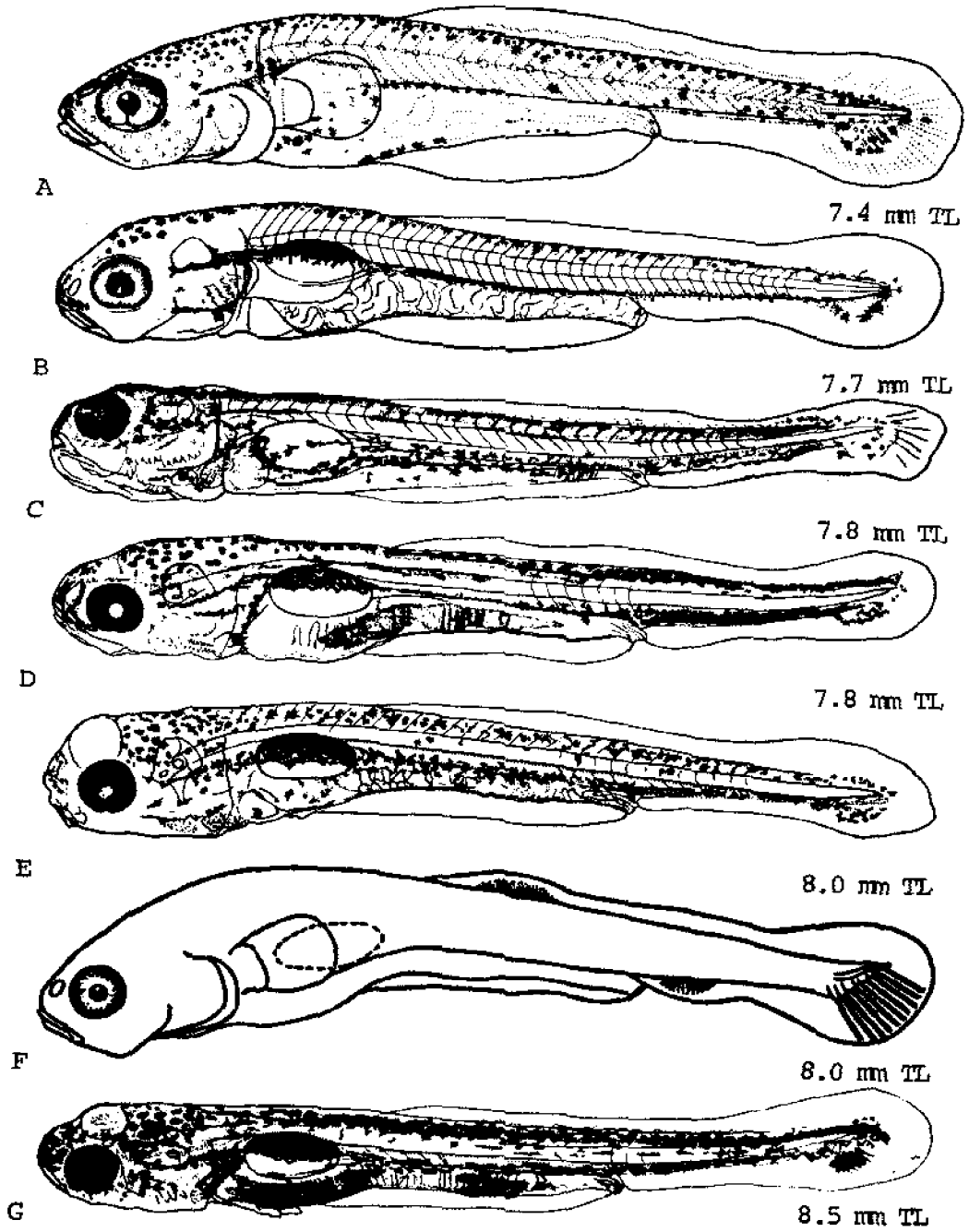

Fig. 133. *Cyprinus carpio*, Carp. A. Larva, 7.4 mm TL, choroid fissure distinct. B. Larva, 7.7 mm TL. C. Larva, 7.8 mm TL. D. Larva, 7.8 mm TL. E. Larva, 8.0 mm TL. F. Larva, 8.0 mm TL, urostyle flexed, ventral caudal fins well-developed. G. Larva, 8.5 mm TL. (*A, Nakamura, M., 1969: pl. 82. B, Bragensky, R. Y., 1960: fig. 3. C-E, C, Balon, E. K., 1958: figs. 4, 7, 9. F, Vasnetsov, V. V.,* et al., *1957: fig. 3.*)

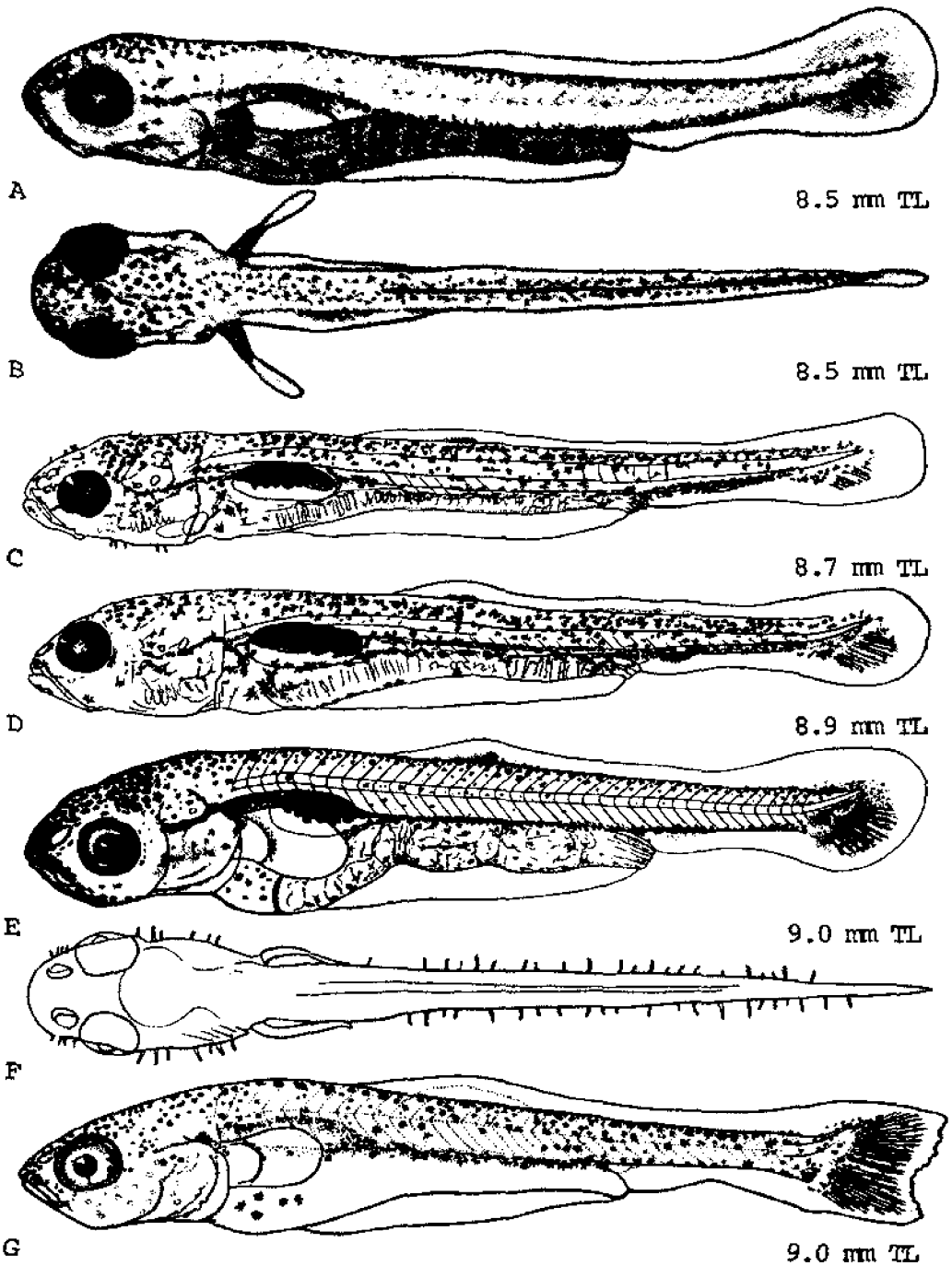

Fig. 134. *Cyprinus carpio*, Carp. A. Larva, 8.5 mm TL. B. Dorsal view of A. C. Larva, 8.7 mm, preanal finfold noticeably elongate, anlage of dorsal fin evident, neuromasts developing. D. Larva, 8.9 mm TL. E. Larva, 9.0 mm TL, anlage of anal fin evident. F. Larva, 9.0 mm TL, showing well-developed external neuromast. G. Larva, 9.0 mm TL, caudal rays well-developed. (*A, B, Taber, C. A., 1969: fig. 6. C-D, F, Balon, E. K., 1958: figs. 10-11. E, Bragensky, R. Y., 1960: fig. 4. G, Nakamura, M., 1969: pl. 82.*)

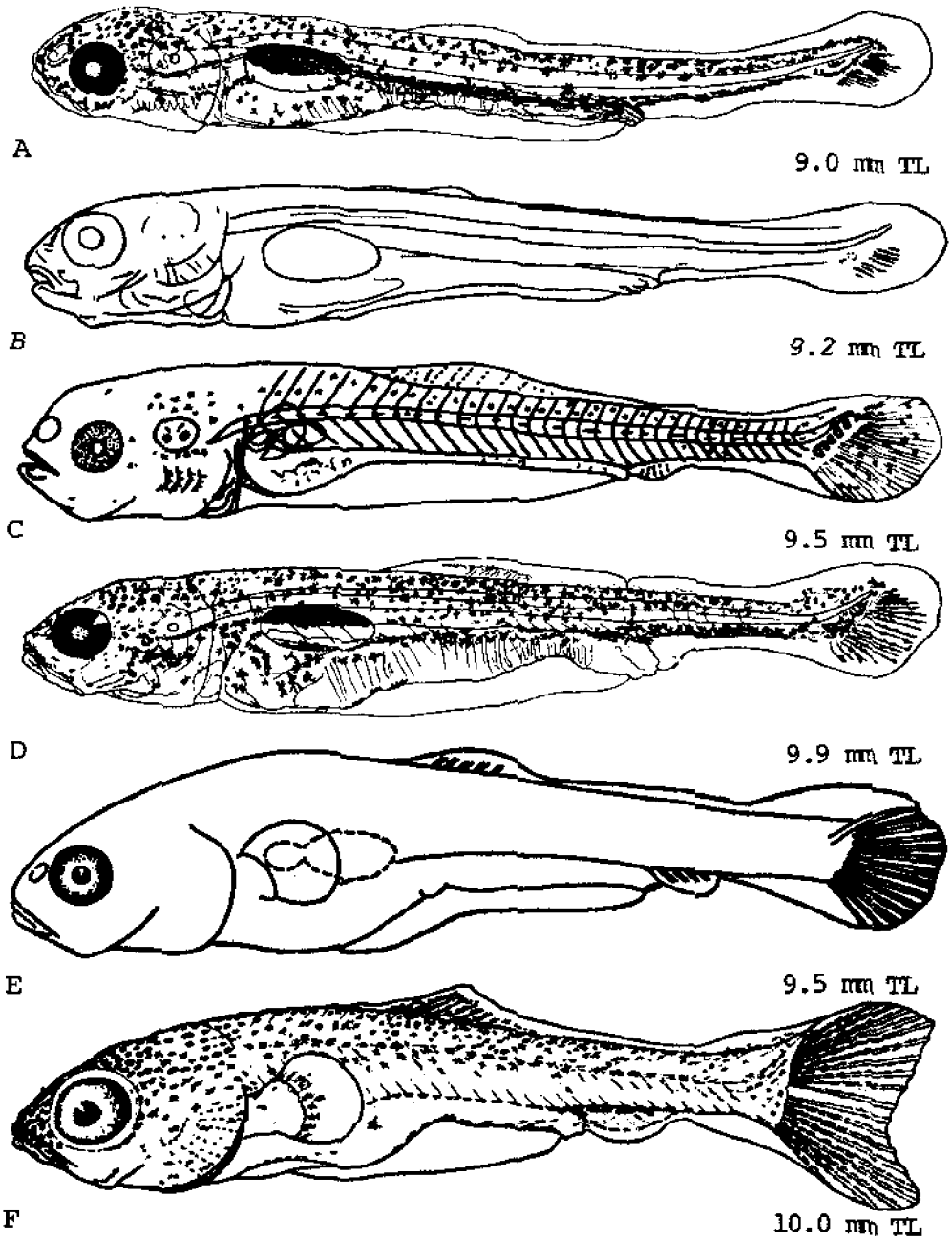

Fig. 135. *Cyprinus carpio*, Carp. A. Larva, 9.0 mm TL, dorsal finfold markedly reduced. B. Larva, 9.2 mm TL. C. Larva, 9.5 mm TL, pigment developed in caudal fin. D. Larva, 9.9 mm TL. E. Larva, 9.5 mm TL, gas bladder dividing, pelvic buds evident, incipient rays in dorsal and anal. F. Larva, 10.0 mm TL. (*A, B, D, Balon, E. K., 1958: figs. 10, 14, 35. C, Hoda, S. M. S., and H. Tsukahara, 1971: fig. 6. E,* Vasnetsov, V. V., et al., *1957: fig. 3. F, Fish, M. P., 1932: fig. 24.*)

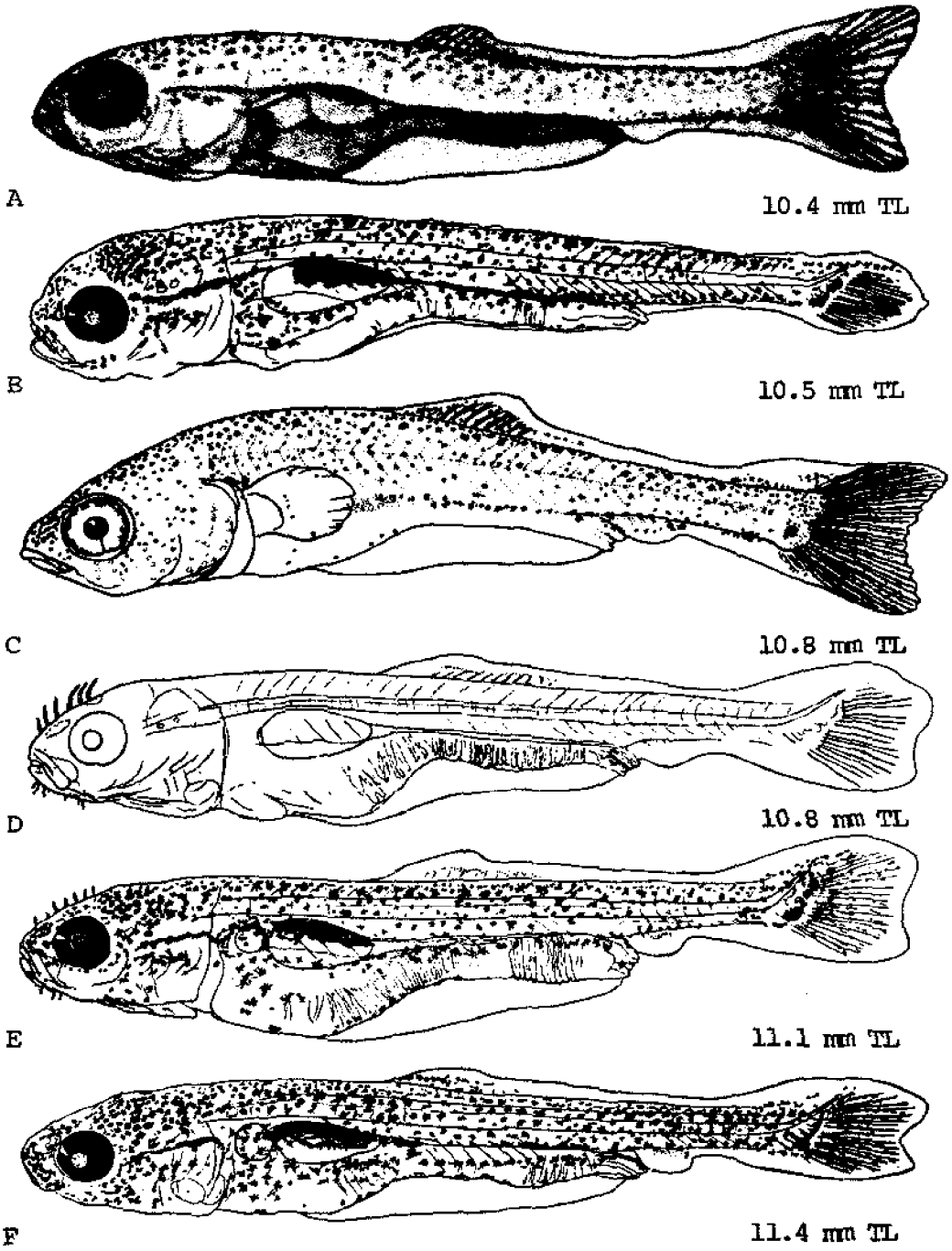

Fig. 136. *Cyprinus carpio*, Carp. A. Larva, 10.4 mm TL. B. Larva, 10.5 mm TL. C. Larva, 10.8 mm TL. D. Larva, 10.8 mm TL (but apparently less developed than previous specimen) showing extreme development of neuromasts on head. E. Larva, 11.1 mm TL. F. Larva, 11.4 mm TL. (*A, Taber, C. A., 1969: fig. 6. B, D-F, 1958: figs. 15, 17, 35. C, Nakamura, M., 1969: pl. 82.*)

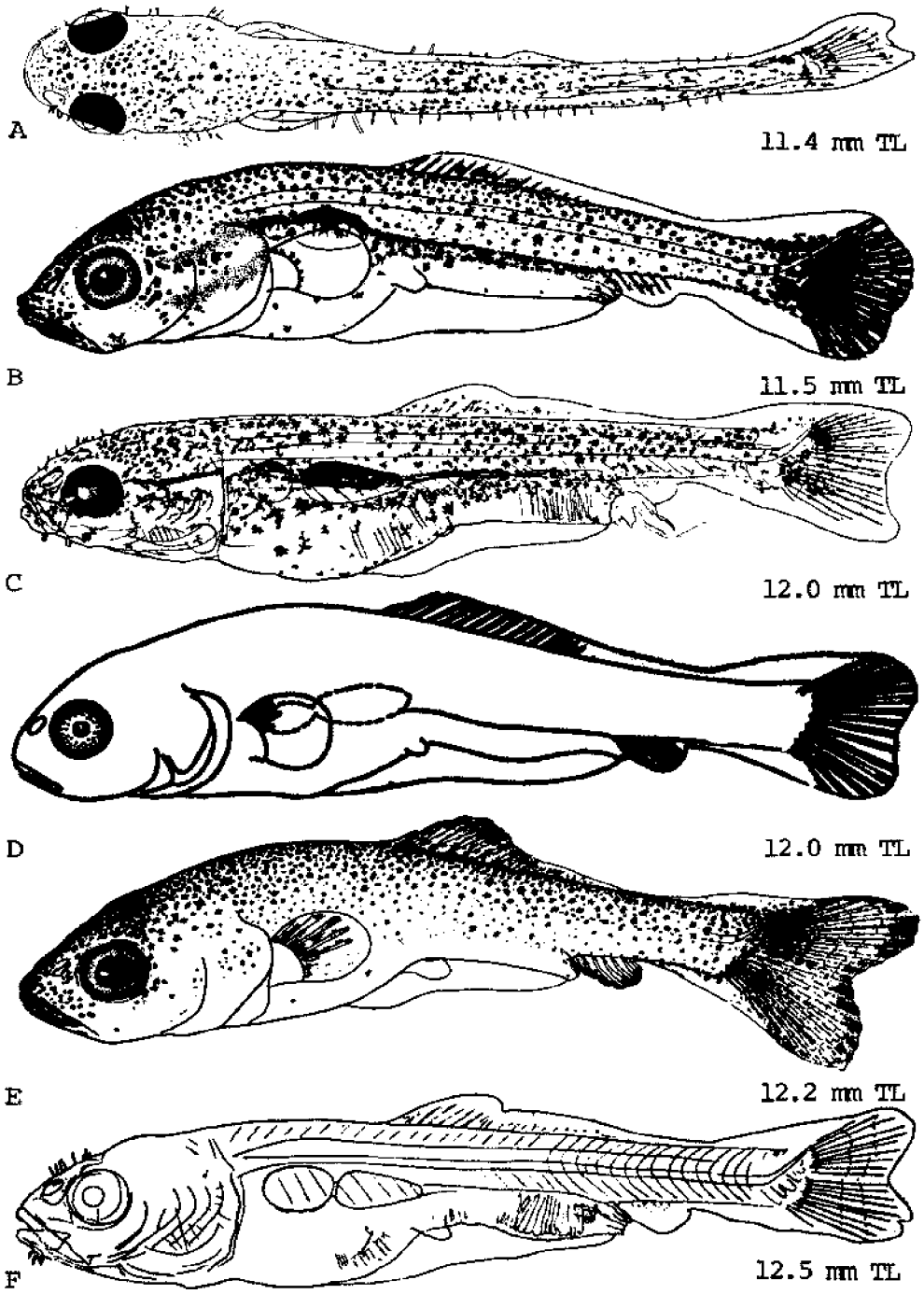

Fig. 137. *Cyprinus carpio*, Carp. A. Larva, 11.4 mm TL. B. Larva, 11.5 mm TL. C. Larva, 12.0 mm TL. D. Larva, 12.0 mm TL, pectoral rays first evident. E. Larva, 12.2 mm TL. F. Larva, 12.5 mm TL. (*A, C, F, Balon, E. K., 1958: figs. 15, 19. B, E, Bragensky, R. Y., 1960: fig. 5. D, Vasnetsov, V. V.,* et al., *1957: fig. 3.*)

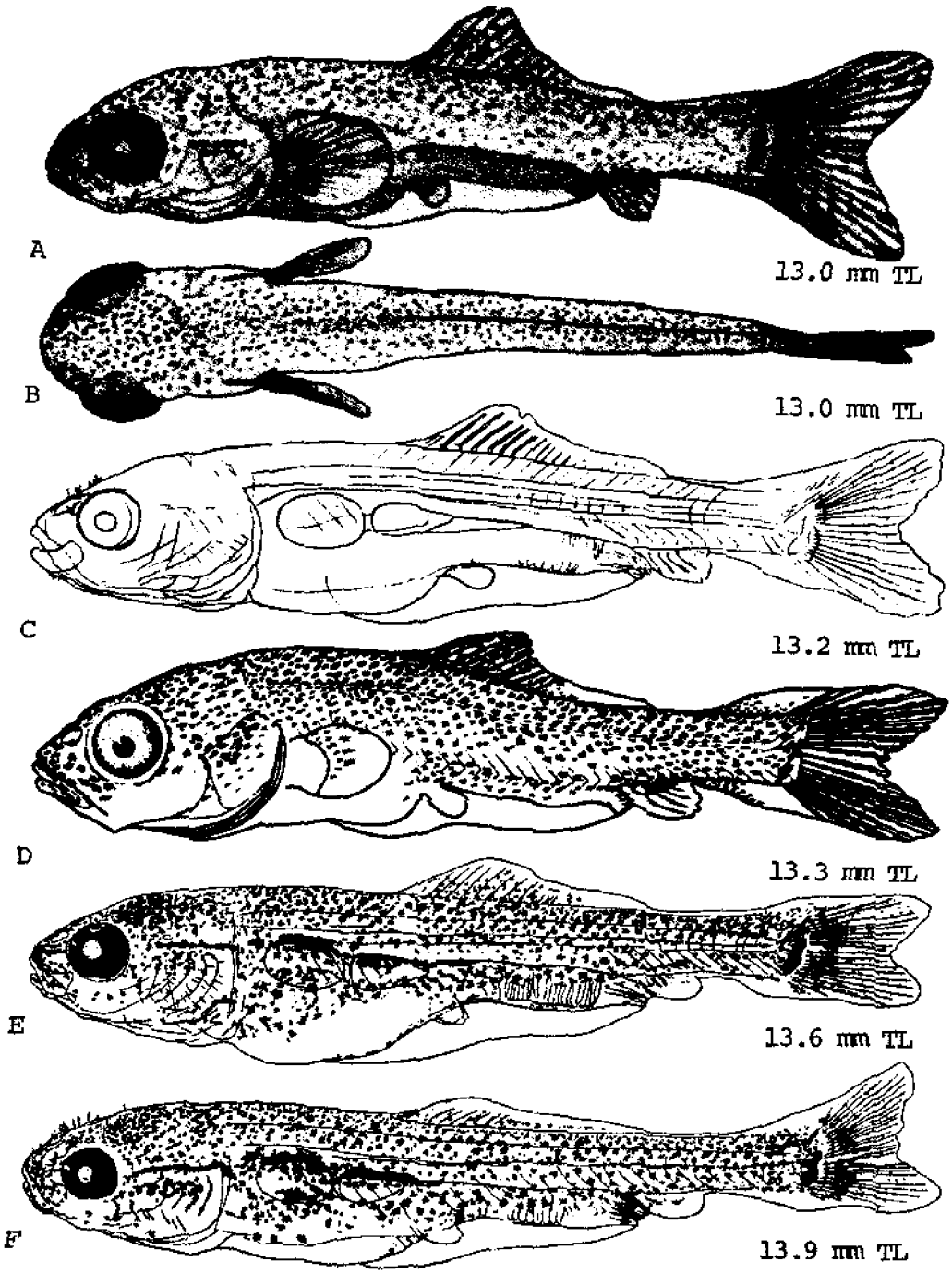

Fig. 138. *Cyprinus carpio*, Carp. A. Larva, 13.0 mm TL, pigment developed in dorsal, caudal, anal, and pectoral fins. B. Dorsal view of A. C. Larva, 13.2 mm TL. D. Larva, 13.3 mm TL. E. Larva, 13.6 mm TL. D. Larva, 13.9 mm TL, but apparently less well-developed than some earlier figures. (*A, B, Taber, C. A., 1969: fig. 6. C, E, F, Balon, E. K., 1958: figs. 18, 20, 23. D. Fish, M. P., 1932: fig. 25.*)

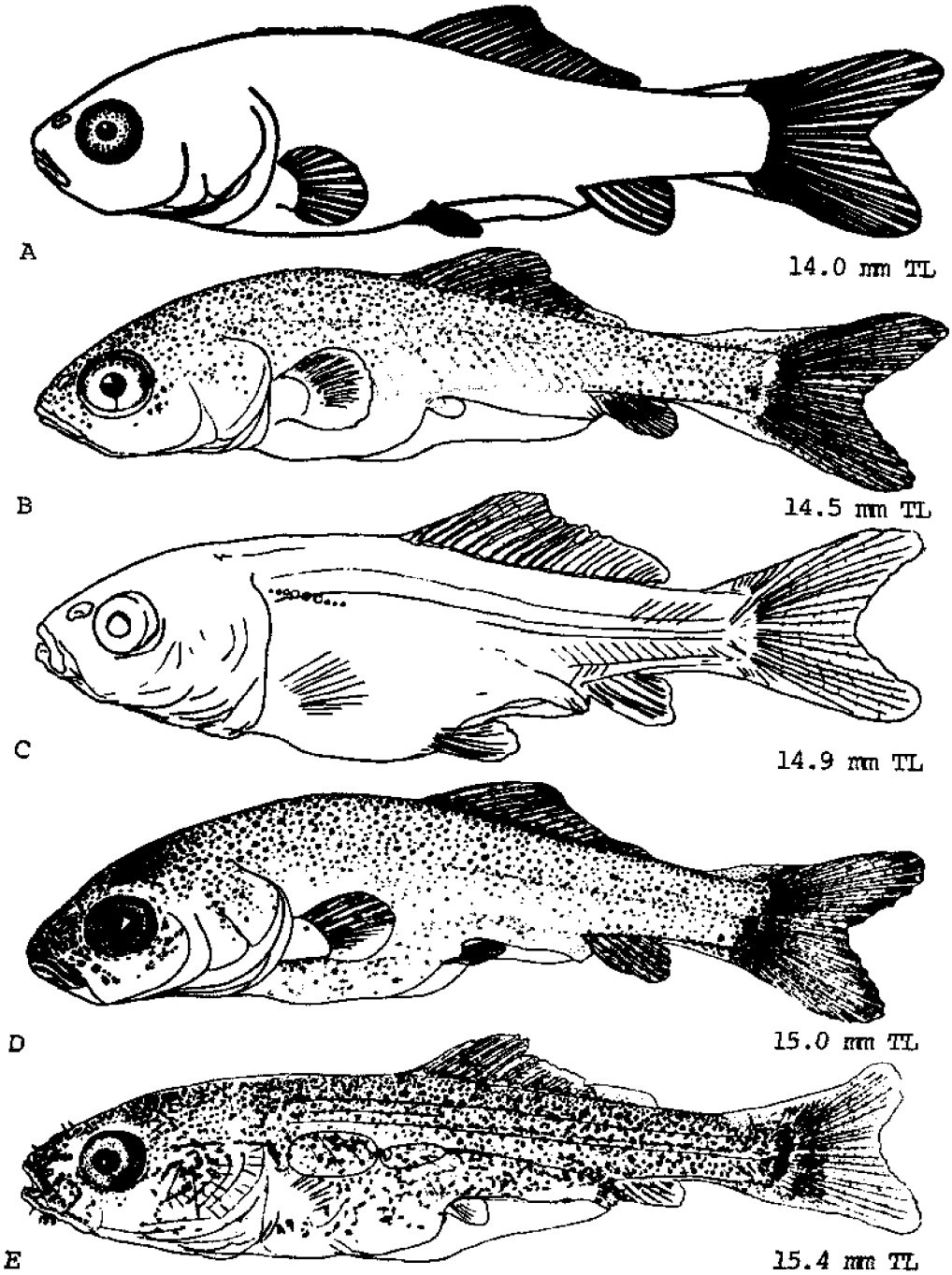

Fig. 139. *Cyprinus carpio*, Carp. A. Larva, 14.0 mm TL. B. Larva, 14.5 mm TL (note poorly developed pelvic fin in comparison to previous specimen). C. Larva, 14.9 mm, scales forming in shoulder region. D. Larva, 15.0 mm TL. E. Larva, 15.4 mm TL, but apparently less developed than previous specimen. (*A, Vasnetsov, V. V.,* et al., *1957: fig. 3. B, Nakamura, M., 1969: pl. 82. C, E, Balon, E. K., 1957: figs. 21, 31. D, Bragensky, R. Y., 1960: fig. 7.*)

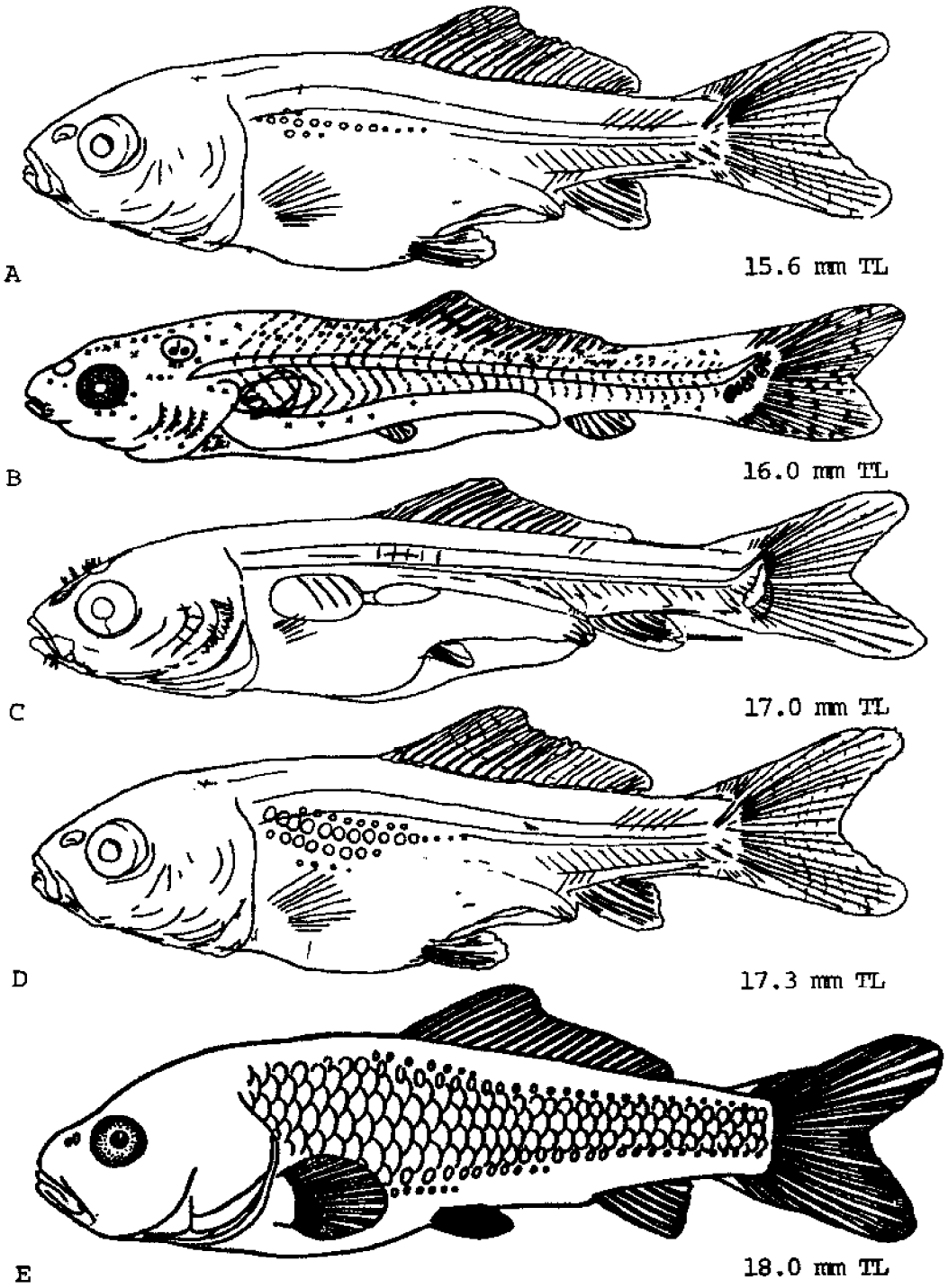

Fig. 140. *Cyprinus carpio*, Carp. A. Larva, 15.6 mm TL. B. Larva, 16.0 mm TL. C. Larva, 17.0 mm TL. D. Larva, 17.3 mm TL. E. Larva or early juvenile, 18.0 mm TL, scales much more developed than in similar-sized specimens. (*A, C, D, Balon, E. K., 1958: fig. 31. B, Hoda, S. M. S., and H. Tsukahara, 1971: fig. 6. E, Vasnetsov, V. V.,* et al., *1957: fig. 3.*)

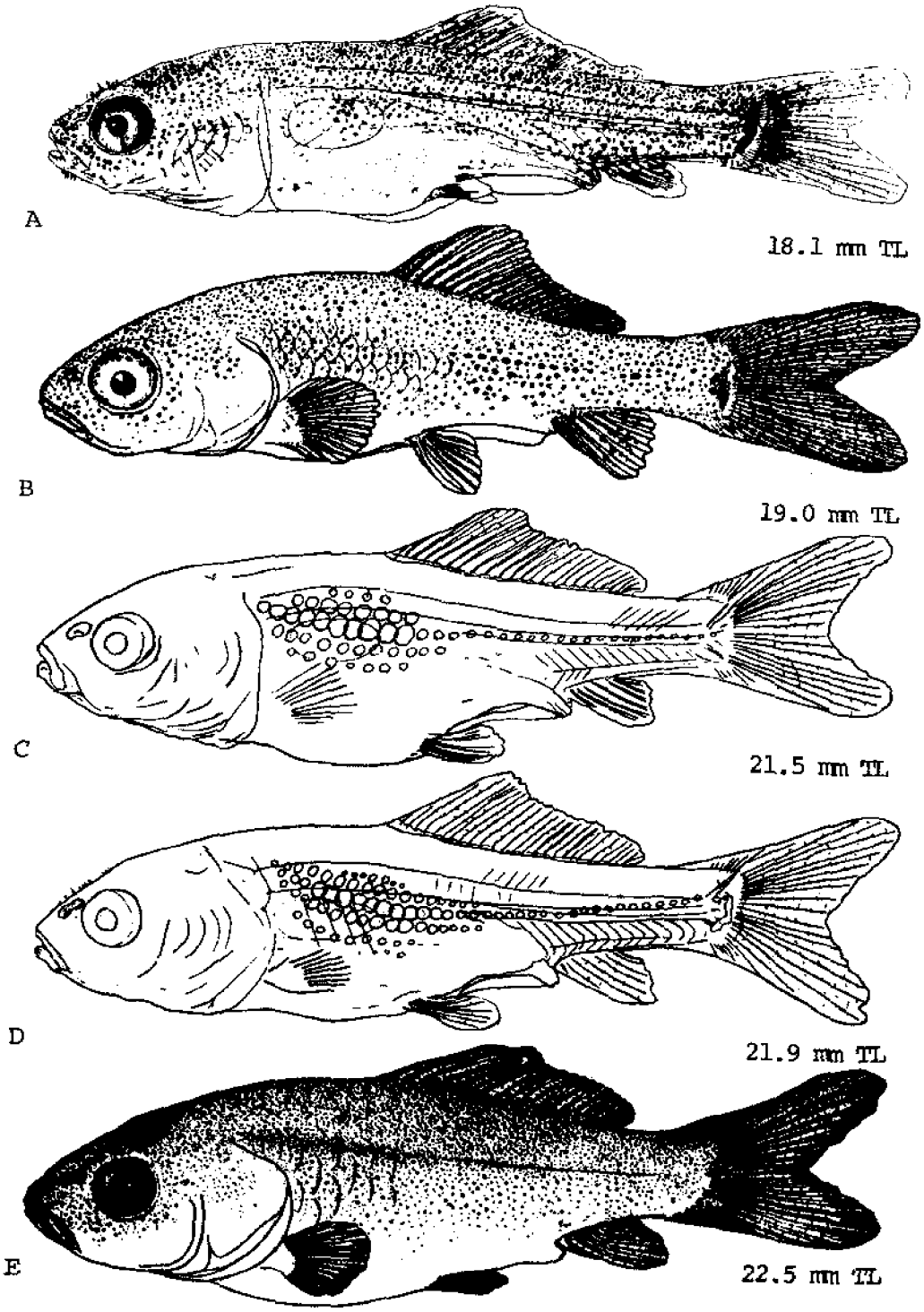

Fig. 141. *Cyprinus carpio*, Carp. A. Larva, 18.1 mm TL. B. Juvenile, 19.0 mm TL. C. Juvenile, 21.5 mm TL. D. Juvenile, 21.9 mm TL. E. Juvenile, 22.5 mm TL. (*A, C, D, Balon, E. K., 1957: figs. 25–26. B, Nakamura, M., 1969: pl. 82. E, Bragensky, R. Y., 1960: fig. 8.*)

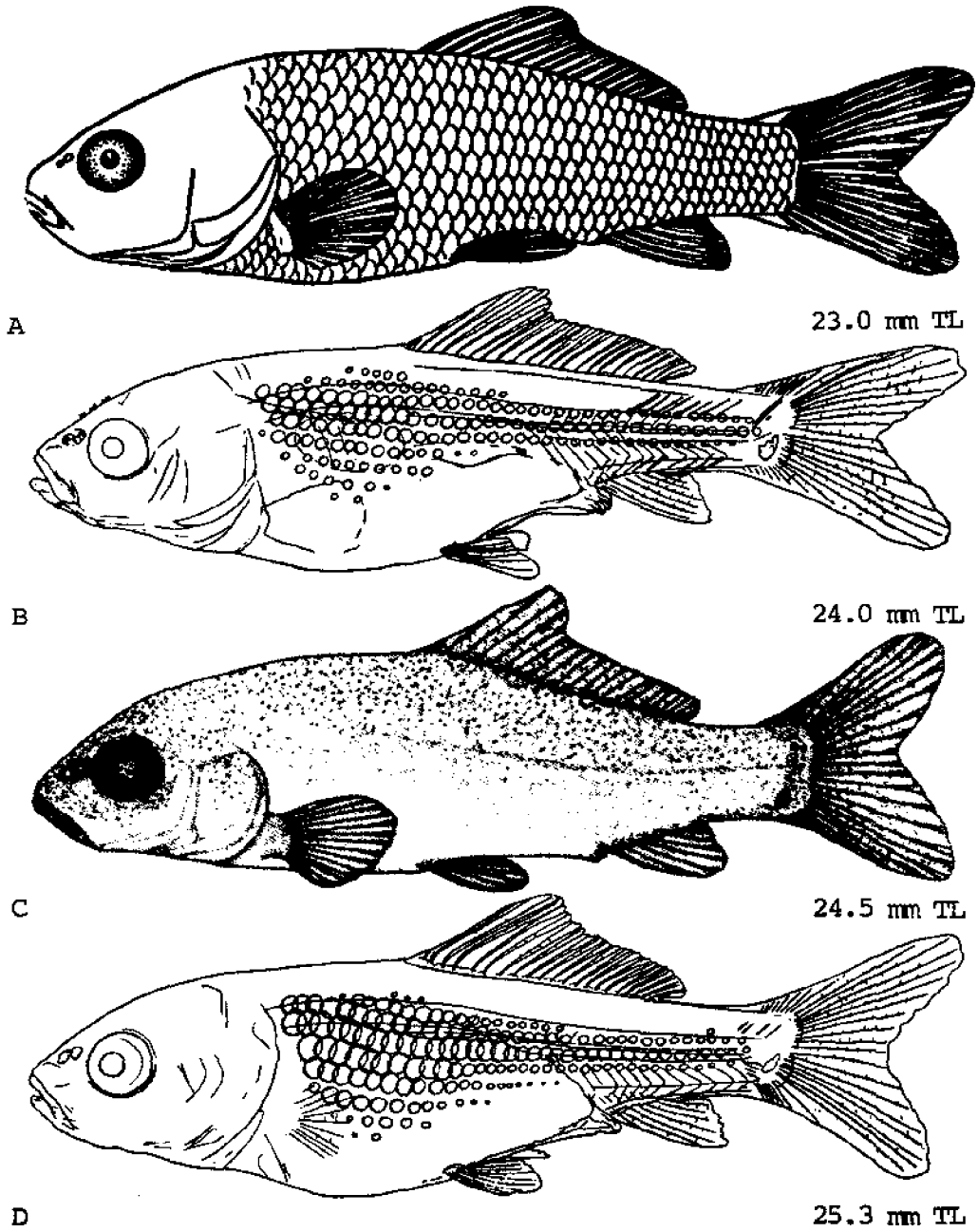

Fig. 142. Cyprinus carpio, Carp. A. Juvenile, 23.0 mm TL, scales completely formed. B. Juvenile, 24.0 mm TL, but scales conspicuously less developed than in previous stage, head neuromast still evident. C. Juvenile, 24.5 mm TL. D. Juvenile, 25.3 mm TL. *(A, Vasnetsov, V. V., et al., 1957: fig. 7. B, D, Balon, E. K., 1958: fig. 27. C, Taber, C. A., 1969: fig. 6.)*

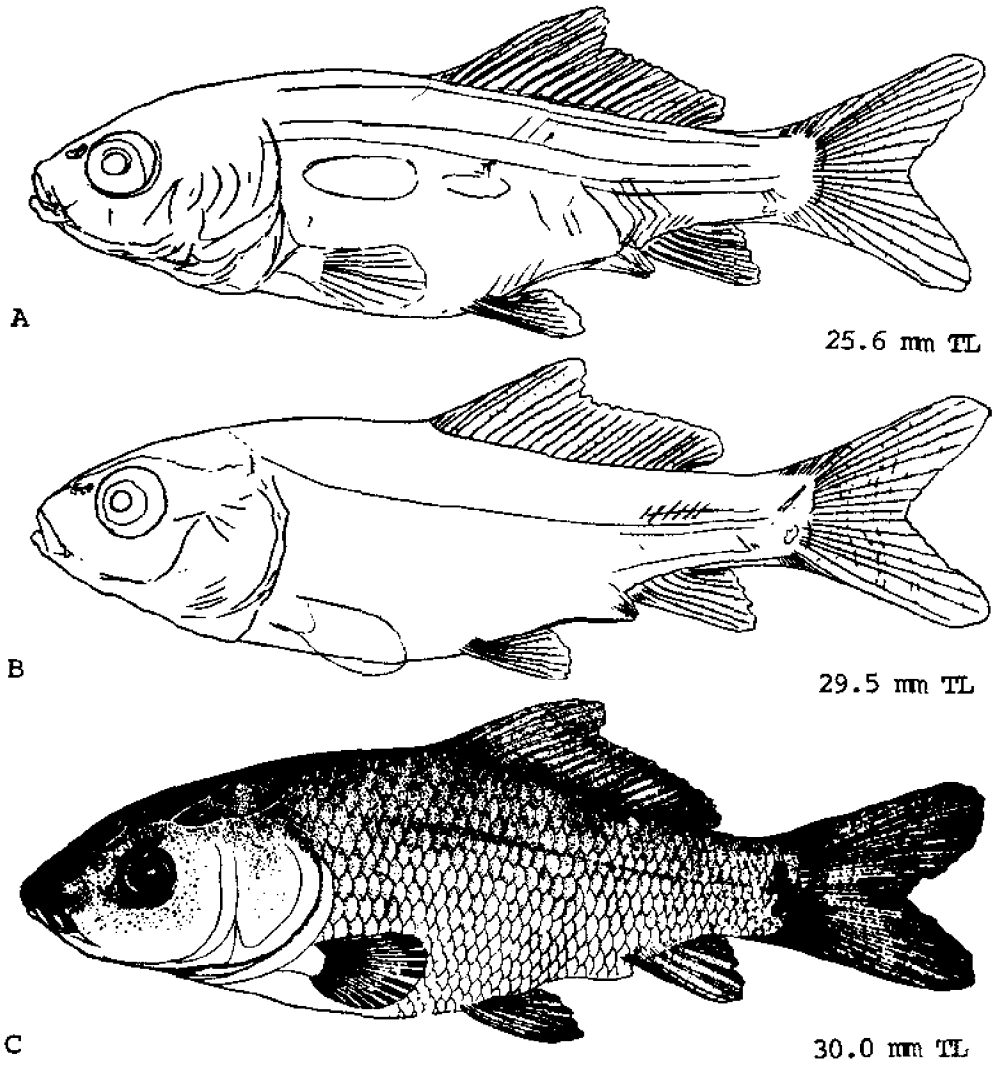

Fig. 143. *Cyprinus carpio*, Carp. A. Juvenile, 25.6 mm TL. B. Juvenile, 29.5 mm TL. C. Juvenile, 30.0 mm TL. (*A, B, Balon, E. K., 1958: fig. 28. C, Bragensky, R. Y., 1960: fig. 9.*)

and dorsum at least to dorsal fin, dense to lateral line, scarcer below. Venter unmarked except for few chromatophores near vent and in subsurface series from vent to caudal. Chromatophores on upper lip, snout, and below eye; iris speckled. At lengths over 30.0 mm color greatly variable, belly lighter than back, operculum with radial streaks, scales fringed posteriorly with black dots.[49] "Fry" generally described as having "golden tints."[55]

AGE AND SIZE AT MATURITY

Females mature at 2 to 5 years; males 1 to 4 years;[38,47,48,50,54] minimum length at maturity for specimens of unstated sex 180–200 mm;[43] otherwise minimum size of females 128 mm SL[48] to 250 mm TL,[38] males ca. 178[15]–220 mm.[38]

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Hybognathus nuchalis Agassiz, Silvery minnow

ADULTS

D. 7 [12]–10 [15] (usually 8, JJL); A. 7 [12]–9 [14] (usually 8, JJL); C. 19; P. 15–16; [8] V. 7–8; [14] lateral line scales 31 [8]–45,[13] predorsal scale rows 13–18; [8] total vertebrae 36–38; [14] precaudal vertebrae 20; [8] pharyngeal teeth 4–4.[10,12]

Proportions as percent SL: Body depth 20.1–27.2; head length 23.0–26.5; snout length 7.0–9.0; eye length 5.6–7.1.[8] Proportions as percent TL: Greatest depth 17.3–20.8; head length 18.3–21.0. Proportions as percent HL: Eye diameter 25.0–33.3; snout length 30.7–35.7; interorbital width 35.7–44.4.[14]

Body subterete; [8] head rather sharp, profile evenly curved; lower jaw included (RJM); mouth small, terminal, somewhat oblique; [12] maxillary not quite reaching eye. Lateral line complete, slightly decurved.[7] Dorsal fin origin slightly in advance of pelvic fin origin; anal fin origin behind posterior margin of depressed dorsal fin.[14] Breeding males with tubercles over top and sides of head, on chin, cheeks, opercles, apical edges of scales of back and

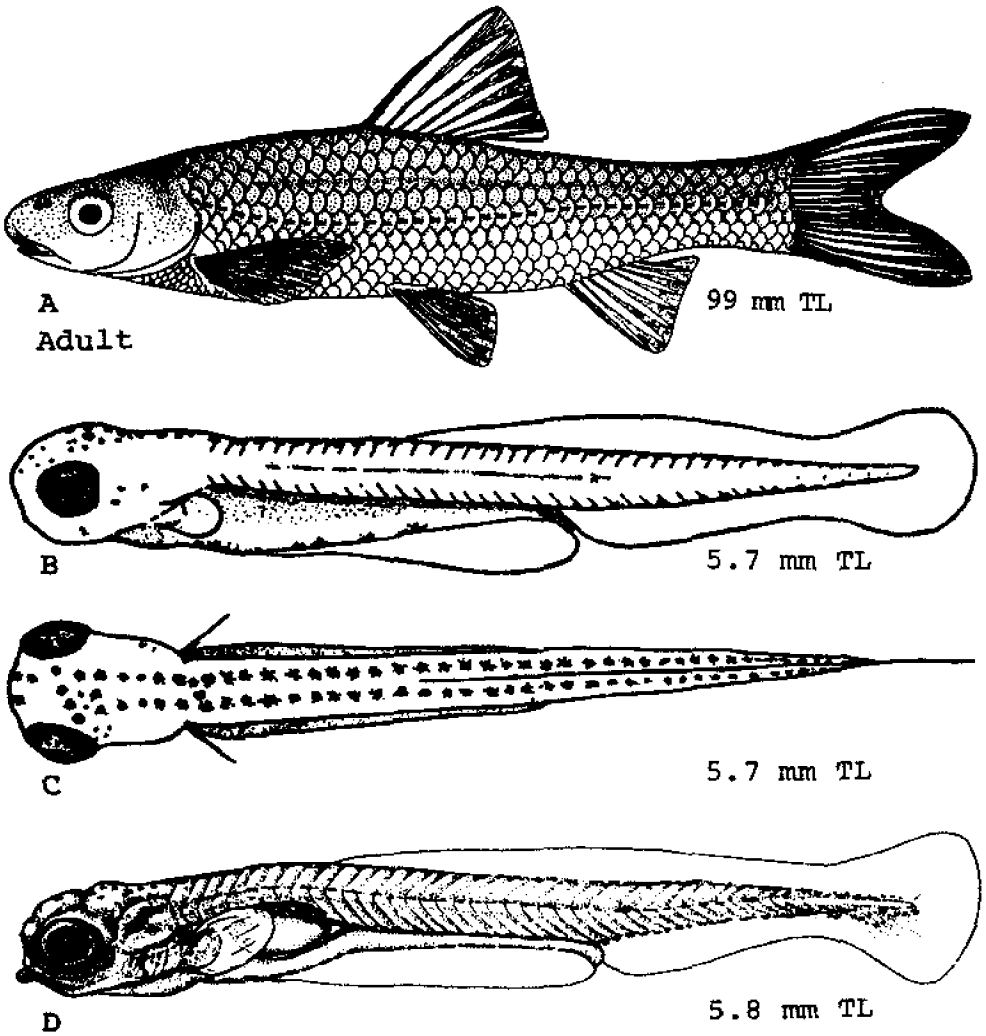

Fig. 144. *Hybognathus nuchalis*, Silvery minnow. A. Adult, 99 mm TL, 80 mm SL. B. Yolk-sac larva, 5.7 mm TL, newly hatched. C. Dorsal view of "B." D. Yolk-sac larva, 5.8 mm TL. (*A, Trautman, M. B., 1957: fig. 97. © Ohio State University Press. Used with permission of author and publisher. B, C, Raney, E. C., 1939: fig. 2. D, Lippson, A. J., and R. L. Moran, 1975: 83.*)

sides, and sides of fins; tubercles on females confined to top of head, and pectoral and pelvic fins.[1]

Pigmentation: Greenish above, silvery on sides, pale below; sometimes with a faint, plumbeous, lateral band posteriorly; fins pale, dorsal and caudal somewhat dusky; peritoneum black.[7] Breeding males light yellow along sides from eye to base of tail; midline of belly silvery; fins faint yellow.[12]

Maximum length: Ca. 159 mm but possibly reaching ca. 178 mm or more.[12]

DISTRIBUTION AND ECOLOGY

Range: Southwestern Quebec and southeastern Ontario to Georgia, west to Louisiana, north and west in the Mississippi and Missouri river systems [14] to Alberta.[15] In Lake Ontario only.[14]

Area distribution: Tidal tributaries of Chesapeake Bay in Maryland [7] and Virginia,[4,5] also recorded from Delaware and New Jersey.[9,18]

Habitat and movements: Adults—large, quiet rivers (RJM), lakes,[11] bayous, and stream pools; usually in slow, moderate,[8] or no current; [10] over mud, sand, and gravel bottoms; [8] also adaptable to pond culture.[6] Undertakes spring spawning migrations, concentrating in shallow water of tributary coves from mid-March to mid-May in New York.[1] Maximum salinity 8.3 ppt.[3]

Yolk-sac larvae—near bottom.[1]

Larvae—rise to surface following yolk absorption and concentrate in small schools near shore, usually among emergent vegetation.[1]

Juveniles—some leave tributary nursery grounds and enter lakes by July 15 in New York; [1] "small fish" over bottom having much vegetation and humus.[11]

SPAWNING

Location: Usually in small coves,[12] over bottom ooze near base of newly sprouted grass in 5–15 cm of water,[1] in ponds on silt bottom which may be partly covered with detritus and decaying vegetation,[5] or in spillpools over sand and gravel in water from 15 cm to 0.6 m deep.[9]

Season: Late April to May or possibly June in New York; [2,6] April and May in Delaware and New Jersey.[9] Mature fish have been taken from April to August in Kansas.[16]

Time: Daylight hours with peak activity between 1200 and 1400 hours.[1]

Temperature: 9 [9]–20.5 C.[1]

Fecundity: 2000 [1]–6600 [14] in specimens 60–90 mm SL.[1]

EGGS

Description: Diameter 1.0 mm. Scattered over decaying [1] and emergent [17] vegetation, and bottom ooze, sometimes becoming buried to a depth of a few millimeters. Essentially nonadhesive, although occasionally attached to bits of bottom debris,[1] often forming clusters; [17] somewhat milky when first deposited.[1]

EGG DEVELOPMENT

Late embryo with light pigment on dorsum, ventral yolk and tail, eyes pigmented.[17]

Incubation: Six to seven days when daytime temperatures vary from 13.3–20.5 C.[1]

YOLK-SAC LARVAE

Mean size at hatching 5.5 mm SL, 6.0 mm TL.

Head not deflected; yolk comparatively small, elongate; anus posterior to midpoint of body. Finfold conspicuously constricted in area of future caudal peduncle.[17]

Pigmentation: Eyes pigmented; chromatophores on cheek, over gas bladder; [17] in double series on dorsal surface terminating anteriorly in scattered group over head,[1] single row along mid-lateral line,[17] along gut and venter,[1] and mid-ventral line over yolk.[17]

LARVAE

Specimens described 6.1–14.0 mm TL.

At 6.1 mm, total myomeres 35 (21 + 14); finfold reduced, incipient rays in caudal. At 7.85 mm, incipient rays in dorsal, anal, and pectoral; urostyle directed upward; gut highly convoluted (NSS). At 14.0 mm, preanal finfold still present.[1]

Pigmentation: In largest specimen pigment more diffuse on dorsum and venter; conspicuous, roughly triangular blotch on top of head.[1]

JUVENILES

Specimen described 17.3 mm TL.

Preanal myomeres 23; postanal myomeres 13; preanal finfold absent; gas bladder constricted (NSS). Dorsal fin origin anterior to pelvic fin origin, anal fin origin behind posterior margin of depressed dorsal.[17]

AGE AND SIZE AT MATURITY

Some females apparently at 1 year; males probably at 2 years. Minimum size of females 50–55 mm SL.[1]

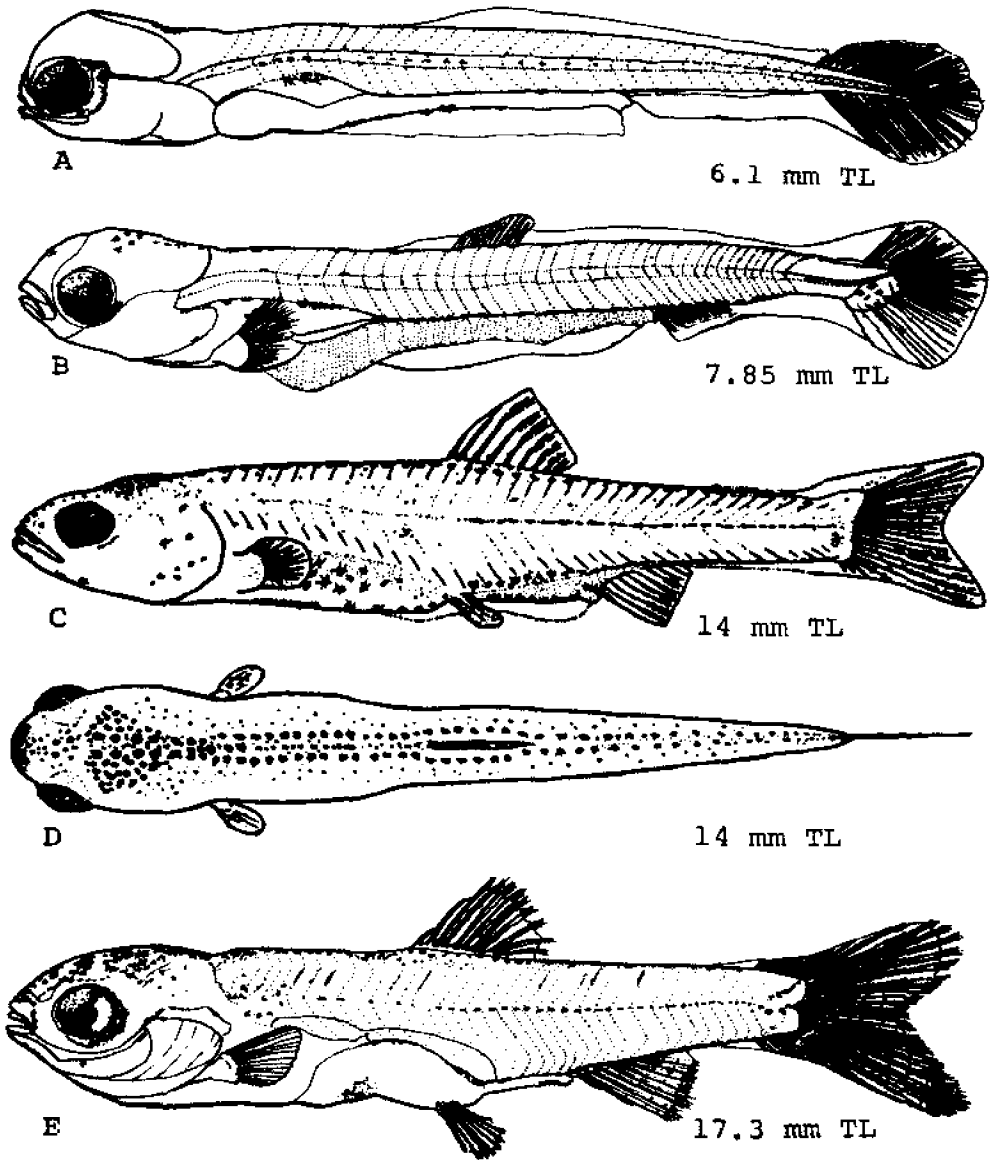

Fig. 145. *Hybognathus nuchalis*, Silvery minnow. A. Larva, 6.1 mm TL. Total myomeres 35, preanal myomeres 21, postanal myomeres 14. B. Larva, 7.85 mm TL. Total myomeres 35. C. Larva, 14 mm TL, 12 mm SL. Scattered pigment over fins. D. Larva, 14 mm TL, dorsal view showing pigment pattern. E. Juvenile, 17.3 mm TL. Myomeres 23 + 13 = 36. (*A, B, E, Mansueti, A. J., and J. D. Hardy, Jr., 1967: figs. 61, 62. C, D, Raney, E. C., 1939: fig. 3.*)

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Notemigonus crysoleucas (Mitchill), Golden shiner

ADULTS

D. 7 [29]–9; [39] A. 8–19; [19] C. 19; [26] P. 16–18; V. 8–9; [39] lateral line scales 40 [22]–57,[21] scale rows in advance of dorsal 23–25; average total vertebrae (excluding Weberian apparatus) 32.7–35.0, depending on locality; [9] gill rakers on first arch 5 + 16; [6] pharyngeal teeth 0,5–5,0,[43] or 0,4–4,0, often hooked.[26]

Proportions as percent TL: Greatest body depth 17.4–26.4; HL 17.1–20.0. Proportions as percent HL: Eye diameter 23.9–33.3; snout length 26.3–34.4.[39] Proportions as times in SL: Body depth 2.85–4.25. Proportions as times in HL: Eye diameter ca. 2.6–4.1.[1]

Body deep, strongly compressed; back elevated; ventral outline decurved; [1] prominent belly keel from pelvics to anal origin.[39] Head small, triangular, somewhat depressed above, scaleless; snout short, blunt; mouth strongly oblique; [1] lower jaw projecting; [39] maxillary reaching only to anterior nostril.[26] Scales cycloid, rather deep; midline of belly naked from pelvics to anus; [1] lateral line

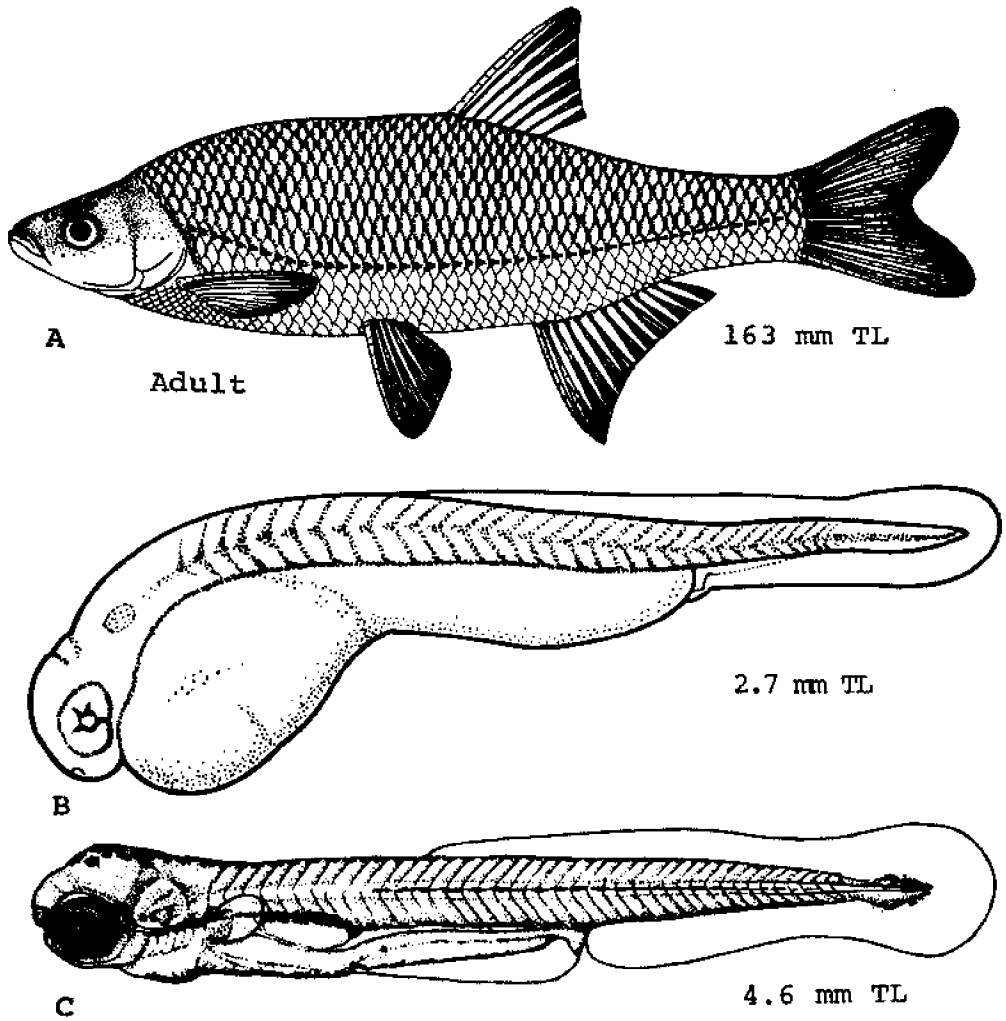

Fig. 146. *Notemigonus crysoleucas*, Golden shiner. A. Adult, 163 mm TL. B. Yolk-sac larva, 2.7 mm TL, newly hatched. Pigment lacking; distinct pectoral fin buds not evident. C. Yolk-sac larva, 4.6 mm TL. (*A, Trautman, M. B., 1957: fig. 59. © Ohio State University Press. Used with permission of author and publisher. B, Snyder, D. E., M. B. M. Snyder, and S. C. Douglas, 1977: fig. 2A. © Fisheries Research Board of Canada. Used with permission of author and publisher. C, Lippson, A. J., and R. L. Moran, 1974: 85.*)

decurved (ECR). Dorsal fin origin posterior to pelvic origin; anal origin approximately below dorsal insertion; pectorals never reaching pelvic fin origin.[39]

Pigmentation: Dorsum golden underlaid with olive-green; sides more golden with silvery reflections; venter yellowish or yellow-silver; fins light olive or yellow.[8] Breeding males with crimson pelvics and orange, black-margined anal fin.[2]

Maximum length: Ca. 305 mm.[1,26]

DISTRIBUTION AND ECOLOGY

Range: From Nova Scotia and Manitoba[25] south to Florida and mouth of Rio Grande,[23] west to Dakotas;[38] widely introduced westward.[8]

Area distribution: Tidal tributaries of Chesapeake Bay in Maryland and Virginia;[1,4,32,44] also Delaware.[37]

Habitat and movements: Adults—typically in weedy lakes, ponds, and quiet streams,[3,18,28,30] also recorded from ditches,[2] canals,[41] swamps, millponds (RJM), sloughs, bayous, muddy holes,[16] and, rarely, rocky creeks;[10] able to live in waters of low oxygen content; recorded over both muddy[26] and clear bottom;[8] rarely in turbid water or water with little or no aquatic vegetation.[8,16] Maximum recorded salinity 14.4 ppt.[1] Usually found in midwater or near surface waters in small, loosely aggregated schools.[26] Maximum depth unknown, but recorded from "deeper waters" of Delaware River.[6] Migratory during

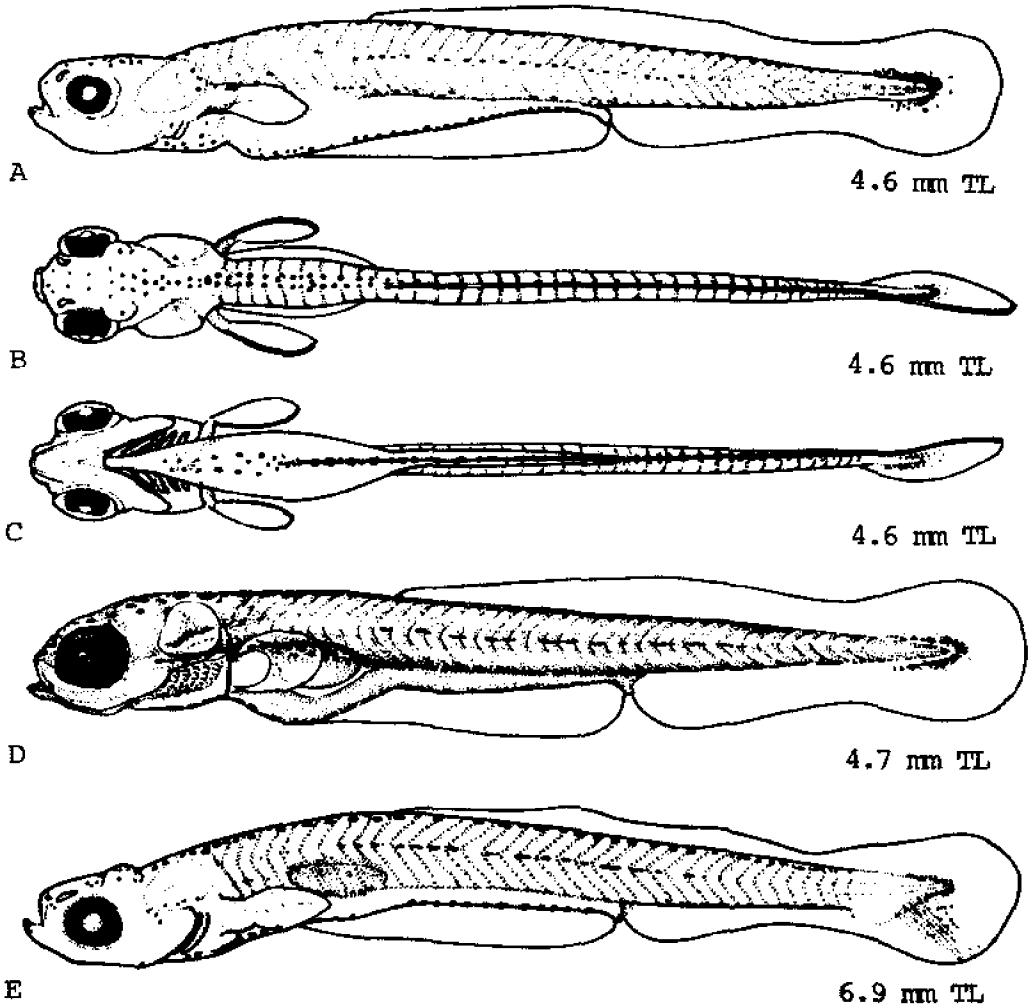

Fig. 147. *Notemigonus crysoleucas*, Golden shiner. A. Yolk-sac larva, 4.6 mm TL. Prominent preanal, mid-ventral line of melanophores. B. Dorsal view of "A." C. Ventral view of "A." D. Yolk-sac larva, 4.7 mm TL. E. Larva, 6.9 mm TL. Incipient rays in caudal fin. (*A-C, E, Snyder, D. E., M. B. M. Snyder, and S. C. Douglas, 1977: figs. 3, 6A. © Fisheries Research Board of Canada. Used with permission of author and publisher. D, Lippson, A. J., and R. L. Moran, 1974: 85.*)

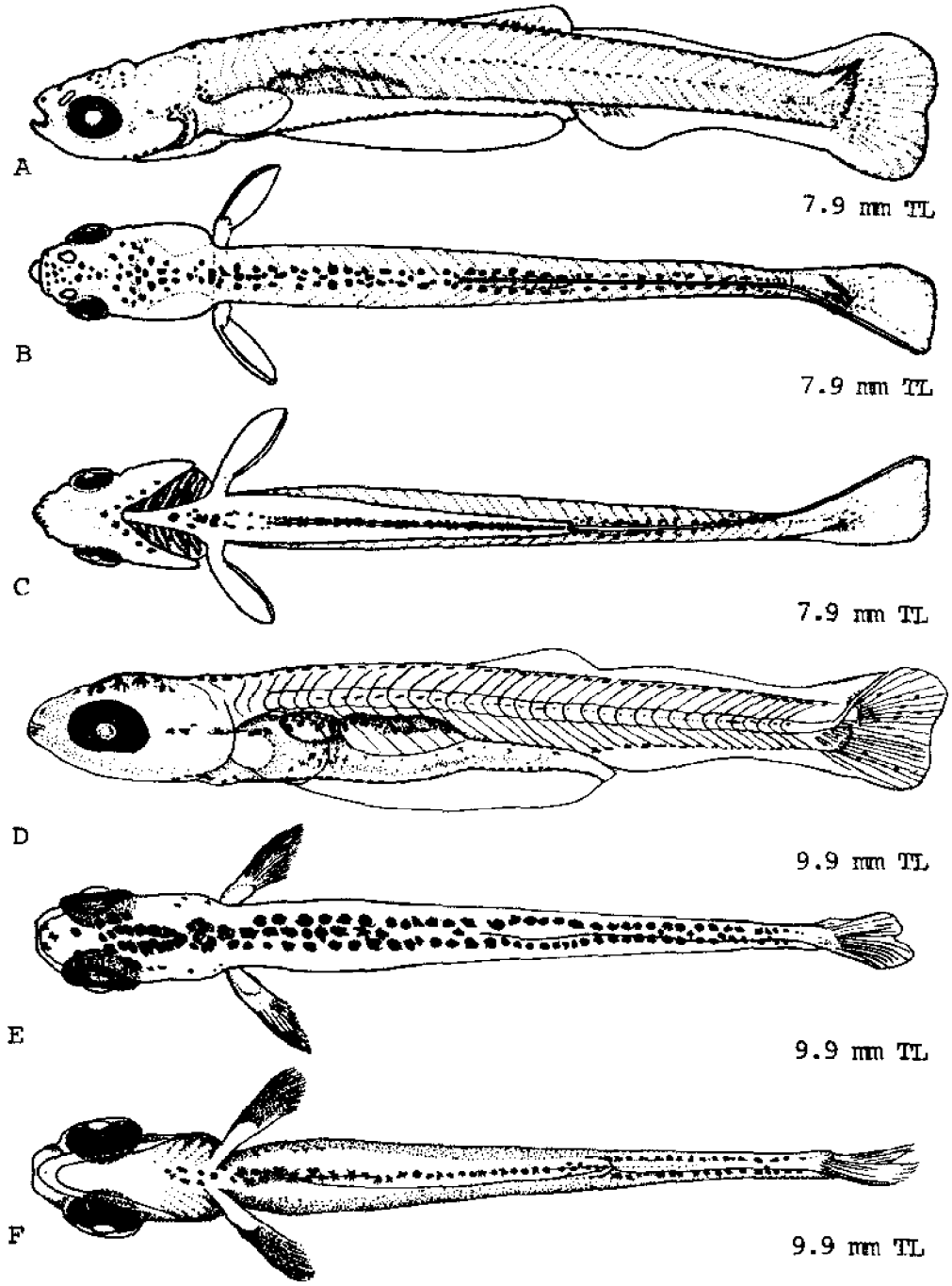

Fig. 148. *Notemigonus crysoleucas*, Colden shiner. A. Larva, 7.9 mm TL. Rays evident in dorsal, anal and caudal fins. B. Dorsal view of "A." C. Ventral view of "A." D. Larva, 9.9 mm TL, 9.2 mm SL. Air bladder two-chambered. Urostyle pigmented along dorsal and ventral surface. E. Dorsal view of "D." F. Ventral view of "D." (A-C, *Snyder, D. E., M. B. M. Snyder, and S. C. Douglas, 1977; fig. 7.* © *Fisheries Research Board of Canada. Used with permission of author and publisher. D-F, Original drawings by Mary Fuges, courtesy of Jules Loos.*)

spawning season, with runs beginning in April, in New York.[16]

Larvae—no information.

Juveniles—recorded from brackish water and tidal freshwater of upper Chesapeake Bay among aquatic vegetation over various types of bottom; [1] found near periphery of ponds or in open water of shallows not far from vegetation.[24,33] In lakes with rock shores young remain in deeper water where vegetation may be found.[33]

SPAWNING

Location: Ponds, streams,[5] lakes, sloughs,[7] and sheltered bays; [4] in quiet water among plants,[17] over beds of submerged vegetation,[33] and frequently in nests of *Micropterus salmoides*.[7]

Season: Late March [11] to August,[13] possibly to late October [11] depending on locality; sometimes with 4 or 5 distinct spawning peaks per season.[14]

Time: Early morning to noon.[14]

Temperature: 20–27 C.[14]

Fecundity: Up to 200,000.[35]

EGGS

Location: Attached to filamentous algae, less frequently to rooted aquatic plants [13,26,27,28] or stones,[12] and rarely over bare sand bottom.[7]

Ovarian eggs: Single micropyle.[34]

Fertilized eggs: Diameter 1.0 [27]–1.4 mm (PWJ), adhesive,[5,26,28] lacking oil globules.[30,31]

EGG DEVELOPMENT

Pigmentation of late embryo: Light on dorsum, ventral yolk and tail.[45]

Incubation: 2–3 days at 21–24 C; [42] 4 days at ca. 24–27 C.[14]

YOLK-SAC LARVAE

Minimum size at hatching 2.7 mm TL; average size at hatching ca. 3.0 mm TL.[42] Largest specimen illustrated 4.7 mm TL.[45]

Pectoral fin buds indistinct at hatching.[42] Anus slightly posterior to midpoint of body.[45]

Pigmentation: At hatching unpigmented, including eyes (preserved specimens).[42] At 4.6 mm TL melanophores in double row along mid-dorsal line, scattered over head, row along mid-lateral line, row along ventral aspect of myomeres continuing over air bladder, mid-ventral line over yolk.[45]

LARVAE

Specimens described 6.8–14.8 mm TL.[42] Size at end of stage in some populations ca. 14 mm.[45]

Total myomeres at 6.8–9.5 mm TL 36–38; postanal myomeres at 6.8–9.5 mm TL 15–17; predorsal myomeres at 6.8–9.5 mm TL 11–13.[42]

Proportions expressed as percent TL (at 6.8–9.5 mm): Body depth 11–13; head length 18–20; snout length 2–3; eye diameter 5–6; snout to vent 57–60; predorsal length 38–43.[42]

Pigmentation: Early larvae with mid-ventral row of melanophores on abdomen; sometimes with scattered melanophores only on breast, never abdomen; [46] underside of lower lip and ventral surface of gill covers pigmented.[42] Later larvae with melanophores forming V-shaped marking around end of urostyle or dark spot on dorsal upturned urostyle; [46] pigment extending to upper and lower lips; pigment in mid-dorsal, lateral and ventral lines; dense concentrations over gas bladder and head.[46]

JUVENILES

Minimum size described 18 mm TL.

Preanal myomeres 20–21; postanal myomeres 17; vertebrae 21 + 19 at 18 mm TL. Greatest body depth ca. 4.5 times in SL at 14.5 mm SL.[3]

At 18–24 mm TL body slender, elongate, somewhat compressed, especially in caudal region,[3] at ca. 59 mm TL body less deep than in adult.[6] At 18–24 mm head short; snout pointed; mouth small, terminal, oblique, not quite reaching front of eye; nostril single at 18 mm,[3] double by ca. 20 mm.[20] Fully scaled at 24 mm TL. Dorsal fin higher than long, situated at mid-body; [3] origin posterior to pelvic origin; [45] anal longer than dorsal.[3]

Pigmentation: At 18 mm TL, melanophores on jaws, top of head, fins, dorsum, upper sides of body, and in a broad lateral band from head to caudal; in double ventral series from anus to caudal base; internally in abdominal region. Some specimens with brilliant golden tinge throughout, all with golden tinge about head, fins, and caudal peduncle.[3] At larger sizes fins silvery, body silvery rather than golden; [8,25] lateral band extends from eye [1] or snout [6] to caudal base,[1] disappearing at ca. 120 mm.[45]

AGE AND SIZE AT MATURITY

7 to 8 months [40]–3 years,[15] mostly in 2nd year; [14] 50–70 mm.[15]

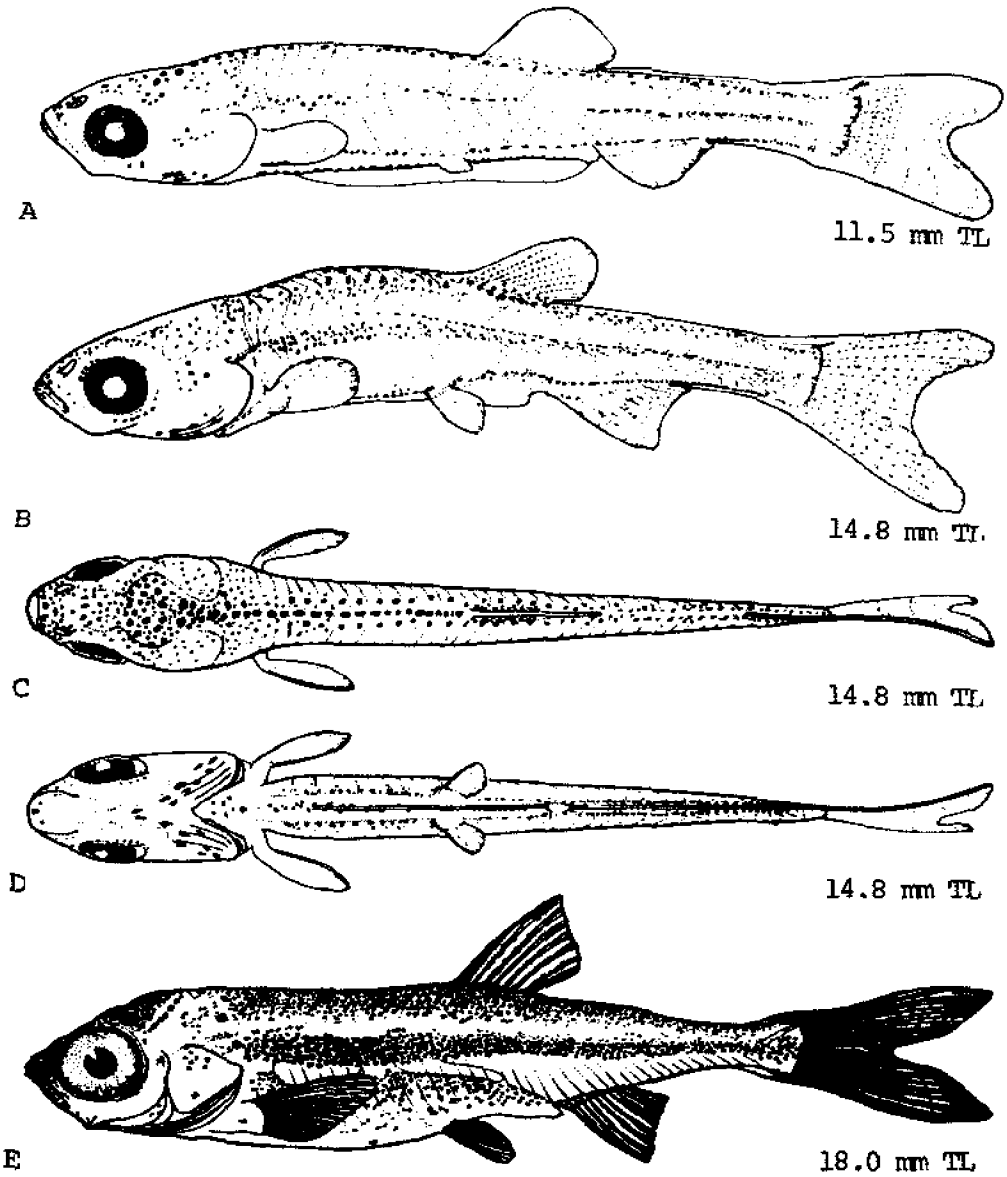

Fig. 149. Notemigonus crysoleucas, Golden shiner. *A.* Larva, *11.5* mm *TL.* Pelvic fins forming. *B.* Larva, 14.8 mm TL. Lateral band of pigment becoming broader. *C.* Dorsal view of "B." D. Ventral view of "B." E. Juvenile, 18.0 mm TL, 14.5 mm SL. Preanal myomeres 20 (21); postanal myomeres 17. (*A-D, Snyder, D. E., M. B. M. Snyder, and S. C. Douglas, 1977: figs. 10A, 11.* © *Fisheries Research Board of Canada. Used with permission of author and publisher. E, Fish, M. P., 1932: fig. 52.*)

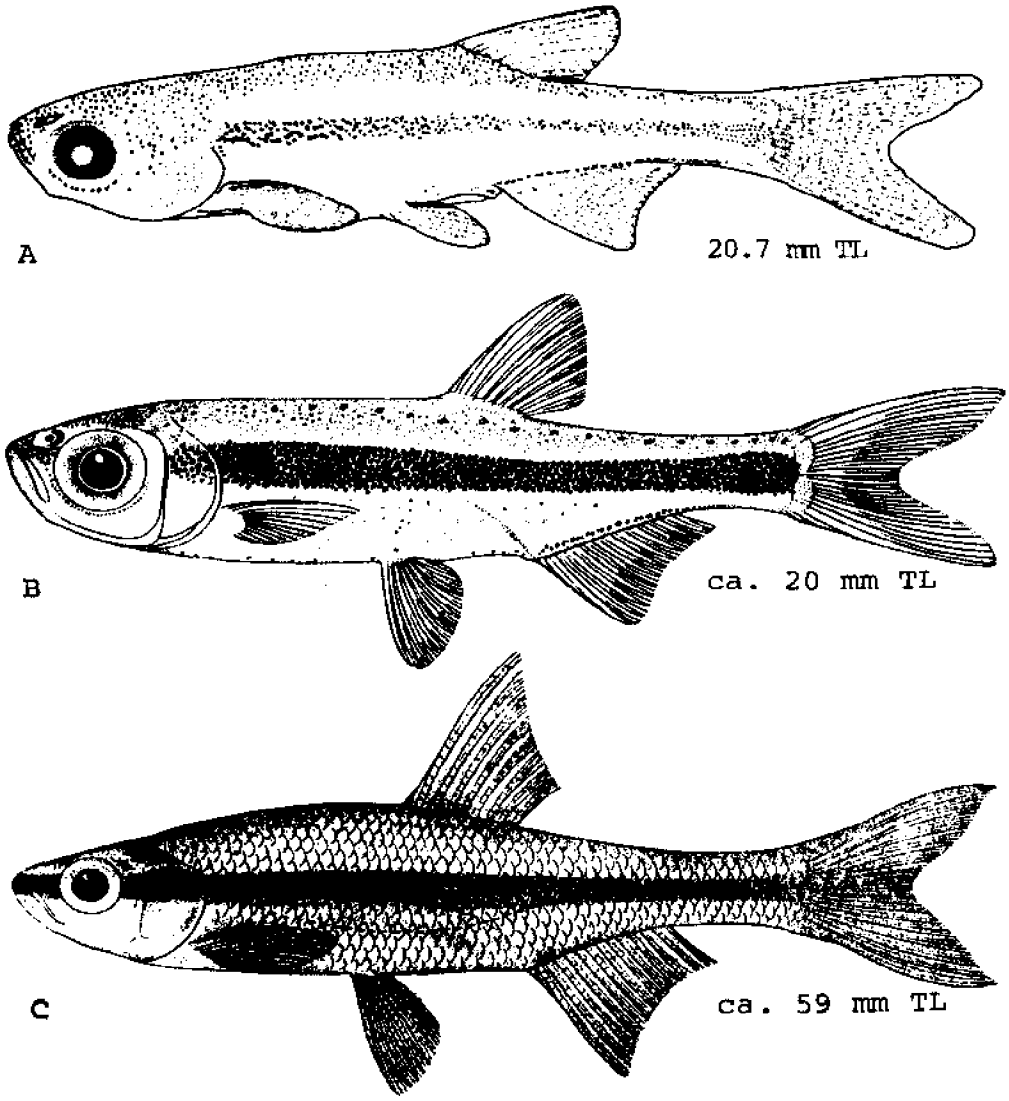

Fig. 150. *Notemigonus crysoleucas,* Golden shiner. A. Juvenile, 20.7 mm TL. B. Juvenile, ca. 20 mm TL. C. Juvenile, ca. 59 mm TL. (*A, Snyder, D. E., M. B. M. Snyder, and S. C. Douglas, 1977: fig. 14A. © Fisheries Research Board of Canada. Used with permission of author and publisher. B, Fowler, H. W., 1945: fig. 84. C, Fowler, H. W., 1906: 136.*)

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Notropis amoenus (Abbott), Comely shiner

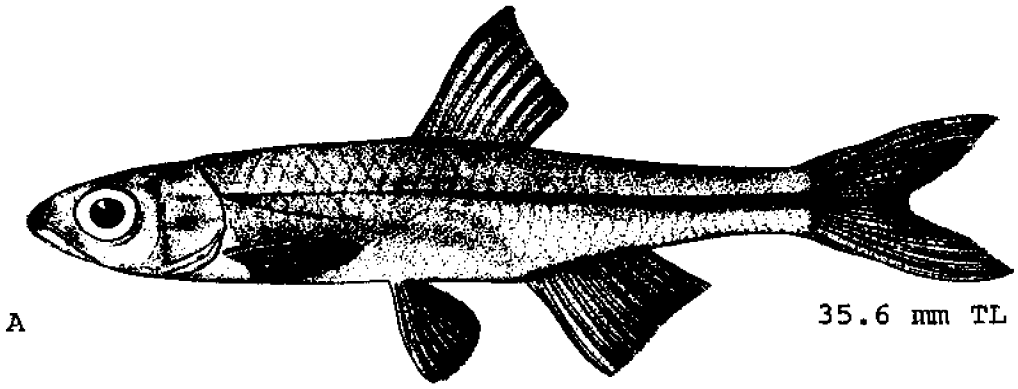
ADULTS

D. 7–9 (usually 8);[9] A. 10–12[6] (modally 11); P. 26–36 (both fins); V. 7–9 (usually 8); lateral line scales 35–47 (usually 37–41), predorsal scales 17–38, body circumferential scales 24–36 (usually 26–31), scales above lateral line 13–19 (usually 14–17, modally 17 in the upper Potomac), below 8–15 (usually 10–13), caudal peduncle scales 12–19 (usually 13–17), above lateral line usually 6–8, below usually 4–6,[9] scales below lateral line to anal origin 3–4, to pelvic origin 2–4;[7] gill rakers on lower limb of first arch 5–9 (usually 6–8); vertebrae 37–42 (usually 38–40);[9] pharyngeal teeth usually 2,4–4,2.[3]

Proportions as percent SL: HL 22.3[9]–27.9;[8] snout length 6.3[9]–8.6;[6] predorsal length 54.0–58.1; body depth 16.4–25.1; caudal peduncle depth 8.0–10.5;[9] dorsal origin to base of tail 44.2–48.6.[6] Body width into body depth 1.6–1.7.[9]

Body long, compressed, lower 2/3 of sides almost vertical,[5] widest at point close behind head, deepest at or slightly anterior to pelvic origin. Snout pointed, length usually equal or slightly exceeding length of fleshy orbit. Mouth terminal, large, oblique extending back to below anterior margin of orbit, rising anteriorly to the level of the upper half of the eye. Lateral line incomplete on head, on body complete, strongly decurved, reaching lowest point slightly in advance of pelvic fin origin. Fins moderate in size, angulate, dorsal insertion well behind pelvic insertion; anterior rays of dorsal exceed posterior rays of depressed fin, posterior edge of anal fin falcate, caudal lobes equal in size. Breeding males with tubercles persent on ray 1 of pectoral fin, small tubercles on rays 2 to about 10 (several tubercles per ray segment); large gravid females with minute tubercle-like structures present.[9]

Pigmentation: Pale, translucent green above, sides silvery; mid-dorsal stripe variable in width and intensity, slightly less developed posterior to dorsal fin; a plumbeous lateral band, originating over hypural, well-developed on caudal peduncle forward to near anal fin origin,[9] diffuse, poorly



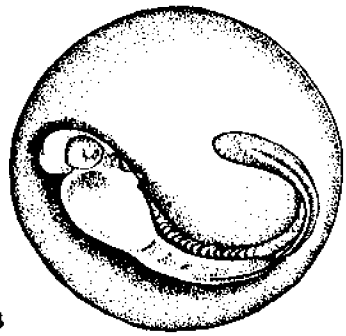


Fig. 151. *Notropis amoenus*, Comely shiner. A. Probable juvenile, 35.6 mm TL. Anal fin of adult more falcate. B. Egg, late stage embryo, diameter 3.2 mm. (*A, Fowler, H. W., 1906: 148. B, Original drawing by Mary Fuges, courtesy of Jules Loos.*)

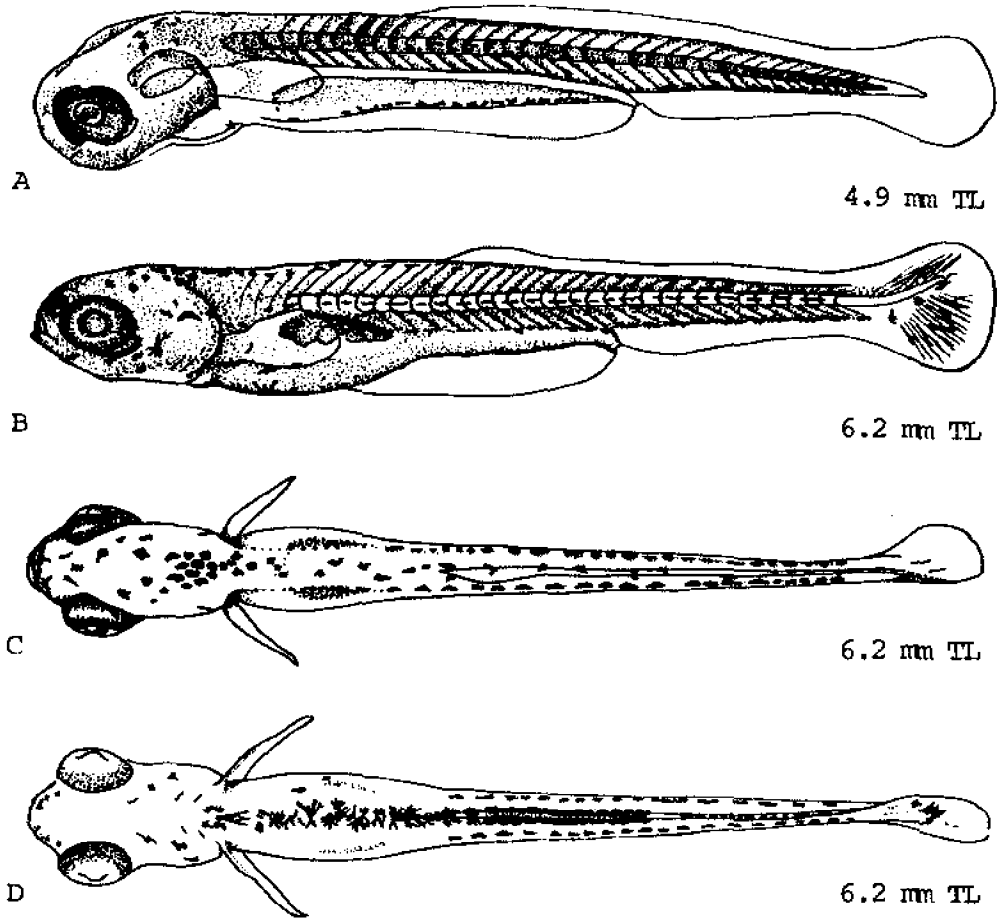


Fig. 152. *Notropis amoenus*, Comely shiner. A. Yolk-sac larva, 4.9 mm TL, 4.8 mm SL. Preanal myomeres 23; postanal myomeres 13. B. Larva, 6.2 mm TL. Incipient rays in caudal fin. C. Dorsal view of "B." D. Ventral view "B." (A-D, Original drawings by Mary Fuges, courtesy of Jules Loos.)

developed or lacking on anterior half of body;[4,5,8] broad silvery lateral band from caudal base to cleithrum.[9] Top of head with rather evenly distributed melanophores;[5] upper lip heavily pigmented on anterior half, posterior portion usually with scattered melanophores; pigment at mandibular symphysis expanded into Y- or V-shaped posterior extension, remainder of undersurface immaculate; pigment normally on upper half of opercle and preopercle. Fin membranes immaculate, melanophores border dorsal and caudal rays, rays 1–6 on pectorals, 1–3 on anal, pelvic rays usually unbordered; opercle, preopercle and iris silvery. Males do not develop chromatic breeding colors.[9]

Maximum length: Ca. 102 mm.[1,4]

DISTRIBUTION AND ECOLOGY

Range: All major and many minor Atlantic coast drainages from Hudson River, New York to Cape Fear, North Carolina; also Seneca Lake, New York.[9]

Area distribution: All major rivers of western Chesapeake Bay; also Choptank River;[9] rare or restricted in Delaware.[13]

Habitat and movements: Adults—midwater species usually found in moderate to large streams, creeks, or rivers in water 0.6 m or deeper; in northern areas entering small streams of relatively low gradient;[9] pools or backwaters[2] in areas of considerable current, channels in slow moving water; no apparent preference of bottom type, in water clear to turbid, colorless to dark stained;[9] once recorded from a "brackish" creek[10] but not normally in saline waters.[11]

Larvae—no information.

Juveniles—no information.

SPAWNING

Location: Sometimes in abandoned nests of *Nocomis micropogon;* other sites are probable (JJL).

Season: Breeding males and ripe or nearly ripe females from April to late August throughout range.[9]

Time: A closely related species *Notropis atherinoides*[9] spawns at night.[12]

EGGS

Fertilized eggs: Perfectly spherical, colorless, nonadhesive; membrane thin, fragile; perivitelline space ca. 2/3 egg radius (JJL).

EGG DEVELOPMENT

Similar to eggs of *N. atherinoides* but hatch later, after pectorals and eyes form and head and body pigmentation develops (JJL).

YOLK-SAC LARVAE

Hatching length ca. 4.9–5.2 mm TL. Size range described 4.9–5.2 mm TL (4.8–5.0 mm SL).

At 4.9 mm TL preanal myomeres 23; postanal myomeres 13 (JJL).

At 4.9 mm TL greatest depth 0.6 mm, eye diameter 0.3 mm, length to vent 3.0 mm (JJL).

Head little deflected initially; pectorals evident; cement glands absent. Yolk small, elongate, conical (JJL).

Pigmentation: Eyes black at hatching; melanophores scattered on top of head; dorsal body with a few or no melanophores; single mid-ventral row of abdominal melanophores; a few melanophores along horizontal myoseptum appearing dash-like externally. Sometimes with melanophores evident along ventral urostyle (JJL).

LARVAE

Size range described 5.2–11.8 mm TL (4.7–10 mm SL).

At 5.6 mm TL (5.4 mm SL) preanal myomeres 23–24, postanal myomeres 13–14; at 8.6 mm TL (7.7 mm SL) preanal myomeres 25, postanal myomeres 13 (JJL).

At 5.6 TL (5.4 mm SL) greatest body depth 0.65 mm; diameter of eye 0.31 mm; length to vent 3.4 mm. At 8.6 mm TL (7.7 mm SL) greatest body depth 1.3 mm; diameter of eye 0.66 mm; length to vent 5.2 mm (JJL).

At 6.1 mm TL incipient caudal rays present; at 8.6 mm TL incipient dorsal and anal rays present; at 11.8 mm TL pectoral and incipient pelvic rays present. At 5.2 mm TL urostyle straight, at 6.1 mm TL oblique. At 5.2 mm TL gas bladder one-chambered, at 8.6 mm TL two-chambered (JJL).

Pigmentation: Melanophores scattered on top of head; sparse dorsal body melanophores initially in a single row posterior to head, later in a double or triple row and a double row along dorsal caudal peduncle. A single row of mid-ventral body melanophores (some melanophores may be present on lower sides), row of lateral body melanophores that extended internally on horizontal myoseptum. Internal melanophores in patch over gas bladder, in band over gut, scattered along body cavity. At 6.1 mm TL melanophores on ventral urostyle. At 8.6 mm TL melanophores on snout and lips, a diffuse caudal spot present, ventral urostylar pigmentation still evident. At 11.8 mm TL caudal spot no longer evident. (Urostylar pigment along ventral surface, rather than both dorsal and ventral surface, or dorsal surface alone as in *Notemigonus crysoleucas,* JJL.)

JUVENILES

Pigmentation: Size range unknown. Upper and lower lips clearly outlined (JJL). Deep lying pigment in a narrow band along anal fin base.[9] Addition of many scattered melanophores broadening the lateral body stripe anteriorly occurs by 14 mm TL; these additions completed posteriorly by 18 mm TL (JJL). Individuals below 25 mm with two heavy lines of melanophores along under surface of caudal peduncle.[9] Specimen 35.6 mm TL essentially adult-like.[14]

AGE AND SIZE AT MATURITY

No information.

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Notropis analostanus (Girard), Satinfin shiner

ADULTS

D. 8; A. 7–10 (usually 9); P. 11–17; scales in lateral line 32–38 (usually 35–37, mode 36); predorsal circumferential scales above lateral line 11–15; teeth 1,4–4,1.[5]

Body depth 22–30% SL (usually 24–27%); length of orbit 6–8% SL.[6]

Head triangular; snout rather sharp; mouth terminal or subterminal; end of jaw to about anterior level of orbit.

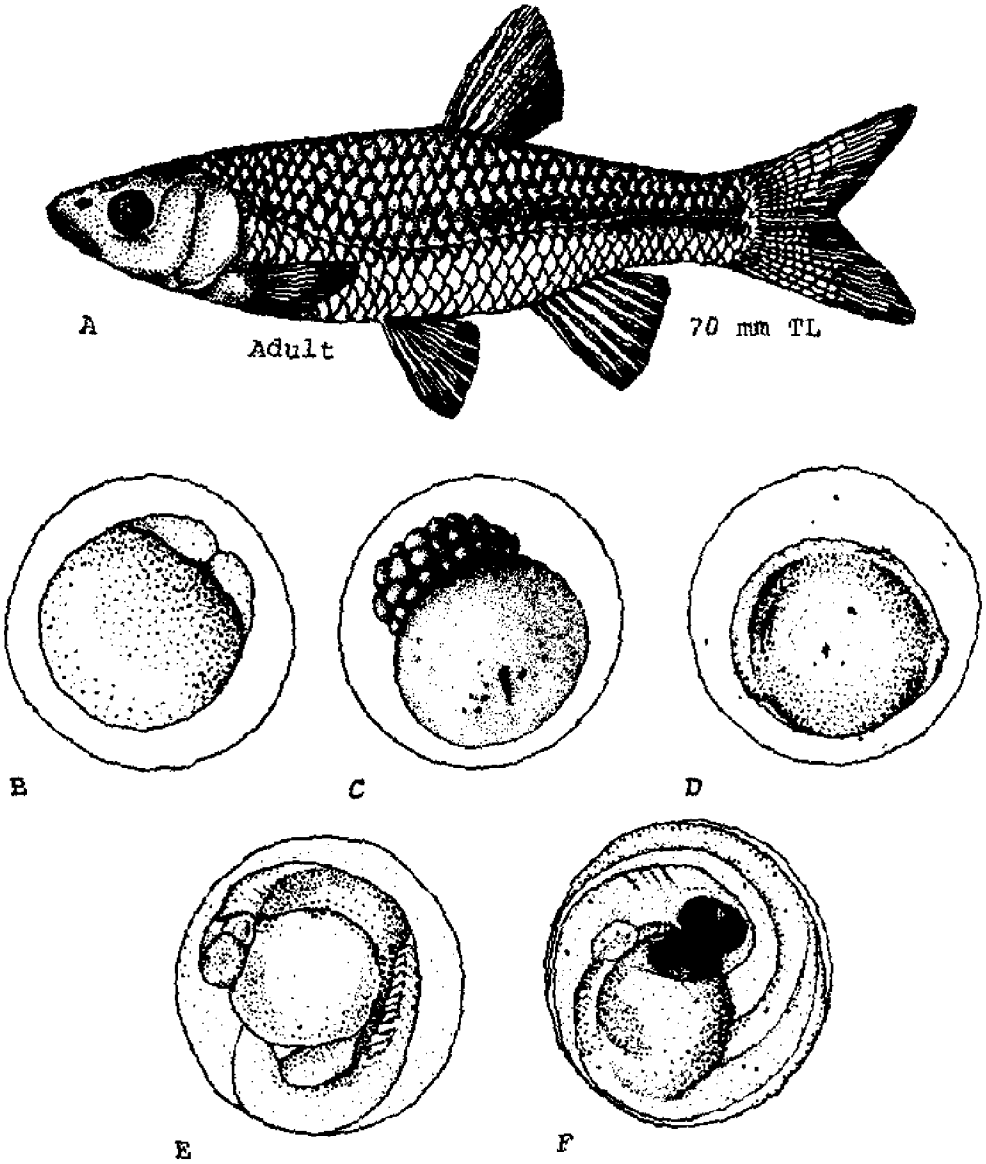

Fig. 153. *Notropis analostanus*, Satinfin shiner. A. Adult, 70 mm TL, 55 mm SL. B. Egg, 2-cell stage, 1 1/4 hours. This and all following eggs developed at ca. 20 C. C. Egg, morula, 4 1/2 hours. D. Egg, early embryo, 23 hours. E. Egg, tail-free embryo, 44 hours. F. Embryo, 116 hours. Eyes darkly pigmented. (A, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 65. B-F, Stone, U. B., 1940: pls. 5, 6.)

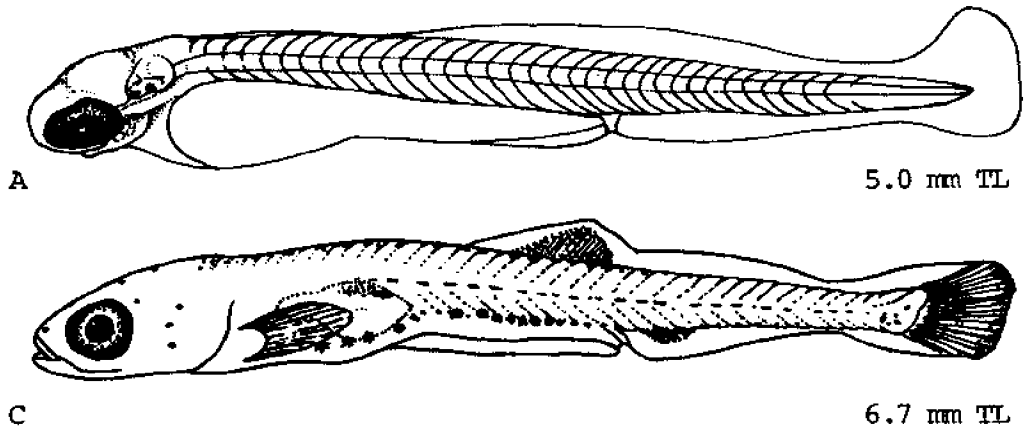

Fig. 154. *Notropis analostanus*, Satinfin shiner. A. Yolk-sac larva, 5.0 mm TL, 4.75 mm NL, newly hatched. Preanal myomeres 20; postanal myomeres 12+. B. Larva, 6.7 mm TL, 5.8 mm SL. (*A, Stone, U. B., 1940: pl. 6, redrawn by Elizabeth Ray Peters. B, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 66B, after Stone, U. B., 1940.*)

Body usually deep. Lateral line slightly decurved from posterior margin of opercle to below middle of dorsal. Breeding males with scattered medium-sized tubercles on top of head, snout, between eye and snout, and on rays of all fins. Scales large, appearing diamond-shaped.[5]

Pigmentation: Silvery blue above;[11] lateral band dark on posterior half of body, light anteriorly; a dark mid-dorsal stripe; belly immaculate; top of head and side of snout plumbeous; both lips pigmented;[5] dorsal at least moderately pigmented on all interradial membranes, elongate blotches on last three membranes,[14] pelvics immaculate. Breeding males with iridescent bluish sheen, fins milky, dark pigment near anal base.[5]

Maximum length: Ca. 102 mm.[9]

DISTRIBUTION AND ECOLOGY

Range: Atlantic coastal drainages from Mohawk-Hudson to Santee River, South Carolina; isolated populations in Great Lakes drainage.[5]

Area distribution: Tidal tributaries of Chesapeake Bay in Maryland (RJM) and Virginia;[2] coastal plain of Delaware.[15]

Habitat and movements: Adults—small to large streams; tidal portions of some large rivers; mountain and upper piedmont streams in the Carolinas;[5] also reservoirs.[1] Undertake spawning migrations to shallows.[8] Maximum salinity 2.0 ppt (RJM).

Larvae—yolk-sac larvae mostly at bottom except for sporadic upward movements.[9]

Juveniles—no information.

SPAWNING

Location: Usually in slow moving water ca. 5.0 cm to 46.0 cm deep in shallow lakes and streams with submerged logs, sticks, or roots. Adults in spawning condition observed on riffles, but apparently not spawning there.[8]

Season: May to late August in Maryland.[4,7]

Time: 0600–1730 hours, most vigorous in direct sunlight.[3]

Temperature: 18.3 °–30.0 C.[8]

Fecundity: 409–864.[8]

EGGS

Location: May be deposited singly but usually in clusters of a few to several hundred in crevices or on underside of submerged branches, logs, sticks, stumps, or posts or between rocks and debris on bottom.[4,8,10]

Unfertilized eggs: Ca. 1.0 mm in diameter when "nearly ripe." Micropyle prominent, funnel-shaped.[8]

Fertilized eggs: Mean diameter 1.5 mm when alive, 1.4 mm when preserved. Spherical; pale yellow. Egg capsule very adhesive during water-hardening, minutely papillose under magnification. Yolk somewhat opaque, granular;[12] tiny oil globules dispersed throughout yolk[5] which gives yolk a granular appearance (JJL). Perivitelline space ca. 1/3 egg radius.[12]

EGG DEVELOPMENT

At mean temperatures of 19.8 C–20.4 C:[8]

One hour blastodisc prominent.

1 hour, 15 minutes	2-cell stage.
2 hours, 45 minutes	8-cell stage.
4 hours, 15 minutes	morula.
19 hours, 15 minutes	germ ring.
23 hours	early embryo; brain visible.
116 hours	eyes pigmented.

Incubation: 8–9 days at 20.5 C; 11 or more days at ca. 19.5–20.3 C.[8]

YOLK-SAC LARVAE

Size "just after hatching" 5.0 mm TL; duration of stage 1–1 1/2 days.[8]

Preanal myomeres 20; postanal myomeres 12+.[8]

At 5.0 mm TL, length to vent 3.03 mm; eye diameter 0.36 mm; body depth 6.7 times in SL.[8]

Body quite slender; mouth inferior; eyes large, oval; pectorals evident.[8]

Pigmentation: Lacking except in eyes.[8]

LARVAE

Specimen described 6.7 mm TL.

Length to vent 4.0 mm; eye diameter 0.57 mm. Gas

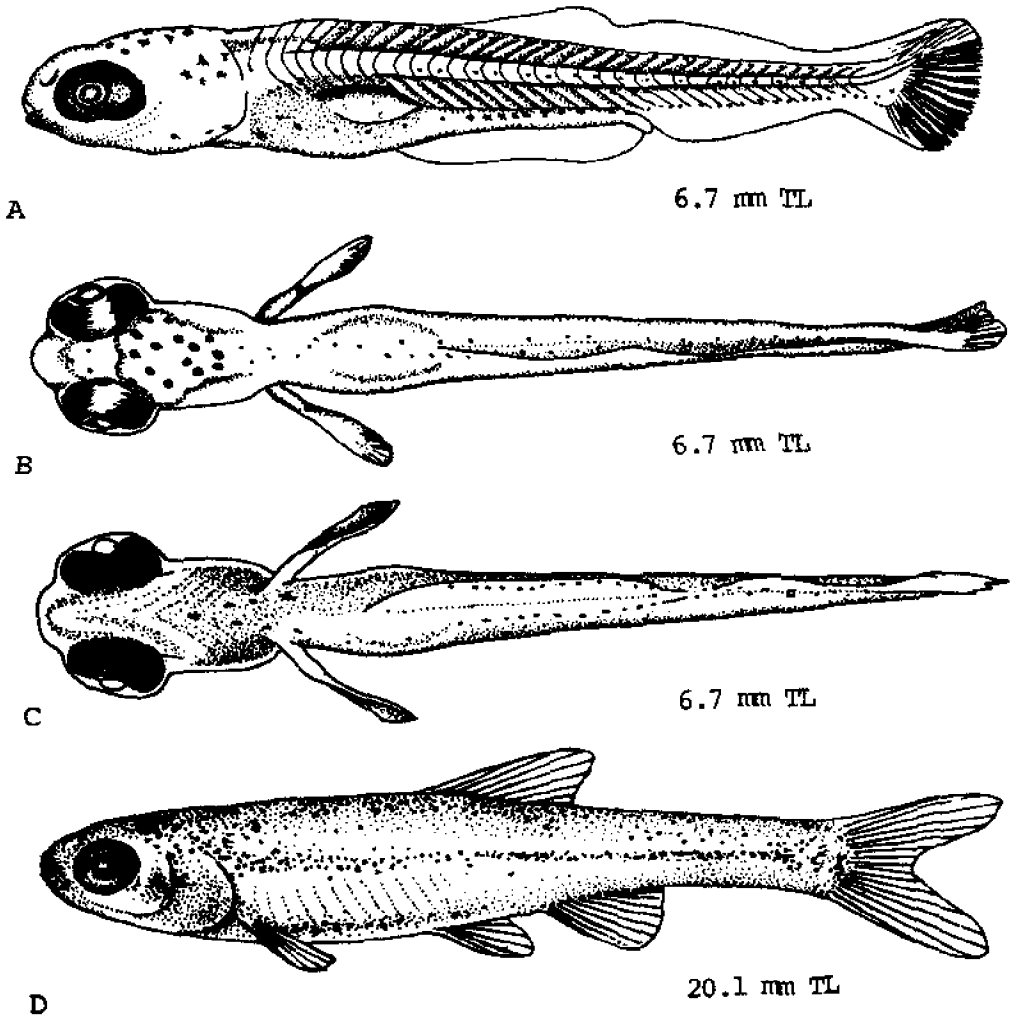

Fig. 155. *Notropis analostanus*, Satinfin shiner. A. Larva, 6.7 mm TL. B. Larva, dorsal view of "A." C. Larva, ventral view of "A." D. Juvenile, 20.1 mm TL, 16.0 mm SL. Scales present. (*A-C, Original drawings by Mary Fuges, courtesy of Jules Loos. D, Stone, U. B., 1940: pl. 8, redrawn by Elizabeth Ray Peters.*)

bladder 2-chambered. In some specimens incipient rays in dorsal and anal; pelvics scarcely evident.[8]

Pigmentation: A double row of melanophores on dorsum, uniting anteriorly behind head and posteriorly just before caudal; a double row ventrally, uniting anteriorly near gills and posteriorly at anal fin; a single row from anal to caudal; a mid-lateral row of elongate melanophores from gas bladder to base of caudal; melanophores on top of head scattered[8] or in prominent V-shaped pattern (in stage prior to formation of second chamber of air bladder);[13] sometimes with elongate melanophores on breast;[12] scattered melanophores on opercle and base of caudal.[8] Urostyle not darkly outlined with melanophores (JJL).

JUVENILES

Specimens described 12.6–20.1 mm TL.

Preanal myomeres 20; postanal myomeres 14. At 12.6 mm, length to vent 7.1 mm; at 20.1 mm, 10.3 mm. Scales present at 20.1 mm.[8] At ca. 24 mm (identity questionable, JDH) body proportionately less deep; eye larger than in adult.[6]

Pigmentation: At 12.6 mm, pigment similar to previous stage but with three irregular mid-dorsal rows of melanophores from head to dorsal origin and with melanophores developed on snout, cheek, and dorsal half of opercle. At 20.1 mm, pigment increased throughout; mid-dorsal band continued to caudal fin; chromatophores of anterior part of lateral stripes stellate, posterior ones round; ventral rows of chromatophores subsurface anterior to anus; a ring of small elongate melanophores around orbit; a dense, triangular blotch of round melanophores on top of head behind eyes; dorsal and caudal with melanophores along rays; first 3 interradial membranes of dorsal with melanophores (diagnostic for species).[8]

AGE AND SIZE AT MATURITY

Mature by 2nd summer; males ca. 53 mm TL, females ca. 47 mm TL.[8]

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Notropis bifrenatus (Cope), Bridle shiner

ADULTS

D. 7–8 [18] (usually 8, JJL); A. 6–8 [17] (usually 7, JJL); P. 11–13; V. 7–8; [18] scales in lateral line 32 [18]–36; [11] predorsal scales 12–13; [1,5,16] body circumferential scales 22–27; caudal peduncle circumferential scales 11–13; [17] vertebrae 34–36; [18] pharyngeal teeth in main row 4–4.[15]

Proportions as times in SL: Body depth 4.0–4.9; HL 3.7–4.25.[13] Proportions expressed as percent TL: Body depth 15–22; head length 20–23. Proportions expressed as percent HL: Eye diameter 31.2–38.8; snout length 26.6–33.3; interorbital width 33.3–44.4.[18]

Body rather slender, compressed; [13] dorsal and ventral outlines about equally curved; dorsal contour of nape slightly concave or nearly straight; snout very bluntly pointed, scarcely or not at all projecting beyond upper lip; [15] mouth small,[18] rather strongly oblique,[15] extending back almost to anterior margin of eye,[18] rising anteriorly to above level from lower margin of pupil.[15] Lateral line somewhat decurved,[11] typically incomplete with exception of James River and lower Delaware drainage populations. Dorsal fin origin over pelvic fin base, usually over anterior portion. Nuptial tubercles sometimes on head and nape of both sexes,[17] but numerous fine tubercles form shagreen on pectoral rays of males only (JJL).

Pigmentation: Greenish brown [11] to silvery above, silvery white below; [18] moderate to intense lateral band,[17] much wider than pupil; a conspicuous, black caudal spot conjoined with lateral band; mid-dorsal streak weak; [15] "bridle" from orbits over lachrymal bones, usually confined to center of upper jaw; [17] fins transparent; [18] upper lip blackish on exposed and concealed parts, except near edge of gape; entire region around anus conspicuously pigmented; [15] peritoneum silvery; [18] breeding males brassy yellow below black lateral band.[9,13]

Maximum length: Ca. 62 mm TL; [5] possibly to ca. 75 mm.[18]

DISTRIBUTION AND ECOLOGY

Range: Maine to Neuse River drainage of North Carolina; [17] also drainages of Lake Champlain, Lake Ontario, and St. Lawrence River.[1,6]

Area distribution: Tidal and brackish tributaries of Chesapeake Bay north to Havre de Grace, Maryland; [11,12] coastal plain of Delaware.[19]

Habitat and movements: Adults—shallow portions of ponds, lakes, streams and rivers in still or slowly flowing water over mud, silt or detritus in areas of moderate to abundant vegetation; [3,8] also along beaches in open, tidal rivers (RJM). Maximum recorded salinity 11.8 ppt.[2]

Yolk-sac larvae—lie on sides at bottom.[3]

Larvae—initially associated with beds of *Myriophyllum;* ability of larvae to hang from plants [7] indicates presence of cement glands (JJL); later also found in small schools in shallow, open water over barren bottom.[7]

Juveniles—no information.

SPAWNING

Location: Typically among aquatic vegetation in still, frequently turbid, water about 0.6 m deep and ca. 3–10 m from shore; over relatively barren areas by end of spawning season.[4,7,9]

Season: May to early August, depending on locality; [4,7,9] experimentally induced preseasonally by lengthened photoperiod.[10,13,14]

Time: 0430 to 1600 hours, with strongest activity between 0700 and 1400 hours.[7]

Temperature: 14.4–26.7 C.[7]

Fecundity: 1062–2110 in specimens 34.0–44.0 mm long, with number increasing with size; possibly not all developing to maturity during one season.[4]

EGGS

Location: Demersal,[3] possibly falling to bottom through aquatic vegetation.[7]

Unfertilized eggs: Adhesive; perfectly spherical; micropyle single; egg proper white, future perivitelline space pearly gray.[3]

Fertilized eggs: Become nonadhesive; [7] pale golden; translucent; diameter 1.5 mm; perivitelline space ca. 1/3 egg radius; oil globules lacking.[3]

EGG DEVELOPMENT

At mean temperature of 23.9 C:

17 minutes	outline somewhat asymmetrical; germinal disc prominent; pale yellow; moderately opaque.
1 hour, 10 minutes	first cleavage.
1 hour, 14 minutes	second cleavage.

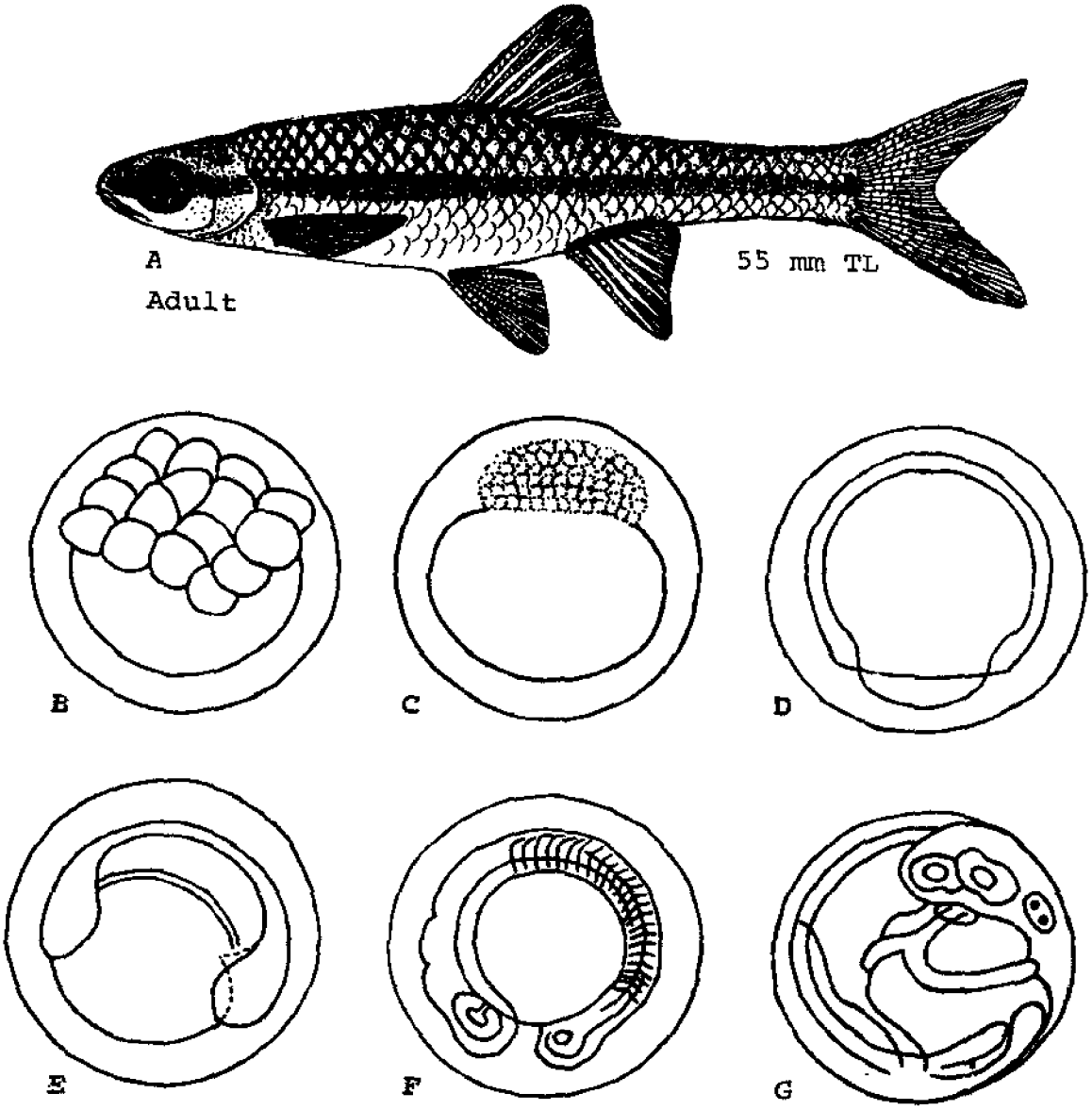

Fig. 156. *Notropis bifrenatus*, Bridle shiner. A. Adult, 55 mm TL, 43.5 mm SL. B. Egg, 16-cell stage, 2 hours and 13 minutes. This and all following eggs 1.5 mm, developing at ca. 24 C. C. Egg, morula, 3 hours and 35 minutes. D. Egg, late gastrula, 9 hours and 40 minutes. E. Egg, embryonic axis established, 15 hours and 40 minutes. F. Egg, early embryo, 23 hours and 10 minutes. Optic vesicles, Kupffer's vesicle, and some somites developed. G. Egg, near hatching, 56 hours and 25 minutes. Vascular network over surface of yolk. (*A, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 67A. B-G, Harrington, R. W., Jr., 1947a: fig. 1.*)

1 hour, 42 minutes	third cleavage.
2 hours, 13 minutes	fourth cleavage.
8 hours, 20 minutes	blastoderm extends to equator of yolk.
12 hours, 10 minutes	yolk completely invested with blastoderm.
15 hours, 40 minutes	embryo evident; keel of epiblast and shallow medullary groove present.
23 hours, 10 minutes	optic invaginations, Kupffer's vesicle, notochord, somites formed or forming.
28 hours, 15 minutes	tail free; yolk mass reduced; otoliths present; heartbeat established.

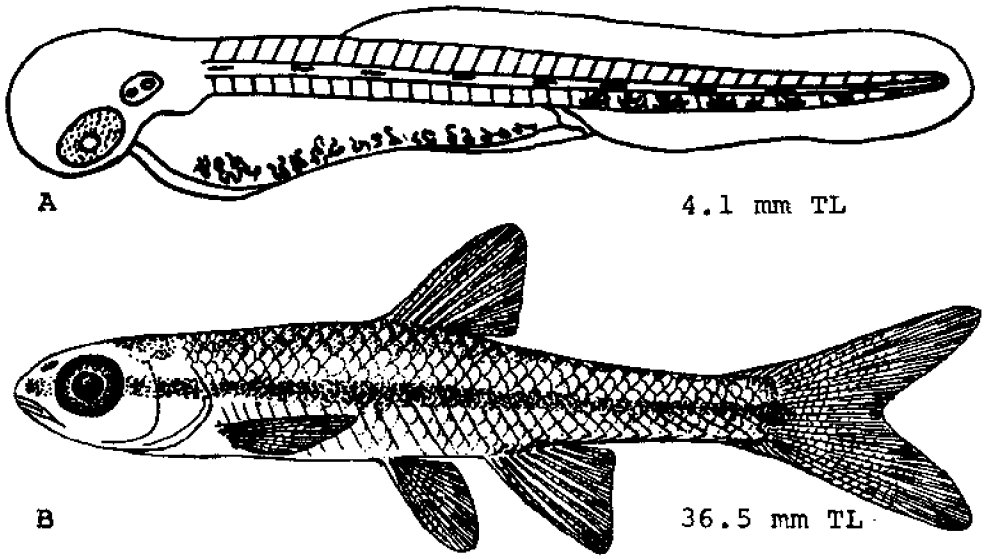

Fig. 157. *Notropis bifrenatus*, Bridle shiner. A. Yolk-sac larva, 4.1 mm TL, newly hatched. B. Juvenile, 36.5 mm TL, 28 mm SL. Total myomeres 32; preanal myomeres 17; postanal myomeres 15. (*A, Harrington, R. W., Jr., 1947: fig. 1. B, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 67D.*)

32 hours, 20 minutes	eyes partially pigmented; lens formed; tail extended beyond auditory vesicles.[3]

Incubation: 57–71 hours.[3]

YOLK-SAC LARVAE

Hatching length 4.1 mm TL. Duration of stage apparently ca. 2–3 days.[3]

Body elongate; head not sharply deflected over yolk; yolk mass elongate, proportionately small at hatching, inconspicuous by second day. Gills apparently developed by second day. A single, anterior, oval-shaped gas bladder by third day. Finfold initially broad, originating ca. 1/3 TL from anterior end. Pectoral buds minute or absent at hatching; pectorals forming at 8 hours, conspicuous at two days. Notochord straight; reticulate.[3]

Pigmentation: At hatching, eye pigmented; body transparent; melanophores along sides, over lower part of yolk sac and ventrally from anus to tail; at eight hours, a slight golden tinge; at 3 days, small chromatophores on head and dorsum.[3]

LARVAE

Size range described 7.0–13.0 mm TL (6.4–10.0 mm SL); age 9–28 days.[3]

At ca. 7.0 mm, gas bladder 2-chambered; urostyle oblique; incipient rays in caudal; pelvic fin buds evident at ca. 10.5 mm.[3]

Pigmentation: Initially, black slender lateral band present. At ca. 10.5 mm, lateral band broad; caudal spot proportionately larger than in juveniles and adults.[3]

JUVENILES

Minimum size described 10.2 mm TL; age 43 days.[3]

At 36.5 mm, myomeres still visible; preanal myomeres 17, postanal myomeres 15 (AJL).

Caudal peduncle longer, more slender in "young";[11] dorsal and ventral outlines less curved; head and eye larger than in adult; lateral line not evident (AJL).

Pigmentation: Caudal spot larger than in adult; dorsal pigmentation light, extending halfway to lateral band (AJL). "Young" pale straw above.[7]

AGE AND SIZE AT MATURITY

Majority of males during 2nd summer, some females during 3rd summer;[4] specimens of unstated sex within 6 months of hatching.[13] Minimum size of males ca. 25.0 mm SL, females ca. 31.0 mm SL[3] (a 25 mm specimen contained 270 small eggs having some yolk, but was considered to be immature[4]).

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Notropis chalybaeus (Cope), Ironcolor shiner

ADULTS

D. 7–8 [11] (usually 8 [12]); A. 7–9 [7] (usually 8 [12]); lateral line scales 32 [4]–42 [11] (usually 33–34, posterior one to ten lateral line scales often unpored [12]), scales above lateral line 7–9, below 4–5, lateral line scales before dorsal 11–16; [11] vertebrae 33–37, mode 35; [12] pharyngeal teeth 2,4–4,2.[11]

Proportions as percent SL at 40–50 mm SL: Greatest depth 21–23; length to vent ca. 60.0–67.4; greatest diameter of eye 8.3–9.7.[1]

Mouth moderately oblique; lower jaw included; snout rather blunt.[3] Lateral line usually incomplete,[7] decurved,[10] and with more than 10 unpored scales. Breeding males with nuptial tubercles well-developed only on lower jaw and upper surface of pectorals,[7] where they

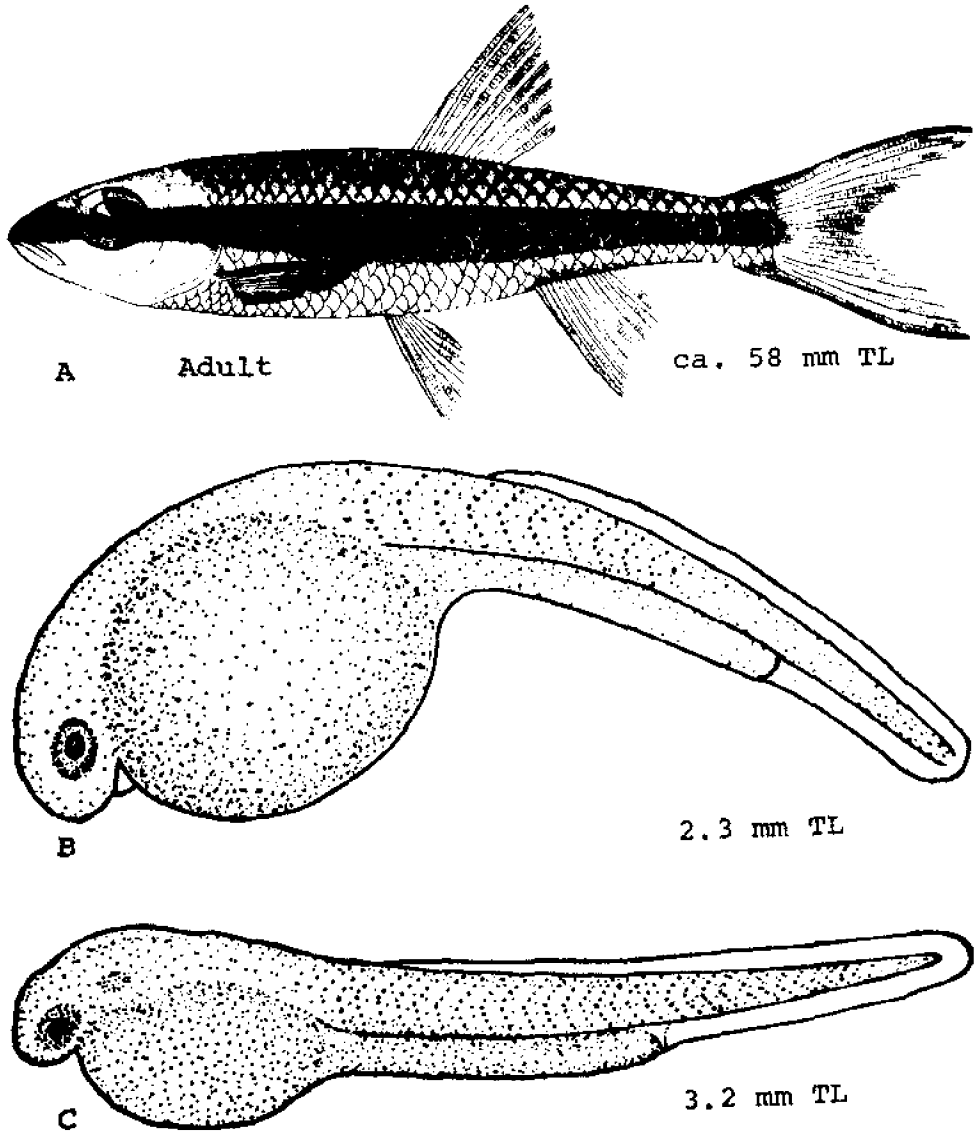

Fig. 158. *Notropis chalybaeus*, Ironcolor shiner. A. Adult, ca. 58 mm TL. B. Yolk-sac larva, 2.3 mm TL, 2.25 mm SL, newly hatched. C. Yolk-sac larva, 3.2 mm TL, 3.1 mm SL, one day. (A, *Fowler, H. W., 1906: 147*. B, C, *Marshall, N., 1947: fig. 3.*)

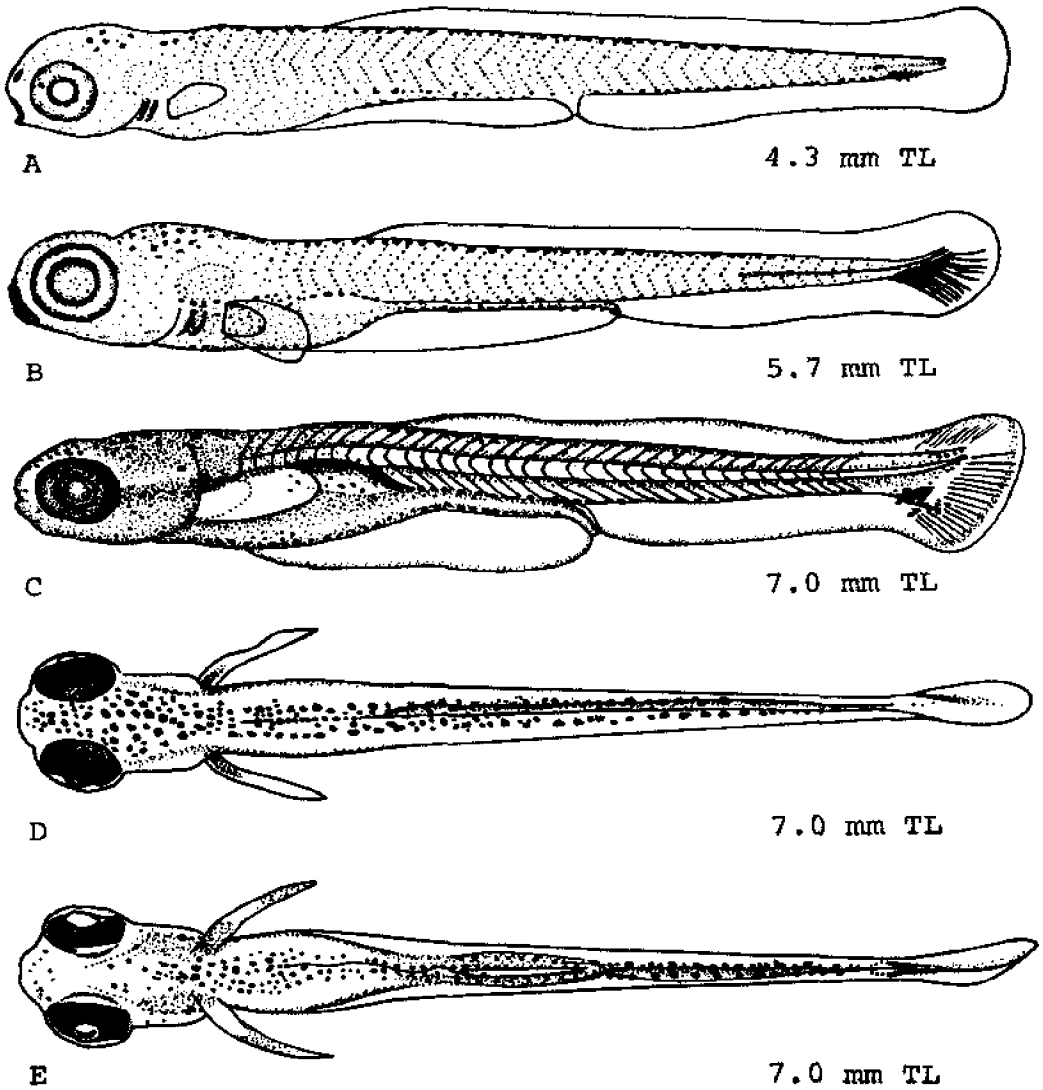

Fig. 159. *Notropis chalybaeus*, Ironcolor shiner. A. Larva, 4.3 mm TL, 4.1 mm SL, 5 days. B. Larva, 5.7 mm TL, 5.4 mm SL, 19 days. C. Larva, 7.0 mm TL. Pigment spot on lower portion of caudal fin. D. Dorsal view of "C." E. Ventral view of "C." (*A, B, Marshall, N., 1947: figs. 3, 4. C-E, Original drawings by Mary Fuges, courtesy of Jules Loos.*)

form a dense shagreen of fine tubercles consisting of 2 to 5 close-set longitudinal rows on upper surface of rays.[12]

Pigmentation: Dark above, pale yellow below; a broad, lustrous black, lateral band from snout to caudal base;[10] basicaudal spot scarcely or not at all wider and not darker than stripe on peduncle. Oral valves, floor and roof of mouth heavily pigmented.[7] Breeding males orange in dark water, rosy in clear water,[1] chromatic colors of breeding females much more subdued.[12]

Maximum size: 51 mm SL;[7] seldom exceeds 45 mm.[12]

DISTRIBUTION AND ECOLOGY

Range: *Atlantic coastal plain from Delaware* River to central Florida and Texas; up Mississippi Valley into Illinois, Indiana, and Michigan.[3,9]

Area distribution: Reported from tidal fresh and slightly brackish water in Potomac River drainage, Maryland (FJS); also coastal plains of southern Maryland and Delaware.[13]

Habitat and movements: Adults—lakes[8,11] and slow,

weedy streams in marshy or swampy areas of coastal plain;[5] along edges of swift, deep rivers;[1] associated with sphagnum banks;[2] usually found over sandy bottom[1,8] in areas of abundant aquatic vegetation.[9] Maximum salinity apparently between 0.04 and 0.7 ppt in Florida.[7]

Larvae—gregarious, frequently at surface in spawning area.[1]

Juveniles—no information.

SPAWNING

Area: Sand-bottomed pools.[1]

Season: Early or mid-April to late September in Florida; probably somewhat shorter in northern localities.[1]

Time: Throughout daylight hours at times of low, quiet water.[1]

Fecundity: Ca. 50 eggs recorded from a single stripping.[1]

EGGS

Location: Broadcast at random; demersal; adhesive shortly after deposition, becoming attached to sand grains and similar materials.[1]

Freshly stripped eggs: Diameter 0.8–0.9 mm; originally yellow, becoming pale cream.[1]

EGG DEVELOPMENT

At air temperatures varying from 7.8 to 25.0 C (mean ca. 16.7 C):

Few minutes after fertilization	blastodisc contracted and forming white dome above yolk.
Ca. 1 hour, 30 minutes	4-cell stage.
Ca. 2 hours, 30 minutes	early morula; blastoderm a gray cap on top of lighter colored yolk.[1]

Incubation: 52–56 hours at mean temperature of ca. 16.7 C.[1]

YOLK-SAC LARVAE

Hatching length ca. 2.3 mm TL; length at end of stage ca. 4.0 mm.

Proportions as percent SL: Greatest depth 36.0 at 2.3 mm to 15.0 at 3.7 mm; length to vent 81.0 at 2.3 mm to 62.0 at 3.7 mm; eye diameter 5.0–8.0 throughout stage.[1]

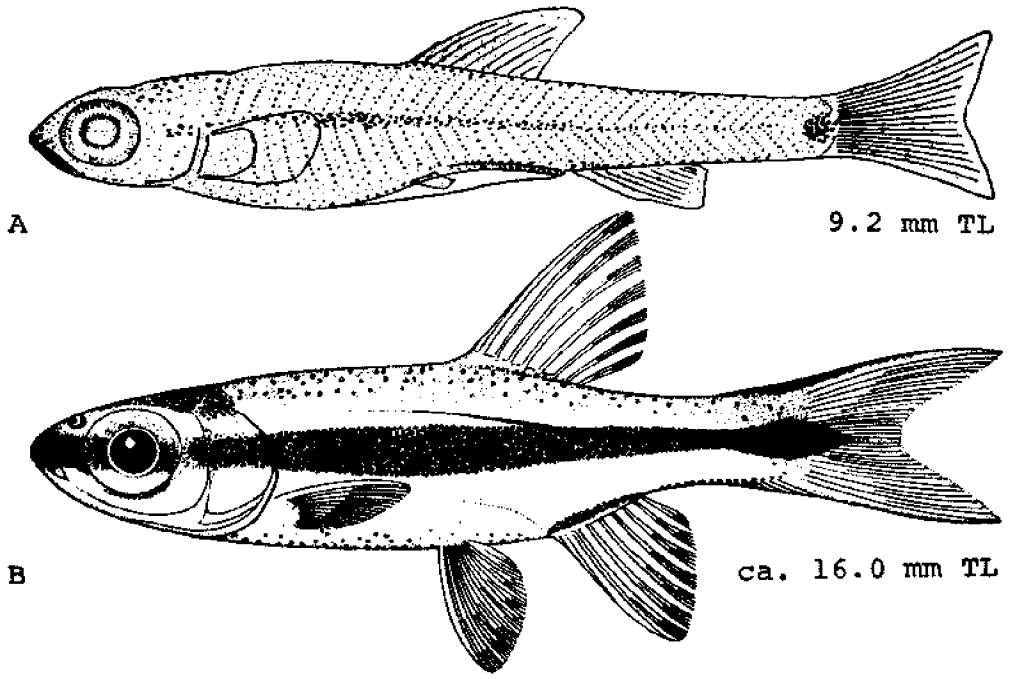

Fig. 160. *Notropis chalybaeus*, Ironcolor shiner. A. Larva, 9.2 mm TL, 7.4 mm SL, 47 days. Pelvic buds present; preanal finfold retained. B. Juvenile, ca. 16.0 mm TL. (*A, Marshall, N., 1947: fig. 4. B, Fowler, H. W., 1945: fig. 96.*)

Myomeres indistinct; few, if any, added after hatching. Dorsal outline arcuate at hatching. Head sharply deflected initially, less so at 3.2 mm. Yolk large, spherical at hatching; more than 1/2 reduced at 1 day; further reduced and cylindrical at 3 days (3.9 mm). Eyes poorly developed at hatching, and remaining so at 3.2 mm. Pectoral buds evident at 3.9 mm.[1]

Pigmentation: At 3.9 mm, melanophores present in mid-dorsal and posterior ventral regions; eye very slightly pigmented.[1]

LARVAE

Specimens described 4.3–9.2 mm TL. Duration of stage *ca. 42 days.*

Proportions as percent SL: Greatest depth 10.0–20.0; length to vent 60.0–68.0; eye diameter ca. 6.0–11.0; HL ca. 16.0–25.0.[1]

Body noticeably more elongate at 4.6 mm; mouth functional, gills and gas bladder visible at 4.3 mm. Caudal rays first evident at 5.7 mm, fin bifurcate at 9.2 mm. Dorsal and anal forming at 7.0 mm and with rays at 9.2 mm; pelvic buds visible at 9.2 mm. Finfold very slightly constricted in caudal region at 4.3 mm. Urostyle turned obliquely upward at 5.7 mm, concealed at 6.2 mm.[1]

Pigmentation: At 4.3 mm, melanophores along almost entire dorsal and ventral surfaces of body; at 5.7 mm, additional large blotch of melanophores over dorsal surface of head; at 6.2 mm, caudal spot developing[1] and solid bands of dorsal and ventral body melanophores not divided into rows (JJL); at 9.2 mm, a line of melanophores on mid-lateral surface from head to caudal spot.[1]

JUVENILES

Specimens described 14.8[1]–16.0 mm TL.[6]

Proportions expressed as percent SL: Greatest depth *19.0; length to vent 63.0; diameter of eye 11.0.*[1]

Pigmentation: At 14.8 mm, pigmentation essentially same as at 9.2 mm;[1] at ca. 16.0 mm, lateral stripe extended to caudal fin; a dense patch of chromatophores along dorsum and venter, concentrated from origin of anal to caudal base and along dorsal margin of caudal fin.[6]

AGE AND SIZE AT MATURITY

No information.

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Notropis hudsonius (Clinton), Spottail shiner

ADULTS

D. 7–9 [23] (usually 8 [24]); A. 7–9 (usually 8); [23] P. 12–17 (usually 13–15); [24] V. 7–10 [23] (usually 8 [24]); lateral line scales 33 [23]–42,[24] predorsal scales 11 [23]–23,[18] scales around body above lateral line 11–14, below 11–17; caudal peduncle scales around body above lateral line 5–7, below 5–6; vertebrae 35–40 (including urostylar vertebra) (usually 37–38), precaudal vertebrae 16–20 (usually 18–19), caudal vertebrae 17–21 (usually 18–20); gill rakers on upper arm 1–3, lower 4–8; [23] pharyngeal teeth 2,4–4,2 or combinations to 0,4–4,0; [8] branchiostegals 3 + 3.[25]

Proportions as times in SL: Body depth 3.6–5.8; [3] head length 3.7 [18]–4.8.[3] Proportions expressed as percent TL: Greatest depth 15.6–23.2; HL 17.4–21.4. Proportions expressed as percent HL: Eye diameter 25–40; snout length 25–35.[24] Proportions expressed as percent of standard length: Predorsal length 38.5–59.4; preanal length 61.5–73.1; prepelvic length 44.0–52.6; body depth 18.3–29.8; head length 20.5–26.7; eye diameter 5.8–9.1; dorsal base 11.3–17.0; anal base 8.1–13.2.[23]

Body rather slender,[3] to stout,[24] compressed; [3] head bluntly triangular; snout rounded, overhanging mouth; [24] mouth small,[25] slightly to moderately oblique; [13,25] front of upper lip on level with bottom of pupil.[13] Lateral line complete,[3] straight posteriorly, decurved anteriorly.[23] Dorsal fin origin over or slightly anterior to pelvic origin; [25] pectoral fins not reaching pelvic insertion, pelvics not reaching anal origin. Tiny breeding tubercles present on both sexes, widely distributed over entire body.[23]

Pigmentation: Overall coloration silvery and pale [23] with yellow or golden overtones in some areas.[24] Greenish above, sides silvery, venter pale; [3,16] silvery lateral band about as wide as a single scale, overlying dark pigment which if visible is best developed posteriorly; black caudal spot variable in size and intensity,[23] normally obscured by silvery scale pigmentation in live specimens from study area (JJL), usually separated from lateral band. Dark mid-dorsal stripe from nape to caudal peduncle; pigment on first two scale rows below lateral line. Top of head fully pigmented, ventral surface occasionally with pigment on lower jaw; upper jaw pig-

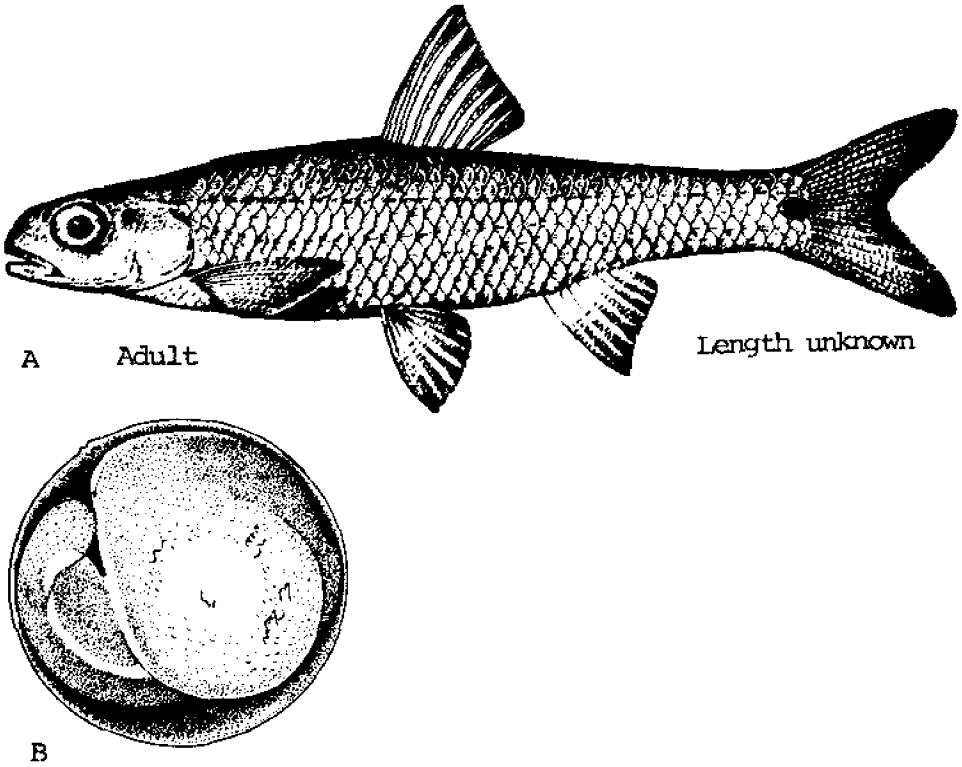

Fig. 161. *Notropis hudsonius*, Spottail shiner. A. Adult, length unknown. B. Egg, tail-free embryo, diameter 1.3 mm. (*A, Truitt, R. V., B. A. Bean, and H. W. Fowler, 1929: 40. B, Original drawing by Mary Fuges, courtesy of Jules Loos.*)

mented; iris silvery, pupil black.[23] Fins pale, translucent; [3,16] black pigment on rays of all fins except pelvic; [23] white ventral edge on caudal fin; [25] pigment frequently at anal base; peritoneum silvery with some black flecks.[23]

Maximum size: Ca. 147 mm,[8] but possibly reaching ca. 152 mm.[19]

DISTRIBUTION AND ECOLOGY

Range: Quebec south along Atlantic coast to Georgia, west across northern United States and southern Canada to the Mackenzie River system in the Northwest Territories.[25]

Area distribution: Tidal tributaries of Chesapeake Bay; [3] Delaware River Estuary; [27] and New Jersey.[28]

Habitat and movements: Adults—usually large rivers, lakes and reservoirs, in clear, sandy or rocky shallows; [8,9] attaining greatest abundance in clear water; at southern portion of range in cooler upland waters; [23] found in areas of moderate to large amounts of submergent vegetation; [6] essentially bottom fish but sometimes taken in midwater trawls at night; [21] inhabiting deeper waters in daytime, moving inshore at night; [25] maximum salinity 10.7 ppt; [2] maximum depth 46 m.[22]

Larvae—no information.

Juveniles—"young" frequently in schools in shallow water with abundant vegetation.[9]

SPAWNING

Location: Gravel riffles [10] that may be near mouths of brooks,[4,5] and sandy shoals,[17] along shores of large lakes,[1] at water depths from near shore to 9 m; in patches of *Cladophora*.[21] Recorded as spawning in schools [21] and possibly in small groups.[26,27]

Season: April [10] (ECR) to late August or early September,[21] possibly delayed in years of high water level during late spring.[11]

Time: Observed at dusk.[4]

Temperature: Ripe specimens observed in probable spawning areas at 11.5 C [27]–ca. 18.3 C; [5] definitely identified eggs (reared) found at 20 C (JJL).

Fecundity: 100 [7]–8898.[21]

EGGS

Location: Demersal, scattered over clean sand or gravel in lakes and rivers,[4,15,17] also reported as occurring in clusters on bottom, and in algal masses.[26]

Ripe ovarian eggs: Average diameter 0.76 mm.[7]

Fertilized eggs: Diameter ca. 1.0 mm to ca. 1.4 mm (JJL).

EGG DEVELOPMENT

Late embryo with light pigment on dorsum, ventral yolk and tail, eye unpigmented.[26]

YOLK-SAC LARVAE

Note: *Putative early description by Fish* [1] *based on incorrect identification (JJL).*

Specimens described: 4.7–5.3 mm TL.

Preanal myomeres 24; postanal myomeres 14 (JJL).

Yolk mass elongate, without large oil globule. Head relatively blunt, not deflected; mouth moderate, inferior; lower jaw included. Eye large; interorbital space wide; notochord straight; pectorals are evident; cement glands are absent (JJL).

Pigmentation: In newly hatched, eye pigmentation pale or absent; [26] but it darkens quickly after hatching. Single band of ventral body melanophores; on the yolk this band is comprised of numerous scattered melanophores (JJL).

LARVAE

Specimens described 8–9 mm [26] and 14.25 mm TL.[1]

At 14.25 mm TL, D. 8; A. 9; preanal myomeres 23–24; postanal myomeres 14.[1]

At 14.25 mm TL body moderately elongate; head conical; snout blunt; mouth small, nearly horizontal; lower jaw slightly shorter than upper. Gas bladder two-chambered. Pelvics beneath dorsal origin; caudal fin forked. Urostyle oblique.[1]

Pigmentation: By 8–9 mm double row of melanophores along mid-dorsal line forming patch over head; one row along horizontal myoseptum; in series along ventral body myomeres concentrated over air bladder, extending to caudal region; scattered pigmentation along mid-ventral surface between isthmus and vent.[26] At 14.25 mm chromatophores on opercle, beneath lower jaw [1] (but tip of lower jaw lacks pigment, JJL), internally over gas bladder, in 3 rows along dorsum, in surface and subsurface series along future lateral line, in double series posterior to anus, and on dorsal and caudal fins. A prominent black spot on caudal base.[1]

JUVENILES

Minimum size described 18.0 mm TL.[7]

At 19.0 mm, preanal myomeres 22; postanal myomeres

18.[1] At ca. 27–30 mm, eye large; lateral line incomplete (AJL). Scales developing at 18–20 mm;[7,14] not fully formed in some specimens at ca. 24 mm;[12] fully formed in specimens 27.5 mm (AJL). In "young" origin of anal fin equidistant from caudal base to pectoral base, less than eye diameter behind end of dorsal base; pelvics reaching to or a little beyond anal origin.[3]

Pigmentation: At 19.0 mm, head sparsely pigmented; 3 rows of chromatophores along dorsum to caudal; subsurface chromatophores along entire lateral line ending at caudal spot; small irregular chromatophores in dorsolateral region with few below lateral line.[1] At ca. 24.0–30.0 mm, lateral band and caudal spot well-developed; dorsal scales with pigmented edges; pigment ventrally from anal origin to caudal base[12] (AJL).

AGE AND SIZE AT MATURITY

Some females by 1 year;[7] minimum size ca. 59 mm.[21]

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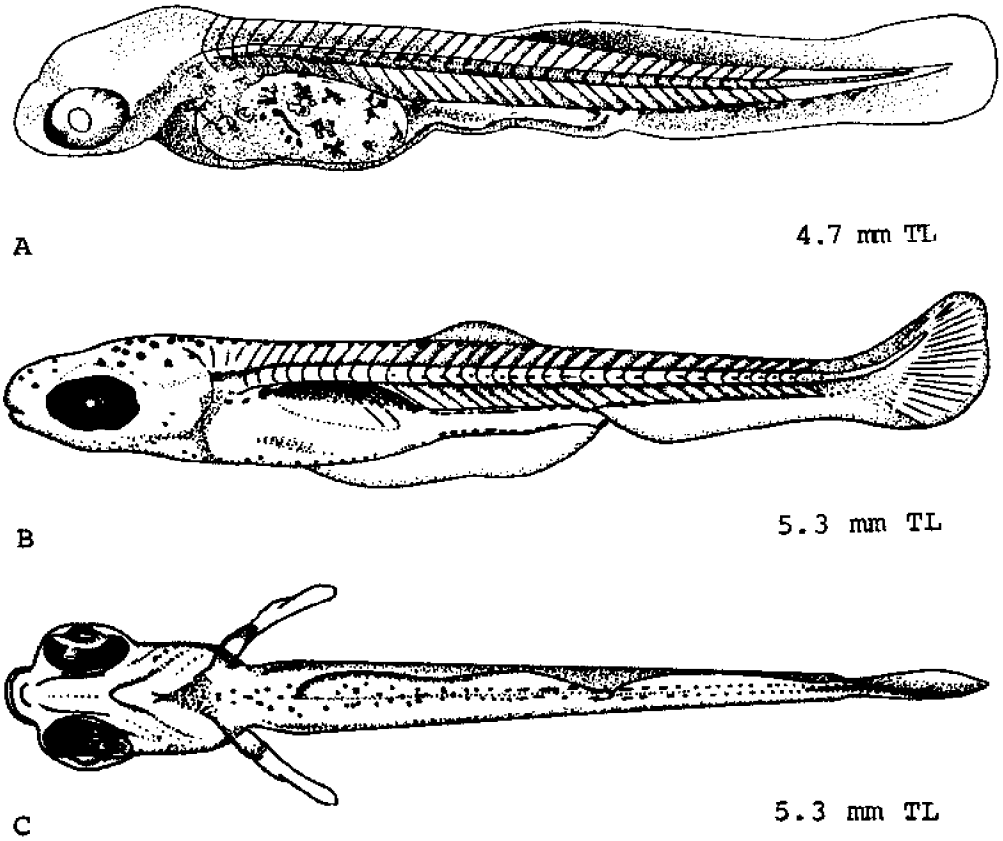

Fig. 162. *Notropis hudsonius*, Spottail shiner. A. Yolk-sac larva, 4.7 mm TL, newly hatched, eye pigmentation pale; preanal myomeres 24, postanal myomeres 14. B. Yolk-sac larva, 5.3 mm TL; eye darkly pigmented. C. Ventral view of "B." (*A-C, Original drawing by Mary Fuges, courtesy of Jules Loos.*)

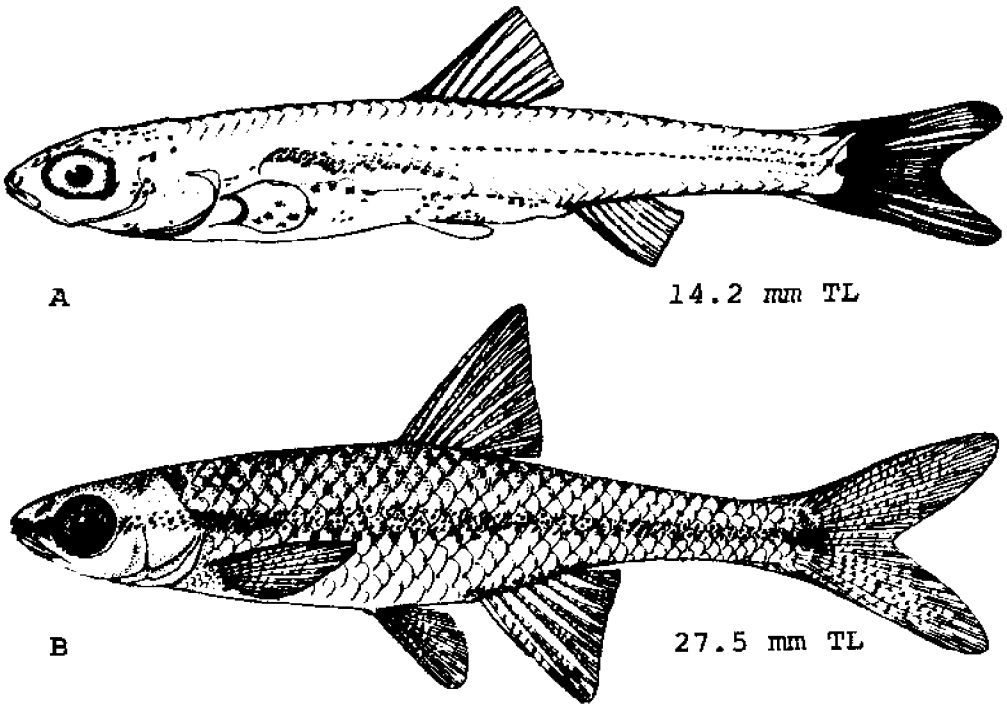

Fig. 163. *Notropis hudsonius*, Spottail shiner. A. Larva, 14.2 mm TL, 11.5 mm SL. Preanal myomeres 21 (22); postanal myomeres 16. B. Juvenile, 27.5 mm TL, 22.0 mm SL. (*A, Fish, M. P., 1932: fig. 40. B, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 70.*)

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ADDITIONAL REFERENCE

Shapiro, S. M., 1975.

Semotilus corporalis (Mitchill), Fallfish

ADULTS

D. 8;[12] A. 7–9 (usually 8); P. 16–18; V. 8–9 (usually 8); lateral line scales 43[16]–50;[17] predorsal scales 18[12]–23;[17] vertebrae 42–44; pharyngeal teeth usually 2,5–4,2.[16]

Proportions expressed as percent TL: Greatest depth 17.0–21.1; head length 20.1–23.7. Proportions expressed as percent HL: Eye diameter 17.3–29.4; snout length 28.5–40.5; interorbital width 32.0–41.1.[16]

Body oblong, robust, weakly compressed; head large, convex; snout bluntly conic,[6] projecting beyond upper lip.[16] Mouth large,[6] slightly subterminal, lower lip included;[16] small barbel near corner of mouth,[6] usually apparent on large adults;[16] maxillary barely reaching front of orbit.[6] Dorsal fin origin directly, or nearly so over pelvic origin.[16] Breeding males with tuberculated scales on caudal peduncle forward to anal fin.[8]

Pigmentation: Olive brown to black, becoming silvery on sides and white ventrally; dark crescent-shaped or triangular bars at base of each scale along sides;[13] dorsal and caudal fins dusky, other fins plain;[9] peritoneum silvery;[16] breeding males with belly and lower fins rosy or crimson.[6]

Maximum length: Ca. 508 mm.[18]

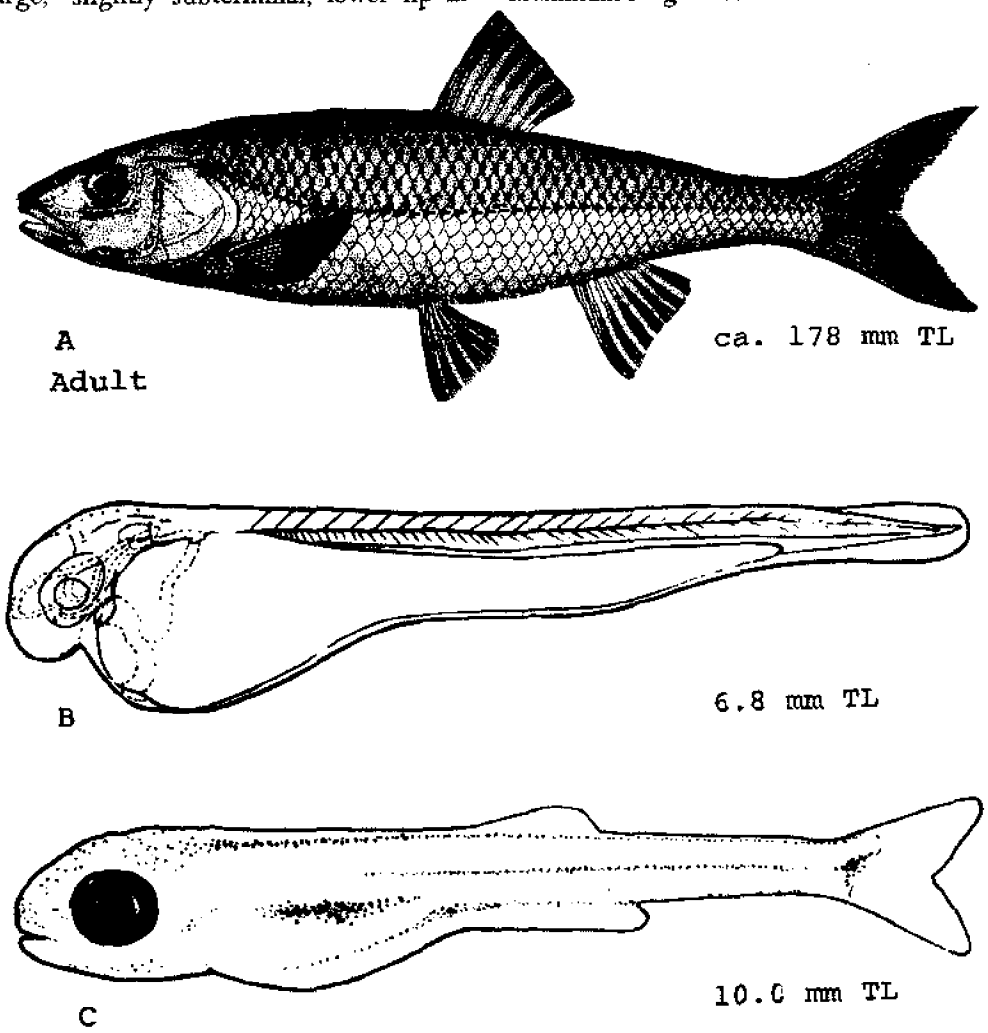

Fig. 164. *Semotilus corporalis*, Fallfish. A. Adult, ca. 178 mm TL. B. Yolk-sac larva, 6.8 mm TL. Chromatophores scattered on dorsal surface of head, otherwise pigment lacking. C. Larva, 10.0 mm TL. Mouth slightly inferior. (*A, Goode, G. B.*, et al., *1884: pl. 228. B, C, Reed, R. J., 1971: figs. 2A, B.*)

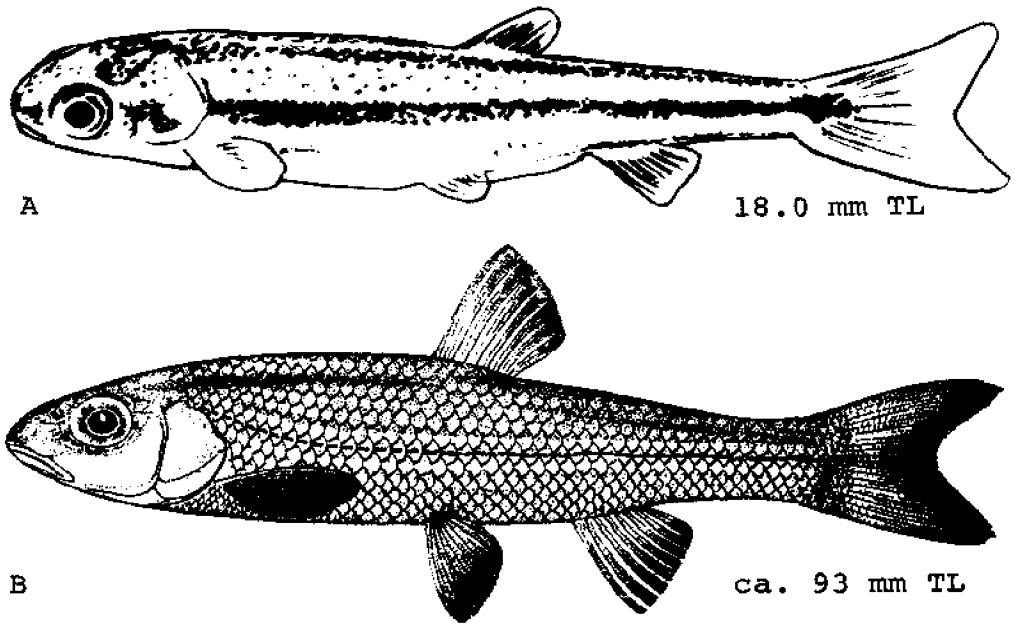

Fig. 165. *Semotilus corporalis*, Fallfish. A. Juvenile, 18.0 mm TL. Mouth terminal, somewhat oblique. B. Juvenile, ca. 93 mm TL. (*A, Reed, R. J., 1971: fig. 2C. B, Fowler, H. W., 1945: fig. 82.*)

DISTRIBUTION AND ECOLOGY

Range: James Bay region, northern St. Lawrence tributaries, Lake Ontario [4] and Lake Superior drainages; [5] south, east of the Appalachians, to Virginia.[4]

Area distribution: Tidal tributaries of lower Chesapeake Bay; [1,2] coastal plains of southern Maryland and Delaware (rare or restricted in latter).[19]

Habitat and movements: Adults—clear streams and lakes, often near waterfalls or rapids, but also abundant in standing water.[14] Frequently in deep water, but also in small schools near shoreline.[8]

Larvae—"fry" apparently remain near nest for short period after hatching.[3]

Juveniles—specimens ca. 25 mm long from pools in small streams and along swampy shores; 50 mm individuals over sand and scattered stone in open spaces among bulrushes, also in small streams; large specimens in 0.9–1.5 m of water.[14]

SPAWNING

Location: In pebble nest built by male [7] in fairly quiet water of pools, riffles [15] or shallow margins of ponds and lakes.[14] Nest sometimes ca. 2 m in diameter and up to ca. 1 m high; [15] if directly influenced by current, characterized by keel-like crest which may lie crosswise or with flow,[8,15] if outside current, perfectly dome-shaped.[8]

Season: As early as May in Maine; [7] April to June in New York; [15] females in spawning condition in early April in Patuxent River, Maryland (RJM).

Temperature: Spawning activity ceases at less than 14.4 C.[8]

Fecundity: 1000 [18]–12,321±1387.[8]

EGGS

Description: Deposited in a "pocket" within nest at level of original stream substrate.[8]

Unfertilized eggs: Nonadhesive; mean diameter 2.16±.09 mm.[8]

Fertilized eggs: Adhesive; mean diameter 2.70±.07 mm.[8]

EGG DEVELOPMENT

At 17.0 C±0.5:

2 hours, 45 minutes	two-cell stage.
3 hours, 30 minutes	four-cell stage.
4 hours	eight-cell stage.
5 hours	sixteen-cell stage.
10 hours	early blastula.
19 hours	late blastula.
25 hours	early gastrula.

31 hours	late gastrula.
42 hours	yolk plug.
45 hours	neurula.
50 hours	optic vesicle.
63 hours	body pigmentation.
70–75 hours	motility.
105–111 hours	retinal pigment.
138–144 hours	hatching.[8]

Incubation: 7–9 days at average temperature of 15.5 C,[7] 5 days, 18 hours to 6 days at 17.0 C.[8]

YOLK-SAC LARVAE

Mean length at hatching 6.82±0.32 mm TL. Duration of stage 5 days at 17 C.

In newly hatched larvae caudal fin undefined; pectoral buds absent;[8] pectoral fin buds form prior to yolk absorption (JJL).

Pigmentation: Light scattering of chromatophores on head.

LARVAE

Size range described 9.0–18.0 mm TL.

At 9.0–10.0 mm mouth functional, somewhat inferior, at 18 mm terminal, oblique. Dorsal fin forming at 9.0–10.0 mm; anal fin forming at 12 mm; anal fin with rays at 14 mm; caudal fin rays present at 9.0–10.0 mm, caudal begins to notch at 12 mm; pectoral fin rays present at 9.0–10.0 mm; pelvic fin buds appear at 14.0. By 18 mm all fins fully developed; scale formation evident. At 9.0–10.0 mm anus functional; two-chambered air bladder present.[8]

Pigmentation: At 9.0–10.0 mm double row of chromatophores along dorsal and ventral surfaces; single lateral row from opercle to caudal; top of head well pigmented. At 12.0 mm general increase of chromatophores; pigmentation more dense between eyes and top of head; lateral row darkened; distinct caudal spot present. At 14.0 mm lateral stripe very dark; caudal spot enlarged; pigment on ventral surface concentrated from origin of anal fin to base of caudal.[8] At ca. 16.5 mm pigment on dorsal surface from upper lip to caudal, more dense on top of head; scattered pigment on operculum, lower lip; row of pigment below eye; fins immaculate.[10] At 18 mm pigmentation of caudal spot, ventral stripe, and dorsal surface continues.[8]

JUVENILES

Size range described ca. 18[8]–ca. 93 mm TL.[10]

At 33.0 mm, scale formation complete.[8] At ca. 93 mm TL eye proportionately larger than in adults.[10]

Pigmentation: Caudal spot fades at 65–75 mm TL.[8]

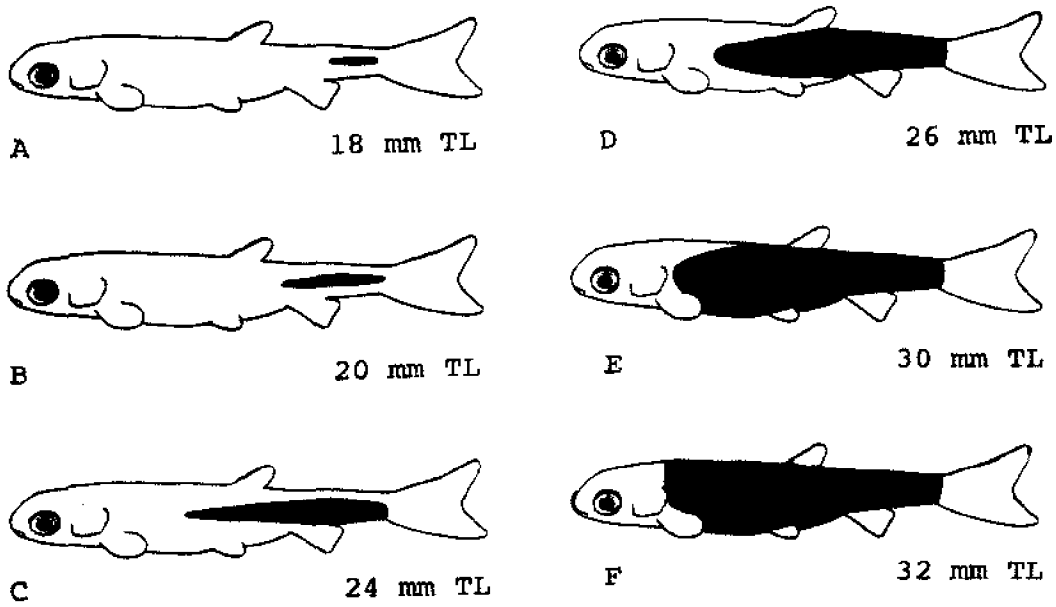

Fig. 166. *Semotilus corporalis*, Fallfish. A-F. Pattern of scale development. A. Juvenile, 18 mm TL. Scale platelets appear as narrow band on caudal peduncle. B. Juvenile, 20 mm TL. C. Juvenile, 24 mm TL. D. Juvenile, 26 mm TL. E. Juvenile, 30 mm TL. F. Juvenile, 32 mm TL. (*A-F, Reed, R. J., 1971: fig.* 3.)

AGE AND SIZE AT MATURITY

Males mature by II+, females IV+.[8] Fowler reports females 75 mm long with fully developed eggs,[11] while Kendall and Goldsborough found that in small brooks fallfish reach maturity when "only a few inches" long.[9] Reed states that the latter may be in error.[8] Fowler found no tuberculated males under ca. 305 mm,[11] Reed found the tuberculated condition more noticeable in males over 300 mm TL.[1]

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Carpiodes cyprinus
Catostomus commersoni
Erimyzon oblongus
Moxostoma macrolepidotum

suckers
Catostomidae

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FAMILY CATOSTOMIDAE

The suckers, of which there are 12 genera and 58 species, are freshwater fishes found in China, northeast Siberia and North America. These fishes are small to moderately large with subcylindrical to laterally compressed bodies, short heads, ventral protrusible mouths with somewhat fleshy sucking lips, one row of 16 or more pharyngeal teeth and no stout barbed dorsal or anal spines.

Catostomid fishes are bottom dwellers in lakes, ponds and slow-moving streams. Most undertake spawning migrations in the spring, ascending smaller streams where their eggs are buried under gravel. Eggs of the described species from the Mid-Atlantic region are about 2.0–3.0 mm in diameter, lack oil globules and are nonadhesive after water-hardening. Regional yolk-sac larvae range from about 4.8 mm TL at hatching (*Erimyzon oblongus*) to as much as 12 mm TL (*Catostomus commersoni*).

In some species, the yolk-sac larvae may remain buried in gravel for one to two weeks after hatching. At hatching the yolk is a spherical anteriorly and elongate posteriorly. The anus is at or near the beginning of the posterior third of the body, the head is deflected over the yolk and the mouth is incomplete. The yolk sac is later reduced to a slender tube and the mouth develops in a high terminal position. During the larval stage the mouth migrates to a completely inferior position.

Described catostomid and cyprinid larvae from the Mid-Atlantic region are similar in many ways but may be separable on the basis of preanal myomere counts. The reported range for suckers (27–33) is higher than that for cyprinids (18–25).

Carpiodes cyprinus (Lesueur), Quillback

ADULTS

D. 22[1]–31;[13] A. 7[11]–9 (usually 7) C. ca. 18; P. usually 15; V. 8–10[16] (usually 10[10]); lateral line scales 33–42,[1] scales above lateral line 7–9;[12] vertebrae 37[13]–40; gill rakers 25–29; branchiostegal rays 3.[16]

Proportions as times in SL: Depth 2.2–3.4;[1] *head length* 2.8–3.9; dorsal fin height 1.9–3.3.[12] Proportions as times in TL: Head length 3.7–4.0.[11] Proportions as times in HL: *Eye diameter 4.0–8.8.*[1] *Proportions as percent TL:* Greatest depth 22.2–28.9; caudal peduncle depth 9.0–11.9; dorsal base 25.5–30.4. Proportions as percent HL: Interorbital width 31.2–40.9; snout length ca. 26–36.[16]

Body oblong, robust,[10] laterally compressed; back highly arched.[16] Head naked,[10] deep, short, narrow; snout short, ending in rounded point; eyes forward of midpoint of head;[16] jaws toothless; sucker mouth small, inferior, horizontal,[10,16] lacking barbels;[11] maxillary reaching anterior edge of orbit; pharyngeal teeth present. Scales cycloid. Lateral line complete, almost straight.[16] Anterior dorsal *rays greatly elevated,*[10] *as much as 5 to 6 times longer* than posterior rays; dorsal origin slightly anterior to mid-

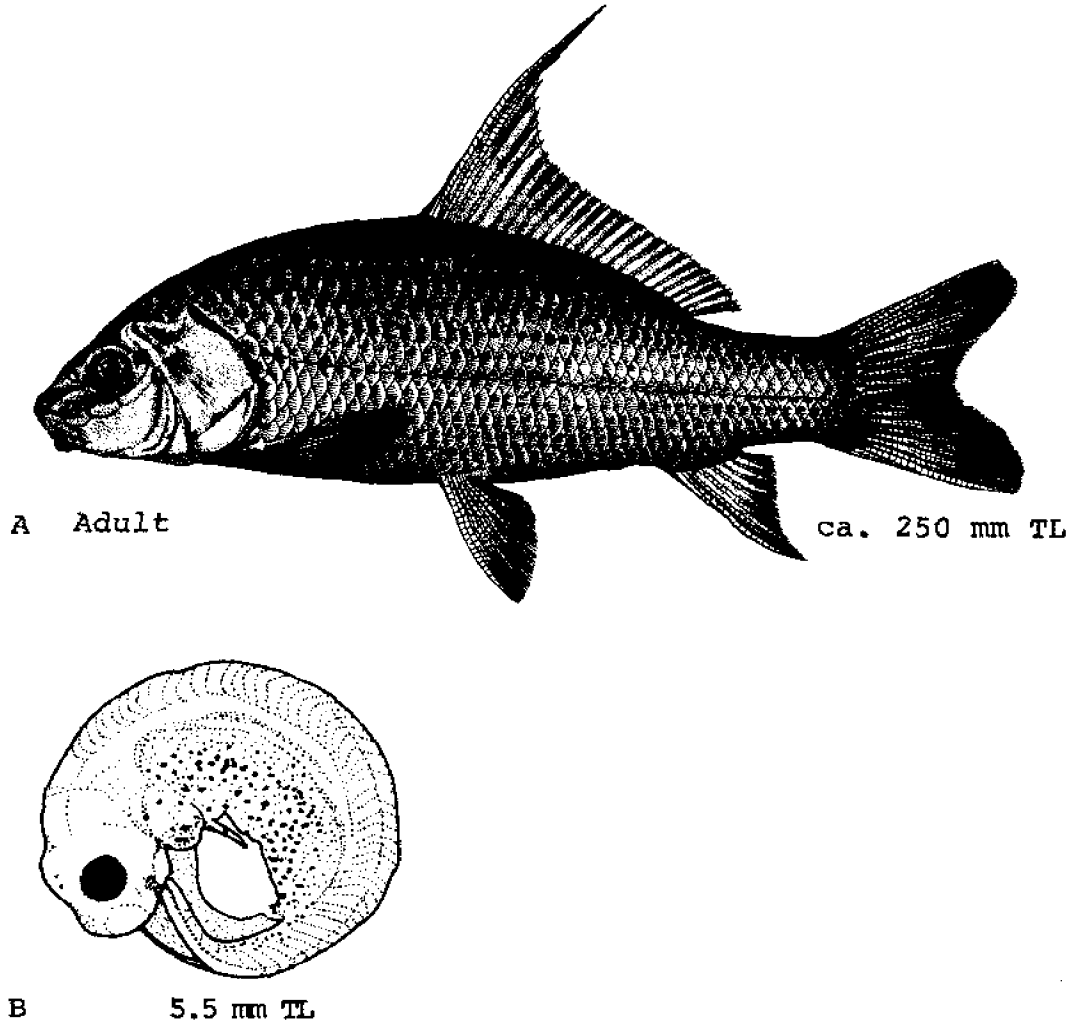

Fig. 167. Carpiodes cyprinus, Quillback. A. Adult, ca. 250 mm TL. B. Yolk-sac larva, 5.5 mm TL, newly hatched. (*A, Goode, G. B., et al., 1884: pl. 225. B, Gerlach, J. M., 1973: fig. 3A, delineated by Marthe Anne Cole. Used with permission of author.*)

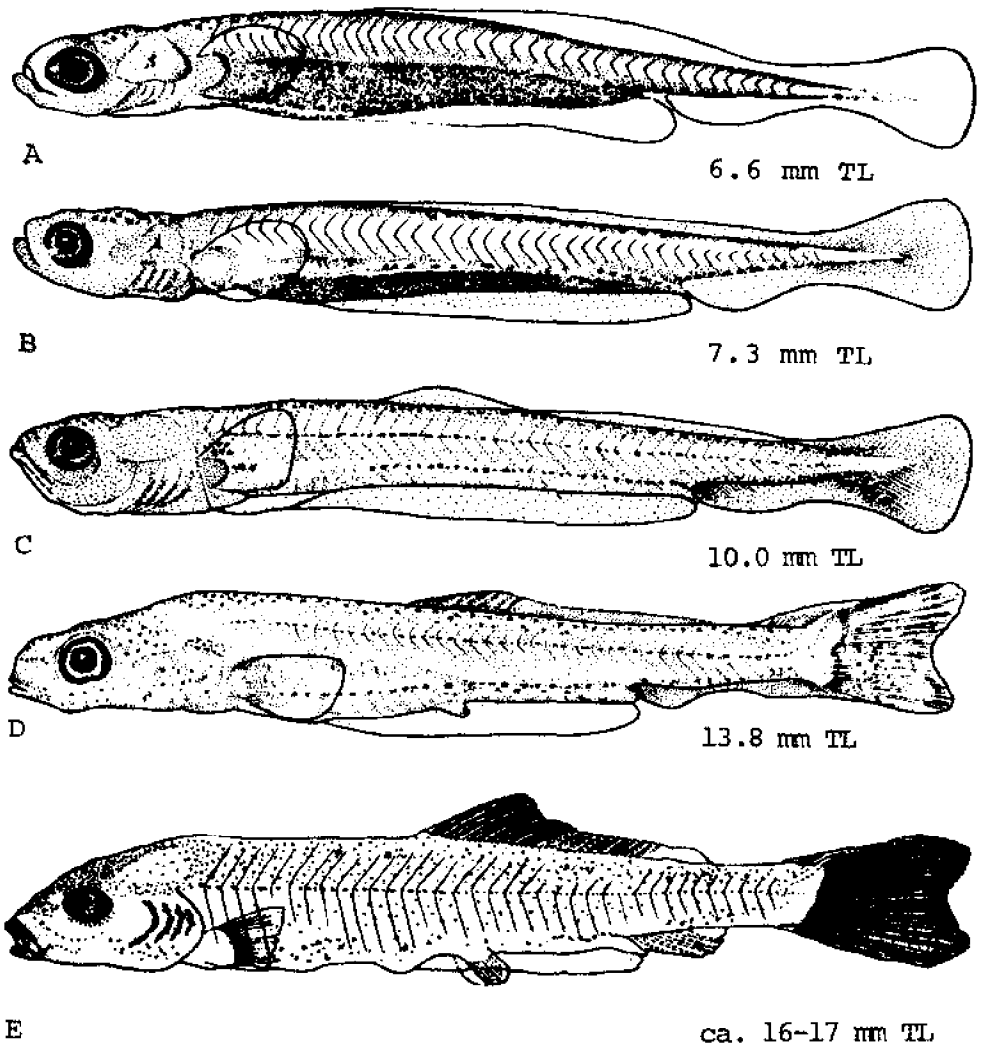

Fig. 168. *Carpiodes cyprinus*, Quillback. A. Yolk-sac larva, 6.6 mm TL. B. Larva, 7.3 mm TL. C. Larva, 10.0 mm TL, mouth still terminal, superior. D. Larva, 13.8 mm TL, mouth inferior; notochord flexed. E. Larva, ca. 16–17 mm TL (length based on Gerlach, 1973). (*A-D, Lippson, A. J., and R. L. Moran, 1974: 92-93. E, Howarth, J. N., 1961: fig. 15.*)

point of body.[16] Breeding males with tubercles on sides of head ventrally from level of top of eye, from mouth to branchiostegals, on dorsal ray 1, pectoral rays 1 to 8–9 or more, pelvic rays 1–2,[14] and up to lateral line scale row 30.[15] Tubercles apparently absent on females in Iowa,[14] present in western Nebraska.[15]

Pigmentation: Bronze-olive above,[1] sides silver[16] with gold reflections; venter milk or yellowish white; tip of snout and lips often milk white; anterior and distal edge of dorsal fin black;[1] fins transparent to dusky; pelvic fins lighter than dorsal fin;[16] paired fins edged with white.[11]

Maximum length: Possibly to ca. 660 mm.[1]

DISTRIBUTION AND ECOLOGY

Range: Central Alberta,[16] southern Manitoba and Great Lakes[3] to Kansas[17] and western Florida;[8] known on Atlantic coast in St. Lawrence,[2] Delaware, Susquehanna, Potomac, James, and Roanoke systems, and from Peedee system, North Carolina, southward (REJ).

Area distribution: Known only in Susquehanna, Potomac and James River systems of Chesapeake drainage (REJ); Delaware River.[6]

Habitat and movements: Adults—generally lakes, creeks, and large rivers;[5,9] in the Mid-Atlantic region from large

rivers and reservoirs only (REJ). In Lake Erie over bottoms of sand, sandy gravel, silt, or clay;[1] in Iowa found in shallow areas along shore in flooded, weedy places, on riffles in August.[4] Migratory during spawning season.[5]

Larvae—no information.

Juveniles—no information.

SPAWNING

Location: Over sand, silt, or mud in streams or overflow bayous.[5,11]

Season: Late April through May in Iowa.[5]

Fecundity: 15,235–63,779.[18]

EGGS

Location: Deposited at random.[5]

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

Minimum size at hatching 5.4 mm TL, maximum size at end of stage 7.9 mm TL.

Preanal myomeres 27–29, postanal myomeres 5–9.[13]

Proportions as percent TL: Snout to vent 69. Proportions as percent HL: Snout length 10; eye diameter ca. 39.[13]

At hatching body long, slender, slightly curved; yolk sac 66–80% of body depth, slightly indented near middle, protrudes ventrally; preanal length more than twice postanal; mouth a small oral pit located ventrally. At 5.6 mm lower jaw forming in some specimens, at 6.1 mm begins to take shape; at 6.6 mm mouth in high terminal position, partially open, horseshoe-shaped. At 5.6 mm auditory vesicle evident as bulge between eye and pectoral fin; four internal gill arches evident; at 6.1 mm gills exposed, preopercle discernible, nares appear as single oval depressions. At hatching pectoral fin bud present, at 6.6 mm rudiments of rays evident. At hatching continuous finfold from near eighteenth preanal myomere, bifurcated at anus, extending about 4/5 length of yolk sac. By 6.6 mm gut straight, heart visible. At 6.1 mm gas bladder evident.[13]

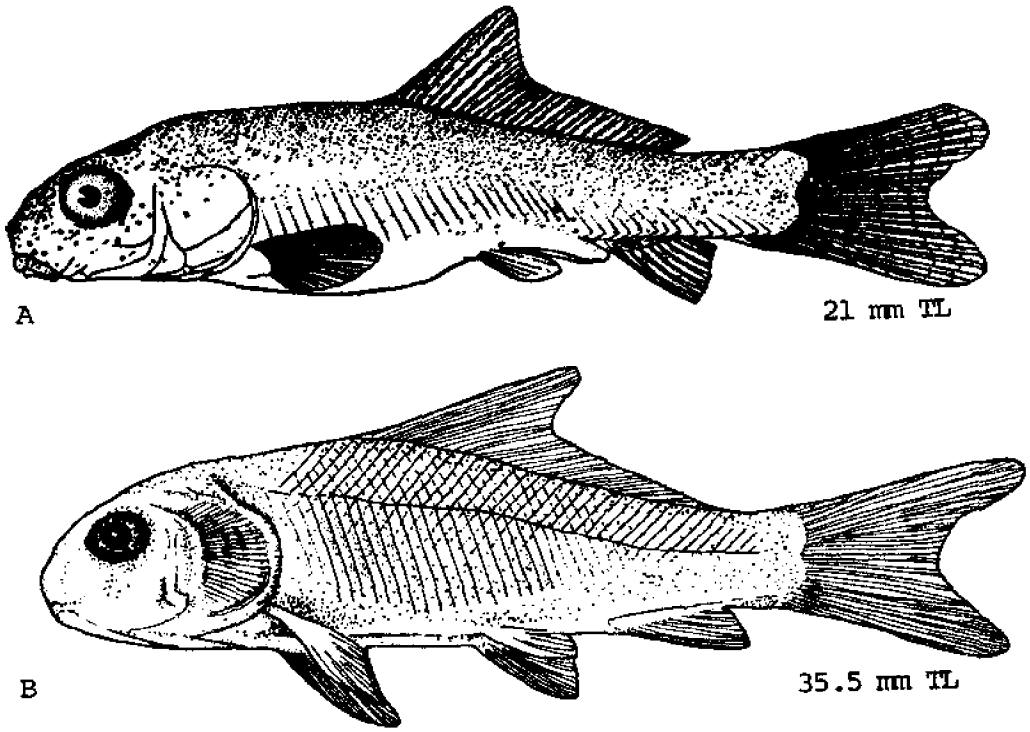

Fig. 169. *Carpiodes cyprinus*, Quillback. A. Juvenile, 21 mm TL. B. Juvenile, 35.5 mm TL; scalation complete. *(A, Fish, M. P., 1932: fig. 18. B, Gerlach, J. M., 1973: fig. 8C, delineated by Marthe Anne Cole. Used with permission of author.)*

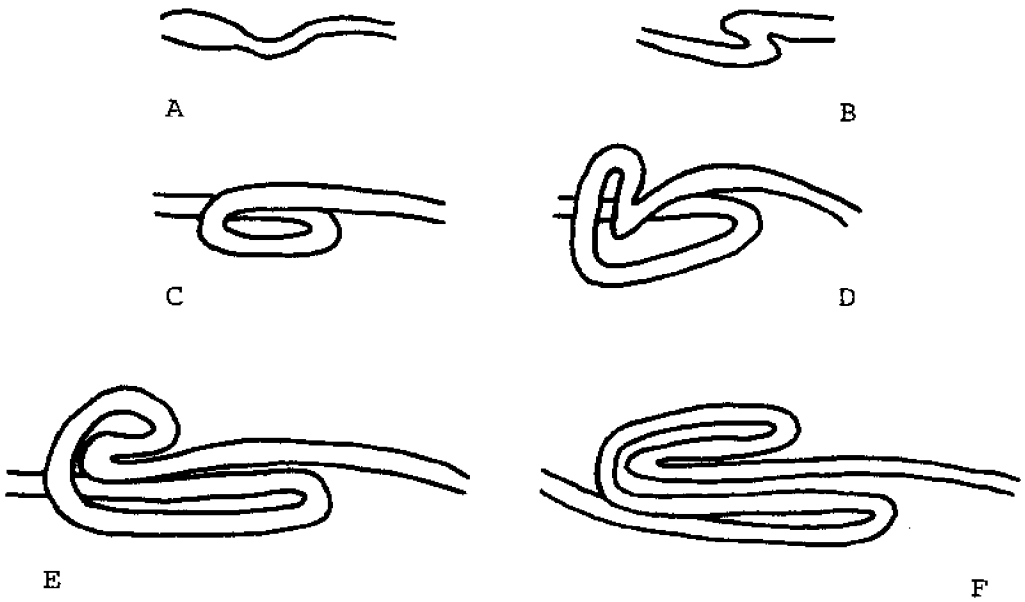

Fig. 170. *Carpiodes cyprinus*, Quillback. Gut development. A. 15 mm TL, ventral view. B. Variant of "A." C. 17 mm TL, first complete loop. D. 21 mm TL, second loop developing. E. 25 mm TL, further development of second loop. F. 26 mm TL, two loops complete. (*A-F, Gerlach, J. M., 1973: fig. 9. Used with permission of author.*)

Pigmentation: At hatching, dark pigment scattered over ventral surface of yolk sac; in short series along ventral postanal region; scattered melanophores sometimes in occipital area; eye heavily pigmented. At 6.1 mm expanded melanophores along dorsal surface of gas bladder. At 6.6 mm two rows of expanded melanophores along dorsal surface, narrowing to one row near caudal finfold; smaller melanophores in occipital region resemble 'Y'; scattered pigment in interorbital region; along lateral line and gill arches; series of ventrolateral melanophores beginning along gut line; typical larval pigmentation pattern present.[13]

LARVAE

Specimens described 7.0–16 mm TL.

D. at 12.0–12.9 mm, $\bar{x}$ 1.4; A. at 13.0–13.9 mm, $\bar{x}$ 0.3; C. at 9.0–9.9 mm, $\bar{x}$ 6.2; V. at 15.0–15.9 mm, $\bar{x}$ 0.5. Preanal myomeres 27–30; postanal myomeres 5–10.[13]

Body gradually becoming more robust; at ca. 12.0 mm snout area increasing, plicae appearing; at 15.0 mm snout tip in vertical line with lower lip. At 7.0 mm to 8.9 mm mouth assumes more horizontal position, at ca. 13 mm almost inferior, upper lip about level with lower rim of eye, at 16 mm completely inferior, forward edge of upper lip below eye, lower lip posterior to upper. At 13.8 mm eye about 1/4 head length. At 12 mm otic vesicles not bulging. At 13.8 mm, operculum just covers gills. At 7.0–8.9 dorsal fin lobe differentiating from finfold, rays evident at 12.4 mm becoming falcate at 15 mm; by 15 mm, anal fin with countable rays; at 9.0 mm caudal rays visible, tail usually emarginate at 13.8, usually forked at 15 mm; pelvic fin bud with basal elements at 15 mm. By 16.0 mm median ventral finfold still evident. At 9.0 mm urostyle beginning to turn upward, by 15 mm completely oblique. Gut 'S' shaped at .5 mm, by 17 mm one loop complete. At ca. 12.0 mm gas bladder two-chambered.[13]

Pigmentation: By 9.0 mm, melanophores distinct along gill arches; scattered in opercular and branchial regions, around heart, below urostyle; dorsal pigment increased in region of upper lip, nares, interorbital and occipit. At 12.4 mm pigment spreading dorsolaterally and increasing in head area; internal ring of melanophores encircles heart when viewed ventrally. At 15.0 mm, heart-shaped cluster of melanophores in occipital area; melanophores forming border around nares and orbital rim.[13] Chromatophores developed in dorsal and caudal fins.[8]

JUVENILES

Minimum size described 18 mm TL.

At 18.0–28.9 mm TL preanal myomeres 25[7]–29;[13] postanal myomeres 6[13]–12+;[7] extremes of variation ascribed to possible differences in counting methods.[13]

Proportions as percent TL: Snout to vent ca. 56; head length ca. 24. Proportions as percent HL: Eye diameter ca. 24–25; snout length ca. 20–22.[13]

By 18 mm body and head quite broad; head sloping down from nape, snout most anterior projection; nares U-shaped in appearance, by 25 mm divided into two in most specimens. By 18 mm quill length over half that of dorsal base; dorsal and caudal strongly marginated. At 21 mm, principal rays bifurcate; ossification of fin rays complete; median ventral finfold absent; scales visible around caudal peduncle, scalation complete by 35 mm. Gut with two complete coils by 26 mm.[13]

Pigmentation: At 18 mm, pigment heavily distributed *over dorsolateral surface; sparse below lateral line;* increasing around snout, upper lip and cheek; some melanophores along lower jaw, operculum and branchial region; increased pigment on anal and pectoral fins.[13] At 21 mm, chromatophores on upper jaws, sides and top of head, on dorsolateral aspects of body, in a double row along anal fin and beneath caudal peduncle, in a single mid-dorsal row to caudal, and on at least the dorsal and caudal fins.[7] By 35 mm white margination of paired and anal fins.[13]

AGE AND SIZE AT MATURITY

No information.

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Catostomus commersoni (Lacépède), White sucker

ADULTS

D. 11[22]–15[3] (10–11 in subspecies *utawana*);[22] A. 6–8; C. usually 18; P. 16–18[29] (15–17 in *utawana*);[22] V. 9[14]–11;[29] scales in lateral series 53[29]–85;[11] predorsal scales 25–35 (30–35 in *utawana*);[22] total vertebrae 44–48;[40] precaudal vertebrae 25–28;[8] gill rakers 20–27; pharyngeal teeth 40–42 + 39–43; branchiostegal rays 3 + 3.[30]

Proportions as times in SL: Body depth 4.45–4.82; head length 4.09–4.35.[3] Proportions as percent TL: Greatest body depth 14.1–20.0; caudal peduncle depth 6.5–8.6; head length ca. 20; dorsal fin base 10.7–15.0. Proportions as percent HL: Interorbital width 35.2–49.5; snout length 35.7–50.0. Proportions as percent snout length: Eye diameter 41.3–66.6.[29]

Body elongate,[3] round to oval in cross-section forward; greatest depth at origin of dorsal fin. Head naked, bluntly pointed, rounded on top;[29] snout blunt,[30] mouth

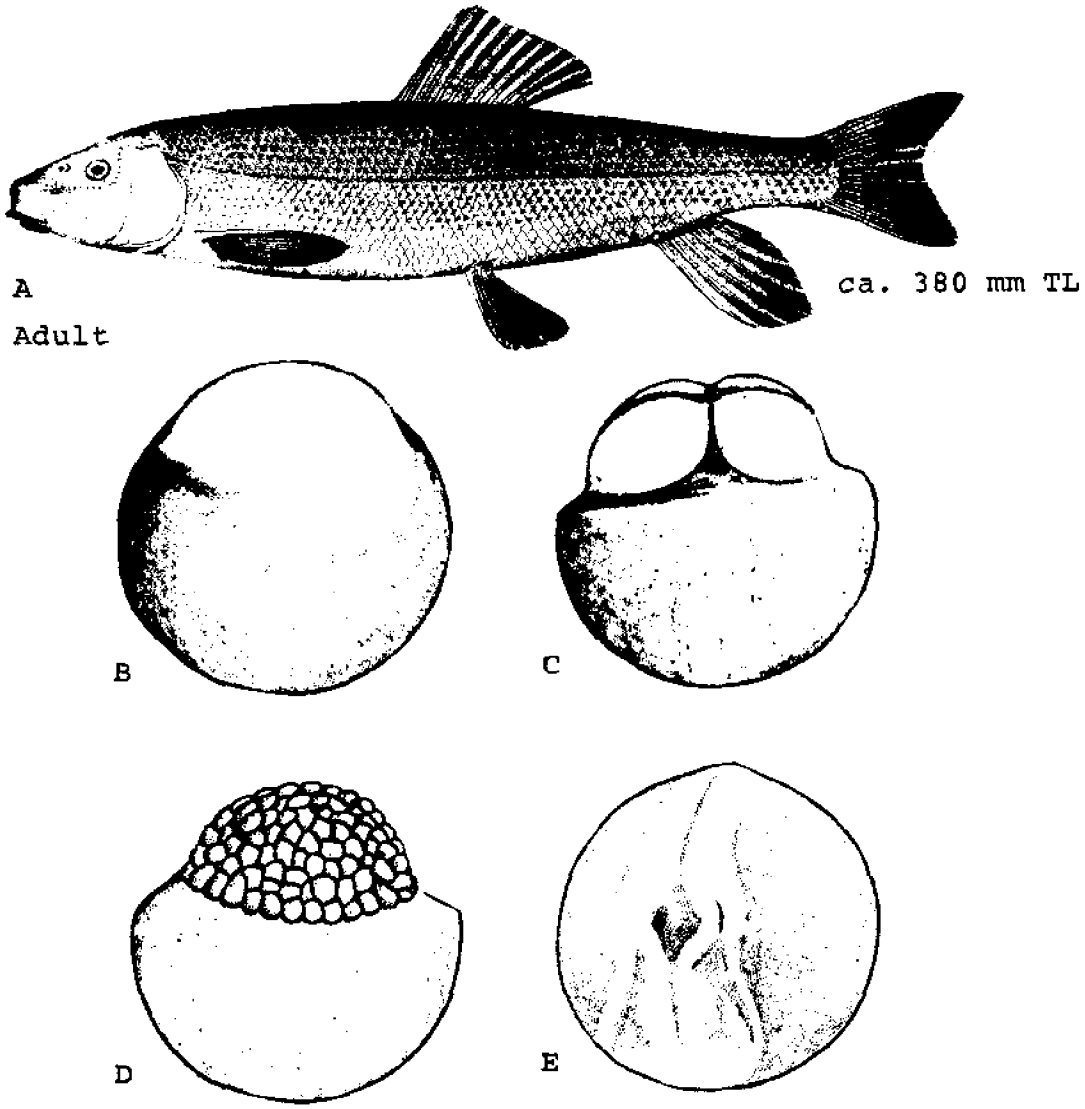

Fig. 171. *Catostomus commersoni*, White sucker. A. Adult, ca. 380 mm TL. B. Egg, blastodisc, 4 hours. This and subsequent eggs incubated at mean temperature of 10.3 C. Egg capsule removed. C. Egg, four-cell stage, 6 hours. D. Egg, morula 21 1/2 hours. E. Egg, late embryo, 8 days. Tail reaches almost to head. (*A, Goode, G. B., et al., 1884: pl. 223. B-E, Stewart, N. H., 1926: figs. 2, 3, 6, 12.*)

inferior, suctorial,[29] lips papillose, lower broader than upper;[3] gill rakers somewhat knobbed on both surfaces of arch. Scales moderately small, larger on peduncle. Dorsal fin almost at midpoint of body, origin anterior to pelvics.[29] Breeding males with moderate to large nuptial tubercles on anal and caudal fins,[30] small to minute tubercles on other fins, head, and body; tubercles reduced in size or absent in females.[29]

Pigmentation: Uniformly dark dorsally,[40] bluish green,[8] olive,[11] brown[29] or black;[30] scale margins generally darker;[11] sides greenish yellow[40] to silvery white,[30] venter white. Dorsal and caudal fins light slate,[11] dusky[3] or clear;[41] lower fins immaculate,[30] dusky[29] or white,[41] often tinged with yellow[40] or orange.[41] Breeding males black to olive above with lavender sheen;[11] black (subspecies *commersoni*) to reddish (*utawana*) lateral band continued around snout and, above this, a band of whitish yellow overcast with pink; lower fins light to *faint yellow;*[15] *in Saskatchewan, black to reddish band* replaced by cream-colored band,[29] with no band evident west or north of Rocky Mountains.[30]

Maximum length: 635 mm TL,[4] but possibly reaching ca. 760 mm.[11]

DISTRIBUTION AND ECOLOGY

Range: Labrador and Nova Scotia,[30] south to Georgia, Arkansas and northeastern Oklahoma,[12] north through Alberta and British Columbia to Mackenzie River;[29] introduced widely, especially in Southwest.[11]

Area distribution: Tidal tributaries of lower Chesapeake Bay[10] and slightly brackish water of upper bay near Havre de Grace, Maryland.[3]

Habitat and movements: Adults—ubiquitous; winter in deeper water;[21,23,24,28] sometimes taken under moderately low oxygen conditions (RJM). Undertake spawning migrations with majority moving upstream between noon and midnight, usually at night,[6,19,31,32] when water temperature reaches ca. 4–5 C or higher;[4,13,21] in central British Columbia migration apparently ceases at temperatures lower than 10 C.[31]

Maximum salinity ca. 2.0 ppt (RJM). Maximum depth below 46 m.[29]

Larvae—yolk-sac larvae probably remain in sand or gravel one to two weeks before emerging.[31] Specimens 10–12 mm long in large schools over sand and pebble bottom in water ca. 20 cm deep.[25] At 12 to 14 mm downstream movement occurs, between dusk and dawn, in greater numbers on foggy or overcast nights.[31,34] Specimens 12–17 mm near surface, usually in moderate current and frequently associated with *Elodea*.[2] "Youngest" seem to prefer shallow water over muddy bottom with little vegetation.[4]

Juveniles—bottom feeders at ca. 16–18 mm.[2] At 17–58 mm, in bayous with abundant pond weed, rushes and other aquatic plants, and over sandy river bottoms among *Potamogeton*.[36] "Fry" and "immature" in shallow muddy sloughs among weeds and along shores of lakes and ponds.[35]

SPAWNING

Location: In streams of all sizes,[11] usually in moderately swift water of riffles,[15,32] sometimes in rapids[29] or over sand or gravel bottoms;[6,15,17,20] usually in water less than 30.0 cm deep,[37] occasionally at a depth of only 5.1 cm;[21,34,35] also in still pools,[15] lakes and impoundments.[11,17,18] The subspecies *utawana* spawns in swift, cold mountain streams[26] and shows an affinity for shady, sheltered areas.[21,24]

Season: March[5] to early July, depending on locality.[4,5]

Time: Usually at night, but also during daylight hours.[4,6,15,21,24]

Temperature: Ca. 6.0–23 C.[11]

Fecundity: Varies according to length and subspecies; 775 at ca. 121 mm (in *utawana*) to 111,000 at ca. 483–508 mm;[16] maximum ca. 140,000.[9]

EGGS

Description: Demersal; deposited singly or in small groups.[15]

Unfertilized eggs—diameter 2.0[2]–2.82 mm. Round, white[1] or pale yellow,[2] lacking oil globules; finely granular and slightly adhesive. Micropyle single.

Fertilized eggs—diameter ca. 2.0 (in *utawana*)[22] to 3.0 mm. Nonadhesive after water-hardening. Lacking large oil globules, but with numerous, clear droplets of minute size in yolk, and along edge of blastodisc.[2]

EGG DEVELOPMENT

At 5 C:

15 hours	first cleavage starts.
20–24 hours	4-cell stage.
25–30 hours	16- or 32-cell stage.
40–45 hours	large-celled morula, 50–100 cells; first outward movement of periblast material.
72 hours	small-celled morula, blastodisc nearly hemispherical; cellular envelope pebbled in appearance.
96–120 hours	morula flattened but not spreading.

At 10 C:

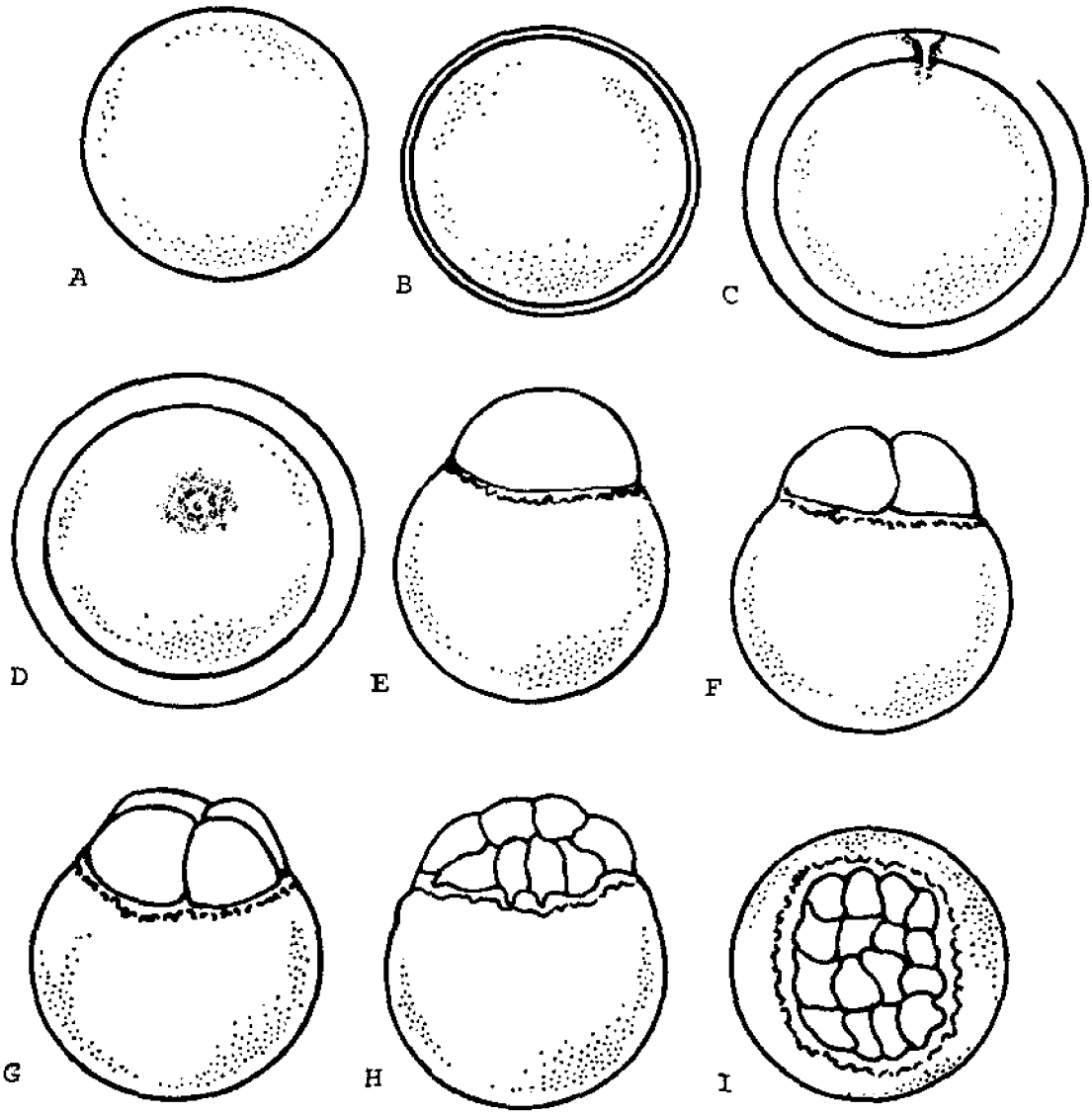

Fig. 172. *Catostomus commersoni*, White sucker. A. Egg, freshly deposited. B. Egg, one minute after fertilization. C. Egg, six minutes after fertilization, micropyle evident. D. Egg, twelve minutes after fertilization. E. Egg, fertilized but uncleaved. This and subsequent eggs with egg capsule removed. F. Egg, two-cell stage. G. Egg, four-cell stage. H. Egg, eight-cell stage. I. Egg, sixteen-cell stage. (*A-I, Long, W. L., and W. W. Ballard, 1976: figs. A-I.*)

6 hours	first cleavage starts.
8–10 hours	4-cell stage.
10–12 hours	8-cell stage.
13–15 hours	16- or 32-cell stage.
18–24 hours	large-celled morula, 50–100 cells; first outward movement of periblast material.
24–28 hours	small-celled morula, blastodisc nearly hemispherical; cellular envelope pebbled in appearance.
30–40 hours	small-celled morula; cellular envelope smooth.
42–48 hours	morula flattened but not spreading.
54–96 hours	blastodisc actively thinning and spreading, rim 1/2 to 2/3 distance to equator of yolk sphere.
84–96 hours	axial quadrant of blastodisc swollen; vague germ ring.

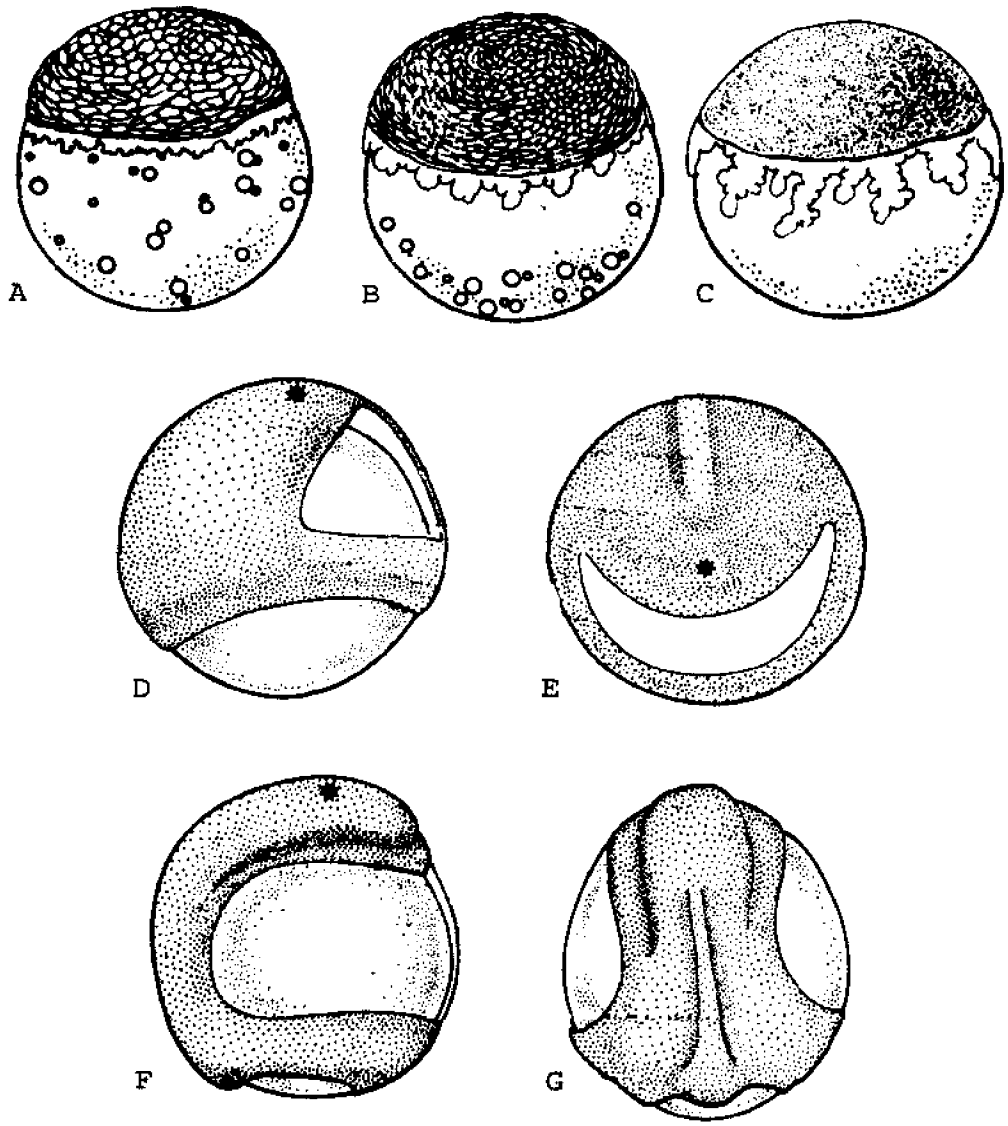

Fig. 173. *Catostomus commersoni*, White sucker. A. Egg, large-celled morula. This and subsequent eggs with capsule removed. B. Egg, small-celled morula. C. Egg, morula flattening, but not spreading. D. Egg, blastodisc rim 1/3 distance below equator. Star marks animal pole. E. Egg, axial strand and yolk mass as seen from anterior end. F. Egg, yolk plug diameter less than 1/4 diameter of whole egg. G. Dorsal view of "F." (*A-G, Long, W. L., and W. W. Ballard, 1976: figs. 1J-L, 4A-D.*)

84–108 hours	blastodisc rim reaches to equator; complete narrow germ ring; axial quadrant thicker, slight terminal node visible externally.
96–112 hours	blastodisc 1/3 distance below equator toward vegetal pole; germ ring visible externally.
108–126 hours	yolk plug diameter less than 1/4 diameter of egg, axial strand visible; convergence in embryonic shield indicates brain area.
144 hours	periblast material gathered at yolk plug; embryonic shield with superficial groove along midline, wide flat neural plates on each side, crescent of head mesoderm around this neural area anteriorly, continuous with lateral mesoderm, ends in wide areola of germ ring mesoderm around yolk plug; first somites forming.
156–168 hours	yolk plug usually closed over; brain area shows three vague swellings; 4–10 pairs of somites; at 8-somite

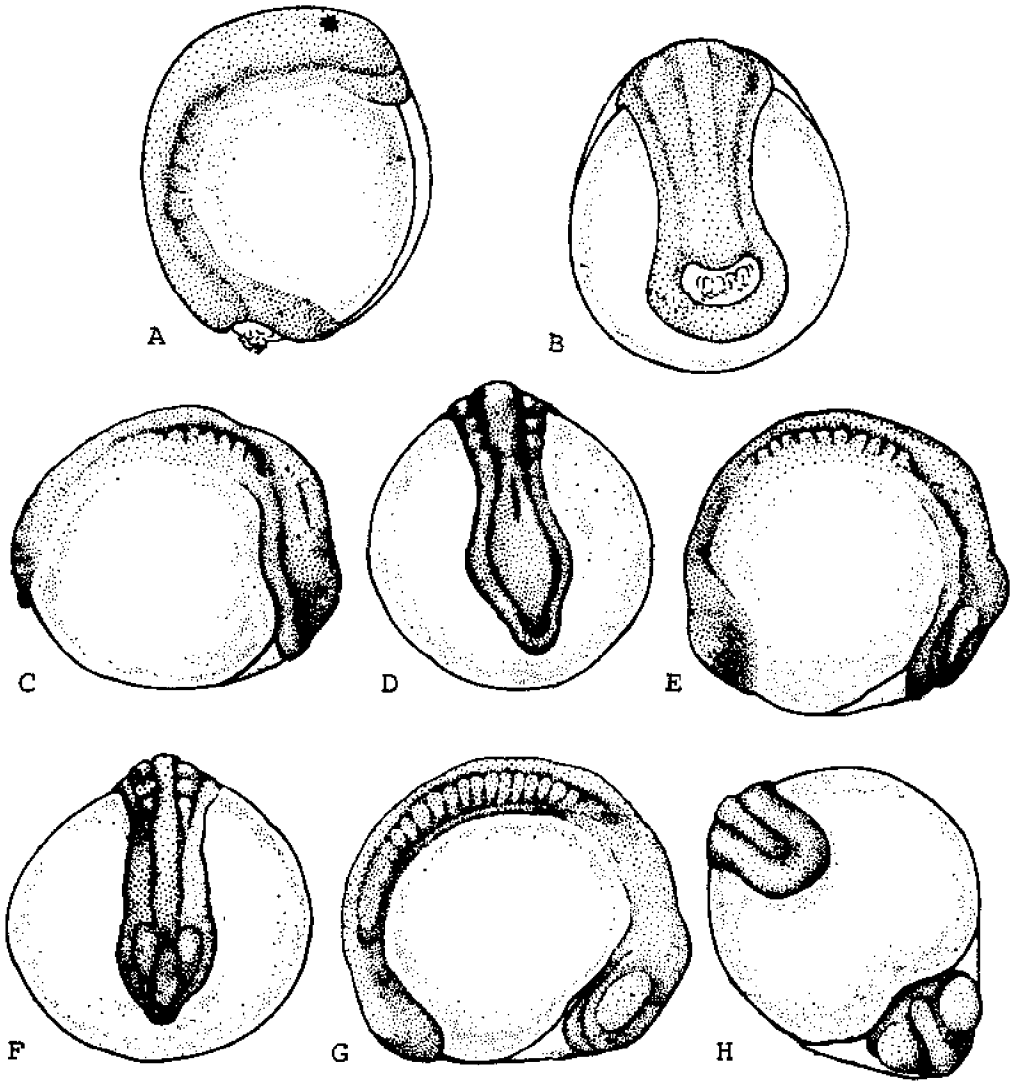

Fig. 174. *Catostomus commersoni*, White sucker. A. Egg, periblast material in wrinkles within yolk plug. This and subsequent eggs with capsule removed. B. Posterior view of "A." C. Egg, 4–10 pairs of somites. Brain area shows three vague swellings. D. Egg, yolk plug usually closed over. E. Egg, trunk mound raised but not undercut. F. Egg, optic vesicles free of brain except stalks. G. Egg, 15–20 pairs of somites. H. Egg, yolk-sac cavity evident. (*A-H, Long, W. L., and W. W. Ballard, 1976: figs. 4E, F, S.*)

	stage optic vesicles begin to segregate posteriorly from brain mass.
168–192 hours	trunk-tail mound raised; optic vesicles attached to brain by stalks only; 15–20 pairs of somites, primitive kidney ducts and ear placodes appear.
240 hours	20–25 pairs somites, eyes with lenses.
264 hours	movement at trunk; cerebellum distinguishable; yolk sac begins to narrow under posterior body; heart sometimes visible.
288 hours	trunk-tail bud with ca. 5 pairs somites; first indication of median finfold, heart pulsating but no blood flow.
312–360 hours	ca. 10–15 pairs of somites posterior to yolk sac, continuous dorsal-ventral finfold, blood visible.
336–408 hours	15–20 pairs somites posterior to yolk sac; mandibular and hyoid sepa-

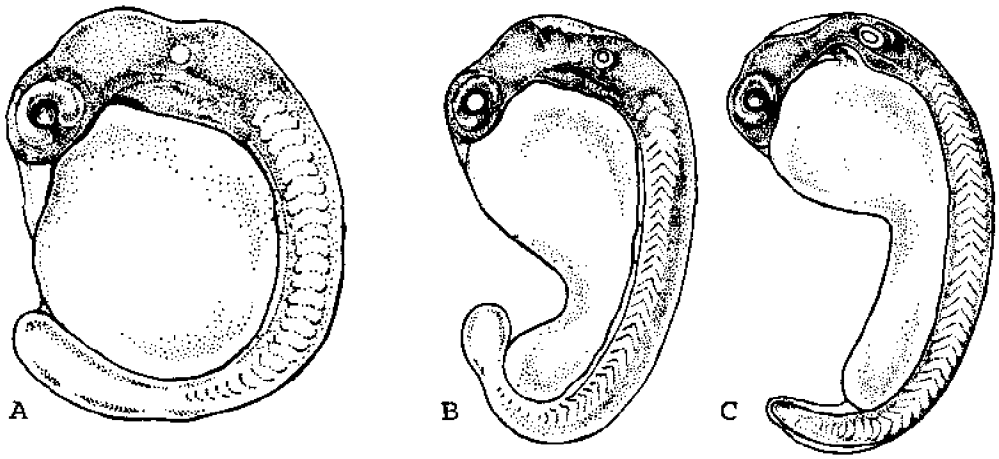

Fig. 175. *Catostomus commersoni*, White sucker. A. Egg, free part of tail smaller than eye, 20–25 pairs of somites. This and subsequent eggs with capsule removed. B. Egg, trunk capable of slight movement, 35 pairs of somites. C. Egg, trunk-tail bud with ca. 5 pairs of somites. First indication of median finfold. (*A-C, Long, W. L., and W. W. Ballard, 1976: fig. 6.*)

	rately present; olfactory placodes and otoliths visible.
408–456 hours	ridges evident at site of future pectoral fins; trunk and tail straight; somites present to end of tail, faint pigmentation in eyes, hatching begins.[29]

At mean temperature of 10.3 C:

2 hours, 30 minutes	blastodisc fully differentiated.
6 hours	4-cell stage.
8 hours	"eighteen-celled stage."
10 hours, 30 minutes	36-cell stage.
21 hours, 30 minutes	morula.
Ca. 44 hours	blastoderm flattened on top.
54 hours	blastoderm nearly to equator of egg.
92 hours	yolk entirely invested by blastoderm.
149 hours	body of embryo visible as a straight white ridge, narrow and rather high, nearly encircling egg and terminating at anterior end as a flat rounded expansion.
174 hours	brain and optic evaginations visible.
198 hours	lateral boundaries of head and body visible; tail almost around to anterior limit of head.
224 hours	yolk no longer spherical, but divided into a posterior cylindrical region and a spherical anterior region; notochord visible.
246 hours	length of embryo greater than circumference of yolk; eyes pigmented.[2]

At 18 C:

2 hours, 30 minutes	first cleavage starts.
4–5 hours	4-cell stage.

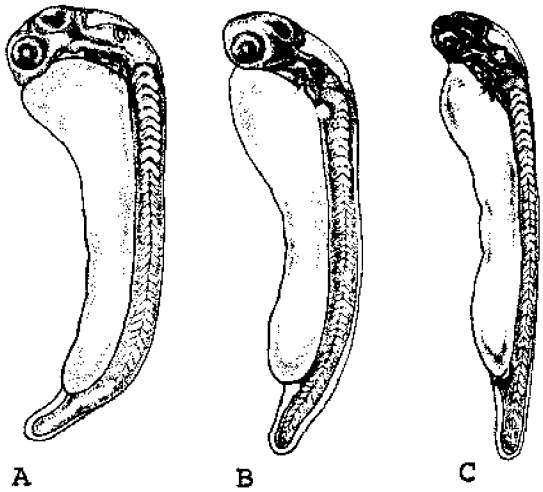

Fig. 176. *Catostomus commersoni*, White sucker. A. Egg, trunk-tail bud posterior to yolk sac with ca. 10–15 pairs somites. This and subsequent eggs with capsule removed. B. Egg, olfactory placodes and otoliths visible, ca. 15–20 pairs of somites posterior to yolk sac. C. Egg, hatching begins in some specimens at this stage. Faint pigmentation in eye, pectoral fins represented by ridges. (*A-C, Long, W. L., and W. W. Ballard, 1976: fig. 7.*)

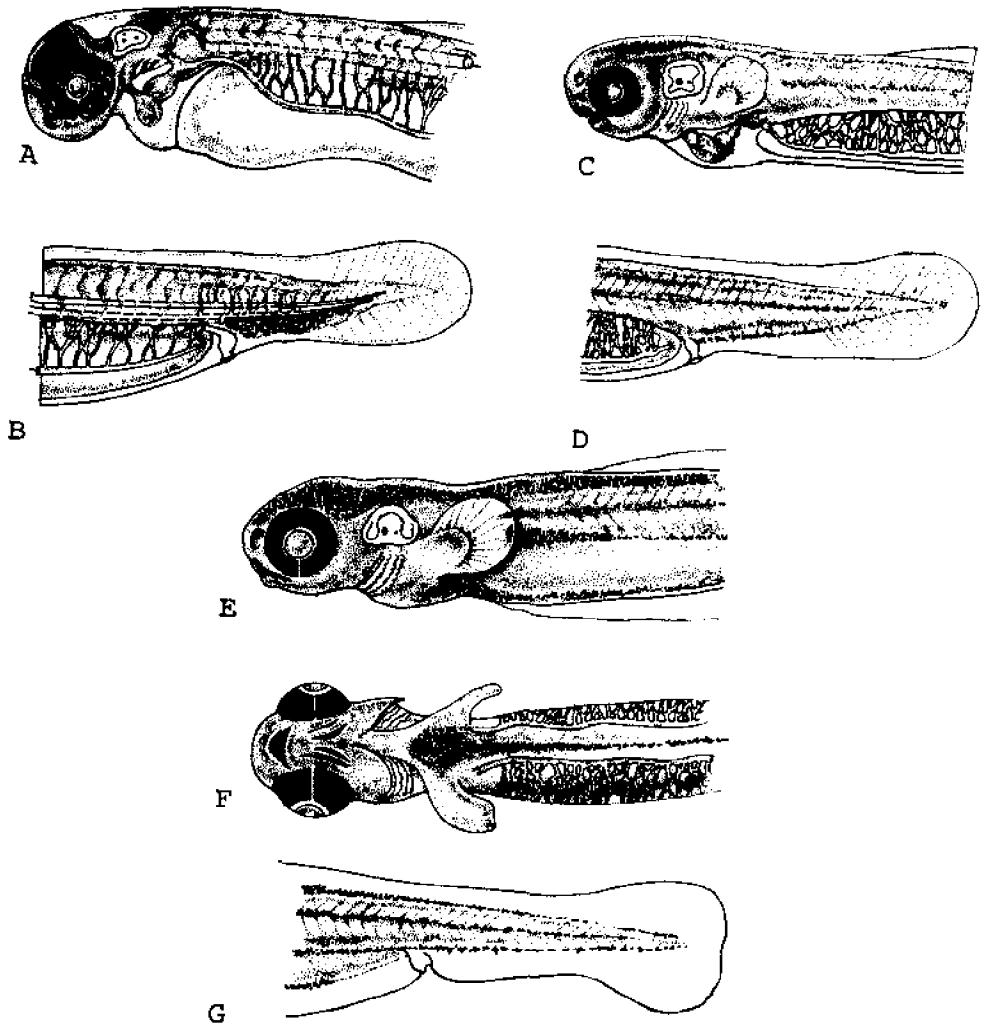

Fig. 177. *Catostomus commersoni*, White sucker. A. Yolk-sac larva, anterior portion, newly hatched, ca. 12 mm TL. Pectoral fins appear as discs, eye dark gray. B. Posterior portion of "A," melanophores on trunk. C. Yolk-sac larva, *anterior portion. Pectoral fins circular, jaws functional.* D. *Posterior portion of "C."* E. *Yolk-sac larva,* anterior portion, 15 mm TL. F. Ventral view of "E." G. Posterior portion of "E." *(A-G, Long, W. L., and W. W. Ballard, 1976: figs. 8–9.)*

5–7 hours	16- or 32-cell stage.
8–12 hours	large-celled morula, 50–100 cells; first outward movement of periblast material.
16 hours	small-celled morula, blastodisc nearly hemispherical; cellular envelope pebbled in appearance.[39]

Incubation: 4 days at 21.1 C; 7 days at 15.6 C;[6] 12 days at average of 11.7 C;[7] 8 days at average of 11 C;[31] 17–19 days (hatching begins) at 10 C;[39] 12 to 21 days at average of 10.3 C.[2]

YOLK-SAC LARVAE

Size at hatching highly variable; 6.0[5]*–8.0 mm TL*[2] *for* some specimens, ca. 12 mm TL for others.[39] Maximum size at end of stage reported as ca. 12.0 mm TL,[2] however, some specimens with yolk reach at least 15 mm TL.[39] Length vs. age highly variable, its embryological significance doubtful (WLL).

Specimens described 6.0[5]–15 mm TL.[39]

Body depth 1/6 TL at hatching. Body slender; head de-

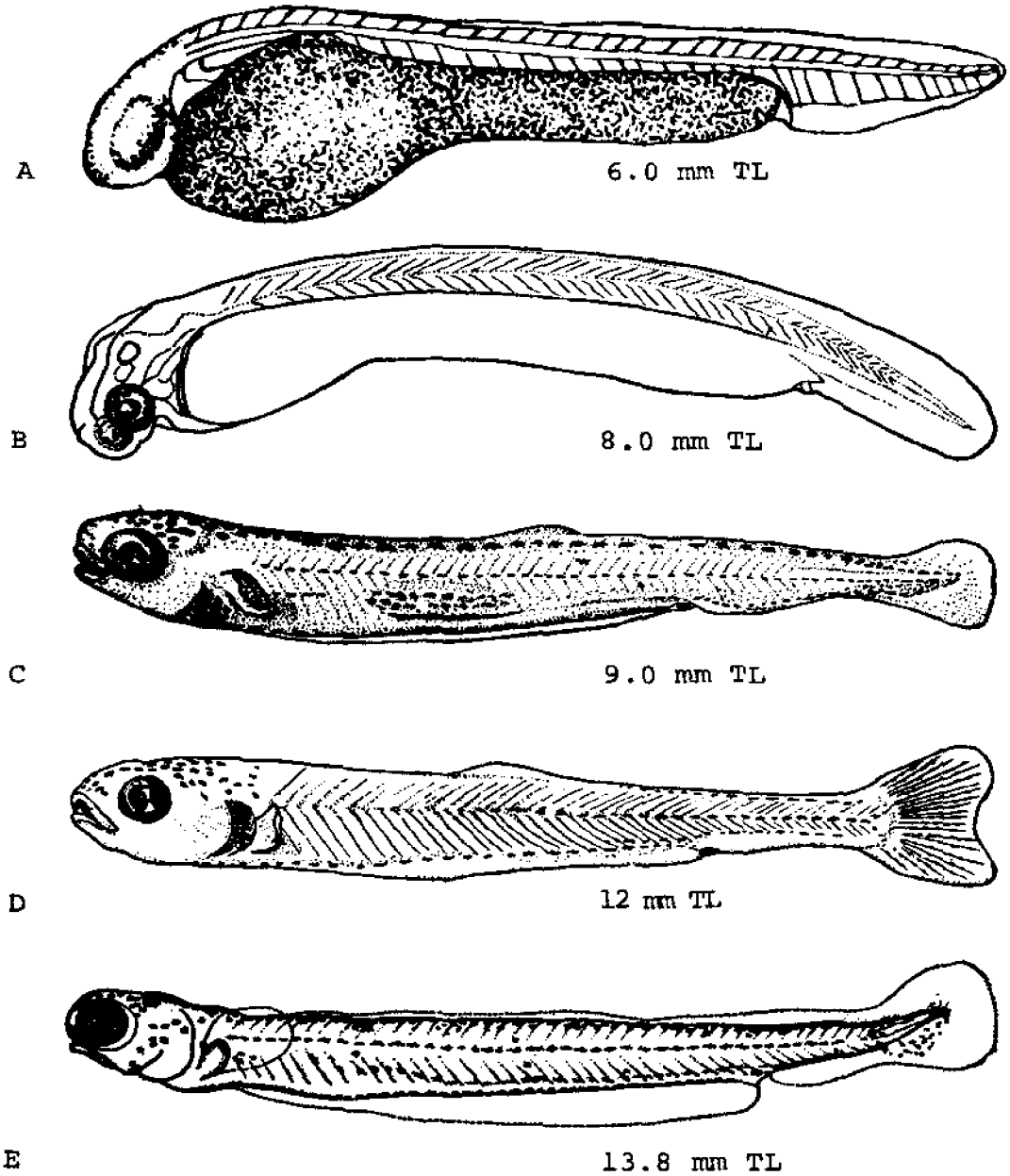

Fig. 178. *Catostomus commersoni*, White sucker. A. Yolk-sac larva, 6.0 mm TL, newly hatched. B. Yolk-sac larva, 8.0 mm TL, newly hatched. C. Larva, 9.0 mm TL, gill exposed. D. Larva, 12 mm TL, gas bladder one-chambered. E. Larva, 13.8 mm TL, dorsal finfold retained. (*A, Crawford, D. R., 1923: fig. 3. B-D, Stewart, N. W., 1926: figs. 20–22. E, Fish, M. P., 1932: fig. 19.*)

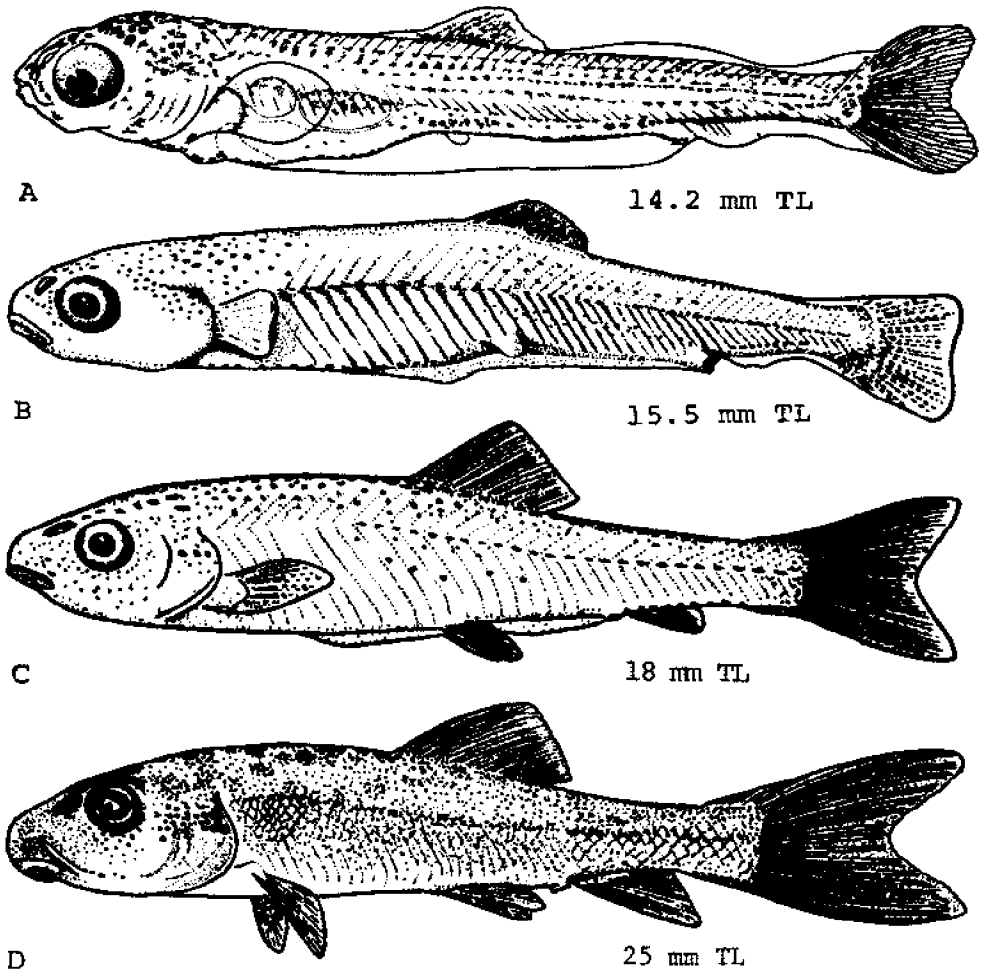

Fig. 179. *Catostomus commersoni*, White sucker. A. Larva, 14.2 mm TL. Gas bladder two-chambered; ventral buds formed. B. Larva, 15.5 mm TL. Mouth becoming inferior. C. Juvenile, 18 mm TL. Mouth inferior, entirely below eye. D. Juvenile, 25 mm TL. Scalation complete. (*A, Fish, M. P., 1932: fig. 20. B-D, Stewart, N. H., 1926: figs. 23, 25, 26.*)

curved; olfactory placodes evident as circular thickenings of epidermis; mouth incomplete at hatching, open at 9.0 mm in some specimens,[2] functional by 15 mm in larvae hatching at ca. 12 mm TL.[39] Eye large, slightly elliptical; auditory vesicles simple ovoid sacs at hatching. Branchial apparatus complete by 9.0 mm.[2] Operculum partially covers first branchial arches at 15 mm in specimens hatching at ca. 12 mm TL.[39] Yolk sac initially cylindrical throughout[2] or spherical anteriorly.[5] Heart S-shaped, pericardial cavity a dome-shaped bulge at anterior edge of yolk sac.[2] Gas bladder visible at 15 mm in specimens hatching at ca. 12 mm TL.[39] At hatching pectoral buds present;[2] appear as discs larger than lens, smaller than eye; by 15 mm TL circular, larger than eye in specimens hatching at ca. 12 mm TL.[39] At hatching caudal with or without incipient rays; finfold originating near midpoint of dorsum and terminating at vent.[2]

Pigmentation of specimens hatching at ca. 12 mm TL: At hatching eye dark gray, first melanophores appear on trunk. Seven to 10 days after hatching melanophores on head, row along mid-dorsal region, series along mid-lateral line, melanophores posterior to anus along ventral body ridge. By 15 mm TL row of pigment above intestine and gas bladder, row below yolk and pericardium; iris unpigmented.[39]

LARVAE

Specimens described ca. 9.0[2]–ca. 16.0 mm TL.[5]

At 14.2 mm, preanal myomeres 33; postanal myomeres 10+.[1]

Eyes very large, 3 times in HL at 9.0 mm. Mouth initially horseshoe-shaped, nearly vertical; at 14.0 mm mouth opening on level with lower rim of eyes; at 16.0 mm opening entirely below eyes. First loop of intestine formed at 16–17 mm; length of digestive tract equal to length of fish. Gas bladder first visible at 11.0 mm, connected to gut up to 14.0 mm,[2] and 2-chambered in a specimen 14.2 mm.[1] Liver first visible at 11.0 mm. Incipient dorsal and anal at 9.0 mm; caudal rounded at 10.9 mm,[3,3] 2-lobed at 12.0 mm;[2] pelvics developing at 14[1] to 15 mm; dorsal finfold lost by 9.0 mm[2] or retained to ca. 14.2 mm;[1] preanal finfold long, wide at 14.0 mm; urostyle oblique at 14.0 mm.[2]

Pigmentation: At 9.0 mm, a double row of large chromatophores along mid-dorsal region and ca. 30 smaller ones on top of head; a row of small chromatophores along mid-lateral line and a double row along venter. At 12.0 mm, chromatophores along caudal rays.[2] At 13.75 mm, eyes silvery, edged with black; 3 rows of chromatophores along dorsum and in a single mid-lateral series; a predominately subsurface series starting behind head, concentrated over dorsal surface of gas bladder and continuing in massed line to vent; ca. 57–60 large, rounded stellate chromatophores along ventral ridge from behind head to vent and continuing as massed line to end of body; small pepper-like chromatophores near caudal base.[1] At 14.0 mm, chromatophores along dorsal rays.[2] At 14.2 mm specimen has pigmentation essentially as in earlier stages, but with series of subsurface chromatophores above and below vertebral column connected laterally at myoseptums, along ventral aspect of notochord, and along margins of gill arches.[1] At 16.0 mm, large yellow and black chromatophores scattered over body.[5]

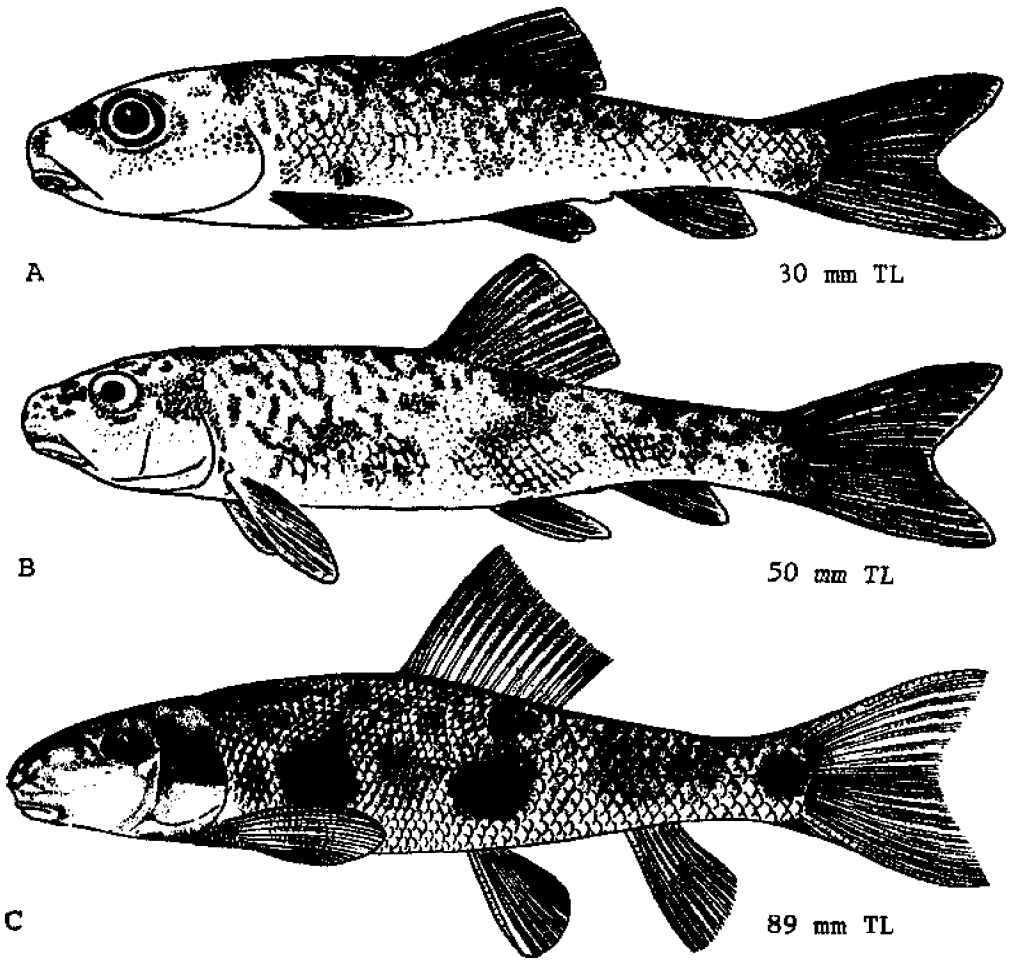

Fig. 180. *Catostomus commersoni*, White sucker. A. Juvenile, 30 mm TL. B. Juvenile, 50 mm TL. Eye high; papillae on lips. C. Juvenile, 89 mm TL. Sides and back characteristically mottled. (*A-B, Stewart, N. H., 1926: figs. 27, 28. C, Fowler, H. W., 1906: 156.*)

JUVENILES

Minimum size described 18.0 mm TL.[2]

HL 3.5–4.25 times in body length in "young."[14]

At 18.0 mm, nostril apparently divided; preanal finfold retained. Scale formation first evident at ca. 22.0 mm, complete by 25.0 mm. Papillae present on lips at 43.0 mm. Gut nearly twice length of fish at 24.0 mm.

Pigmentation: At 18.0 mm, scattered chromatophores on dorsolateral surfaces and operculum. At 20.0 mm, all fins pigmented; scattered chromatophores over entire body. At 25.0 mm, scale margins becoming outlined with pigment; several spots or blotches of dark pigment on sides; sides with distinct golden iridescence.[2] "Young" mottled and blotched with black, the blotches sometimes more or less confluent.[3]

AGE AND SIZE AT MATURITY

Three[38] to possibly 8[23] years depending on subspecies and locality; usually 3 to 4 years in Ontario.[28]

Minimum size ca. 76 mm.[25,27]

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Erimyzon oblongus (Mitchill), Creek chubsucker

ADULTS

D. 9 [3]–14; [5] A. 7–8; V. 8–10; scale rows to end of hypural 39–45; [13] scales in transverse series 13–14; [3] gill rakers on lower limb of first arch 7–10.[13]

Proportions as times in SL: Body depth 2.75–4.2; head length 3.45–4.2.[13]

Body oblong, compressed; head short. Scales large, closely overlapping.[3] Lateral line lacking on body.[15]

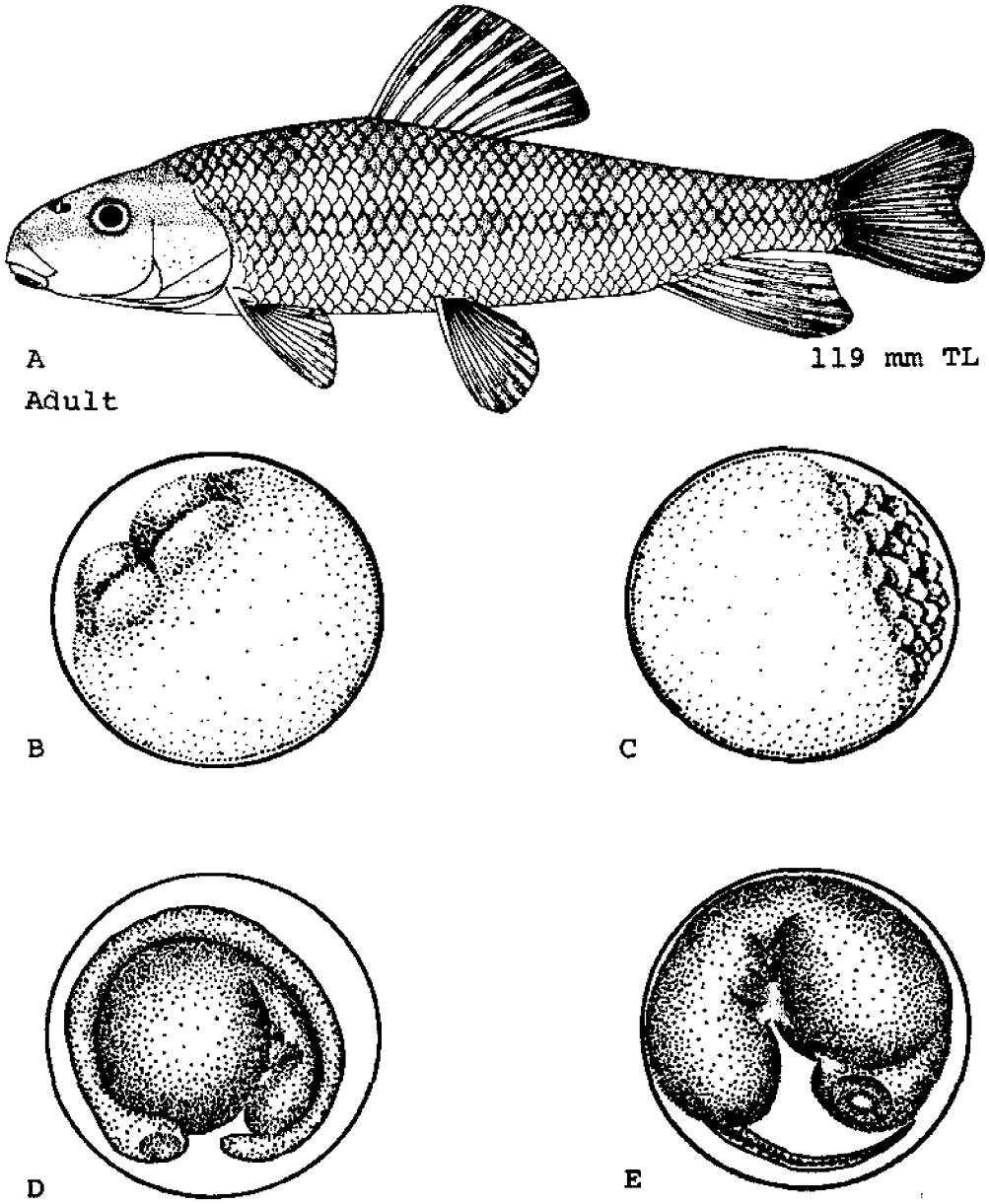

Fig. 181. *Erimyzon oblongus*, Creek chubsucker. A. Adult, 119 mm TL, 98 mm SL. B. Egg, four-cell stage, 2 hours. Development of this and following embryos at 20 C. C. Egg, morula, 3 hours. D. Egg, tail-free embryo, 50 hours. E. Egg, embryo, 74 hours. (*A, Trautman, M. B., 1957: fig. 56, © Ohio State University Press. Used with permission of author and publisher. B-E, Carnes, W. C., Jr., 1958: pls. 2, 3, 4; figs. 3, 5.*)

Breeding males usually with three large tubercles on each side of snout; [2] pearl organs along dorsal, anal, and caudal rays.[14]

Pigmentation: Brownish olive with coppery luster above, pale beneath; fins more or less dusky, sometimes reddish.[3]

Maximum size: Ca. 457 mm.[10]

DISTRIBUTION AND ECOLOGY

Range: Minnesota east to Atlantic coast; reported from New Brunswick and Nova Scotia,[8] but records are possibly erroneous; [19] south on Atlantic coastal plain to Waccamaw River drainage in North Carolina,[17,25] in Mississippi drainage south to Texas and Florida.[8]

Area distribution: Tidal tributaries of Chesapeake Bay to Havre de Grace, Maryland; [3,28] Delaware; [27,28] Virginia; [11] New Jersey.[12]

Habitat and movements: Adults—a bottom species [2,20] inhabiting clear, rapid to slow moving streams, frequently in areas of thick vegetation; also lakes [1,16,22] and millponds (RJM). Undertake spawning migrations to headwaters of streams in spring [16,23] and move downstream to larger creeks following spawning.[4] Maximum salinity 2.17 ppt.[18]

Larvae—no information.

Juveniles—in small schools over vegetation along lake shores; [1,21] also in quiet pools of small streams.[5]

SPAWNING

Location: Presumably headwaters of small creeks over sand and gravel,[4,14] also in ponds over muck bottoms.[26]

Season: March and April in North Carolina, with movements chiefly during evening hours.[14]

Minimum temperature: Ca. 11.0 C.[14]

Fecundity: 7500 [9]–83,013.[14]

EGGS

Description: Demersal; adhesive, attached to objects on bottom and to each other.[14]

Ripe eggs—1.84 mm in diameter; spherical; light to deep golden yellow; perivitelline space very narrow; oil globules lacking.[14]

EGG DEVELOPMENT

At ca. 20 C (fluctuating from 17–23 C):

One hour	blastodisc formed; first cleavage evident.
2 hours	4-cell stage.
2 hours, 35 minutes	8-cell stage.
3 hours	morula.
24 hours	some eggs with incipient neural crest.
50 hours	embryo completely surrounds yolk; tail tip free; eyes barely distinguishable.
74 hours	tail completely free; yolk mass oval anteriorly, tubular behind; movement established.[14]

Incubation: 96 hours at ca. 20 C (fluctuating from 17–23 C).[14]

YOLK-SAC LARVAE

Hatching at 4.8 mm TL; maximum size described 6.0 mm.

Head initially deflected over yolk, free at 6.0 mm; mouth poorly developed at 5.9 mm. Auditory vesicles small, elongate at hatching, no longer visible at end of stage. Yolk sac spherical anteriorly and elongate posteriorly at hatching, reduced to slender tube at 5.9 mm. Pectoral buds present at hatching; preanal finfold extended forward toward head as yolk is absorbed.[14]

Pigmentation: At 6.0 mm (ca. 2 days old), chromatophores apparently formed in finfold; at 5.9 mm (ca. 4 days old), chromatophores on head above and below eye, along anterior half of dorsal surface and anteroventral surface of yolk.[14]

LARVAE

Specimens described 7.7–7.9 mm TL.

Mouth clearly visible and gas bladder formed at 7.7 mm; gill arches forming at 7.9 mm. At 7.7 mm, pectorals well-developed; incipient rays in caudal.[14]

Pigmentation: At 7.7 mm, chromatophores throughout body with single row along vertebral column. At 7.9 mm, pigmentation more pronounced, with distinct, broken, dark line laterally.[14]

JUVENILES

Minimum size described 34 mm TL.

Eye larger than in adult. Scalation incomplete at 34 mm (AJL), apparently complete at ca. 45 mm.[12]

Pigmentation: A distinct dark lateral band [3] of widely spaced chromatophores evident at 34 mm (AJL), later broken into blotches forming transverse bands; [3,15] caudal fin amber.[8,24]

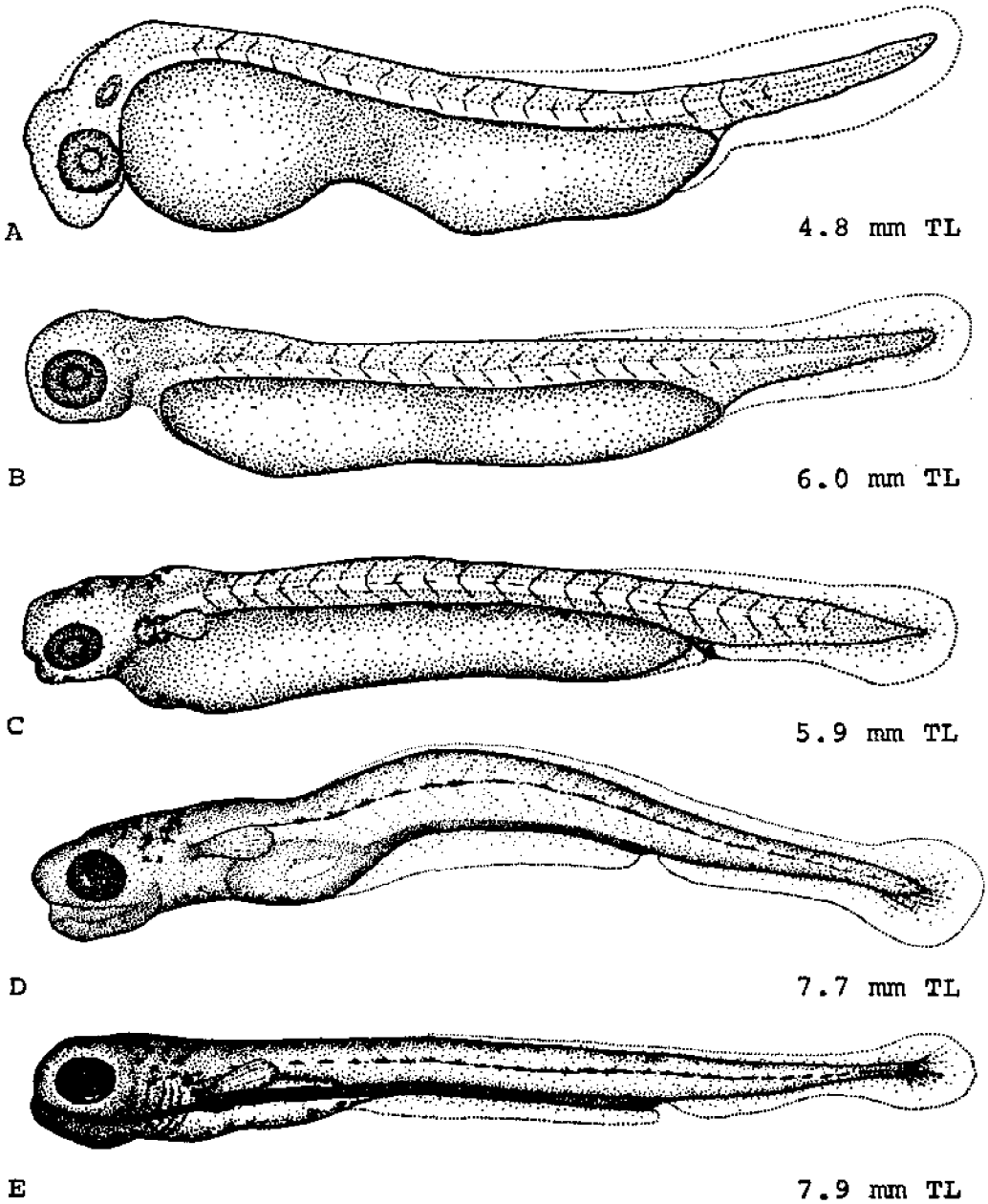

Fig. 182. *Erimyzon oblongus*, Creek chubsucker. A. Yolk-sac larva, 4.8 mm TL, just hatched. Yolk sac, 3.05 mm long; pectoral buds present but not shown. B. Yolk-sac larva, 6.0 mm TL, ca. 2.2 days. C. Yolk-sac larva, 5.9 mm TL, ca. 3.9 days. D. Larva, 7.7 mm TL, ca. 7.4 days. E. Larva, 7.9 mm TL, ca. 20.4 days. (A-E, Carnes, W. C., Jr., 1958: pls. 5–9.)

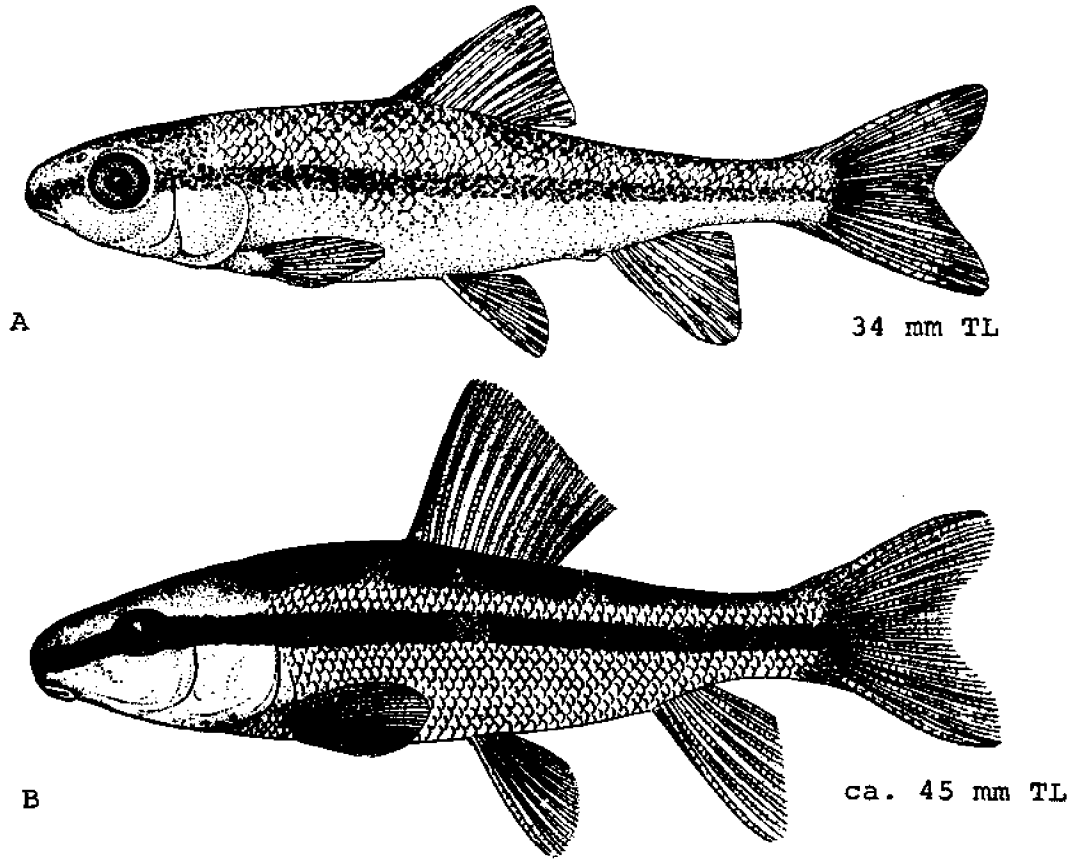

Fig. 183. *Erimyzon oblongus*, Creek chubsucker. A. Juvenile, 34 mm TL, 28 mm SL. B. Juvenile, ca. 45 mm TL. (*A, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 77C. B, Fowler, H. W., 1906: 160.*)

AGE AND SIZE AT MATURITY

Smallest males possibly ca. 61 mm, based on presence of breeding tubercles.[4]

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Moxostoma macrolepidotum (Lesueur), Shorthead redhorse

ADULTS

D. 10–15 (usually 12–13);[24] A. 6[22]–8 (usually 7); C. 17–19 (usually 18); P. 14–19 (usually 16–18);[24] V. 8–10[14] (usually 9[24]); lateral line scales 39[24]–48[18] (usually 42–44), circumferential scales 28–37, predorsal scales 12–19, caudal peduncle scales 11–16 (usually 12); post-Weberian vertebrae 37–40; gill rakers 22–30;[24] branchiostegals 3.[22]

Proportions as percent TL: Greatest body depth 18.0–22.9; caudal peduncle depth 7.2–9.3; HL 17.0–19.0.[22] Proportions as percent SL: Body depth 22.0–31.3; HL (over 150 mm SL) 18.2–24.5; orbit (over 200 mm SL) 3.6–5.4; caudal peduncle depth 9.2–12.1; snout length 8.2–11.5.[24] Proportions as percent HL: Snout 37.5–47.9; interorbital width 36.3–48.0. Proportions as percent snout length: Eye 50.0–83.3 in "smaller" specimens, as low as 36.9 in larger.[22] Proportions as times in SL: Body depth 3.2[19]–4.3;[2] HL 4.2[19]–5.4.[2] Body moderate (REJ), laterally compressed, back with moderate arch.[22] Head small,[2] naked short, slightly humped behind eye, snout somewhat bulbous, overhanging mouth. Mouth rather small, inferior, gape barely reaches nostril;[22] lips small to moderate, posterior margin straight or forming very obtuse angle, surfaces in most forms deeply plicate, lateral or nearly entire portions of lower lip transversely and deeply cut into large papillae, *M. m. pisolabrum* with upper lip thickened medially, bulbous. Dorsal fin margin moderately to quite falcate (straight only in some large adults), 4th pectoral ray usually longest, in adult males anal fin quite pointed and elongate. Intestine well coiled,[24] swim bladder with 3 chambers.[22] Males with breeding tubercles on caudal and anal rays, minute tubercles scattered on dorsal and paired fins, head and all scales; females with minute tubercles on dorsal and paired fins, and head.[24]

Pigmentation: Body dark olive to tan-olive dorsally, olive-yellow laterally with copper to bronze overcast,[24] ventral surface milk white or yellowish.[2] Dorsal fin bright to pale red,[24] or with red leading tip, dark edge and dusky to orange in main area;[22] caudal fin bright red or carmine over most of fin, except in certain Atlantic slope populations where red color is less developed to absent; anal fin red to orange; paired fins generally salmon, reddish orange, or yellowish orange, except Atlantic slope populations where color varies from salmon, pale yellow to basically white.[24]

Maximum length: Ca. 620 mm.[2]

DISTRIBUTION AND ECOLOGY

Range: *M. m. macrolepidotum* occurs from the Santee to Delaware drainage; St. Lawrence–Great Lakes basin; southwestern Hudson Bay basin; and upper Mississippi and Missouri basin. Replaced by *M. m. pisolabrum* in western lower Mississippi and lower Missouri basins and by *M. m. breviceps* in the Ohio basin.[24]

Area distribution: In western Chesapeake drainage from Susquehanna to James systems, except unknown between Patuxent and Susquehanna rivers (REJ). Apparently not now occurring in New Jersey[15] and Delaware.[14,24]

Habitat and movements: Adults—primarily in larger clear streams,[12] rivers[15] and lakes[24] over bottoms of sand, gravel or bedrock;[2] also reported over mud and silt bottom, in sluggish current or stagnant water.[25] Introduced in millponds and reservoirs (RJM). Migratory, ascend streams to spawn.[4,6,9] Maximum salinity, 3.0 ppt (RJM), maximum temperature 37.2 C.[23] *M. m. macrolepidotum* usually found in fast moving water over

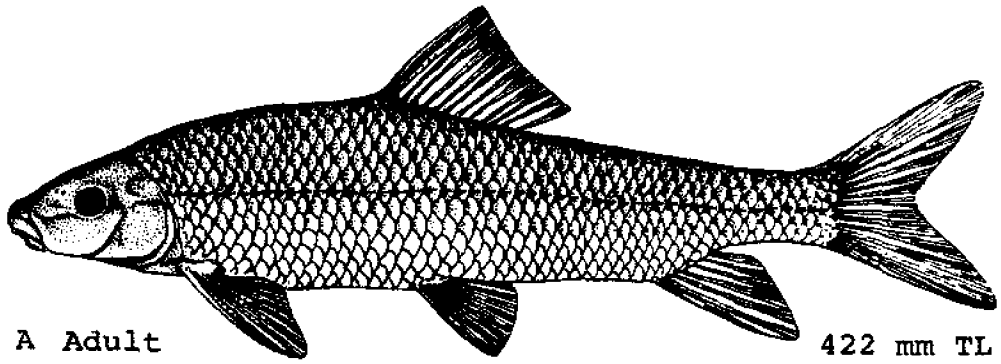

Fig. 184. *Moxostoma macrolepidotum*, Shorthead redhorse. A. Adult female, 422 mm TL. (*Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 78A, after Greeley, J. R., 1930.*)

rock, gravel, or rubble bottom, less frequently in turbid water over heavily silted bottom.[3] *M. m. pisolabrum* most commonly at uppermost end of riffles with swift flow at depths of ca. 61 cm.[27] *M. m. breviceps* inhabits areas of moderate current in shallow, open pools or at the foot of riffles almost always over clean gravel bottom.[26]

Larvae—no information.

Juveniles—fast water [3] in streams [6] and rivers (REJ).

SPAWNING

Location: Riffles or gravel rapids in streams 9.1–12.2 m wide; [7,8,11] over sand bottoms (RJM); in clear water near edges of sandbars in water 15–21 cm deep; in troughs ca. 90 cm long and 50 cm wide and circular "nests" ca. 40–55 cm in diameter.[29]

Season: April to June in Maryland (RJM).

Time: Night; [6] also 1000 to 1600 hours (ECR).

Temperature: 11.1 [3]–21.7 C.[24]

Fecundity: 13,500 [3]–29,732.[25]

EGGS

Location: Scattered in small lots,[11] buried in the bottom by vigorous spawning (ECR).

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

Minimum size unknown.

Head 3.5–4.0 times in SL in "young" less than ca. 75 mm.[2] Head 4.0 or more in SL in young-of-year.[23]

AGE AND SIZE AT MATURITY

Mature by age group III.[3]

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Arius felis
Bagre marinus

sea catfishes
Ariidae

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FAMILY ARIIDAE

While there are many families and species of catfishes, there are only two truly marine families, the Ariidae and the Plotosidae. In the Atlantic, any marine catfish will be an ariid. This family is not confined to marine waters. Though incapable of completing their life cycle in freshwater, they commonly enter the lower reaches of rivers. Numerous species and genera and reported for this family with the majority of them being tropical or subtropical.

Adults are characterized by being scaleless, having an adipose fin, and a forked caudal fin, three pairs of barbels, some bony plates on the head and near the dorsal fin origin and strong dorsal and pectoral spines. The only fish in this region with which they could be confused are the freshwater ictalurid catfishes. They are separated from these most easily by the lack of a pair of nasal barbels.

Both of the species included here are buccal incubators with the male carrying the large, yolky eggs. The yolk-sac larvae are quite advanced in development at hatching and complete transformation into juveniles by the time of yolk absorption.

Arius felis (Linnaeus), Sea catfish

ADULTS

D. II, 7 [27] (I, 7 [17]); A. 18 [27]–20; [18] C. 19–20 + 7 + 8 + 19–20 = 53–55; [27] P. I, 6–10 (WRT); V. 6; [18] total vertebrae 50–52, precaudal 22, caudal 28–30.[27]

Body rather elongate, tapering to slender tail. Head depressed, flattened above; three pairs of barbels, 2 pairs on lower jaw (WRT); maxillary barbels nearly as long as head.[17] Posterior margin of anal fin not deeply indented.[6]

Pigmentation: Steel blue above, sides and belly silvery; lower fins plain.[17]

Maximum length: Ca. 610 mm.[2]

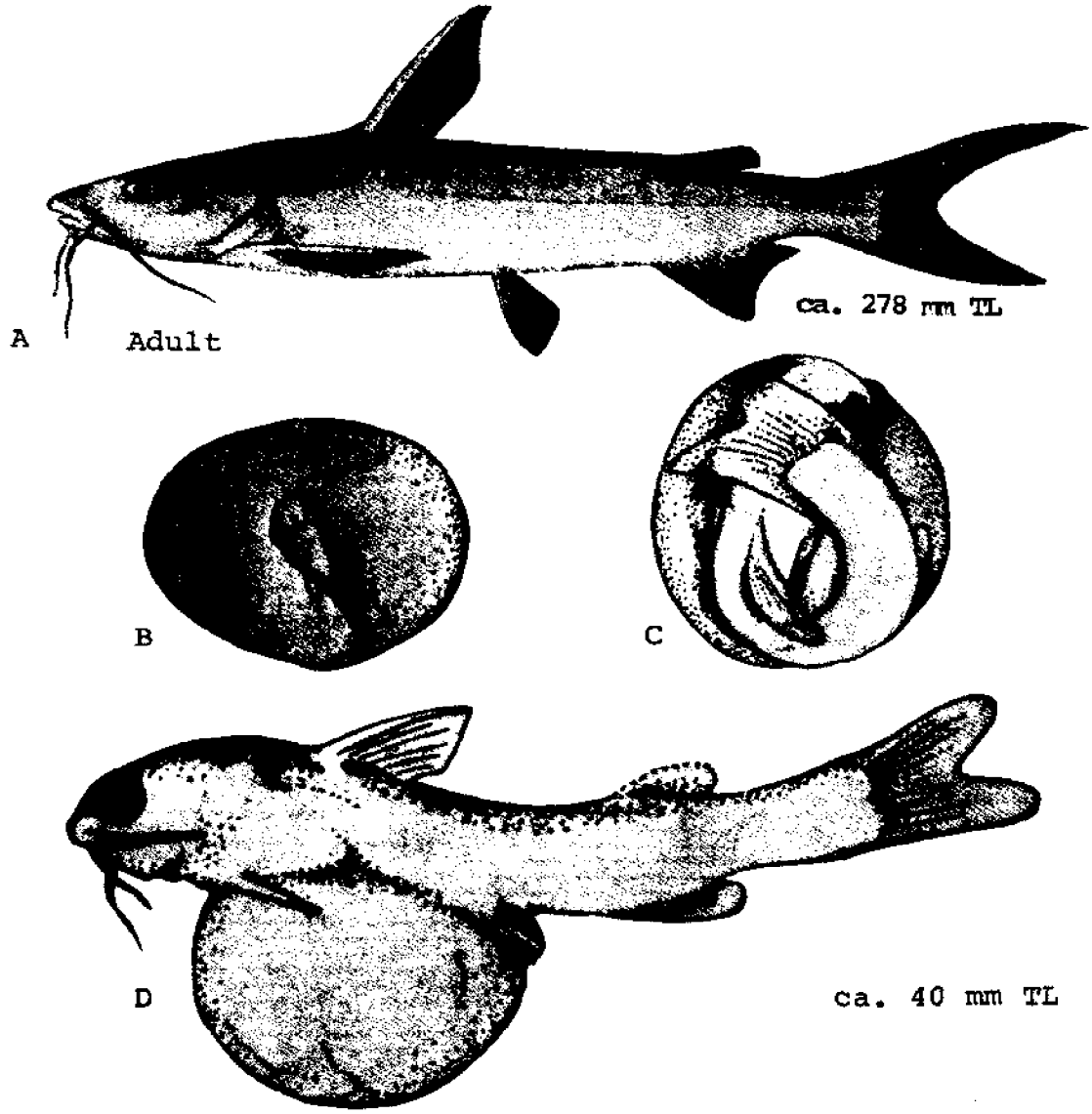

Fig. 185. *Arius felis*, Sea catfish. A. Adult, ca. 278 mm TL. B. Egg, chorion removed; embryo with most myomeres formed. C. Egg, chorion removed; late embryo; barbels and fins present. Dorsal pigmentation and well-developed hypural plate not illustrated. D. Yolk-sac larva, ca. 40 mm TL. (*A, Goode, G. B., et al., 1884: pl. 236. B-D, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 80B-D, after Merriman, D., 1940.*)

DISTRIBUTION AND ECOLOGY

Range: Cape Cod to Yucatan, Mexico [20] (records from Panama [9] are apparently in error, WRT).

Area distribution: Lower Chesapeake Bay.[5]

Habitat and movements: Adults—shallow, coastal water over sand or mud bottom during summer; [1] sometimes in schools.[13] Recorded from freshwater; [8,14,19] common in salinities up to 45 ppt; maximum salinity 60 ppt; [12] most abundant at 25 C and higher.[24] Maximum depth 27.4 m.[1] In Texas found in bays in spring, departing to Gulf of Mexico in fall; [10] abundant in Alabama from April to September, some overwintering occurs in deep channels in upper Mobile Bay and delta areas; [21] in Louisiana abundant from May through October [24] and January; seasonal migration does not occur in southern Florida.[26]

Yolk-sac larvae—carried in mouth of male parent; [1,2] sometimes in mouth of female parent.[26]

Juveniles—apparently more numerous than adults in waters of low salinity; [10,11] recorded from freshwater.[25]

SPAWNING

Location: In Gulf of Mexico area, back bays in water as shallow as ca. 0.6–1.2 m; probable salinity 13–30 ppt.[3]

Season: Males observed with young in mouths from first of May to first week in August.[4,6,15,22] "Young" 48 and 58 mm taken in December off Alabama.[21] Female incubating eggs taken from Charlotte Harbor, Florida in July.[25]

Fecundity: Ca. 20–64 mature ova produced each season.[6]

EGGS

Location: Carried in mouth of male [1] and sometimes female parent.[25] It has been suggested that (1) eggs are deposited initially in sandy depressions from which they are picked up by male parent,[6] and (2) females use flap-like modifications on pelvic fins to assist in placing eggs directly in mouth of male.[1] Demersal when dropped by parent.[3]

Ripe ovarian eggs: Diameter 12–19 mm; [6] greenish; [4] micropyle single, stellate; ca. 0.5 mm in diameter.[3]

Fertilized eggs: Maximum diameter 14–18 mm; [4] somewhat oval or elliptical, rarely round; [6] egg capsule with thin, colorless adhesive film; adhesiveness lost as development proceeds.[3]

EGG DEVELOPMENT

At 29.5–30.5 C: [4]

4 hours	2-cell stage.
7 hours	4-cell stage.
9 hours	8-cell stage.
11 hours	16-cell stage.
20 hours	blastula.
29 hours	gastrula.

Development of embryos of unknown age: [4]

5–7 mm	body straight; brain divisions, optic vesicles, and olfactory placodes visible; blood circulation established; movement in tail.
9–15 mm	embryo embedded in yolk; pectoral fins leaf-like; pelvic buds formed, 3 gill buds present; vitelline vessels over 1/2 yolk; pigment lacking except in retina.
18–24 mm	pigment in pectoral region.
23–25 mm	6 barbels, olfactory bulbs, cerebral hemispheres, optic lobes, and 4 branchial arteries differentiated; light pigmentation developed.
38–45 mm	opercular cartilage and membrane formed; all external features developed; dorsal region of head, body, and tail pigmented.[4]

Just prior to hatching, membrane covering head becomes increasingly transparent.[18]

Incubation: Possibly ca. 30 days to hatching with larvae retained in parent's mouth an additional 2–4 weeks.[6]

YOLK-SAC LARVAE

Hatching size apparently ca. 29 [1]–45 mm.[4] Size range described 29 [1]–ca. 52 mm.[7,10] Duration of stage, up to ca. 55 days under laboratory conditions.[6]

Yolk sac large, round; rays developed or developing in all fins except pectorals; eyes large.[6]

LARVAE

Since fin ray complement is complete before yolk absorption, this stage does not exist for this species.

JUVENILES

Size described 68–88 mm.

D. I, 6 [23] (questioned, PWJ).

Proportions expressed as times in SL: Head 3.5–4.4; depth 4.7–5.5; predorsal distance 2.8–3.0. Eye 4.3–5.5 in head.[23]

Body elongate, slightly compressed toward tail; head subconical, maxillary barbels almost reaching end of

pectoral spine; dorsal and pectoral spines of approximately equal length; caudal deeply forked, upper lobe longer.[28]

Pigmentation: Grayish to steel blue above, silvery below. Dorsal, pectoral and anal fins dusky, leading edges of pelvic and pectoral fins whitish, caudal fin bright bluish bordered by rim of darker blue, adipose fin dark blue, vertical fins often with greenish tint.[23]

AGE AND SIZE AT MATURITY

Smallest mature female 126 mm; smallest brood male 142 mm.[1]

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Bagre marinus (Mitchill), Gafftopsail catfish

ADULTS

D. I[6] (II),[17] 7; A. 22–28;[6,10] C. 22–23 + 7 + 8 + 21 = 58–59;[17] P. I, 11–14; V. 6;[6,10] total vertebrae 53–54, precaudal 22, caudal 31–32.[17]

Body robust; head depressed. Teeth villiform in bands on jaws and palate. Two pairs of barbels, one pair on lower jaw; maxillary barbels long, flattened, sometimes reaching nearly to base of pelvics. Dorsal and pectoral spines with extended filaments;[6] anal fin with a prominent V-shaped indentation on posterior margin.[2]

Pigmentation: Dorsum steel blue, sides silvery, venter white; dorsal and anal fins white or bluish; caudal fin dusky or gray.[6]

Maximum length: Ca. 571 mm.[6]

DISTRIBUTION AND ECOLOGY

Range: Cape Cod to northern South America.[3,7,12]

Area distribution: Chesapeake drainage north to Rock Point, Potomac River, Maryland.[6]

Habitat and movements: Adults—a bottom species of coastal waters and estuaries;[1] recorded from fresh water,[11] but most abundant between 5 and 30 ppt;[4] leave estuaries in fall, return in spring.[4,9]

Yolk-sac larvae—retained in mouth of male parent; if removed, demersal, but sometimes floating at surface.[1]

Juveniles—leave estuaries in fall, return in spring; temperature range 10.0–34.9 C, preference 25.0 C and higher.[13]

SPAWNING

Location: Probably mud flats.[1]

Season: May[2] to August[16] off Florida, with spawning rarely lasting over 10 days.[4,5] Females with well-developed eggs taken off Alabama, March 31 to April 15.[14]

Fecundity: Ca. 20[2]–68.[5]

EGGS

Location: Carried in mouth of male, sometimes in spaces between branchial arches; number of eggs per male 2–55.[1]

Ripe ovarian eggs: Longest diameter 15.0[1]–21.5 mm.[8]

Fertilized eggs: Golden yellow;[8] oval or elliptical, rarely round;[2,5] longest diameter 15–26 mm; average longest diameter of 327 eggs, 19.5 mm.[5]

EGG DEVELOPMENT

At unspecified temperature. When embryo is 17 mm long, eye pigmented; tail free. At 20–25 mm, embryo sunken into egg; head twisted to side with only one eye visible; yolk vascular system well developed; caudal fin rays formed; pigment along dorsum.[1] Prior to hatching, 2 barbels on lower jaw differentiated; filaments of pectoral and dorsal fins formed.[2]

YOLK-SAC LARVAE

Length at hatching ca. 45 mm TL.[5] Length at end of stage 78[4]–100 mm.[5]

Apparently larvae are retained in mouth of male parent until yolk is absorbed. Time period in mouth, beginning with fertilization, 42[2]–70 days. At 57 mm TL, choroid fissure faintly visible; dorsal spine ca. 1/4 TL.[1]

Pigmentation: Black stippling on head, along dorsum, and in distinct lines along myomeres.[1]

LARVAE

Since the fin ray complement is complete prior to yolk absorption, this stage does not occur in this species.

JUVENILES

Minimum size ca. 80–100 mm TL.[5]

Proportions expressed as times in SL (at 87–119 mm): Head 3.7–4.1; depth 4.4–5.1; predorsal distance 3.1–3.4. Eye 4.4–5.2 in head.[13]

At 87–119 mm SL, snout very short, blunt; maxillary barbels almost reaching anal fin base. Dorsal fin filament reaching base of adipose fin; caudal deeply forked, upper lobe much longer; pectoral spine longer than dorsal spine, its filament almost reaching anal fin base.[13] At time of yolk absorption, all adult characteristics visible.[2]

AGE AND SIZE AT MATURITY

Females, 265 mm.[2]

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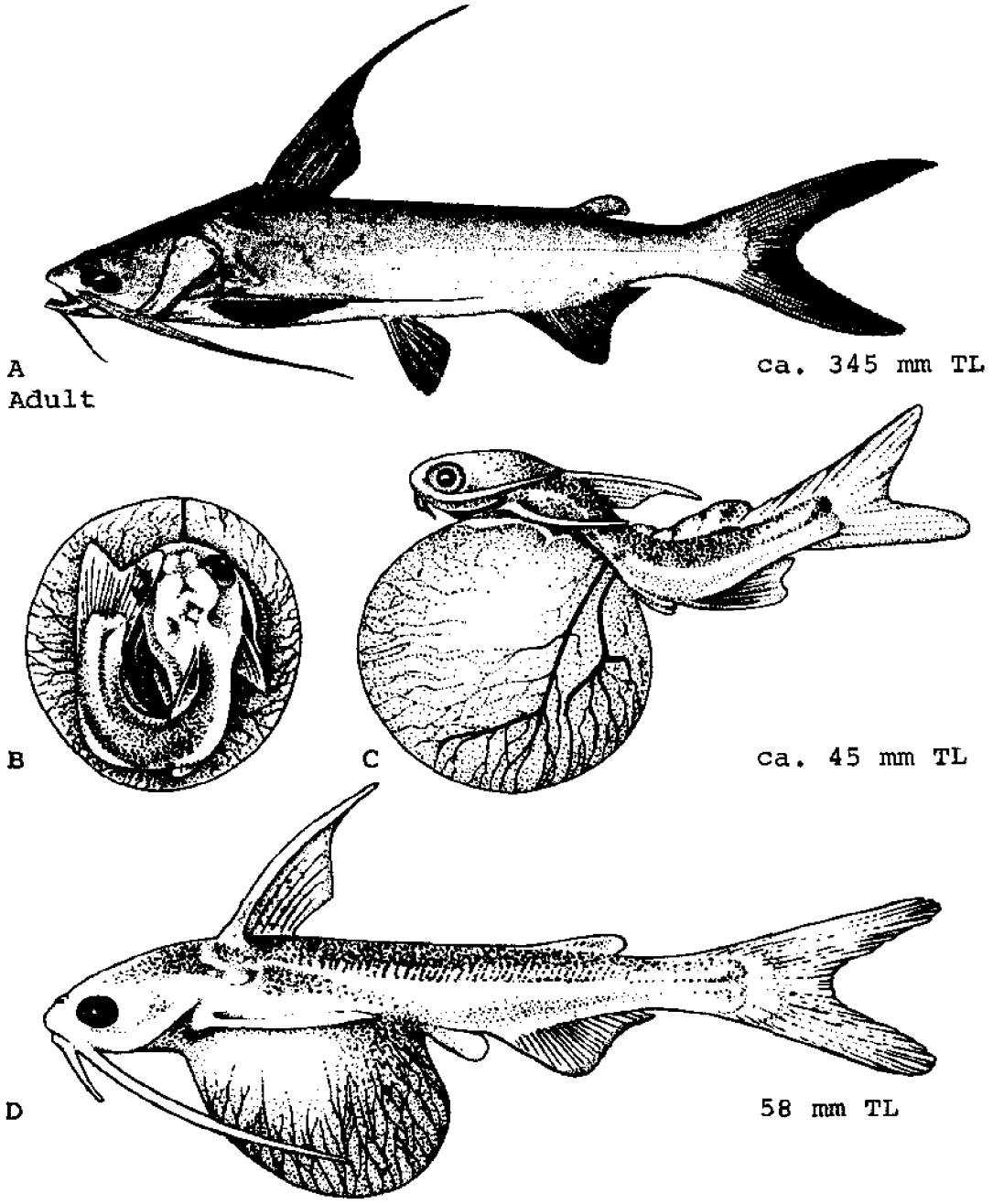

Fig. 186. *Bagre marinus*, Gafftopsail catfish. A. Adult, ca. 345 mm TL. B. Egg, 18.5 mm in diameter; just before hatching. C. Yolk-sac larva, ca. 45 mm TL; recently hatched. D. Yolk-sac larva, 58 mm TL. (*A, Goode, G. B.*, et al., *1884: pl. 235. B-D, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 79B-D, after Gudger, E. W., 1918.*)

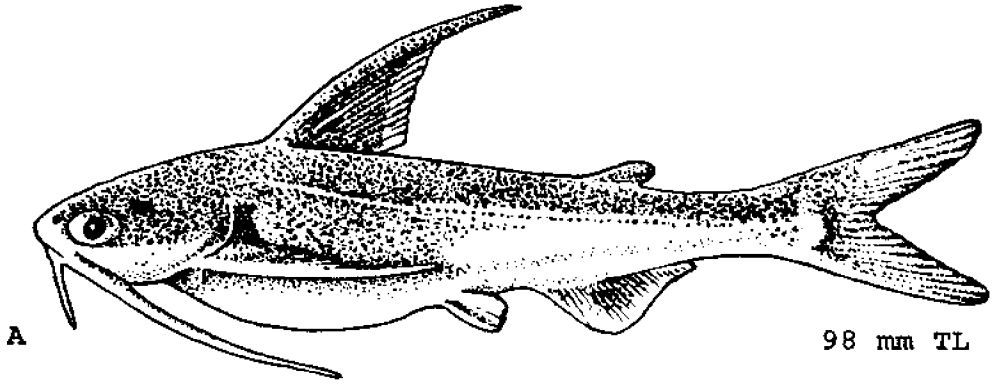

Fig. 187. *Bagre marinus*, Gafftopsail catfish. A. Yolk-sac larva, 98 mm TL. (*Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 79E, after Gudger, E. W., 1918.*)

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Ictalurus catus
Ictalurus natalis
Ictalurus nebulosus
Ictalurus punctatus
Noturus gyrinus
Noturus insignis

freshwater catfishes
Ictaluridae

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FAMILY ICTALURIDAE

Catfishes are primarily inhabitants of freshwater lakes and rivers in temperate and subtropical regions of North and Central America. A few species are known to enter tidal waters of low salinity. Most active at night, ictalurids generally hide or remain in deeper waters during daylight.

These fishes have a laterally compressed body behind the dorsal fin, a large flattened head with four pairs of barbels, smooth, scaleless skin, an adipose dorsal fin and stout spine on the dorsal and each pectoral fin.

This family is composed of about five genera and 40 species. Two genera and six species are known from the Mid-Atlantic region. These six species spawn in excavated nests, man-made objects or natural cavities in fresh or slightly brackish waters.

Described eggs from this region are large (3–6 mm in diameter), occurring in masses that are guarded and aerated by one or both parents. Newly hatched yolk-sac larvae have well formed mouths, maxillary and mandibular barbels and large oval yolks.

The adult complement of fin rays is evident at yolk absorption, thus development proceeds directly from yolk-sac larvae to juvenile.

Ictalurus catus (Linnaeus), White catfish

ADULTS

D. I, 5 [8]–7; [19] A. 21–26; [24] P. I, 8–9; V. 8.[19]

Body depth 3.5–4.75 times in TL; eye 6.9–7.84 times in HL; pectoral spine 2.22–2.41 times in HL.[2,3]

Body rather robust, somewhat compressed; [2,3] bony supraoccipital does not reach dorsal spine.[24] Head depressed, broad; mouth very broad; lower jaw slightly included; teeth villiform, in bands on jaws; four pairs of barbels. Pectoral spine stout, not as long as longest soft ray; caudal fin moderately forked.[2,3]

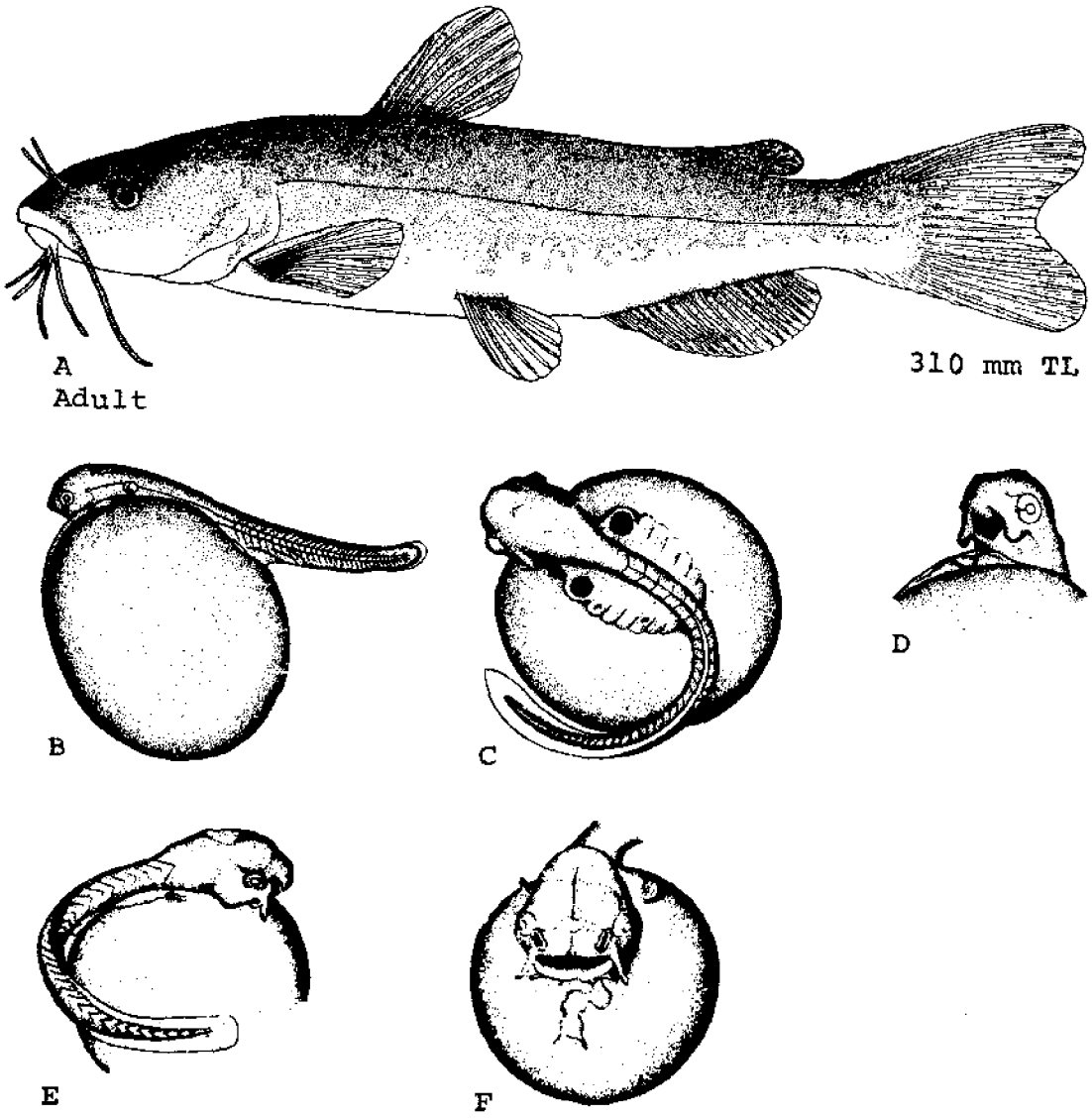

Fig. 188. *Ictalurus catus*, White catfish. A. Adult, 310 mm TL, 253 mm SL. B. Embryo removed from egg, 2 days. Development of this and following embryos at an unspecified temperature. C. Embryo removed from egg, 3 days. Operculum, pectoral buds, and myomeres formed. D. Head of 3-day-old embryo. Maxillary barbels at corners of open mouth; heart developed. E. Embryo removed from egg, 4 days. Mandibular barbels forming. F. Head region of embryo, 5 days. (*A, Trautman, M. B., 1957: fig. 105. © Ohio State University Press. Used with permission of author and publishers. B-F, Ryder, J. A., 1887: figs. 155, 156, 159, 161, 162.*)

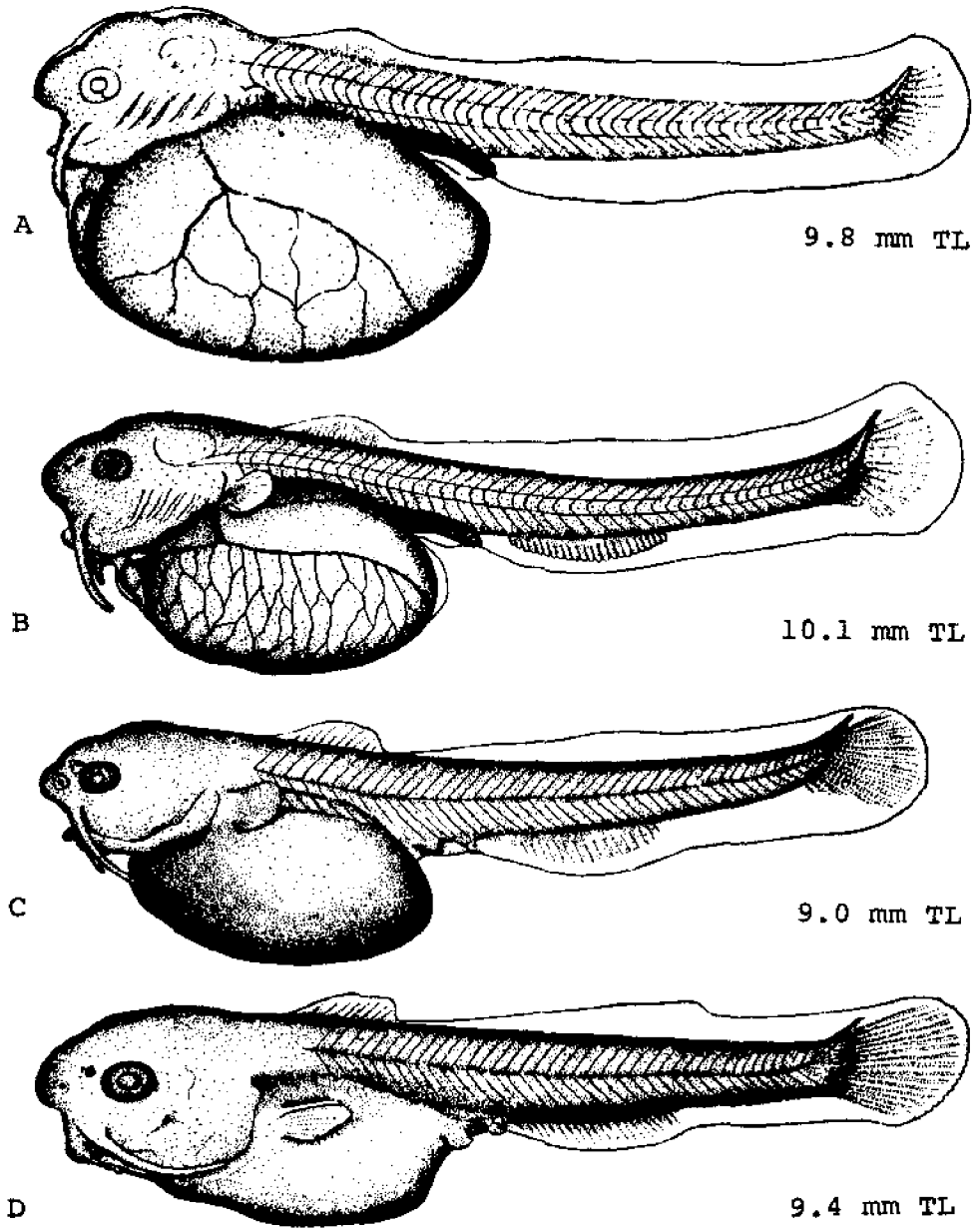

Fig. 189. *Ictalurus catus*, White catfish. A. Yolk-sac larva, 9.8 mm TL, just hatched. B. Yolk-sac larva, 10.1 mm TL, 1 day. Nasal barbel forming just anterior to posterior nare. C. Yolk-sac larva, 9.0 mm TL, 2 days. D. Yolk-sac larva, 9.4 mm TL, 3 days. Pelvic buds developed. (*A-D, Ryder, J. A., 1887: figs. 163–166.*)

Pigmentation: Grayish above and on sides, white below; head olive gray; anal whitish, edged with gray;[2,3] no distinct dark spots on body. Breeding individuals bluish black to dusky blue above, whitish blue below.[4]

Maximum length: Ca. 610 mm.[24]

DISTRIBUTION AND ECOLOGY

Range: Coastal streams from Pennsylvania[4] and New York,[7] south to Lake Okeechobee, Florida,[3] and west along the Gulf coast to Escambia drainage system[22] (records from Texas[14,15] are apparently in error, WRT);

introduced on Pacific coast,[21] in Nevada,[7] and Lake Erie.[11]

Area distribution: Tidal tributaries of Chesapeake Bay north at least to Patapsco River;[2,10,30] larger tidal creeks of Delaware River Estuary;[29,30] New Jersey coastal areas.[31]

Habitat and movements: Adults—river channels[2] and streams in sluggish current;[4] also lakes,[6] ponds and bayous, frequently over heavily silted bottom,[4] avoiding areas of dense vegetation;[25] capable of extensive movement away from tagging sites, but with no apparent seasonal migratory tendencies;[18] movement to remain within a certain isohaline regime may occur.[23] Maximum salinity 14.5 ppt,[9] lethal salinity tolerance (LC_{50}, 60 hr.) 14 ppt; upper lethal temperature (LC_{50}, 12 hr.) at 20 C acclimation, 29.2–31.0 C.[23] Preferred depth: Ca. 3.0–9.1 m from April through June, ca. 9.1–15.2 m in July and August, surface to ca. 27.4 m in September and October, below ca. 15.2 m after fall turnover.[26] Occur regularly in small numbers near surface over depths of ca. 30.5–76.2 m.[25]

Larvae—no information.

Juveniles—initially guarded by parents; remain in schools until end of first summer.[20] Capable of growth at 11 ppt *or less.*[27]

SPAWNING

Location: Still or running water[8] in nests usually built near sand or gravel banks; nest large, up to 91.4 cm across and 45.7 cm deep.[12]

Season: Late May to early June in Pennsylvania, lasting about 1 week;[13] probably in early July in California;[6] *mid-July in captivity.*[1]

Time: Eggs deposited sometime prior to 1000 hours in reported one case.[16]

Temperature: Ca. 21 C.[8]

Fecundity: 1000[8]–3500.[5]

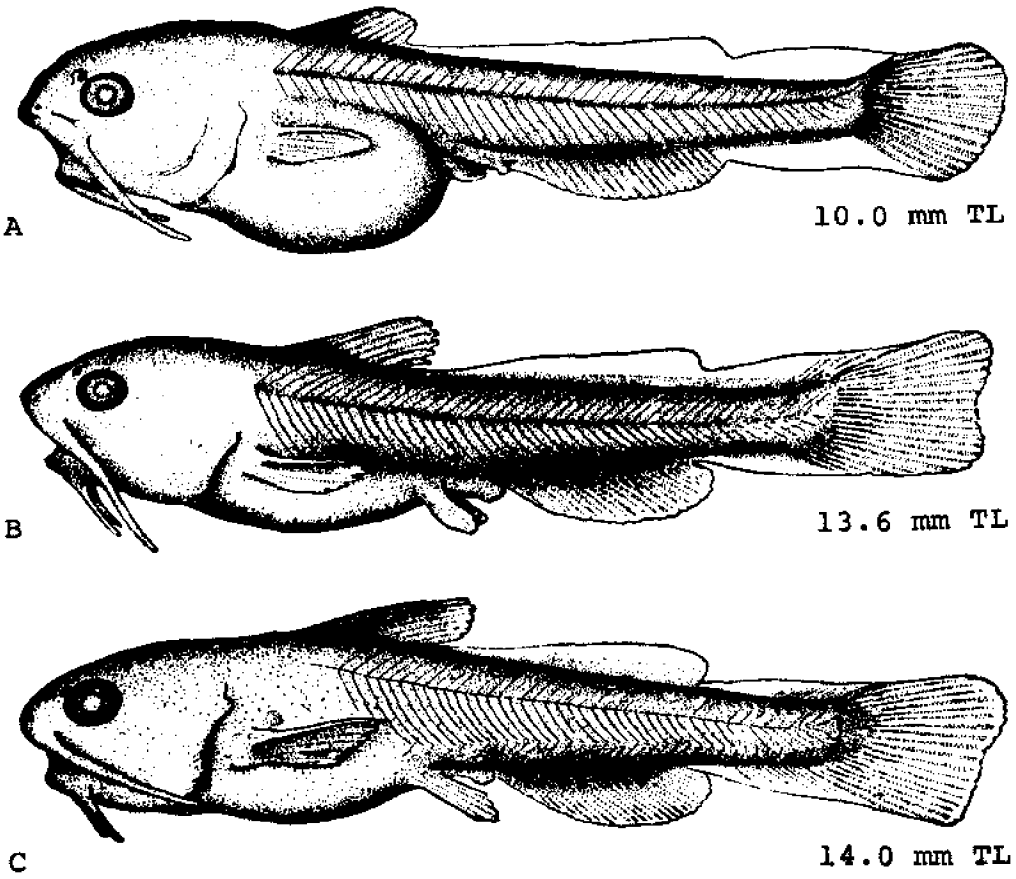

Fig. 190. *Ictalurus catus,* White catfish. A. Yolk-sac larva, 10.0 mm TL, 4 days. B. Yolk-sac larva, 13.6 mm TL, 5 days. Nasal barbels elongating. C. Juvenile, 14.0 mm TL, 9 days. (*A-C, Ryder, J. A., 1887: figs. 167–169.*)

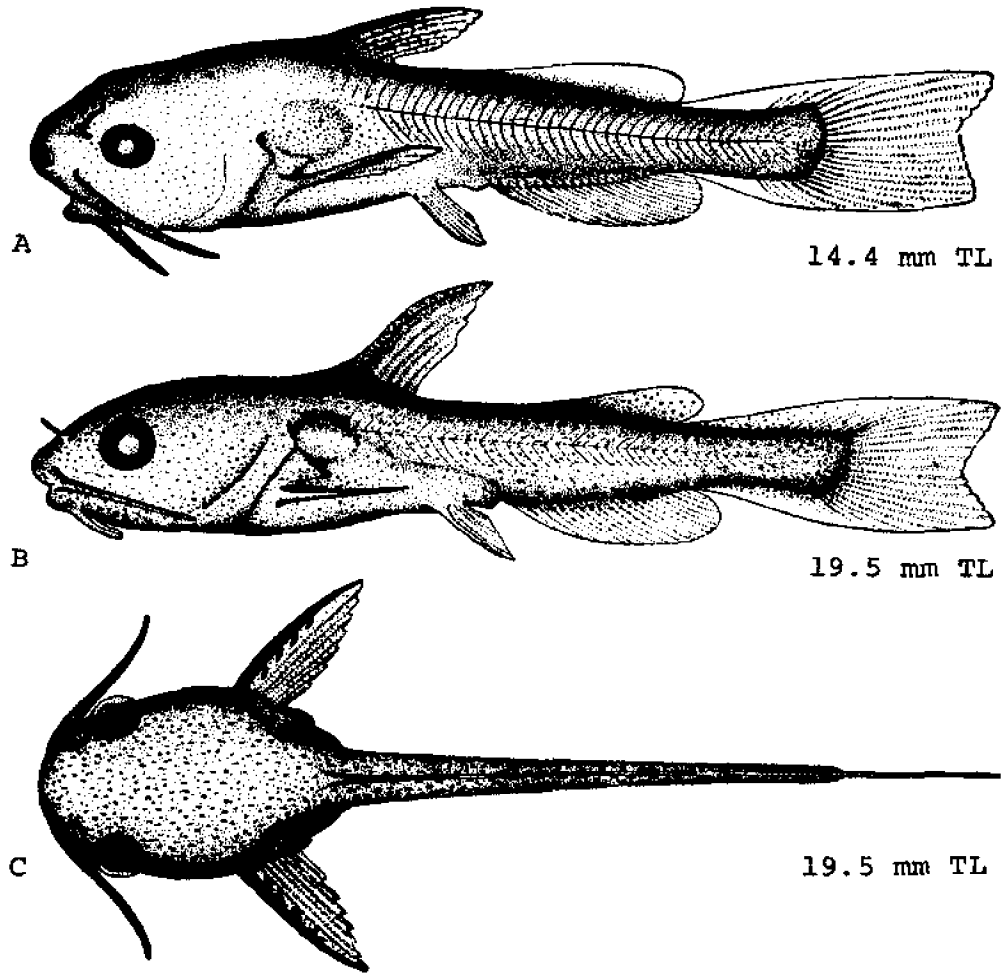

Fig. 191. *Ictalurus catus*, White catfish. A. Juvenile, 14.4 mm TL, 14 days. Gas bladder evident. B. Juvenile, 19.5 mm TL, 82 days. C. Dorsal view of "B." (*A-C, Ryder, J. A., 1887: figs. 170–172.*)

EGGS

Note: *Ryder*[1] *may be describing* I. nebulosus *or* I. punctatus *rather than* I. catus *(WRT)*.

Location: Demersal,[1] sometimes covered with 127–152 mm of gravel;[12] deposited in masses, one of which measured 203 mm long, 102 mm wide, 12.7 to 19.5 mm thick, and contained ca. 2000 eggs. Egg masses guarded and aerated chiefly by male parent.[1,12]

Ripe eggs: Diameter 4.0–4.5 mm.[5]

Fertilized eggs: Diameter ca. 4.2 mm;[16] spherical;[1] yellowish white;[12] adhesive; yolk granular,[1] ca. 3.2 mm in diameter;[18] egg capsule double,[1] with adhesive, non-gelatinous and highly elastic outer envelope.[1,16] Ryder[1] mentions minute "corpuscles" within the perivitelline space.

EGG DEVELOPMENT

Note: *Observe same caution as with above concerning data from Ryder*[1] *(WRT)*.

At unspecified temperature:

Second day	tail-free stage; rudimentary branchial arches and clefts, nasal pits, maxillary barbels and finfold developing; mouth not open.
Third day	tail with movement; vascular system, pectoral buds, and anlage of operculum present; finfold complete; mouth open; maxillary barbels developing as flat lobes at angle of mouth.
Fourth day	barbels of lower jaw forming.
Fifth day	incipient anterior dorsal fin and caudal rays evident.[1,16]

Incubation: 2–6 days at unspecified temperature; [1,12] 6–7 days at ca. 23.9–29.4 C.[26]

YOLK-SAC LARVAE

Hatching length 9.0–9.75 mm TL. Specimens 1–4 days *old vary randomly from 9.0–10.0 mm in length, while* a specimen 5 days old is 13.6 mm in length.

Yolk oval at hatching. Nostril divided by 1st day. Choroid fissure no longer visible by 2nd day. Urostyle oblique at hatching. Four barbels evident on 1st day; nasal barbels first evident on 4th day. Heart prolonged downward over anterior pole of yolk at hatching; gas bladder evident by 4th day. Incipient rays in caudal at hatching, in dorsal and anal by 1st day, and in pectorals by 2nd day; rays fully formed except in pelvics by 13.6 mm (5th day). Pelvic buds evident on 2nd day. Finfold somewhat widened in region of incipient adipose by 2nd *day, and with definite notch at posterior margin of* developing adipose by 3rd day.[1]

Pigmentation: Became progressively darker after hatching, at 4 days dark brown except on belly.[26]

LARVAE

Adult fin ray complement evident before yolk absorption, therefore, as defined in this volume, the larval stage does not occur.

JUVENILES

Minimum size described ca. 14.0 mm TL.[1]

Proportions as percent of SL in specimens 24.9–57.0 mm *SL: Body depth 24.5–26.1; head length 26.8–29.1;* anal length 24.6–26.4; predorsal length 32.9–35.6; pectoral spine 15.9–20.5; dorsal spine 17.5–20.5.[19]

Eye 4.25–4.8 times in SL in "young." [2] Body tadpole-like; postscapular process evident at 19.5 mm. At ca. 14.0 mm, teeth present. Posterior end of gas bladder with indication of 2 lobes at 14.4 mm, evident externally as rounded prominence behind shoulder girdle at 19.5 mm. At ca. 14.0 mm, lower lobe of caudal shorter than upper. At 14.4 mm, lower lobe of caudal longer than upper; *pectoral spine nearly horizontal; adipose free.*[1] Pelvics inserted a little nearer tip of snout than base of caudal in young.[2] Lateral line incomplete anteriorly at ca. 80 mm.[17]

Pigmentation: Adult-like at 19.4 mm.[1]

AGE AND SIZE AT MATURITY

1–2 years; [13] ca. 152 [8]–211 mm FL.[6]

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Ictalurus natalis (Lesueur), Yellow bullhead

ADULTS

D. I, 6–7 [12] (WRT); A. 23–28,[12,16] possibly to 31; [11] P. I, 7–8; [18] V. 8; [12] vertebrae usually 38+Weberian ossicles; gill rakers 14–16 (usually 10+4); branchiostegal rays usually 8–9.[18]

Proportions as percent TL: Greatest body depth 19.2–25.1; head length 22.1–27.1; interorbital width 38.2–54.9; snout to dorsal origin 29.1–34.4; dorsal fin base 6.8–8.7; anal fin base 20.2–27.4. Proportions as percent head length: Eye diameter 9.4–20.5; interorbital width 38.2–54.9; snout length 36.2–43.4.[18]

Body laterally compressed behind anal fin, scaleless.[18] Head broad,[5] wide, paired nostrils widely separated, posterior pair opening through base of long snout barbels; undersurface of head flat, two pairs of barbels, inner pair shorter; mouth terminal, moderately long, wide, gape reaching almost to eye, upper jaw somewhat longer than lower, maxillary barbels reaching or surpassing operculum. Dorsal fin anterior to midpoint of body, spine ca. 3/4 fin height, straight, barbs on posterior edge very weak; adipose fin long, fleshy,[18] free posteriorly;[7] pectoral spine more than 1/2 fin length,[18] posterior edge with sharp serrations; caudal square[7] or rounded.[19]

Pigmentation: Yellow-olive, brown, brownish black or slate black above; sides yellowish, sometimes,[7] or never[18] mottled; bright yellow, yellow-white or milk white below;[7] upper barbels light to dark brown, chin barbels yellow, buff to pale pink, barbels lacking black pigment or spots;[18] fin membranes weakly pigmented,[13] bases darker,[18] anal fin usually with dark horizontal median band and dusky or black margin;[7] peritoneum gray, not heavily speckled.[18]

Maximum length: 465 mm.[14]

DISTRIBUTION AND ECOLOGY

Range: North Dakota to Great Lakes and St. Lawrence drainage, south to Gulf coast, and southwest to eastern

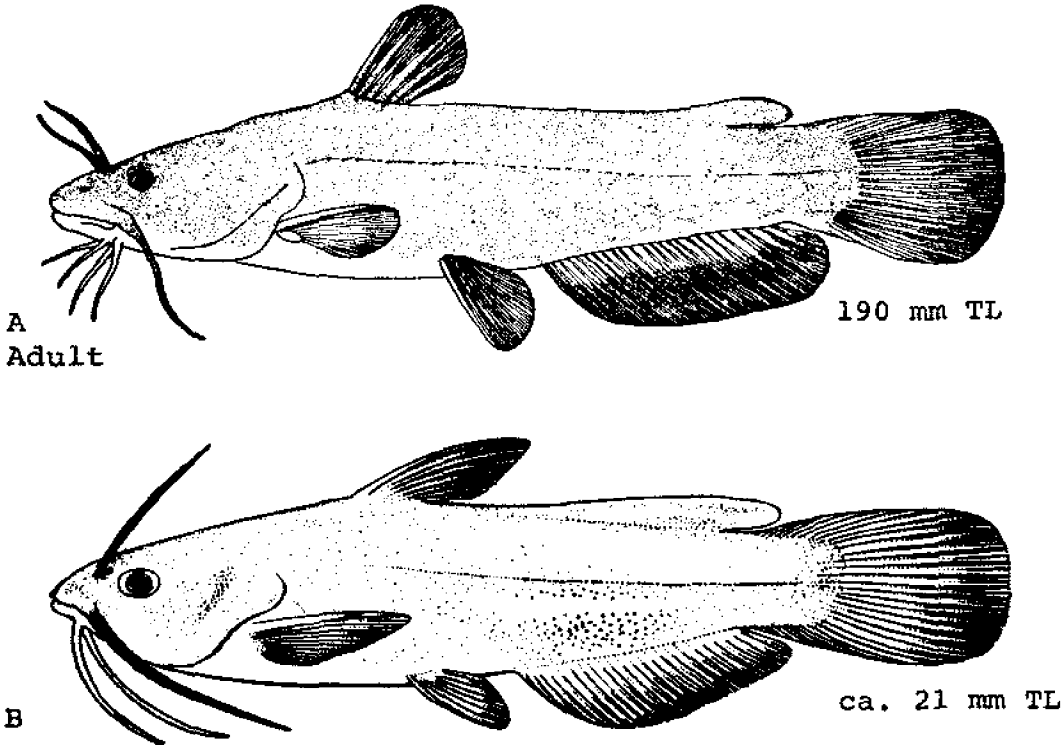

Fig. 192. *Ictalurus natalis*, Yellow bullhead. A. Adult, 190 mm TL. B. Juvenile, ca. 21 mm TL. (*A, Trautman, M. B., 1957: fig. 106. © Ohio State University Press. Used with permission of author and publisher. B, Fowler, H. W., 1935: fig. 34.*)

Oklahoma and northeastern Mexico;[7] introduced in Pacific states[8] and elsewhere.[7]

Area distribution: Tidal tributaries of Chesapeake Bay in Virginia[4,15] and Maryland; also recorded from coastal plain of Delaware;[21] New Jersey.[22]

Habitat and movements: Adults—moderate to very heavy areas of aquatic vegetation in shallow portions of large bays, lakes, ponds, streams and brooks in clear water of base or low gradient.[7]

Yolk-sac larvae and juveniles—guarded by parent fish[6] (probably by male only[20]) until late July or August[6] or until young are ca. 50 mm long.[16]

SPAWNING

Location: Depths of 45.7 to 121.9 cm[6] with eggs deposited in shallow, saucer-shaped nest[9,14] which is somewhat larger than fish itself[2] and usually located beside or beneath a bank, log, or tree root;[6] also in inclined burrows as much as 61.0 cm deep.[18] In aquaria, nests occur in both open and sheltered areas.[20]

Season: Mid-May to early June,[1,2,6] and lasting ca. 2 weeks.[2]

Fecundity: 1650[3]–7000.[6,14]

EGGS

Location: Adhesive, sometimes attached to roots in nest; number of eggs per nest ca. 300–700;[2] deposited in clusters which are attended by male only.[20]

Fertilized eggs: Golden,[20] to yellowish white;[2] diameter 2.5–3.0 mm.[20]

EGG DEVELOPMENT

Incubation: 5–10 days at unspecified temperature.[6]

YOLK-SAC LARVAE

No information.

LARVAE

Adult fin ray complement evident before yolk absorption, therefore, as defined in this volume, the larval stage does not occur.

JUVENILES

Specimens described 17[1]–21 mm TL.[10]

Preanal vertebrae 15; postanal vertebrae 27. Maxillary barbel equal to HL at 17 mm. Dorsal and pectoral spines well-developed and caudal fin rounded at 17 mm.[1]

Pigmentation: At 17 mm, small, round, closely set chromatophores on head, body, and fins; underside of head and body from lower jaw to vent colorless; chin barbels white.[1] Specimens less than ca. 50 mm long often entirely black above.[7]

AGE AND SIZE AT MATURITY

During 3rd year,[6] minimum ca. 127 mm.[20]

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Ictalurus nebulosus (Lesueur), Brown bullhead

ADULTS

D. I, 6 [20] (rarely I, 7); [34] A. 19–26,[22] C. 17 principal rays (WRT); P. I, 7 [34]–9 (WRT); V. 8; [21] vertebrae 34–39 + Weberian ossicles; gill rakers, usually 9 on upper limb, 4–5 on lower; branchiostegal rays usually 9, 9.[34]

Proportions as percent TL: Greatest body depth 17.7–26.3; caudal peduncle depth 8.1–9.9; HL 22.6–26.3; snout to dorsal origin 30.4–34.3; dorsal fin base 6.6–9.3; anal fin base 17.5–20.7. Proportions as percent HL: Interorbital width 45.2–53.2; eye diameter 10.0–18.7; snout length 35.6–44.2.[34]

Body rounded and heavy forward, laterally compressed behind dorsal fin, scaleless.[34] Head somewhat narrow, depressed,[20] slightly rounded to concave on top, undersurface broad, flat; four pairs of barbels, longest pair of maxillary barbels extend to end of operculum or base of pectoral fin, moderately long flattened snout barbels located at posterior nostrils, undersurface of head with two pairs of heavy flattened barbels, inner pair shorter; snout moderately long, broad, shallowly rounded; mouth terminal, horizontal, wide, upper jaw slightly longer than lower, maxillary extending to posterior nostril. Dorsal spine somewhat more than 1/2 fin height, barbs on posterior surface weak or absent; caudal fin truncate [34] to emarginate; [10] posterior end of adipose fin free from caudal; [40] pectoral spine almost as long as fin, barbs large and recurved.[34]

Pigmentation: Olive gray to almost blue-black above,[34] with or without an overlaid mottling of darker coloring; lighter on sides; [20] pale yellow,[34] white-gray or pinkish below; [20] all barbels dark brown to nearly black (except base of chin barbels, which may be pale yellow to white); coloration of fins same as body, some dark pigment on fin ray membranes; peritoneum silver to gray.[20]

Maximum length: Ca. 508 mm.[20]

DISTRIBUTION AND ECOLOGY

Range: Southern Canada through eastern United States to Gulf states and southern Florida; [13,27,28] widely introduced on Pacific coast of North America, in Europe, parts of U.S.S.R.,[10] and Canada.[11]

Area distribution: Tidal tributaries of Chesapeake Bay in Virginia [7] and Maryland (RJM); coastal plain of Delaware.[36,45]

Habitat and movements: Adults—a schooling, bottom species,[26] usually restricted to deeper canals,[35] sometimes forming dense aggregations.[15] Found over mud or among aquatic vegetation in ponds and sluggish rivers; [19,36] also reservoirs, swamps, ponds, and stagnant water; occasionally in clear, clean water (RJM); largely nocturnal in habits,[12] known to burrow into soft bottom sediments.[38] Maximum salinity 10 ppt [36] (observed dying at 14.0 ppt [14]). Upper lethal temperature at 6 C and 36 C acclimation: 28.9 C and 37.5 C. Lower lethal temperature at 21.0 C and 36 C acclimation: –1.0 C and 7.0 C.[43] Minimum dissolved oxygen level ca. 0.2 ppm at low temperatures.[37] Taken at depths of 12.2 m.[41]

Yolk-sac larvae—in tight mass at bottom,[24] on sides [34] for 5 [44]–16 days.[33]

Juveniles—early juveniles herded about in schools for some weeks [2,16,23,25,33] by one or both parents; [34] sometimes in schools throughout first summer among vegetation or near other suitable cover over more or less muddy bottoms,[12] often in shallow ditches.[35]

SPAWNING

Location: Sluggish, weedy, muddy streams and lakes [30] usually at depths of several inches to several feet.[2] In nests consisting of open excavations in sand, gravel, or rarely, mud, and often in shelter of logs, rocks or vegetation; [12,27,32] in burrows up to 1 m long excavated under roots of aquatic plants; [27] occasionally in cavities of old stumps, stovepipes, old pails,[19] and terra cotta pots.[18] In aquaria, nests are excavated by females only and always constructed under shelters.[42]

Season: Late spring in Maryland (RJM); early April to August or later throughout range [1,2,3,4] and possibly occurring twice yearly.[2]

Time: Early morning [38] to 1400 hours.[2]

Temperature: Ca. 21–25 C.[2]

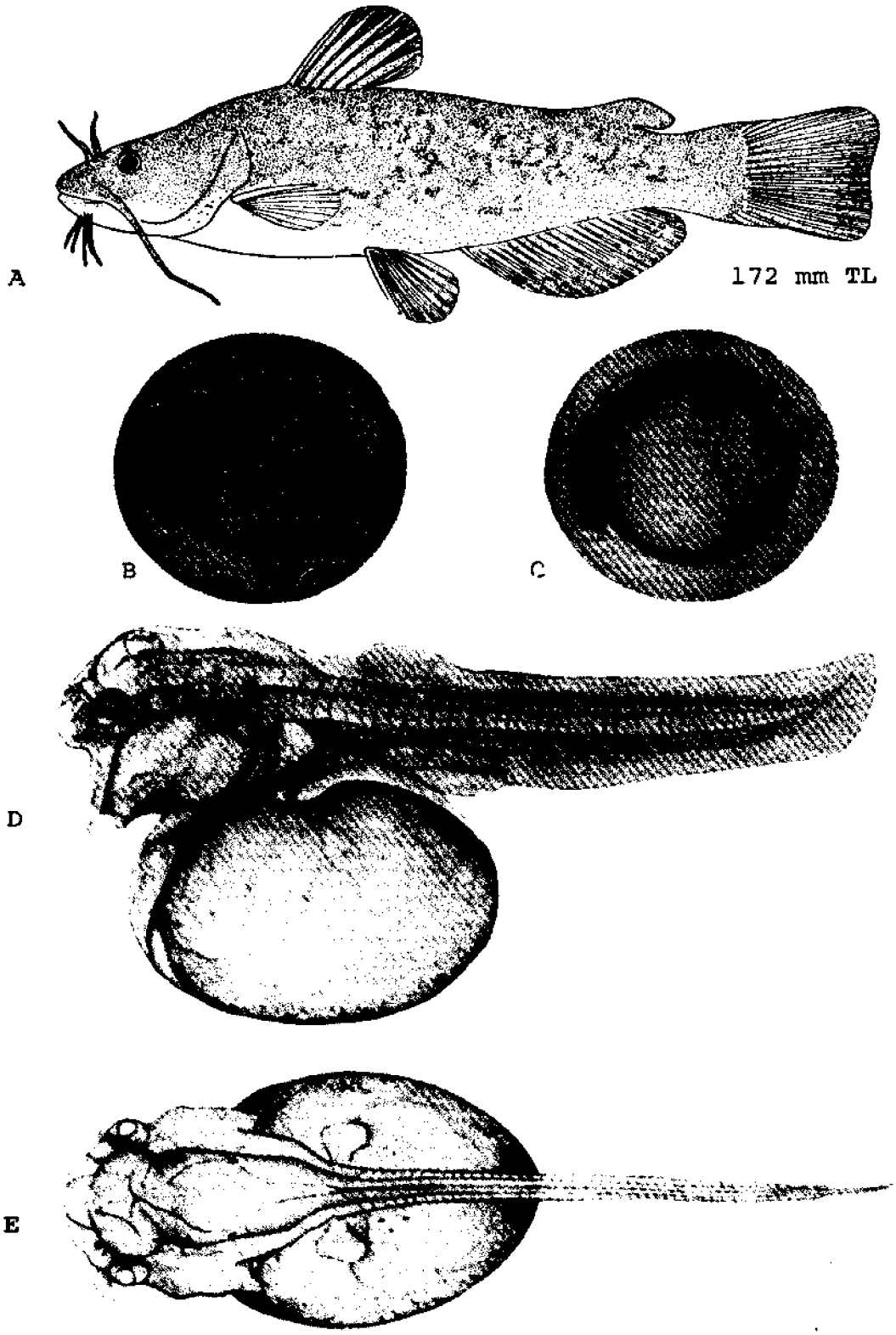
Fecundity: Ca. 2000–13,800.[26]

EGGS

Location: Adhesive; [2] 50 [6]–10,000 or more per nest; [25] deposited in clusters (similar to masses of frog eggs) [23] as much as 10 cm long and 6.4 cm wide.[16] One or both parents usually attend clusters, often with oral agitation.[2,12,31] Eggs exposed to direct sunlight produce poor hatches.[39]

Unfertilized eggs: Single micropyle.[27]

Fertilized eggs: Pale cream,[2] pale yellow,[16] or light orange; [38] nearly transparent. Diameter ca. 3.0 mm,[2] but varying in size from nest to nest often with a size difference of 1.0 mm.[29] Egg capsule transparent, thin; perivitelline space ca. 1/3 egg diameter.[27]


A
172 mm TL
B
C
D
E

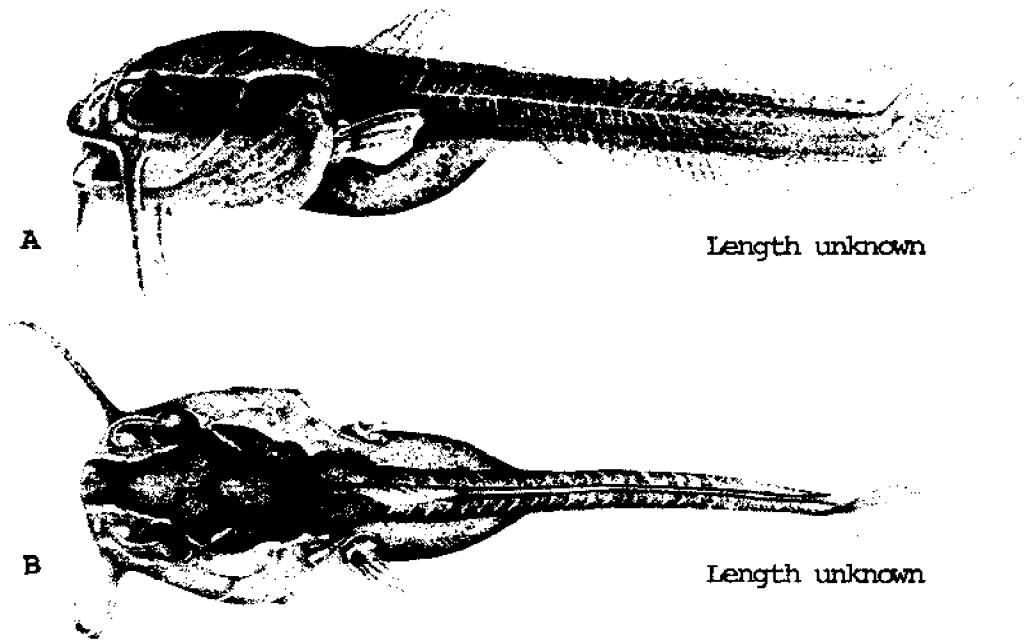


Fig. 194. *Ictalurus nebulosus*, Brown bullhead. A. Yolk-sac larva, ca. 13–14 days from fertilization. B. Yolk-sac larva, dorsal view of "A." (*A, B, Armstrong, P. B., 1962: fig. 51. © Syracuse University Press. Used with permission of author and publishers.*)

EGG DEVELOPMENT

At 20–21 C:

1 hour, 12 minutes	blastodisc evident.
1 hour, 36 minutes	first cleavage.
3 hours	3rd cleavage.
6 hours	morula; blastoderm conspicuously high and dome-shaped.
1 day	embryonic shield evident.
2 days	ca. 14 somites, tail bud well defined; blastopore closed; brain division discernible but ventricles not evident; some movement established; anlagen of otoliths sometimes present.
5 days	pigment developing in eye; pectoral buds and barbels developing.
6 days	dorsal finfold elevated in region of future dorsal fin.[27]

Incubation: 5 days at 25 C;[82] 8 days at 20–21 C[27] (a report of "less than 20 hours" at ca. 25.0 C[33] is probably in error, PWJ).

YOLK-SAC LARVAE

Hatching length 4.0[32]–8.0 mm.[19]

Caudal with incipient rays at hatching.[27] Barbels and spines developed by 3rd day. On ca. 10th day, anterior edge of maxillary barbel serrated; incipient rays in dorsal, anal, and pectoral.[16]

Pigmentation: Transparent and yellowish[16] or cream white at hatching,[2] with few chromatophores on head, yolk mass, and body;[27] by 2nd day, dorsal surface darkened; by 4th day, upper parts uniform bluish black, under parts whitish.[16]

LARVAE

Adult fin ray complement evident before yolk absorption, therefore, as defined in this volume, the larval stage does not occur.

JUVENILES

Specimens described 22 mm TL.

Fig. 193. *Ictalurus nebulosus*, Brown bullhead. A. Adult, 172 mm TL. B. Egg, 2 days, diameter ca. 3.0 mm, ca. 17 somites, dorsal view. C. Lateral view of "B." D. Embryo, 7 days. Egg capsule removed; tail bent over dorsum of head when egg intact. E. Dorsal view of "D." (*A, Trautman, M. B., 1957: fig. 107. © Ohio State University Press. Used with permission of author and publisher. B-E, Armstrong, P. B., 1962: figs. 26, 40. © Syracuse University Press. Used with permission of author and publisher.*)

At 22 mm, vertebrae 14+26; length to vent 9.9 mm; greatest depth 4.5 mm; maxillary barbel about as long as head.[8] "Young" with 6–10 well-developed teeth on posterior edge of pectoral spine.[23]

Pigmentation: At 22 mm, top and sides of head, dorsal aspects of body, fins, and barbels covered with small, close-set chromatophores; belly light.[8] "Young" jet black.[12,17]

AGE AND SIZE AT MATURITY

3 years,[9] minimum ca. 178 mm.[42]

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Ictalurus punctatus (Rafinesque), Channel catfish

ADULTS

D. I, 6;[27] A. 23[38]–30;[5] C. 15 branched or 17 principal rays (WRT); P. I, 8[38]–10;[45] V. 8;[27] vertebrae usually 42–44 + Weberian ossicles; gill rakers 14–18 (usually 9–12 on lower limbs, 5–6 on upper); branchiostegals 7, 7 to 8, 8.[38]

Proportions as percent TL: Greatest body depth 14.2–22.7; head length 19.6–24.6; least caudal peduncle depth 7.0–8.5; snout to dorsal origin 28.0–31.1; dorsal base 6.4–8.3; anal base 19.6–24.9. Proportions as percent HL: Interorbital width 39.1–52.3; eye diameter 10.8–19.3; snout length 35.6–49.2.[38]

Body elongate,[27] laterally compressed behind pelvic fins; skin scaleless;[38] bone ridge from head to caudal spine continuous (in smaller specimens).[45] Head relatively narrow, rather wide in breeding adults (WRT), subconic;[6] with four pairs of barbels,[4] longest pair originates at angle of mouth, extends past head length; snout long, broad, flat to shallowly rounded on top; paired nostrils separated, posterior one of each pair opening through base of short barbel;[38] eyes located in middle[13] to dorsal half of head;[5] undersurface of head flat, broad; mouth inferior,[38] upper jaw longer than lower.[5] Teeth on dentary, premaxillary and pharyngobranchial bones. Dorsal spine less than 2/3 fin height, almost straight, no barbs on posterior surface; pectoral spine 3/4 fin length,[38] strongly barbed (WRT); pelvic fin origin behind insertion of dorsal fin;[38] caudal fin deeply forked,[46] upper lobe longer than lower.[13] Head of males swollen above and behind eyes during breeding season.[38] Urinary and genital ducts with separate external openings in females, common opening in males.[48]

Pigmentation: Silver-blue, dark steel blue,[5] to gray above; lower sides lighter;[38] yellowish, milk white[5] to silver-white ventrally; barbels darkly colored, without spots, base of inner chin barbels often colorless;[38] frequently with scattered dark spots on body, except in larger individuals;[5] edges of dorsal, caudal and anal fins dusky;[13] peritoneum speckled with black.[38] Breeding males generally black or blue-black with black lips; breeding females usually with lighter lips and body, larger females (9.1–13.6 kg) generally black, blue-black or dull gray with mottled to black lips.[45]

Maximum length: Ca. 1202 mm.[38]

DISTRIBUTION AND ECOLOGY

Range: Hudson Bay region,[23] south to Florida[38] and northern Mexico,[23] north through New Mexico,[38] Colorado[32] and Montana to southern Manitoba;[38] widely introduced in Atlantic and Pacific coasts drainages.[17]

Area distribution: All major tributaries of Chesapeake Bay;[56] coastal plain of Delaware.[55,57]

Habitat and movements: Adults—chiefly in channels of large rivers (RJM), in sluggish to swiftly flowing current,[46] and lakes;[23] also ponds, bayous,[33] stagnant pools;[25] in water clear[33] to muddy, over sand, gravel or rubble bottoms which may not be mixed with mud;[46] abundant downstream from sandbars in relatively deep quiet waters;[18] sometimes near waterfalls,[23] or in pools below dams;[33] seldom in dense vegetation. Some populations apparently undertake spawning migrations in small streams;[5] spawning migrations variable, habitat-dependent;[38] individuals may make excursions of up to 290 km in Mississippi River.[35] Peak activity at sunrise and sunset.[51] Maximum salinity 19.0 to 21.0 ppt,[52] usually at less than 1.7 ppt;[41] prefer temperatures above 21.1 C,[22] in one study with greatest concentrations above 33.8 C.[43] Commonly captured at all depths above 21.3 m.[42]

Yolk-sac larvae—apparently guarded by male;[3,16] first 2 to 5 days after hatching[38] in mass on bottom.[3] Upper salinity tolerance ca. 8 ppt.[7] Abnormal development evident at 35.5 C and higher.[30]

Juveniles—early in stage undertake excursions to surface to feed;[38] travel in schools for several days or weeks. After dispersal, feed singly in quiet, shallow water over sandbars, around drift piles, and among rocks;[6] in streams, "young" inhabit shallow riffles and turbulent areas near sandbars;[11] some winter under boulders in rather swiftly flowing water.[5] Strong schooling and hiding tendencies evident at 4 to 10 months. At 90–180 mm in close aggregations during daylight, forming tight school when disturbed, prefer hiding to open areas; at night, school dispersed, scattering occurs when disturbed, never in shelters at night at warm temperatures.[39] Grow at salinities of 11 ppt or less,[40] at 5 to 6 months and older tolerate 11–12 ppt.[47] Upper lethal temperatures: Ca. 36.6, 37.3 and 37.8 C at acclimation temperatures of 26.0, 30.0 and 34.0 C;[30] passive below 4.0 C, remaining in tight clusters both day and night.[39] Lethal dissolved oxygen levels (gradual acclimation): 0.76, 0.89 and 0.96 ppm at 25 C, 30 C and 35 C respectively.[44]

SPAWNING

Location: In semidark nests constructed by male[38] in weedy places near lake shores,[2] under rock ledges,[6] in tunnels in submerged turf,[3] in man-made containers,[14,20] or other protected sites;[46] also small streams,[5] sometimes in very swift water.[21]

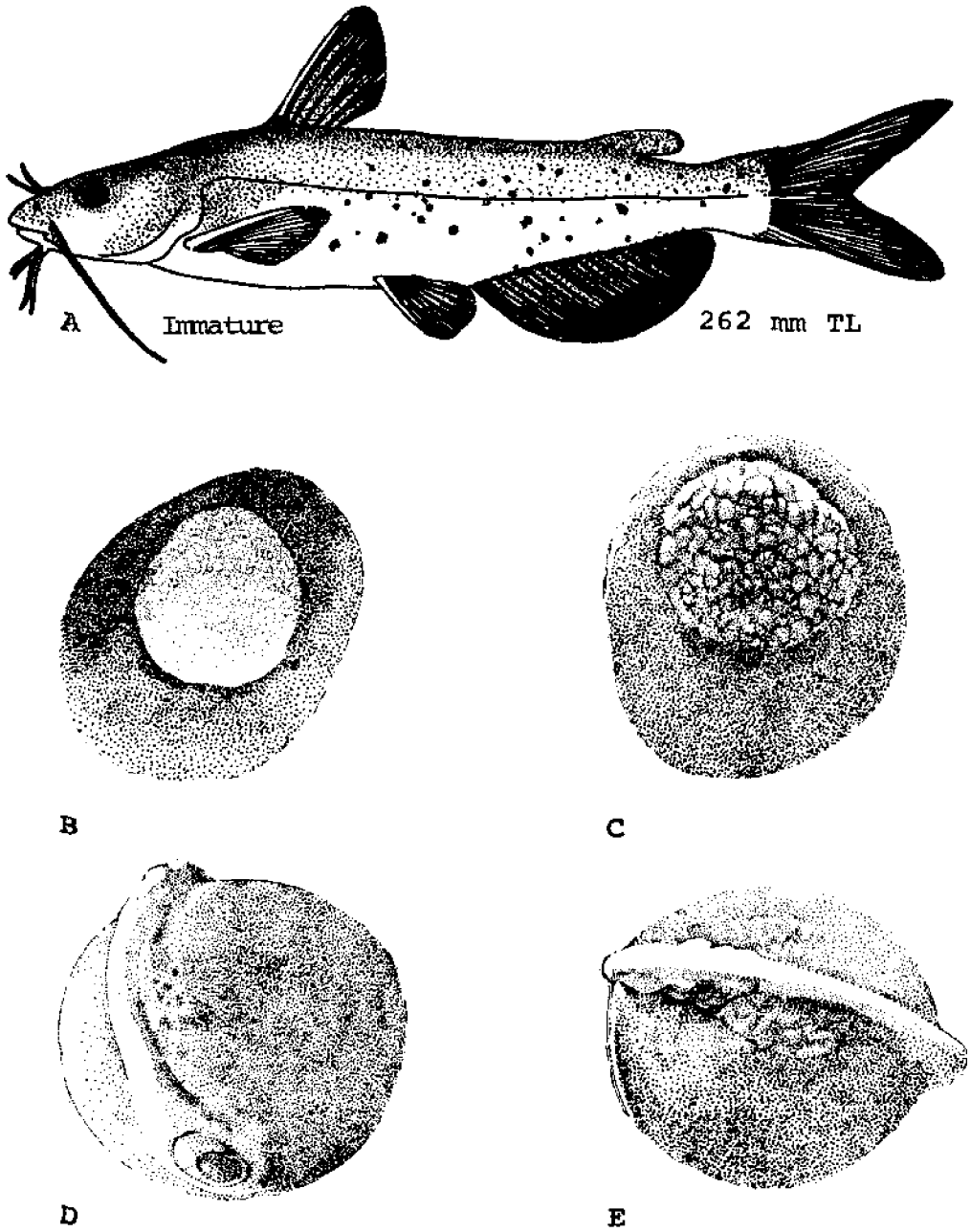

Fig. 195. Ictalurus punctatus, Channel catfish. A. Immature, 262 mm TL, 198 mm SL. B. Egg, blastodisc, 50 minutes. This and all following eggs ca. 3.5 mm; incubated at 24.7–26.8 C. C. Egg, morula, 5 hours. D. Egg, early embryo just before blastopore closure, 27 hours. E. Egg, tail-free embryo, 34 hours, pectoral buds present; ca. 24 somites formed. (*A, Trautman, M. B., 1957: fig. 104. © 1957, Ohio State University Press, used with permission of author and publisher. B-E, From Saksena, V. P., K. Yamamoto, and C. D. Riggs, 1961: figs. 1, 6, 11, 15, 19; delineated by Joan Ellis.*)

Season: March [45] through July,[8,12] possibly to September,[20] sometimes with two spawning peaks per season.[24]

Time: 0030–0730 hours and 1530–1730 hours; 2050 hours under laboratory conditions.[12]

Temperature: Ca. 21–29 C, optimum ca. 27 C.[12]

Salinity: Ca. 2 ppt and less.[49]

Fecundity: 1052 [34]–70,000.[35]

EGGS

Description: Demersal; adhesive; deposited in large gelatinous masses [19] of 2500–20,000.[29] Initially light [19] or golden yellow [11] becoming brownish yellow with age.[31]

Unfertilized eggs: Prior to spawning, 3.5–4.0 mm.[54]

Fertilized eggs: Diameter, 3.53 mm; [16] average diameter with capsule removed, 3.2 mm; [19] egg capsule tough.[11]

EGG DEVELOPMENT

At 24.7–26.8 C; [19]

50 minutes	blastodisc rounded, well defined, raised moderately from yolk surface.
2 hours, 30 minutes to 3 hours, 15 minutes	2-cell stage.
3 hours to 4 hours, 30 minutes	8-cell stage.
5–7 hours	morula.
10 hours	early gastrula.
11–16 hours	germ ring formed; embryonic shield barely evident.
21 hours	blastoderm over 2/5 yolk; embyronic shield forward from dorsal lip region.
23 hours	embryonic shield elongate; incipient neural tube and notochord evident.
25 hours	blastoderm over 3/4 yolk; large yolk plug formed; embryonic keel, neural groove, and anlage of forebrain evident.
26 hours	anlage of optic vesicles, 3–5 somites.
ca. 27 hours	blastopore small; 10–11 somites, brain region evident, optic vesicles and auditory placodes visible.
ca. 30 hours	blastopore closed, 15–16 somites, optic cup, and lens formed, heart a straight tube; anlage of pectoral fin evident; Kupffer's vesicle formed.
34 hours	ca. 24 somites, heart 2-chambered; auditory vesicles large; Kupffer's vesicle nearly obliterated.[19]
ca. 48 hours (temperature unrecorded)	movement established; eyes "fairly well-formed." [25]

Incubation: 5–10 days at 15.6–27.8 C; [38] ca. 7–10 days at ca. 24–26 C; 6–9 days at ca. 27–28 C.[12,14]

Salinity limits: At 1 to 2 days, upper tolerance ca. 10 ppt; [7] 3 days and older 16 ppt.[47]

YOLK-SAC LARVAE

Minimum hatching size ca. 6.4 mm.[28] Duration of stage 3-6 days.[11] Specimens described 12.2–15.0 mm TL.[3]

Body slender at hatching.[16] Yolk mass conspicuously elongate, bluntly pointed posteriorly at ca. 13 mm, shorter and less pointed at 14.5 mm. Mouth well formed and with barbels at ca. 13 mm.[3] Spines developed,[15] but not necessarily visible at or shortly after hatching. At ca. 13 mm, incipient rays in dorsal; pectoral fin short, squarely truncate; pelvics present as short rounded lobes; anlagen of anal and adipose fin evident. Pelvics elongate at ca. 14.5 mm.[3]

Pigmentation: At hatching, body golden,[11,15] transparent; [21] yolk sac pink [14] or light amber.[16] At ca. 13 mm, body bright golden; chromatophores in triangular patch on head, in an ill defined line on either side of mid-dorsal line to caudal base, and sometimes in a broken line along trunk and anal base. At ca. 14.5 mm, pigment present over most of snout and sides of head, in a line from head to caudal base, at all fin bases, and to some extent on fins.[3]

LARVAE

Adult fin ray complement evident before yolk absorption, therefore, as defined in this volume, the larval stage does not occur.

JUVENILES

Minimum size described 32.6 mm TL. Maximum size attained at least 257 mm TL.[5]

At 32.6 mm, 16 preanal vertebrae; 28 postanal vertebrae. Body slender; head slightly convex above; maxillary barbels longer than head. Pectoral spine ca. 2/3 HL; caudal fin forked; posterior margin of adipose fin free.[2]

Pigmentation: Apparently blue immediately after yolk absorption.[28] Body nearly white with sparsely distributed melanophores; subsurface spots pronounced over stomach;

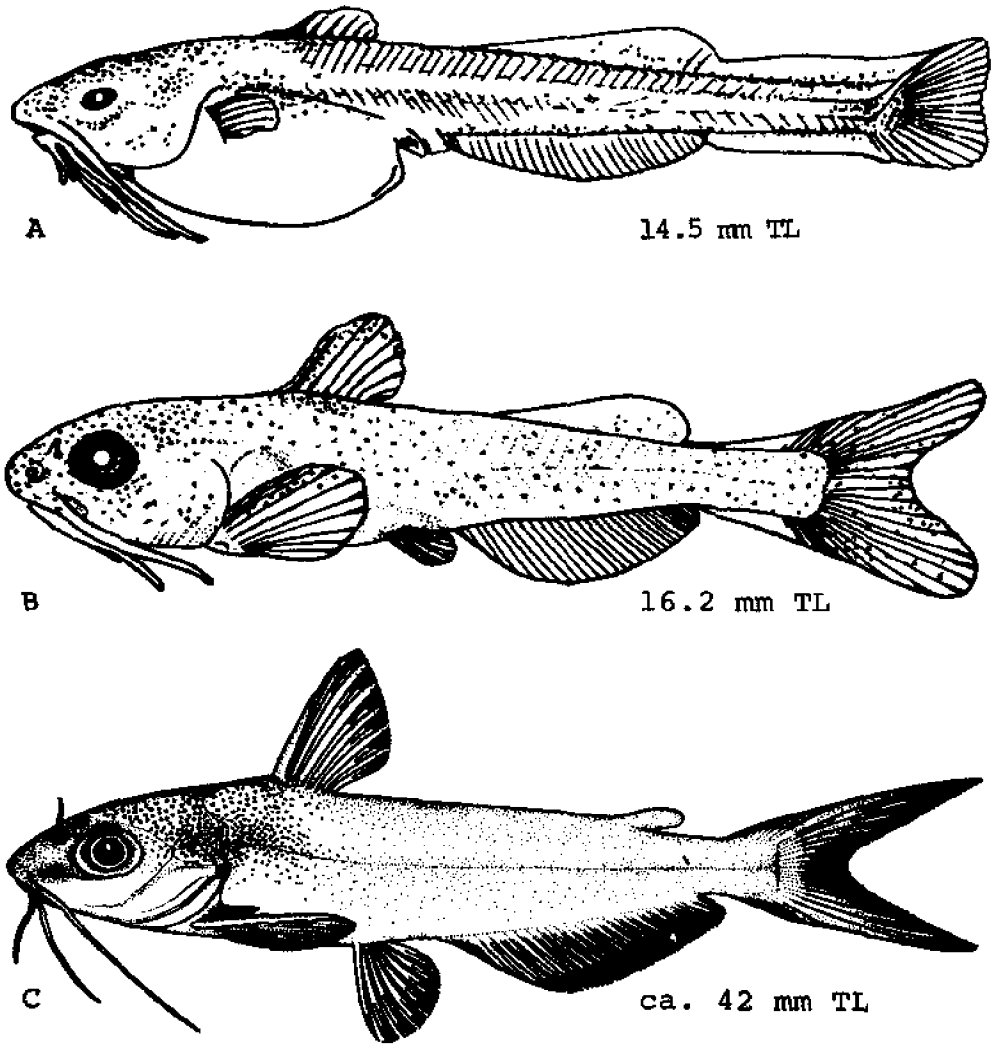

Fig. 196. *Ictalurus punctatus*, Channel catfish. A. Yolk-sac larva, 14.5 mm TL. B. Juvenile, 16.2 mm TL. C. Juvenile, ca. 42 mm TL. (*A, Greeley, J. R., and S. C. Bishop, 1932: fig. 3. B, Lippson, A. J., and R. L. Moran, 1974, after Taber, 1969. C, Fowler, H. W., 1945: fig. 144.*)

chromatophores on all fins.[2] Young with or without spots at ca. 50–75 mm.[6]

AGE AND SIZE AT MATURITY

18 months [53] to 9th year; [36] minimum size for males ca. 165 mm.[60]

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Noturus gyrinus (Mitchill), Tadpole madtom

ADULTS

D. I, 4–7 [11] (mean 5.7 [15]); A. 12–18 [11] (mean 15.2 [15]); C. 50–66 (total count),[11] upper half 27–36 (mean 31.5), lower half 22–32 (mean 26.5); P. I, 5–10 (mean 6.9 [15]); V. 5–10 [11] (mean 8.2 [15]); total vertebrae (except fused anterior vertebrae) 32–37 [11] (mean 34.3); caudal vertebrae 25–28, precaudal vertebrae 7–9, vertebrae anterior to anal fin origin 10–11; [15] gill rakers on first arch 5–10; branchiostegals 8–10; [11] ribs 5–7; hypurals 6 (3+3) to 7 (3+4); internasal pores 1–3; preoperculomandibular pores 8–12 (mean 10.2).[15]

Proportions as percent TL: Greatest depth 16.8–22.9; caudal peduncle depth 10.2–12.9; head length 22.5–26.5; tip of snout to dorsal origin 27.8–31.6; dorsal base 9.5–12.6; *adipose length 14.5–17.0; anal base 10.8–19.4.*[14] Proportions expressed as times in distance from origin of dorsal fin to adipose notch: Tip of caudal fin to adipose notch ratio 0.8–1.5; predorsal length ratio 1.1–1.5; head length ratio 1.4–1.9. Proportions expressed as times in SL: Head length 3.0–3.8. Proportions expressed as times predorsal length: Caudal peduncle depth 2.1–3.1; pectoral spine length 1.6–3.7; dorsal spine length 2.0–4.5.[15] Proportions expressed as percent HL: Interorbital width 38.4–49.4; eye diameter 9.3–16.2; snout length 35.1–42.0.[14]

Body variable, usually short and chubby, sometimes elongate; [11,15] deepest at or in front of dorsal fin; [15] laterally *compressed behind origin of anal fin; steep angle from* tip of snout to dorsal fin origin.[14] Head short, deep, broad; [8] band of teeth on premaxillary with rounded edges, lateral dimension 3 to 4 times anterior-posterior measurement; humeral process distinct; [15] four pairs of barbels; [11] lower jaw subterminal,[2] or terminal.[15] Adipose fin high, shallow notch between adipose and caudal often inconspicuous; [2] caudal fin usually ending in an obtuse point; pectoral spine deeply grooved, nonserrate, smooth *bumps frequently on posterior edge near base;* anterior ends of infraorbital and supraorbital canals separate.[15]

Pigmentation: Light yellow to chocolate brown or olive-gray above, sides lighter, venter yellow-white or white; [2,11] sides usually with a narrow, dark, lateral streak; vertical fins not dark-edged; [8] barbels and fins may be darker or lighter than general body color.[15] Peritoneum not pigmented.[14]

Maximum length: Ca. 127 mm.[4]

DISTRIBUTION AND ECOLOGY

Range: Manitoba to Texas in the West, east to Atlantic coast and north to New York and St. Lawrence River; [11] isolated populations may occur in the Appalachians; [2] introduced in New Hampshire, Massachusetts, Idaho, Oregon,[5,11] and parts of Europe.[15]

Area distribution: Tidal portions of Maryland,[15] and Virginia rivers; [1,9] also Delaware river.[15]

Habitat and movements: Adults—on Atlantic coast chiefly *below the Fall Line,* in waters varying from strongly acid to alkaline; [15] usually clear water in base- or low-gradient streams, springs, marshes, potholes, and lakes with soft *bottom and abundant aquatic vegetation;* [2,11] *sometimes* under sticks and stones.[5] Maximum salinity: 0.98 ppt.[12] Maximum depth: 25 m.[14]

Yolk-sac larvae—no information.

Juveniles—no information.

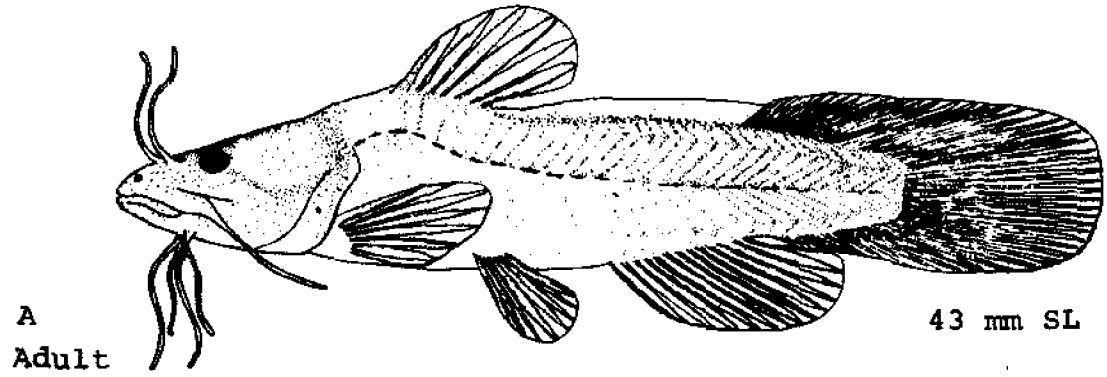

Fig. 197. *Noturus gyrinus,* Tadpole madtom. A. Adult, 43 mm SL. (*Trautman, M. B., 1948: pl. 1, fig. 3.*)

SPAWNING

Location: Low- or base-gradient portions of streams, oxbows, glacial pothole lakes or artificial impoundments over bottoms of muck, mud, or organic debris; [8] recorded in water 0.9 m deep.[10]

Season: May to July in northern localities.[4,6,7]

Fecundity: Ca. 50–93; [3] maximum eggs per nest 117.[15]

EGGS

Location: Deposited in clusters beneath boards or logs, in crawfish burrows, holes in mud, under roots,[6] and in old tin cans.[10]

Fertilized eggs: Average diameter ca. 3.5 mm; [13] adhesive; in discrete clusters surrounded by a gelatinous matrix; yolk light yellow (WRT).

YOLK-SAC LARVAE

No information.

LARVAE

Adult fin ray complement evident prior to yolk absorption, therefore the larval stage, as defined in this volume, does not exist.

JUVENILES

Essentially adult-like at ca. 25 mm TL (WRT).

AGE AND SIZE AT MATURITY

No information.

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Noturus insignis (Richardson), Margined madtom

ADULTS

D. I, 5–7 (usually 6); A. 15–21 (usually 17–19); C. 54–67 (total count), upper half 27–35, lower half 26–33; P. I, 7–10 (usually 9); V. 8–10 (usually 9); precaudal vertebrae 8–11; caudal vertebrae 28–31; vertebrae anterior to anal fin origin 12–14; total vertebrae (except fused anterior vertebrae) 37–42 (usually 38–40); gill rakers on first arch 6–10; branchiostegal rays 9–12; ribs 6–8; hypurals 6 (3+3)–7 (3+4); preoperculomandibular pores 9–12 (typically 11); 2 internasal pores.[8,10]

Proportions expressed as times in distance from origin of dorsal fin to adipose notch: Tip of caudal fin to adipose notch ratio 1.4–1.9; predorsal length ratio 1.3–1.8; head length ratio 1.7–2.3. Proportions expressed as times in predorsal length: Caudal peduncle depth 2.3–3.2; pectoral spine length 2.1–3.8; dorsal spine length 3.1–4.6. Proportions expressed as times in SL: Head length 3.4–4.0. Proportions expressed as times in snout: Eye diameter 1.9–2.6.[8,10]

Body elongate. Head depressed, lower jaw included, premaxillary tooth band usually obtusely angulate at corners, four pairs of barbels. Caudal peduncle deeper than head depth. Dorsal spine moderate in length, stiff; pectoral spine long, slightly curved, up to 9 distinct posterior serrae (may become irregularly fused in old specimens), anterior serrae lacking. Adipose fin broadly united to rounded or truncate caudal fin. Humeral process about equal in length to diameter of pectoral spine.[8,10]

Pigmentation: Yellowish to slate gray, lighter on ventral surfaces; top and sides of body and head uniformly darkly pigmented; barbels usually with some chromatophores, those above dark, those below light; chin in front of mental barbels pigmented; narrow bridge of pigment crosses abdomen in front of pelvics, otherwise abdomen and lower surface of head, except lower lip, usually immaculate (may be lightly pigmented in very large specimens). Fins lightly pigmented, especially near bases; pelvic fins relatively clear; margins of pectoral, anal, dorsal, and caudal fins frequently with dark band or concentration of pigment that is usually darker than basal areas, extreme edges clear; adipose fin dusky near base, clear distally.[8,10]

Maximum length: Ca. 178 mm.[9]

DISTRIBUTION AND ECOLOGY

Range: Lake Ontario drainage,[8] north to Lake Lapeche, Quebec;[3] Atlantic coastal streams from New York to Georgia; and upper New or Kanawha River system; apparently introduced in New Hampshire and Tennessee River basin.[8,10]

Area distribution: Tidal tributaries of Chesapeake Bay in Maryland and Virginia, also reported from Delaware and New Jersey.[10]

Habitat and movements: Adults—high gradient streams usually at or above the Fall Line,[10] usually on riffles (WRT) of clear, rocky streams in water 15 to 46 cm or more deep. Beneath stones[2] and planks,[1] occasionally in quiet water (WRT) and in muddy areas and deep holes, or among aquatic vegetation.[2,9] Apparently gregarious during winter.[1]

Yolk-sac larvae—no information.

Juveniles—among masses of *Potamogeton* and *Elodea*.[2]

SPAWNING

Location: Shallow excavations under stones, usually in quiet water above and below riffles.[1,4]

Season: Probably late June to early July in New York.[2]

Fecundity: 53–223.[2]

EGGS

Description: Adhesive; deposited in compact masses 40–60 mm across, each containing 54[1]–200 eggs.[4]

Ovarian eggs: Orange, ca. 4.0 mm in diameter;[5] micropyle single.[1]

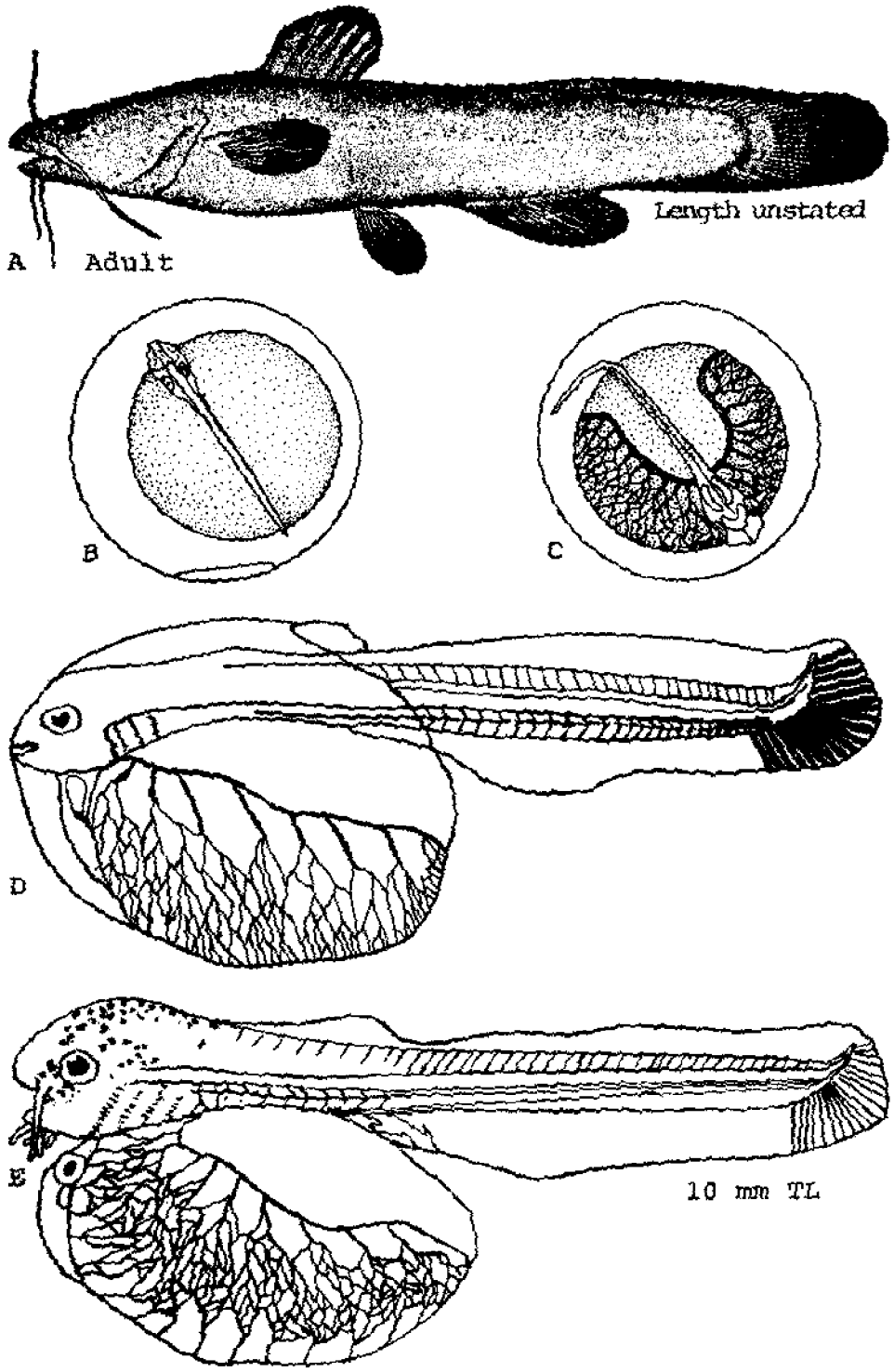
Fertilized eggs: Diameter ca. 3.0[4]–6.0 mm;[1] very pale cream to yellowish white[4] or yellow with orange tinge.[2]

EGG DEVELOPMENT

At 19.8–25.7 C.

At first caudal movement, egg capsule grayish, yolk whitish yellow, body pigment lacking. One day later, embryo 9.0 mm, pectoral fins developing, eye pigmented.[1]

Fig. 198. *Noturus insignis*, Margined madtom. A. Adult. B. Early embryo, no pigmentation. C. Embryo, one day older than "B," eyes pigmented, pectoral buds formed, yolk diameter 4 mm, embryo 9.0 mm. D. Yolk-sac larva hatching, tail-free from chorion. E. Yolk-sac larva, 10 mm TL, newly hatched. (*A, Truitt, R. V., B. A. Bean, and H. W. Fowler, 1929: fig. 6. B, C, Mansueti, A. J., and J. D. Hardy, Jr., 1967: fig. 89B, after Bowman, 1936. D, E, Bowman, H. B., 1936: pl. 12.*)


Length unstated
A
Adult
B
C
D
E
10 mm TL

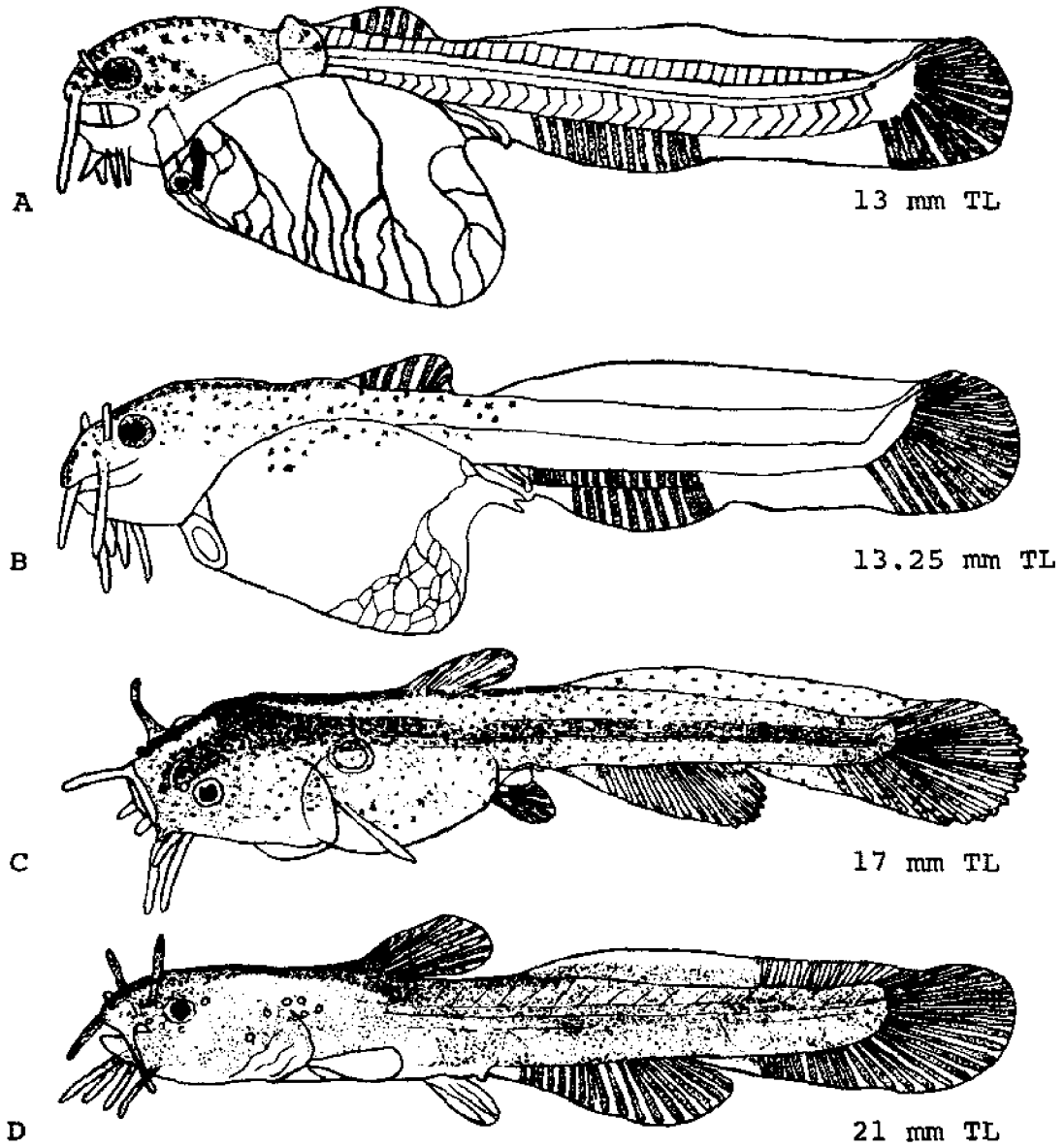


Fig. 199. Noturus insignis, Margined madtom. A. Yolk-sac larva, 13 mm TL, 2 days after hatching. B. Yolk-sac larva, 13.25 mm TL, 4 days after hatching. C. Yolk-sac larva, 17 mm TL, 8 days after hatching. D. Juvenile, 21 mm TL, 16 days after hatching. (*A-D, Bowman, H. B., 1936: pls. 13–16.*)

YOLK-SAC LARVAE

Hatching length 10 mm TL. Largest specimen described 17 mm.

Total myomeres at hatching 38; 9 myomeres to posterior base of dorsal; 29 myomeres behind dorsal.[1]

Head rounded, mouth sub-terminal, all barbels developed at hatching. Yolk mass initially more or less round, becoming smaller and pear-shaped by 13 mm. Branchiostegals and operculum well-developed at 17 mm. Urostyle oblique; origin of dorsal finfold over 1st myomere at hatching; finfold notched posterior to incipient dorsal at 13 mm.[1]

Pigmentation: Stellate chromatophores on dorsal surface of head and at base of maxillary barbel at hatching. At 13 mm, pigment developed on snout and continuous to

anterior margin of incipient dorsal. At 13.25 mm, melanophores spread to origin of finfold and upper surface of yolk sac. At 17 mm, body entirely pigmented with exception of lower parts of head, ventral aspect of yolk sac, and 3 lowest pairs of barbels. By time of yolk absorption, juvenile characteristics essentially developed.[1]

LARVAE

Adult fin ray complement evident prior to yolk absorption therefore the larval stage, as defined in this volume, does not occur.

JUVENILES

Size range described 21[1]–30 mm TL.[7]

Pigmentation: At 21 mm dorsal surface pigmented. All upper barbels and proximal 1/4 of lower pairs pigmented. Unpigmented circular areas around eyes and above gill covers.[1]

By ca. 30 mm, body adult-like, but head somewhat deeper.[7]

AGE AND SIZE AT MATURITY

Females 24 months; males possibly 12 months.[5]

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